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UNIVERSITY OF ALBERTA

Peatland Paleoecology and Peat Chemistry at Mariana Lakes, Alberta

by

Barbara Nicholson

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF Master of Science

IN

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(SIGNED) Barbara Nicholson

PERMANENT ADDRESS:

9505 77 Ave
Edmonton Alberta
Canada

DATED Oct 1 1987

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Peatland Paleoecology and Peat Chemistry at Mariana Lakes, Alberta submitted by Barbara Nicholson in partial fulfilment of the requirements for the degree of Master of Science in Peatland Ecology.

Dale H. Vitt
Supervisor

Michael Hickman

Charles Schweger

S. C. Zoltai

D. Pluth

Date..

Abstract

A complex peatland in Alberta was chosen for a paleoecology and peat chemistry study. Paleoecology was examined through a macrofossil study. The peatland was subdivided into four areas, lake basin, upper fen, lower fen, and forested Sphagnum islands, based on prominent surface vegetation and landform features. Sixteen peat cores were removed from the site, duplicating each of the vegetative-landform features. Releves were conducted at each coring site in order to determine present day vegetation. Water samples were removed for pH, electrical conductivity and major ion analysis. Peat macrofossil assemblages were obtained by using *Twinspan*, on the macrofossil data. Paleo-pH and paleo-moisture profiles were calculated using linear regression transformations and weighted averages based on macrofossil species autecology.

Peat chemistry was analyzed through a comparative study of peat profiles. Bulk density, percentage ash, elemental calcium, and elemental magnesium were analyzed. Relative enrichment and decline between landform areas were assessed. Statistical analysis was used to relate the development model proposed from the paleoecological study to changes in the physical and chemical peat profiles.

Peat initiation at Mariana Lakes began 8180 BP in the lake basins and followed a classical hydroseral succession of terrestrialization. Infilling of the lake basin produced a floating mat that upon enclosure developed into a poor fen. Paludification of the upper fen began 5800 BP, subsequent to terrestrialization in the lake basins, and progressed in a downslope direction. By 2960 BP the entire drainage path was completely paludified. Plant macrofossils, *Twinspan* classification of macrofossil assemblages, and paleo-profiles describe the developmental history of the present day surface features. Lake basin areas have been the most mineral rich, from the time of initiation to the present, displaying a unstable, wet, and relative rich peat history. Upper fen sites have experienced continuous groundwater influence, while lower fen sites have been recently paludified. In contrast to lake basin and fen sites, the forested Sphagnum islands have had a drier more mineral poor history. Island sites have experienced a gradual removal from groundwater flow.

- Peat chemistry analysis reveals a gradual mineral ion reduction occurring in forested *Sphagnum* island profiles with no distinct boundary between minerotrophic and ombrotrophic peats.

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I. INTRODUCTION

This thesis "Peatland Paleoecology and Peat Chemistry at Mariana Lakes, Alberta", examines three aspects of peatland development. Firstly, peat stratigraphy and peatland genesis are considered, where macrofossil remains identify the stages of peatland development. Secondly, peat chemistry is considered, where elemental concentrations reveal relative changes within the peat profile that have resulted from changes in hydrology and water chemistry. The results of the peat macrofossils analysis are given in Chapter 2 and outline changes in community structure that have occurred from the time of peat initiation. Macrofossil assemblages are compared between cores, and relative deposition rates are assessed. Paleo-pH and paleo-moisture profiles are reconstructed from macrofossil data. Chapter 2 concludes with a model of peatland development at Mariana Lakes. This model relates peat stratigraphy to the present surface landform features, which are dependent upon vegetation, water chemistry and hydrology. Chapter 3 addresses peat chemistry. Physical parameters (bulk density and percentage ash), and elemental calcium and magnesium are analyzed. By comparing peat profiles, relative decline and enrichment of these two elements are assessed. Statistical analyses are used to relate the model of development proposed in Chapter 2 to changes in the physical and chemical peat parameters.

II. PEAT MACROFOSSILS

A. INTRODUCTION

[1] Peat formation occurs under a variety of environmental conditions, however the basic requirement for peat accumulation is a cool, wet, anaerobic environment. Under these conditions the peat which accumulates is a stratified deposit of undecomposed and slightly humified plant tissue. Peatgenous plant communities are variable, reflecting local and regional conditions of climate (Damman 1986), nutrient availability (Damman 1978), moisture (Malmer 1958), and shade (Vitt and Slack 1975). In Alberta and western Canada, peatland plant communities have been studied by Jeglum 1971, Horton et al. 1979, Karlin and Bliss 1984, Slack et al. 1980, Vitt and Andrus 1977, Vitt and Bayley 1984, Vitt, Horton, and Malmer unpublished, Vitt et al. 1975, and Vitt and Slack 1984.

Peat formation is initiated and develops either by terrestrialization or paludification (Sjors 1961). Terrestrialization was generally initiated soon after deglaciation often in glacially scoured rock and sediment basins (Everett 1983, Heinselman 1970). This developmental pattern of hydroseral succession begins by nutrient enrichment of a lake basin, followed by algal growth and sedimentation. Depletion of the oxygen levels hinders microbial decay (Everett 1983) and initiates peat formation. Peat within a lake basin develops in three distinct strata (Kratz and DeWitt 1986). Limnic sediments form under areas of open water producing a brown amorphous substance composed of diatoms, algae, pollen, and colloids. Debris peat made up of unstructured plant remains originates from the sides and bottom of the floating mat and is deposited on the lake bottom. Mat peat is formed from highly fibrous interconnecting plant remains. A fen is formed when complete enclosure of the basins by bryophytes and vascular plants occurs.

Paludification (swamping) is responsible for the larger portion of peat in the world (Sjors 1983), particularily in cool, oceanic regions and in the boreal and subarctic zones. Paludification results from increasingly impaired drainage due to peat accumulation (Sjors

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[1] A version of this chapter will be submitted for publication in the Canadian Journal of Botany.

1961) and appears to be climatically induced. Finnish sources have reported extensive paludification occurring at 6500 BP, and 4800 BP (Sjors 1983), while Canadian radiocarbon dates document periods of paludification at 3500 BP, 2400 BP, and 700 BP (Nichols 1969).

Once established, the direction of succession ~~in~~ a peatland is influenced by both autogenic and allogenic factors. Autogenic factors are initiated within the peatland itself and include, shallowing, isolation from the mineral substrate, natural acidification and water divergence (Tallis 1983). Autogenic factors are important in controlling the coalescence of Sphagnum hummocks as well as flow divergence. When water flow becomes channelled into definite flow paths, areas of peat are affected by flowing water only during periods of excessive inflow (Tallis 1983). Accordingly, there is a slow progression towards ombrotrophic conditions in these isolated areas of peat. With increased isolation from the regional ground water, the surface waters become reduced in calcium and bicarbonate ions, and enriched with hydrogen ions (Gorham 1957). In areas of high precipitation and low evapotranspiration, this isolation process may be enhanced, and ombrotrophic bogs can form. Bog development includes changes in hydrology. Water is discharged from the peatland (rather than recharged) as the peat surface becomes convex and raised, and the site experiences a corresponding drop in pH, mineral ions and nutrients.

Allogenic changes are brought about by such external factors as climate and hydrology. In Europe, recurrence surfaces are marked by weakly humified ombrotrophic peat underlain by highly humified peats containing tree stumps (Tallis 1983). These stratigraphic zones have been interpreted as developing as a result of climatic change, including a prolonged period of dryness followed by a period of moisture increase (Tallis 1983). Allogenic changes in hydrology through stream capture were considered by Heinselman (1970) to be responsible for the initiation of ombrotrophic conditions in the Lake Agassiz northern Minnesota peatland.

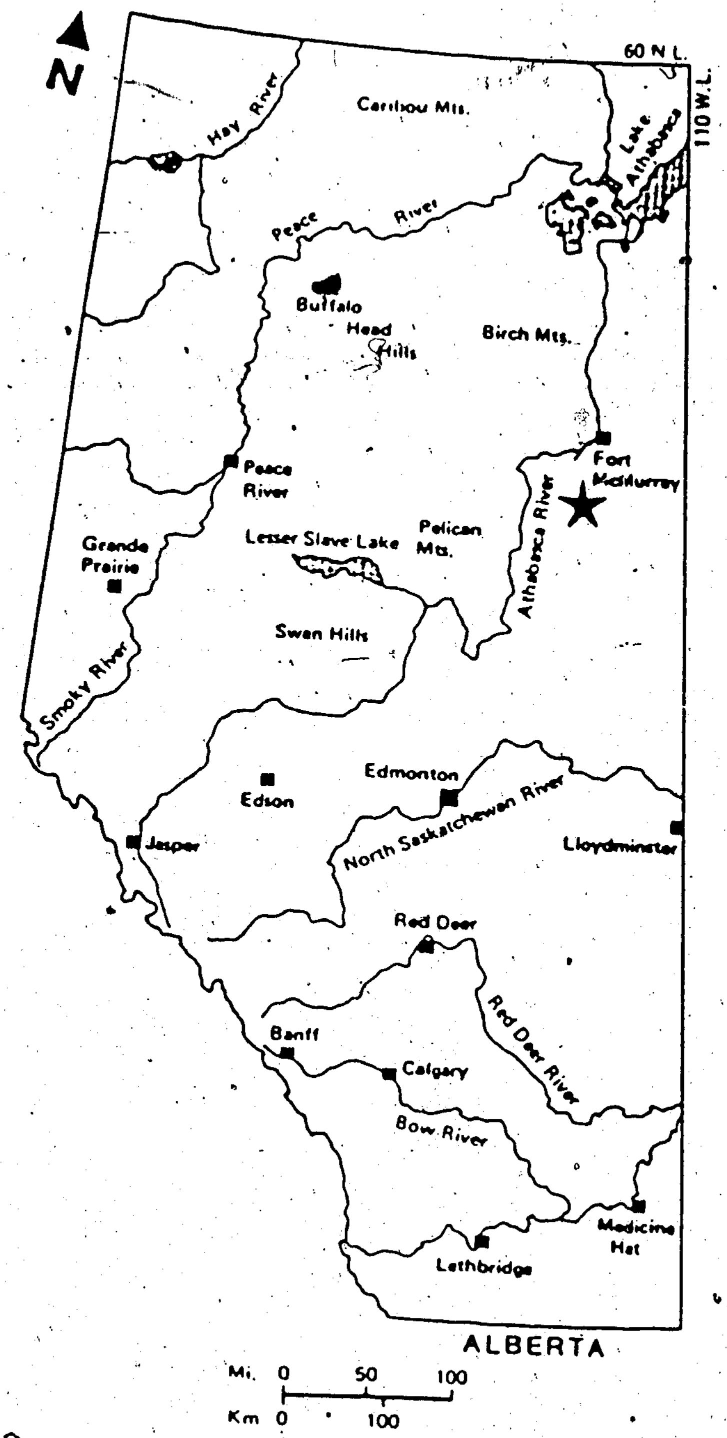
In the boreal zone of continental North America, annual precipitation only slightly exceeds evapotranspiration (Gorham 1957). In this zone, large convex raised ombrotrophic bogs are not present. Instead, isolated ombrotrophic areas develop within complex mires on restricted plateaus where drainage divides have formed or where a waterflow diversion has occurred around upland mineral ridges. Glaser (1983) has described the vegetation and water chemistry characteristics of surface landform features in complex mires of the Black River and Red Lake (Glaser and Wheeler 1981, Janssens and Glaser 1986) peatlands of northern Minnesota. These surface landform features take the shape of raised Sphagnum crests with radiating drainage patterns; Sphagnum lawns; watertracks; and ovoid Sphagnum islands. Glaser (1983) concluded that the presence of the watertracks is related to minerotrophic runoff being channelled onto the peatland, and that Sphagnum islands develop in stagnation zones where minerotrophic runoff is minimal.

Few studies have investigated the interrelationships between peatland formation, hydrology, water chemistry and vegetation. The objectives for this study were to 1) elucidate the developmental history of the surface landform features in an Alberta peatland and 2) relate development to autogenic and allogenic factors. In particular, the questions being considered here are: a) In a complex northern mire, what are the evolutionary stages of peatland development? b)How does peatland development relate to surface physiognomy? c)What are the local influences affecting peatland formation? and d)What effects have regional paleoclimatic events had on peatland development? Through peat stratigraphy and macrofossil analysis, the developmental history and landform development of a complex mire in northern Alberta is examined.

B. STUDY AREA

Mariana Lakes are located in northeastern Alberta, Canada, 100 km southwest of Ft. McMurray at 55° 54'N latitude and 112° 04'W longitude (Fig II-1). These lakes are situated on a broad upland plateau, the Stoney Mountain Uplands, that is elevated 180 m above the surrounding area. Local topography of the upland is subdued, with surface relief varying only 20 m. Much of the peatland complex associated with Mariana Lakes is situated on an east-west drainage divide. Water that flows west from this divide enters a tributary of

Fig. II-1. Map of Alberta, Canada, with the Mariana Lakes study area shown by a star.



Mariana Lakes Peatland

Dropoff Creek and flows north into the House River. The Mariana Lakes study site is a 6.88 square kilometer peatland that is located at the head of the eastward flowing drainage. Water from this peatland enters a large unnamed lake located on the northeast side of the study site and flows southerly into an unnamed tributary of the House River.

The Stoney Mountain Uplands, are a physiographic unit formed by glacial drift overlying a minor rise in the sedimentary bedrock (Hackbarth and Nastasa 1979). The thickness of the glacial till varies from 30 to 180 m (Ozoray and Lytviak 1980) and consists of a variety of materials including glacially disturbed bedrock blocks, gravel, sand, and some clay. Wynnyk *et al.*, (1963) suggested that surficial glacial deposits of sandy outwash material are more prevalent in this area than tills. However, L. Andriashek (Alberta Research Council, oral communication) found the study area to be low lying ground moraine with some evidence of stagnant ice topography and limited glacial fluvial activity.

Stratigraphic profiles at Crow Lake, 10 km south of Mariana Lakes, indicate 1200 meters of sedimentary bedrock, suggesting a history of alternating inudations and exposures by an ancient inland sea (MacIsaac 1984). The uppermost bedrock stratum is the La Biche Formation, a 200 m layer of Upper and Lower Cretaceous marine shales. Lower strata are of marine shales and sandstone and include the Pelican, Joli Fou, Grand Rapids, Clearwater, and McMurray Formations. Information on surficial deposits and bedrock stratigraphy indicates that the area surrounding Mariana Lakes is mineral poor, being underlain by shales and sandstone with sandy outwash overburden.

Upland vegetation of the surrounding area is considered to be Boreal Mixedwood (Rowe 1972). Characteristic tree species of the upland forest communities are: *Populus tremuloides*, *P. balsamifera*, *Betula papyrifera*, *Betula neoalaskana*, *Picea glauca* and *Abies balsamea* on the well drained uplands; *Pinus banksiana* on the sandy areas and drier till soils; and *Picea mariana* and *Larix laricina* in water catchment areas. The peatland is in the Continental High Boreal wetland region, characterized by peat plateaus, palsas, and patterned fens (Zoltai and Pollett 1983).

Climate

The climate at Mariana Lakes can be classified as climate type VIII boreal cold temperate (Walter 1979). Typically the area experiences a low energy climate consisting of short winter days and long summer days. Climate at Mariana Lakes is strongly influenced by continentality. During the winter, this region is dominated by very cold, dry Arctic air masses (Strong and Leggat 1981), whereas during the summer months the mid-Albertan summer storm track, a belt where total summer precipitation values reach 400 mm extends over the Stoney Mountain Uplands, bringing more than 70% of the total annual rainfall to the area. Owing to this excessive summer precipitation, Strong and Leggat (1981) have classified this area as a wet subregion of the Boreal Mixedwood ecoregion.

Climatic parameters for Mariana Lakes have been tabulated from a mean of 1950-1981 weather data for Ft. McMurray 90 km north, Lac LaBiche 100 km south, Calling Lake 100 km south-west and Wandering River 75 km south of Mariana Lakes (Tables II-1 and II-2). Summer climatic data is augumented with data from forestry lookout stations at Algar 35 km northeast, Christina 35 km southeast, May 35 km south-west, Round Hill 65 km southeast, and Stoney Mountain 55 km northeast (Fisheries and Envir. Can., 1982). The mean annual temperature for Wandering River is 0.6° C whereas Calling Lake and Ft. McMurray are cooler with 0.3° C and -0.2° C. Annual precipitation values are the lowest at Ft. McMurray (471.9 mm) and Calling Lake (484.8 mm). Lac LaBiche situated on the edge of the mid Albertan storm track is considerably wetter, receiving 513.5 mm. Summer climatic data from Algar, May, and Stoney Mountain indicate that the Stoney Mountain Uplands are situated within this storm track and are receiving more summer precipiation than areas to the north and south. The peatlands at Mariana Lakes are therefore receiving a large amount of summer precipitation (>400 mm), an amount which is exceeded in Alberta by only a few areas in the foothills (Powell and McIver 1978).

Table II-1. Mean annual precipitation (mm) from 1950-1981, for the area surrounding Mariana Lakes. Twelve month data are from the four nearest towns, while the summer precipitation are from six nearby forestry lookout towers. Data taken from Powell and MacIver (1978), Alberta Environment (1982), and Fisheries and Environment Canada (1982)

Table II-1. Mean Annual Precipitation (mm) from 1950-1981.

Locality	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Mean
Calling Lake	28.1	23.7	17.8	14.5	41.8	90.9	91.3	65.7	46.9	20.2	21.5	22.4	484.8
Ft. McMurray	22.7	18.8	20.7	20.5	36.6	64.1	75.4	76.6	58.5	28.1	25.2	25.0	471.9
Lac LaBiche	27.1	16.4	24.9	16.7	55.7	82.8	88.1	79.8	57.0	19.6	22.5	22.9	13.5
Wandering River	22.0	27.1	14.7	15.8	43.0	89.2	94.8	66.2	46.5	18.3	22.0	25.1	485.1
Algar	-	-	-	-	52.8	88.1	106.3	97.0	72.8	38.2	-	-	-
Christina	-	-	-		48.9	90.8	88.4	77.7	-	-	-	-	-
May	-	-	-		54.1	103.1	115.9	99.8	75.7	25.8	-	-	-
Round Hill	-	-	-	-	39.7	88.4	95.3	89.3	55.5	24.9	-	-	-
Stoney Mountain	-	-	-	-	55.3	98.1	106.8	106.1	88.8	54.1	-	-	-

Table II-2. Mean annual temperature (°C) from 1950-1981, for the area surrounding Mariana Lakes. Twelve month data are from the nearest towns, while the summer temperatures are from six nearby forestry lookout towers. Data taken from Powell and MacIver(1978), Alberta Environment (1982), and Fisheries and Environment Canada (1982).

Table II–2. Mean Annual Temperature (°C) from 1950-1981.

Locality	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Mean
Calling Lake	-19.8	-14.3	-8.0	2.0	8.9	13.4	15.9	14.4	9.1	3.9	[illegible]	-15.3	0.3
Ft. McMurray	-21.8	-15.4	-9.2	2.1	9.7	14.0	16.4	14.8	9.0	3.3	-8.2	-17.0	-0.2
Lac LaBiche	-18.7	-12.3	-7.2	3.2	10.1	14.0	16.1	14.7	9.4	4.4	-6.4	-14.6	1.1
Wandering River	-19.8	-13.3	-6.6	2.8	9.7	13.7	15.8	14.3	9.0	4.0	-7.3	-14.7	0.6
Algar	-	-	-	-	8.0	12.5	14.7	13.5	7.5	-	-	-	-
Christina	-	-	-	-	-	13.3	15.5	13.9	-	-	-	-	-
May	-	-	-	-	8.6	12.8	15.1	13.6	7.8	-	-	-	-
Round Hill	-	-	-	-	9.3	13.3	15.3	13.8	8.3	-	-	-	-
Stoney Mountain	-	-	-	-	8.3	12.7	15.0	13.6	7.7	-	-	-	-

Landform Description

- The peatland complex surrounding Mariana Lakes is extensive, consisting of a network of discontinuous peatlands. This study is restricted to one complex mire. In Fig. II-2 the lightly shaded zones delimit the extent of the mire complex. Converging flow path~~s (arrows in~~ Fig. II-2) indicate that drainage is towards the larger lake located to the northeast. Situated in the western section of the peatland are four teardrop shaped Picea mariana dominated islands (medium shading) and two ovoid Picea mariana-Sphagnum islands (medium shading). Picea mariana-Sphagnum communities are also located along the flanks of the fen and interdispersed in pockets between adjacent mires. Mineral soil ridges (darkest shading) appear sporadically in the peatland and along the mire edge.

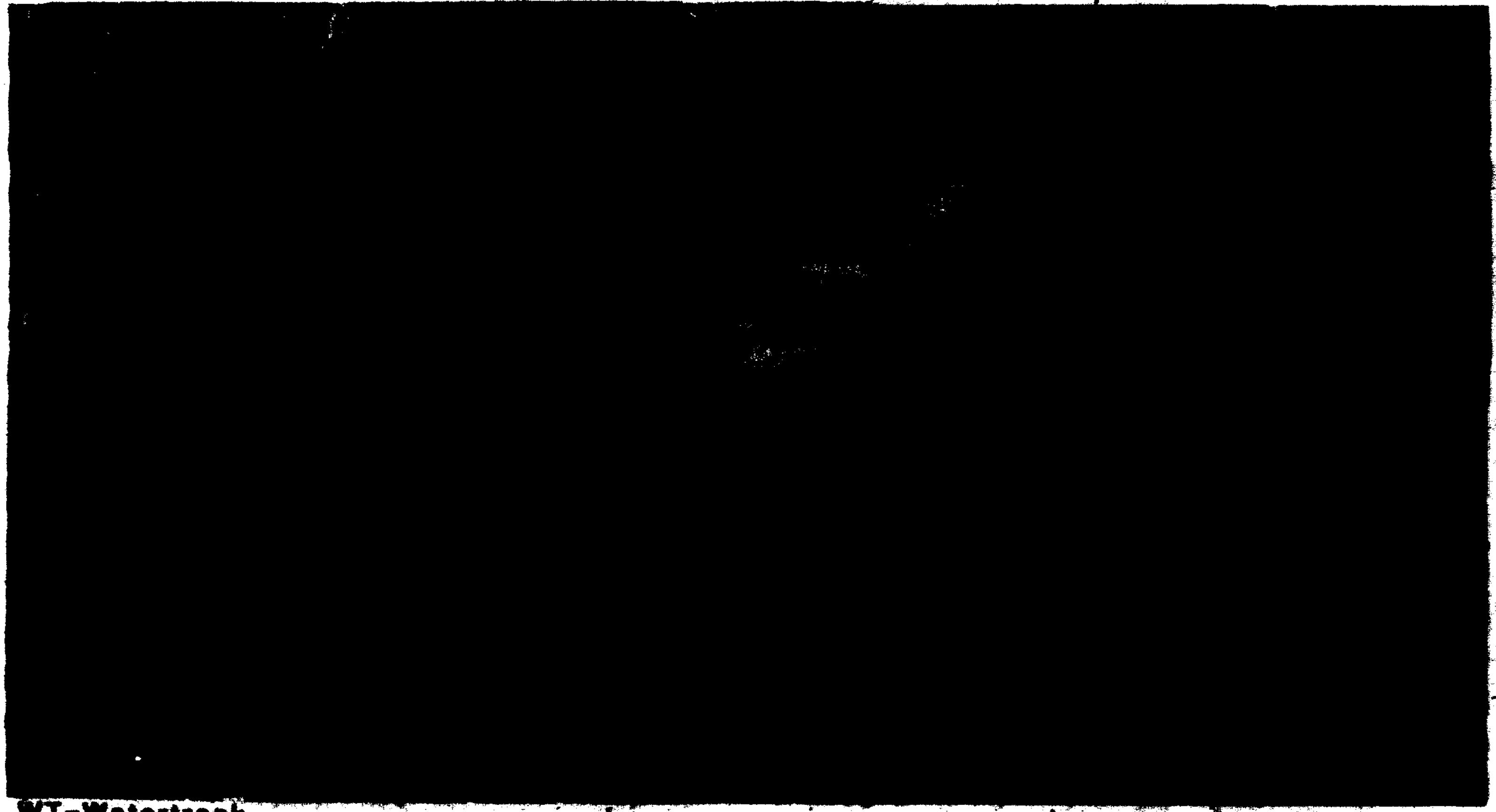
Peatland vegetation at Mariana Lakes is predominantly a broad expanse of Sphagnum lawn. Surface patterning is slight, consisting of Sphagnum hummocks and lawns. Carex limosa, C. chordorrhiza, C. aquatilis, Menyanthes trifoliata, and Andromeda polifolia are prominent members of the poor fen vegetation. Situated within the peatland and along the mire flanks, the Picea mariana-Sphagnum communities are characterized by Ledum groenlandicum, Chamaedaphne calyculata, Pleurozium schreberi, Rubus chamaemorus, and Vaccinium vitis-idaea.

C. METHODS

For the purpose of this study the peatland complex was divided into four areas, based on prominent surface vegetation and landform features. These areas are 1) Lake basin (LB), sites which surround the northeastern and northwestern lake basins. 2) Upper fen (UF), open fen vegetation, geographically located in the northwest section of the mire. 3) Lower fen (LF), open fen vegetation, geographically located in the northeast section of the mire. 4)Forested Sphagnum islands (FS), Picea mariana -Sphagnum covered islands located predominantly in the northwest section of the mire and along the flanks of the fen. Coring sites were selected on the basis of landform features of the peatland, as determined by air photo interpretation. Coring sites form two transects. The first transect traverses the upper

Fig. II-2. Map of Mariana Lakes study area with landform features indicated. Site locations (numbers 1-16) are shown. The mire is divided into four main areas: lake basin (LB) including sites 14,12, and 6; upper fen (UF) including sites 15,11,9,3, and 2; lower fen (LF) including sites 5 and 4; and forested *Sphagnum* islands (FS), including sites 16,13,10,8,7, and 1. Arrows indicate the direction of waterflow.

Mariana Lakes Study Area
Site Location and Landform Features



WT–Watertrack
FS–Forested Sphagnum Islands
UF–Upper Fen
LF–Lower Fen
⟶ Direction of Waterflow

portion of the peatland and includes all landform features, while the second follows the long axis of the mire to the outlet at the larger lake (Figure II-2). Each core site is situated on one of the four main vegetative-landform features; lake basin, upper fen, lower fen, and forested Sphagnum island (Fig. II-2).

Vegetation Sampling

At each of the sixteen coring sites, a releve was conducted to determine the present day vegetation structure. Canopy coverage was estimated to the nearest ten percent. Voucher specimens of all plants were collected and are deposited in the University of Alberta Herbarium (ALTA). Authority names and nomenclature for the vascular plants follow Moss (1983); Carex, Taylor (1983); Sphagnum, Vitt and Andrus (1977); Drepanocladus, Janssens (1983c); other mosses, Ireland (1982); and for the hepatics, Schuster (1966).

Water Chemistry

Surface water samples from natural depressions were taken on July 24, 1984, May 24, 1985, and August 17, 1985, in acid washed bottles of linear polyethylene and analyzed for pH, electrical conductivity, and major ions. PH measurements were taken directly in the field using an Electromate pH meter. Conductivity was analyzed at 25°C and corrected for hydrogen ions (Sjors 1952). Samples used for ion concentrations were filtered and preserved with 1 ml of 4N HCl and analyzed by an inductively coupled argon plasma spectrophotometer.

Peat Macrofossils

Peat cores were taken in duplicate at each coring site with a 5 cm diameter modified Macauley peat sampler. Peat stratigraphy was determined in the field on the basis of botanical composition and state of decomposition. Estimates of the percentages of Sphagnum, sedges, brown mosses, wood, and ericaceous shrubs were recorded for each stratum. Decomposition was determined using the Von Post scale. The first core had a 5 cm section of each stratum removed for bulk density and peat chemistry determinations. The second was kept intact by storing it in a half section of 2 m length polyvinylchloride pipe, wrapped in cellulose acetate. This core was later used for macrofossil analysis and radiocarbon dating.

Sections of peat (4 cm), used for macrofossil analysis were wrapped in thin cellulose acetate and then volumetrically measured using Janssens (1983) displacement technique. This method involves inserting the wrapped peat samples into a specially constructed 250 ml volumetric flask. A graduated cylinder is attached to the volumetric flask. A known volume of water (250 ml) is added to the flask and the amount of the displaced water measured. Following the volumetric measurement, each sample was soaked for 3 days in a 75% aqueous Areosol OT solution, a non-foaming wetting agent to allow for complete dispersion of the organic material. Samples were then wet sieved with a 500 um soil sieve and spiked with [illegible] g (958.88 ±52.32) of poppy seeds.

From each sieved and spiked peat sample, three subsamples were removed and distributed evenly on a channelled plexiglass template. 1% of the sample, as determined by a poppy seed count of 10 seeds, was isolated. Every macrofossil in the 1% subsample was tabulated, measured and identified. For all the bryophyte species only the stems were measured. For monocots (parallel veined graminoid material), ericaceous leaves and wood all identifiable pieces were measured. For *Picea* and *Larix*, needles were measured and counted. In assemblages containing a mixture of several *Sphagnum* species, the relative composition of each species was determined by examining the relative percentage present in the leaves. Three replicates were conducted to determine each percentage. The identification of *Sphagnum* was based on the shape and size of the stem leaves, and pore patterning in the branch leaves. This resulted in the grouping of some specimens of *Sphagnum* into the sections *Acutifolia* and *Cuspidata*. Macrofossil density was calculated using the following equation:

$$\text{mm stem/ml peat} = \frac{\text{Number of poppy seed counted} \times \text{mm stem measured}}{\text{Total number of poppy seeds} \times \text{ml of peat sampled}}$$

Percent frequency of each species was calculated as a proportion of the total mm stem/ml of peat.

Ten grams of peat was removed from the base of each core and at important stratigraphic boundaries, and dated at the Radiocarbon and Tritium Laboratory at Vegreville, Alberta (Table II-6). Additional cores were analyzed by estimating the percentage frequency of main macrofossil components. These data are given in Appendix I and Appendix II, and were used only to provide additional information.

Peat Chemistry

The 5 cm samples of peat removed for peat chemistry were weighed and air dried. A mortar and pestle were used to finely grind the samples. Subsamples of 0.2 to 0.3 g were dry ashed in a muffle furnace at 550°C for 16 hours. Ash residue was digested with 3 ml of 1.5 N HCl, 1 ml of concentrated HNO_3, and evaporated. A further 3 ml of 1.5 N HCl and 5 ml of distilled water was added to the dried salt. Solutions were filtered through Whatman #42 paper, volumetrically adjusted to 25 ml and stored in 30 ml polyethylene bottles. Ion concentrations were determined on an inductively coupled argon plasma spectrophotometer. Ion concentrations are calculated in mg/Kg of sampled peat.

Data Processing

The absolute method of data analysis by Janssens (1983), multiplied by the sedimentation rate (cm/yr) provides macrofossil influx rates in mm stem/cm^2 peat/yr. This method describes the amount of material accumulated per unit area per unit of time (Birks and Birks 1980), by eliminating differences in concentration that are due to substrate compaction. Macrofossil influx rates therefore reflect only changes that are due to the productivity and decomposition of individual taxa, and groups of taxa over time (Battarbee 1972). Conversely, data presented as % frequency indicates relative changes in community structure. Although it can be potentially misleading in zones of low productivity (Pennington and Sackin 1975), where small amounts of material account for large percentages, it can be used to assess effects of climate, hydrology and succession on peatland development. As I was interested primarily in community structure changes, I chose to present the bulk of my data in % frequency. For comparison I have presented three representative cores in macrofossil influx (mm stem/cm^2/yr) values. Total macrofossil accumulation rates for each core has been calculated in order to assess differences in peat productivity between cores.

Twinspan, a polythetic, divisive, detrended reciprocal averaging program (Hill 1979b), was used on % frequency data in order to obtain peat macrofossil assemblages, and to assess the relative similarity between extant releves and the peat macrofossil assemblages generated by *Twinspan*. Releves were ordinated using *Decorana*, a detrended correspondence analysis (Hill 1979a). Paleo-pH of the peat was calculated by deriving a linear regression equation based on weighted extant vegetation cover and water chemistry data from 60 sample plots taken throughout northern Alberta. Regression coefficients reflect each species input into site pH. Weighted macrofossil density data from the peat core macrofossil analysis was used to calculate paleo-pH from linear regression coefficients. Paleo-moisture was calculated by applying a moisture index based on species autecology (Table II-3) as described in Vitt and Slack (1984), Andrus (1974,1986) and Jeglum (1971) to weighted macrofossil density values.

Table II-3. Moisture index of species prevalent as macrofossils at Mariana Lakes. Index is based on species autecology by Vitt and Slack (1984), Andrus (1974, 1986) and Jeglum (1971). Moisture index was used to calculate paleo-moisture.

Table II-3. Moisture Index of Mariana Lakes Macrofossils

Species	Moisture Class
Larix laricina	2
Calliergon stramineum	3.5
Aulacomnium palustre	2
Meesia triquetra	3.5
Equisetum fluviatile	4
Vaccinium vitis-idaea	1
Carex limosa	3
Drepanocladus vernicosus	3
Drepanocladus lapponicus	5
Drepanocladus aduncus	5
Drepanocldus exannulatus	5
Sphagnum subsecundum (s.s)	3
Sphagnum majus	4
Sphagnum angustifolium	3
Sphagnum magellanicum	2
Sphagnum warnstorfii	3
Sphagnum jensenii	4
Sphagnum fuscum	1

D. RESULTS

Extant Vegetation

The 16 extant vegetation releves were placed into four physiographic-vegetation units by the *Twinspan* analysis. These are shown in Table II-4. The releve/species association table as generated by the *Twinspan* is shown in Table II-5. The main division divides the releves into those from open (upper and lower) fen sites, and those from forested Sphagnum islands sites with canopies of Picea mariana. The open fen releves are divided into those releves containing Sphagnum fallax (2,3,4,7) and those containing Carex chordorrhiza (5,9,12,14,15). Within closed canopy Picea mariana-Sphagnum sites, the primary division is based on the dominance of the shrubs Betula glandulosa and Ledum groenlandicum This shrubby character separates releves 11 and 6 from releves 1,8,10,13 and 16 (Table II-4). The vegetation releves relate to water chemistry. See Fig. II-3. Forested Sphagnum islands have the lowest pH (3.6-4.5) and conductivity (0-25 uS/cm) values. Calcium and magnesium concentrations are low at 1.1-2.4 mg/l and 0.2-0.6 mg/l respectively. Open fen sites containing Sphagnum fallax (2,3,4,7) are ionically poor having pH values between 3.8 and 4.2 and conductivity values of 31.8-41.6 uS/cm. Calcium concentrations are between 1.2 mg/l and 2.7 mg/l. Magnesium concentrations are between 0.4 and 0.8 mg/l. Open fen sites containing Carex chordorrhiza (5,9,12,14,15) are more ionically rich having pH values from 4.5-5.4, conductivity values between 0 and 62.8 uS/cm, calcium ion contents of 1.4-3.6 mg/l, and magnesium values of 0.4-1.0 mg/l. The two forested Sphagnum-Betula sites (11,6) are more minerotrophic and have the highest pH and conductivity values (pH 5.12-6.34, conductivity 64-232 uS/cm) and have calcium and magnesium contents of 3.4-15.6 mg/l and 0.9-2.8 mg/l respectively.

Peat Stratigraphy-Macrofossils

Lake Basin Sites (12,14, and 6)

Sites 12,14, and 6 are situated within former lake basins. Of these sites, 12 and 14 surround a small lake on the northwestern side of the study site (Fig. II-2), while Site 6 is in

Fig. II-3. Releves of surface vegetation positioned by *Decorana* ordination showing relationship between physiographic-vegetation units and surface water chemistry. Eigen values (Eig) for the first two axis are included.

Mariana Lakes

Surface Water Chemistry and Decorana Physiographic Types

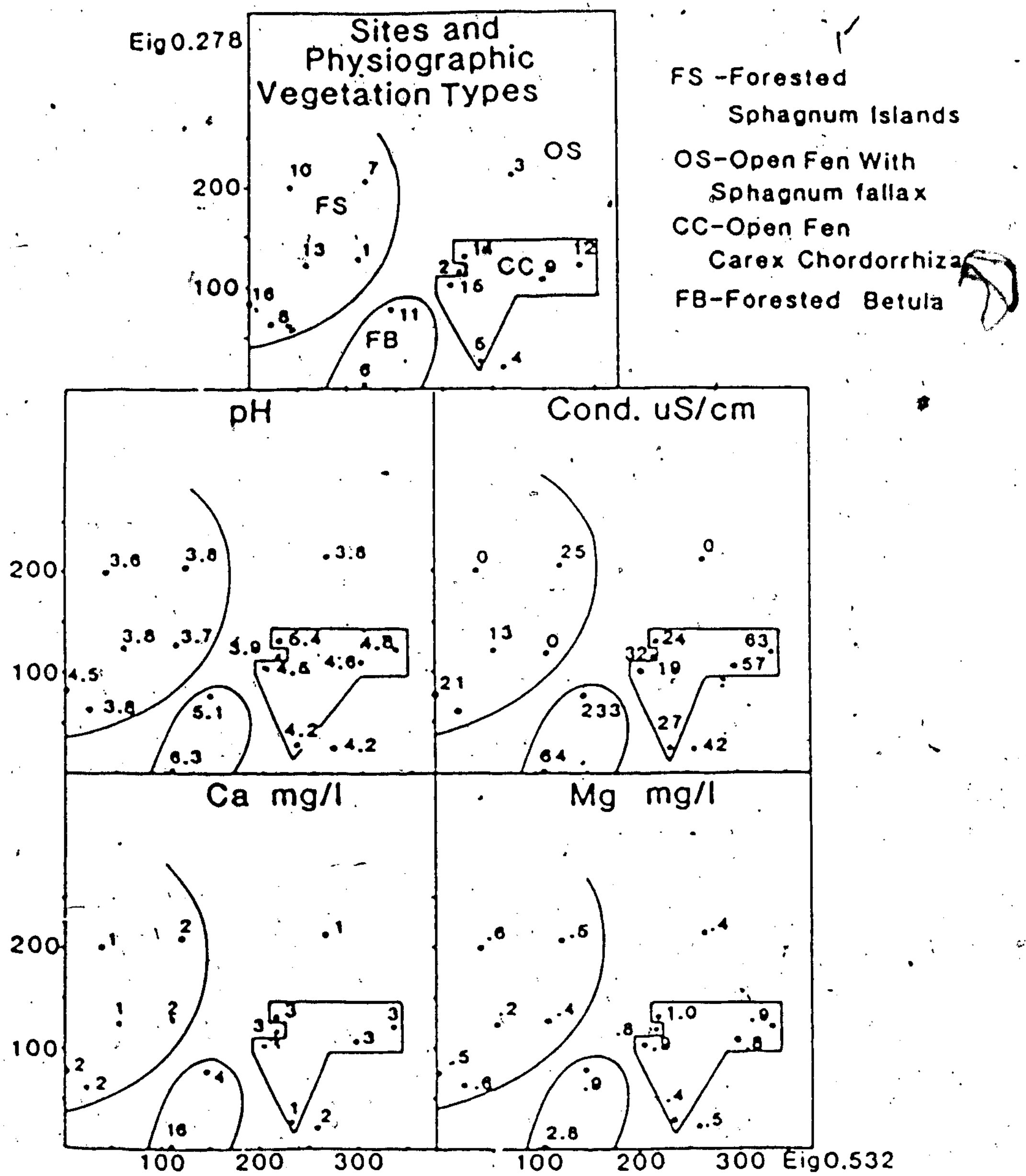
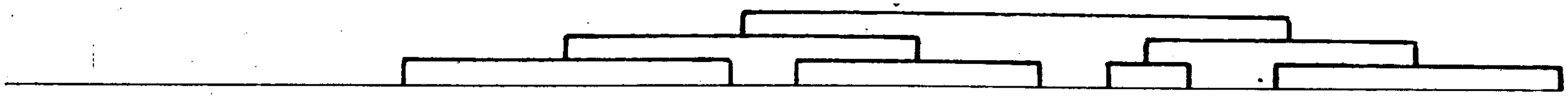


Table II-4. *Twinspan* classification of sixteen extant vegetation releves showing site divisions and indicator species. Water chemistry, pH, corrected conductivity (uS/cm), calcium and magnesium (mg/l) values for each site are indicated.

Vegetation Type		Physiographic Vegetative Unit	Sites	pH	Ca	Cond.
Forested	Sphagnum	FS	1	3.74	1.63	0
		FS	8	3.82	1.52	7.7
		FS	10	3.63	1.12	0
		FS	13	3.77	0.92	13.5
		FS	16	4.50	1.62	21.2
	Betula	FB	6	6.34	15.6	64.0
		FB	11	5.12	3.38	232.7
Open	Sphagnum fallax	OS	2	3.90	2.65	31.8
		OS	3	3.81	1.24	0
		OS	4	4.20	1.83	41.6
		OS	7	3.82	2.43	25.5
	Carex chordorrhiza	CC	15	4.55	2.80	19.5
		CC	9	4.65	2.71	57.4
		CC	12	4.84	3.47	62.8
		CC	14	5.40m	3.63	23.9
		CC	5	4.17	1.40	27.1

Table II-5. Twinspan generated species association for extant surface releves. Numbers are mean cover values on a scale of 1 to 8; •=<0.1. Physiographic-vegetational units are: CC-open fen sites with Carex chordorthiza, OS-open fen sites with Sphagnum fallax, FB-forested sites with Betula sp., FS-forested Sphagnum island sites.



	9 Site	12 Site	14 Site	5 Site	15 Site	2 Site	3 Site	4 Site	7 Site	6 Site	11 Site	1 Site	8 Site	10 Site	13 Site	16 Site
Physiographic-vegetational Units	CC	CC	CC	CC	CC	OS	OS	OS	OS	FB	FB	FS	FS	FS	FS	FS
Carex oligosperma						3	5					1				
Carex sp.						3		4								
Eriophorum Chamissonis							1	2								
Eriophorum scheuchzeri								1								
Sphagnum fallax		1	1		1	4	4	5	2				1			
Scheuchzeria palustris	1	1	1			3		4								
Sphagnum jensenii		4				4	4									
Pinquicula villosa	1					1										
Sphagnum majus	5	4	1			4	4									
Andromeda polifolia	5	5	5	5	5	5	5	5	4		5	4	1	1		1
Polytrichum strictum			2		1	3	3	1	3	1	1	1		1	1	
Carex limosa	4	2	2		1	3		2								
Menyanthes trifoliata	5	5	4					4								
Carex gynocrates			1													
Drosera anglica		1														
Equisetum fluviatile			2													
Juncus stygius			1													
Pedicularis parviflora		1														
Spiranthes romanzoffiana			1													
Utricularia intermedia		2	1													
Gramineae			1													
Drepanocladus lapponicus		1														
Meesia triquetra		1	1													
Riccardia palmata		1														
Sphagnum subsecundum	3	4	1								1					
Carex chordorrhiza	5	3	4	5	4			2		1	3					
Carex rostrata				5				1		1						

Drosera rotundifolia	1	1	2				1				1					
Aulacomnium palustre	3	1	3	1	1	1		1	1	1	1	1			1	
Carex paupercula	1				4						2	3				
Ptilidium ciliare				1								1				
Calliergon stramineum	1	1	1							1	1		1			
Drepanocladus vernicosus		1									1					
Scapania paludicola					1						1					
Sphagnum warnstorfii		1	1		1					1	1			1		
Triglochin maritima		1	1								1					
Betula glandulosa	3		4	2	3	1	1	3		4	5					
Carex aquatilis	1	4		5	4	3	3	1	2	5	4	1				
Larix laricina		1	2			1	1	1	1	3	3					
Tomenthypnum nitens			1		1						1					
Oxycoccus microcarpus	2	3	3	1	3	5	1	3	3	4	4	2	2	3	3	3
Sphagnum angustifolium	5	5	5	5	5	5	4	5	4	5	5	5	5	3	5	4
Sphagnum magellanicum	4	5	4	5	5	4	4	5	4	1	5	4	4	1	5	3
Eriophorum polystachion								1			1					
Eriophorum vaginatum	1				2	1	2	3	2			1		3		1
Pohlia nutans				1		1	1	3			1	1	1	1		1
Maianthemum canadense	1		2		2				4	1	3	3	3			
Salix pedicellaris	1		2	1	1					2	4					
Cephalozia sp.		1	1		1		1						1	1		1
Sphagnum fuscum			5		4	4	5	1	5	1	4	4		5	5	4
Drepanocladus exannulatus					1						2					
Drepanocladus uncinatus		1								1	1					
Calamagrostis canadensis										2						
Caltha palustris										1						
Carex pauciflora										2	3					
Carex tenuiflora											1					
Listera cordata											1					
Salix candida										2						
Campylium stellatum										1						
Cephalozia leucantha										1						
Plagiomnium medium										1						
Sphagnum squarrosum										1						
Hylacomnium splendens										3						
Bryum pseudotriquetrum							1			1	1			1		
Lophozia sp.				1	1		1			1	1	1			1	1
Chamaedaphne calyculata	1			2	2	2	2	1		4	5	4	4	2	4	3
Kalmia polifolia			1						1			3		1		

Picea mariana	1	1	1	1	1	3	2	1	2	4	4	5	4	5	4
Mylia anomala							1		1		1		1		1
Ledum groenlandicum					1	1	1	1	4	3	5	5	5	5	5
Cephalozia lunulifolia										1	1				
Pleurozium schreberi									5	3	1	5	3	1	5
Ptilium crista-crastensis									1			1			1
Rubus chamaemorus							1	1		3	4	2	3	5	5
Cephalozia connivens											1				
Dicranum elongatum											1				
Dicranum undulatum		1								1	1	1	1	1	1
Lepidoza reptans											1		1	1	
Salix sp.												1			
Vaccinium vitis-idaea									1	3		3	3	4	3
Cladina mitis													1	1	1
Cladina rangiferina													1		1
Cladina cenotea														1	
Cladina chlorophaea														1	
Dicranium polysetum														1	1
Parmelia sulcata													1		

the former basin of the larger lake, on the northeastern side of the study site. Basal radiocarbon dates indicate that peat formation began around 8180 (site 12) and 7170 BP (site 14)(Table II-6).

Site 12 (Fig. II-4)

Basal lake sediments at site 12 contain Chara, Drepanocladus, some monocots, and a few ericaceous shrubs. Following colonization by Drepanocladus , Carex limosa/paupercula, monocots and ericaceous shrubs increase in importance, while Chara declines. Drepanocladus sp. becomes particularly dominant from 600 cm to 410 cm, obtaining a frequency as high as 77% at 480 cm. This assemblage of Drepanocladus, Carex, monocots and ericaceous shrubs remains prevalent for 190 cm until at 3400 BP (410 cm) an abrupt transition to a monocot-Sphagnum community occurs. Ninety centimeters of this type of peat accumulates with little variation. An abrupt increase in the abundance of Sphagnum shifts the community composition into Sphagnum dominance at 300 cm with minor percentages of monocots, Carex limosa, and ericaceous shrubs. This phase is transitory and at 250 cm, the site becomes dominated with Drepanocladus, Meesia triquetra and Calliergon stramineum . Farther up the peat column, from 200 cm to 150 cm, Drepanocladus declines and monocots with Sphagnum dominate. Drepanocladus again become dominant from 150 cm to 100 cm and again at 50 cm to 29 cm. However, the prevailing assemblage from 250 cm to the peat surface is a monocot-Sphagnum assemblage that fluctuates considerably, including periods of dominance by monocots, Carex limosa/paupercula, Meesia triquetra, Sphagnum, and ericaceous shrubs.

Site 14 (Fig. II-5)

The peat column at site 14 is considerably shallower than site 12. As with site 12, site 14 begins with the deposition of limnic sediments, characterized by algal detritus, Chara, Drepanocladus , a few monocots and some ericaceous shrubs. In the lower portion of the peat core (390-250 cm) after algal detritus ceases to be deposited, Drepanocladus becomes dominant. Monocots, Carex limosa/paupercula, Larix, and Sphagnum are also present. After 230 cm, Drepanocladus declines and the relative frequency of Sphagnum increases. At a depth of 180 to 200 cm, Sphagnum becomes dominant for a very brief period (20 cm). Ericaceous

Fig. II-4. Macrofossil stratigraphy of Mariana Lakes lake basin site 12. Data is presented in percent frequency of number of stems/ml of peat. Species are: Algal detritus; Chara sp.; Drepanocladus spp. consisting of D. aduncus, D. exannulatus D. fluitans, D. lapponicus, and D. vernicosis; Monocots (paralled veined, graminoid); Carex limosa/paupercula; Meesia triquetra; Calliergon stramineum; Equisetum fluviatile; Aulacomnium palustre; Tomenthypnum nitens; Betula sp.; Larix laricina; Picea mariana; Wood (large fragments); Sphagnum spp., consisting of S. angustifolium, S. contortum, S. fallax, S. jensenii, S. magellanicum, S. majus, S. obtusum, S. platyphyllum, S. subsecundum, S. teres, S. warnstorfii, and the groups Acutifolia and Cuspidata; Ericaceous bark (small fragments); Ericaceous roots; Oxycoccus microcarpus; Chamaedaphne calyculata; Andromeda polifolia; Vaccinium vitis-idaea; Polytrichum strictum; Pohlia nutans; Pleurozium schreberi; and charcoal.

Site 12

Mariana Lakes Macrofossils

%Freq.

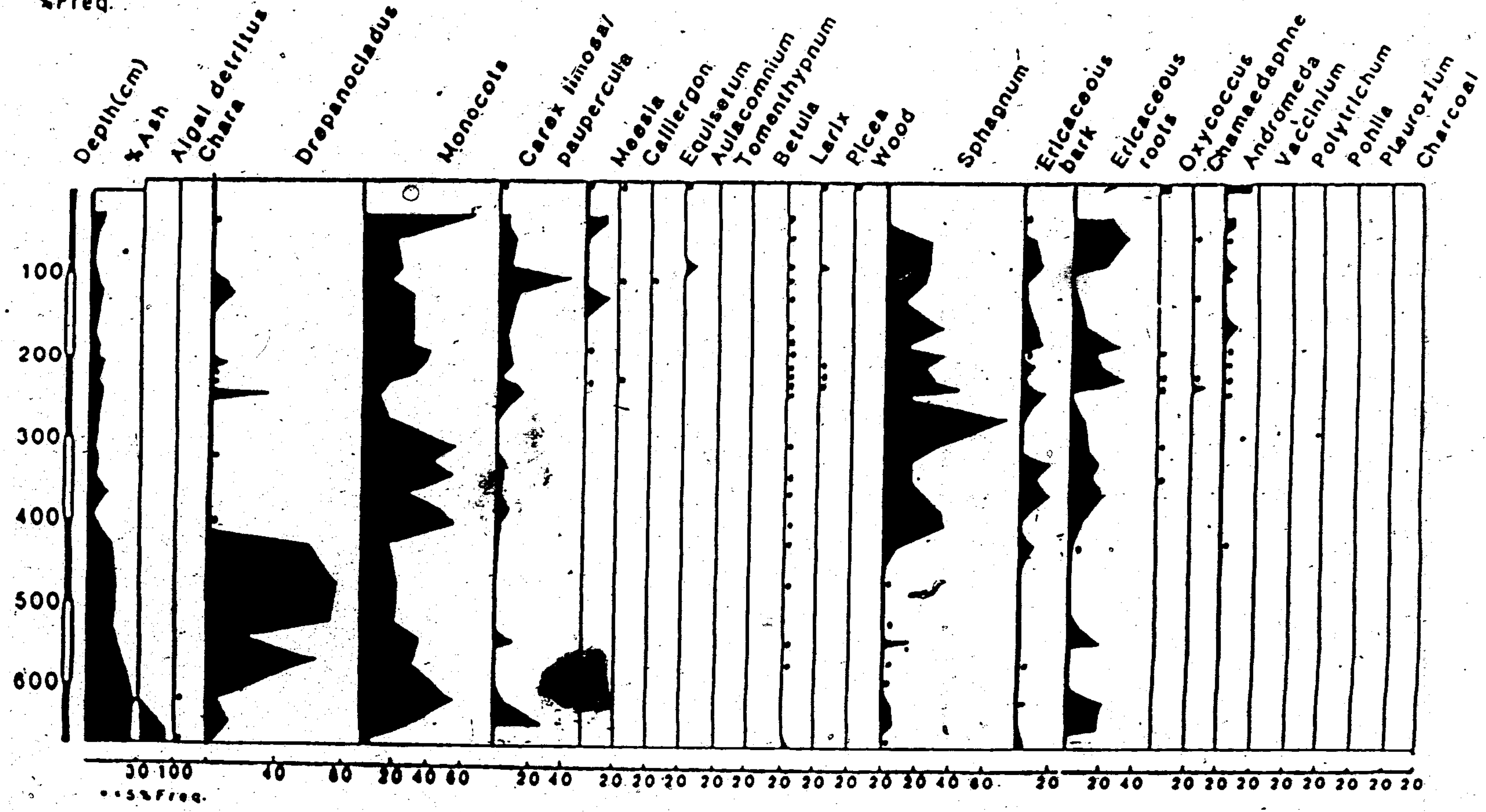


Fig. II-5. Macrofossil stratigraphy of Mariana Lakes lake basin site 14. Data presented in percent frequency of number of stems/ml of peat. See Fig. II-4 for abbreviations.

Mariana Lakes Macrofossils Site 14
%Freq.

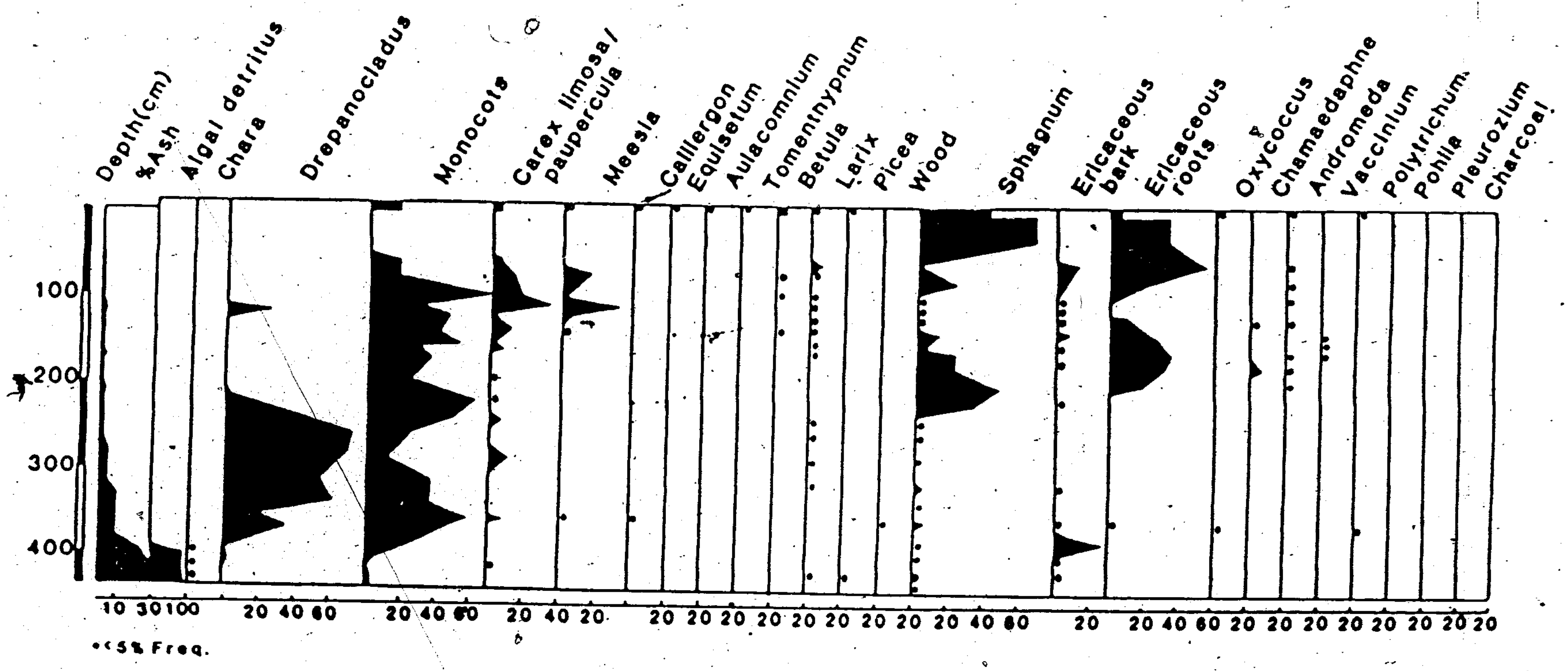


Table II-6. Radiocarbon C-14 dates of 10 gram peat samples from Mariana Lakes, dated at the Radiocarbon and Tritium Laboratory in Vegreville, Alberta. Years are given since 1950 (BP).

Table II-6.

Site	Depth in Core (cm)	Radiocarbon Date-years BP	Lab No.(AECU)
12	200-230	1760±100	256C
12	300-322	2250±130	257C
12	385-400	2960±140	96C
12	400-410	3400±120	98C
12	550-600	6120±130	258C
12	697-705	8180±150	95C
14	200-230	2090±160	259C
14	230-250	2050±130	260C
14	390-400	7740±110	261C
6	88-97	2070±100	251C
6	140-150	4930±130	252C
6	203-218	7170±130	178C
15	100-122	4240±100	264C
9	140-180	5130±100	196C
4	100-130	2960±150	176C
3	236-248	4290±110	179C
8	87-100	1730±80	255C
8	170-182	5800±110	177C
7	77-93	2110±100	253C
7	100-109	2680±100	254C
16	100-114	3710±80	262C
16	150-170	5270±90	263C
16	183-195	6740±100	212C
10	115-135	3190±90	265C
10	175-185	5160±120	101C

shrubs rise sharply after the Sphagnum and a stable community of monocots, ericaceous shrubs and Sphagnum exists for 75 cm. Increased occurrences of Drepanocladus , Meesia triquetra and Betula are recorded at 125 cm. This period is transitory as Drepanocladus declines in the next stratum, but Meesia triquetra, and Betula remain. Present day hummock species of Sphagnum and ericaceous shrubs begin to appear in the peat profile at 90 cm, with an increase in Sphagnum and ericaceous shrubs, and a sudden decrease in monocots, Carex limosa, Meesia, and Drepanocladus.

Site 6 (Fig. II-6)

Organic matter begins to accumulate at site 6 about 7170 BP, with a peat forming assemblage composed of monocots and Carex limosa. At the depth of 172 cm, ericaceous macrofossils become prevalent and increase in importance up to 126 cm. From 126 cm to 108 cm, wood, Larix, and monocots dominate, with a low percentage of Drepanocladus . Above 108 cm, ericaceous shrubs become re-established, followed by a rise in the frequency of monocots. Picea mariana needles become predominant at 97 cm. Following this period, the peat forming assemblage stabilizes with a community rich in monocots, carices, and ericaceous shrubs.

Open Fen Sites

Two distinctly different developmental patterns exist in the open fen communities. Sites 15,9,2, and 3, are fen sites located in the upper reaches of the peatland. They have a relatively long developmental history (4290 BP), as opposed to sites 4 and 5, which are located in the lower reaches of the peatland, and are considerably younger in age (2960 BP).

Upper Fen Sites (15,9,2,3)

Site 15 (Fig. II-7)

This site is representative of the four upper fen sites and is the only one discussed in detail. The first peat forming assemblage at site 15 consists of monocots, ericaceous shrubs,

Fig. II-6. Macrofossil stratigraphy of Mariana Lakes lake basin site 6 and lower fen site 4. Data is presented in percent frequency of number of stems/ml of peat. See Fig. II-4 for abbreviations.

Mariana Lakes Macrofossils
%Freq.

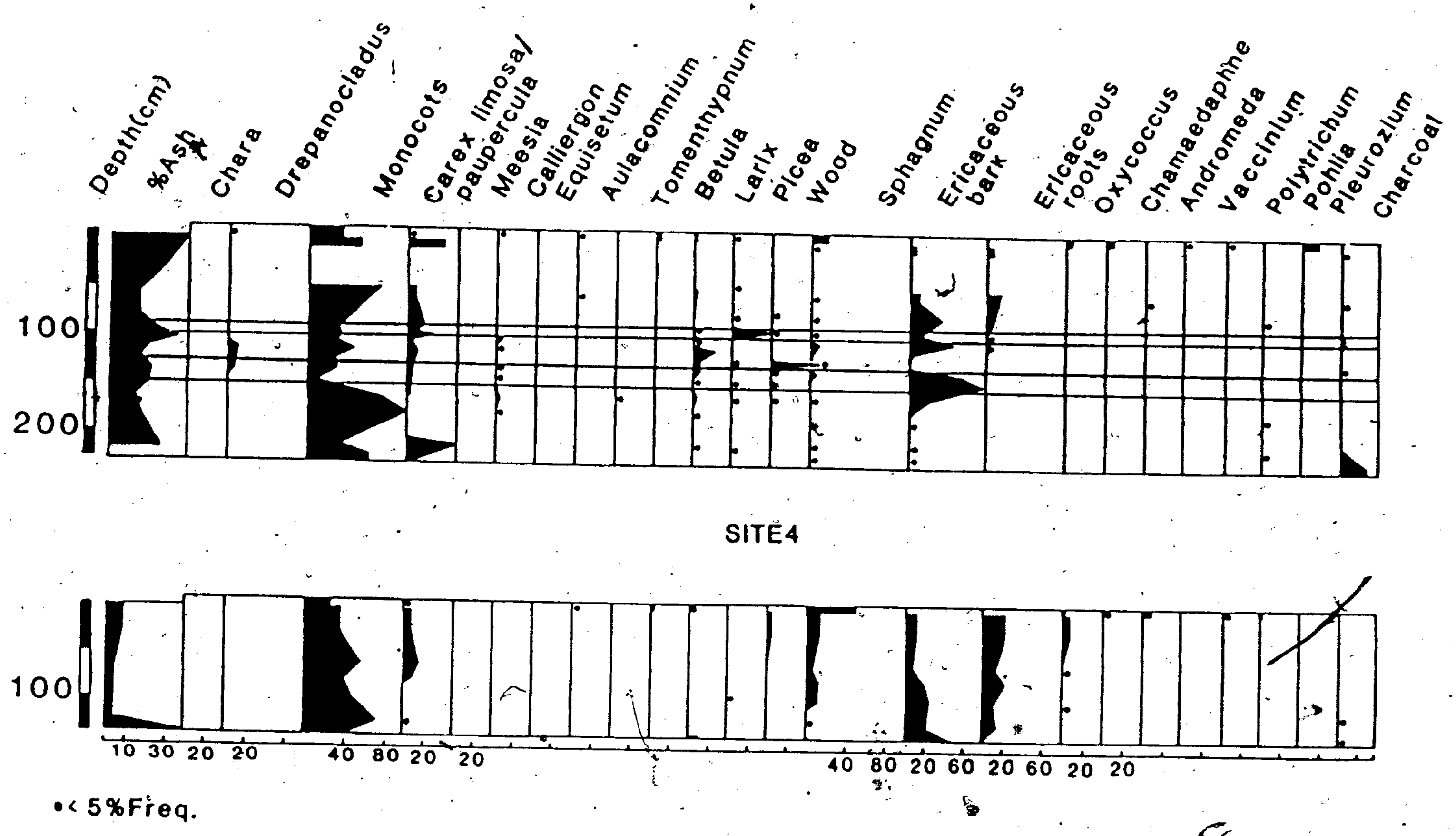
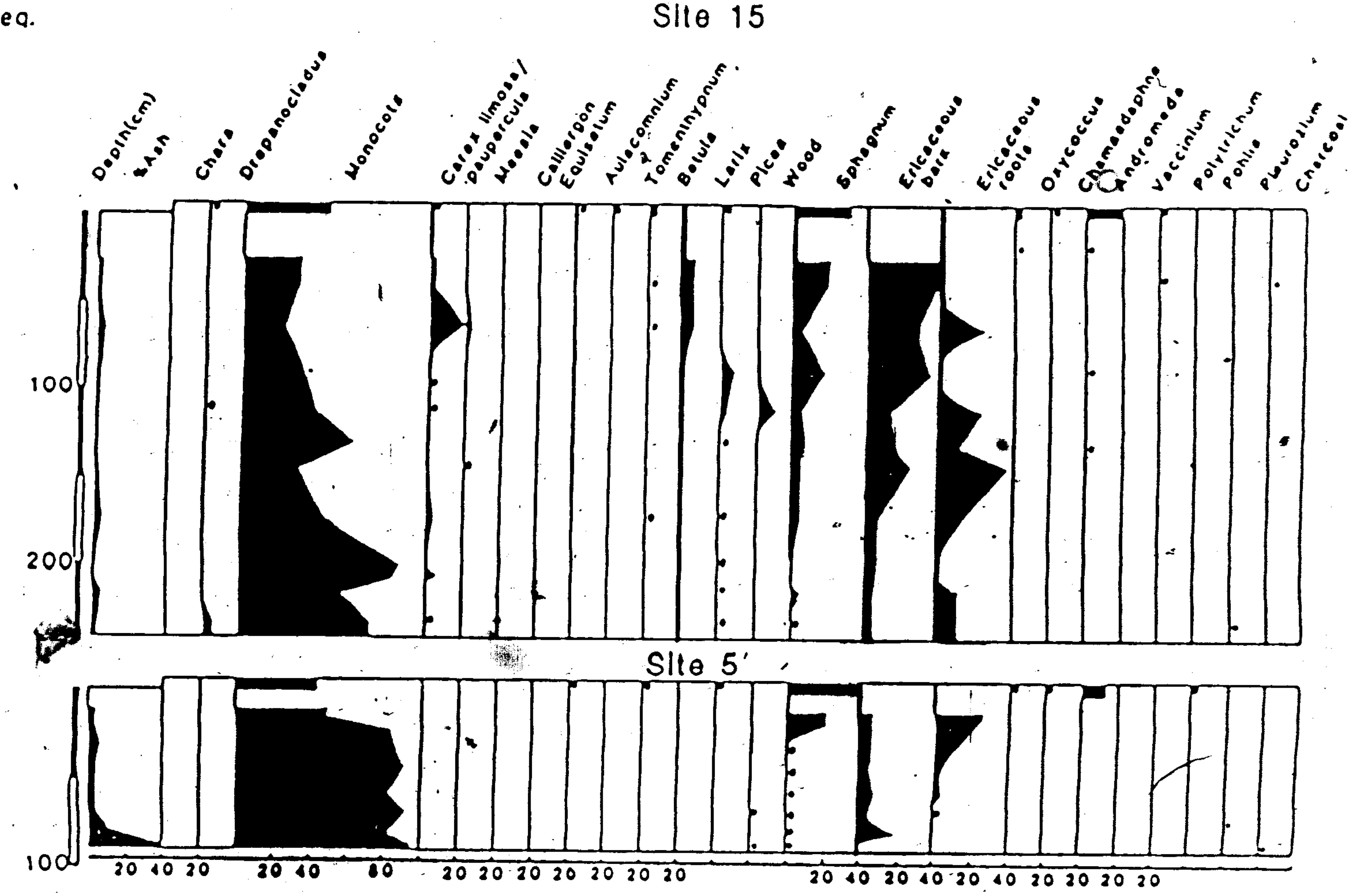


Fig. II-7. Macrofossil stratigraphy of Mariana Lakes upper fen site 15 and lower fen site 5. Data is presented in percent frequency of number of stems/ml of peat. See Fig. II-4 for abbreviations.

Mariana Lakes Macrofossils
%Freq.



Drepanocladus, Sphagnum, Picea mariana and Pohlia nutans. This assemblage exists for a lengthy period (240-150 cm). A gradual increase in the importance of ericaceous shrubs results in an ericad dominated assemblage. Between the depth of 138 cm and 122 cm, a brief reversion occurs, bringing the system back to a monocot-ericaceous shrub dominated assemblage. At 122 cm of peat, the abundance of ericads again increases, and the assemblage remains ericad dominated to the extant surface. Associated with the ericads is a high frequency of monocots, Sphagnum, and Larix laricina with minor amounts of Meesia triquetra and Betula.

Additional Upper Fen Cores (Sites 9,2,3). See Appendix I.

As with site 15, the additional upper fen cores have early peat forming assemblages which are dominated by ericaceous shrubs and monocots. Sphagnum is not present in the basal sediments, but becomes prevalent aft[illegible]48 cm of peat accumulation. In contrast to site 15, each of the three additional cores go[illegible]gh a period of Sphagnum dominance (55-65 cm at site 9, 189-200 cm at site 2, and 50-93 cm at site 3). Peat assemblages which succeed the Sphagnum peat are composed of varying proportions of Sphagnum, monocots, and ericaceous shrubs.

Lower Fen Sites (4,5)

Sites 4, 5 located in the lower reaches of the peatland are younger (2960 BP) and have a less complex peat sequence.

Site 4 (Fig. II-6)

One hundred and thirty centimeters of peat comprise the total peat accumulation at site 4. The initial peat forming community differs from previous fen communities in having 10% Larix macrofossils, and equal percentages of monocots and ericaceous shrubs. Throughout the peat core, monocots and ericads remain the dominant macrofossils. Sphagnum becomes more prevalent towards the upper sections of the core (14%).

Site 5 (Fig. II-7)

Basal macrofossils at site 5 have a high percentage (95%) of monocots. Picea is present, but in low abundance (3%). After 7 cm of peat accumulation, ericaceous shrubs become present in the core, and the monocot-ericaceous shrub assemblage remains dominant to the present day surface. Sphagnum is not a significant component of the peat profile until recently, where at a peat depth of 10 cm it obtains a relative frequency of 22%. Presently at site 5 Sphagnum covers 40% of the surface.

Sphagnum Island Sites (10,16,8,7,)

Site 10 (Fig. II-8)

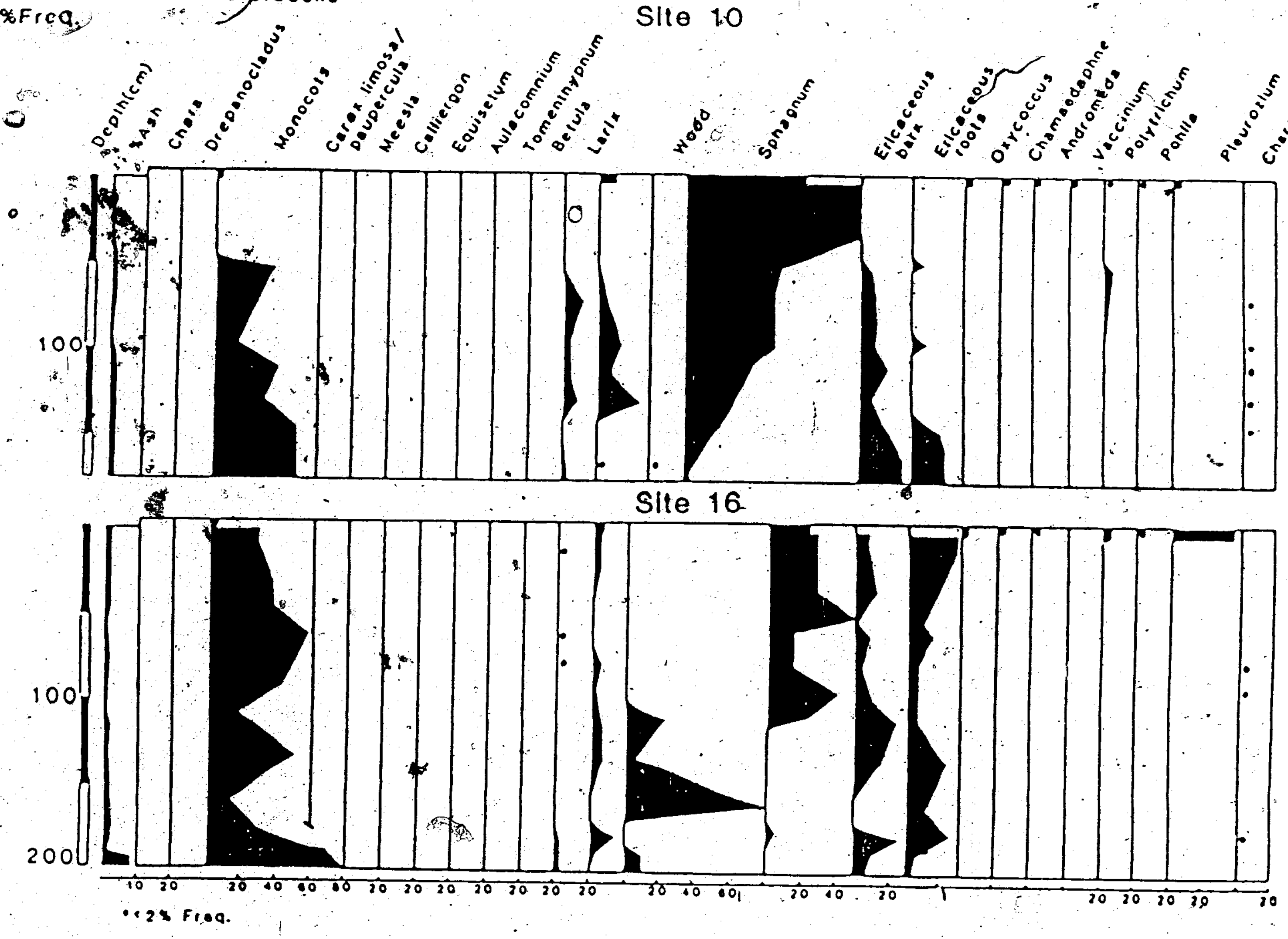
The basal peat at Site 10 contains a large percentage of monocots (47%) and ericaceous (44%) macrofossils. Wood comprises a low, but significant portion (7%) and is composed of both Larix and Picea fragments. At 135 cm, Sphagnum increases from a basal abundance of 3% to a dominance of 30%. Monocots remain high at 28%, and Picea increases to 26%. From this level upward, Sphagnum increases (to a maximum 52% frequency), monocots fluctuate from 14-37%, and Larix and Picea remain stable at 17%. Polytrichum strictum becomes prevalent at 85 cm. At 44 cm, monocots disappear from the fossil record and Sphagnum composes 100% of the profile. At present, the site is a dry Sphagnum fuscum dominant area.

Site 16 (Fig. II-8)

The peat assemblage structure of Site 16 at peat initiation has a high monocot component (77%), and a low ericaceous shrub component. As peat accumulates, monocot dominance declines and ericaceous shrubs expand, based on profile abundances of ericaceous bark and roots. A wood inclusion occurs from 170-150 cm. Following the occurrence of wood fragments, site 16 returns to monocot-ericad dominance. Thirty-six centimeters of this peat type is deposited, followed by another wood inclusion at 110 cm. A high percentage of Sphagnum and ericads is associated with this second inclusion. Monocots, together with

Fig. II-8. Macrofossil stratigraphy of Mariana Lakes *Sphagnum* islands sites 10 and 16. Data is presented in percent frequency of number of stems/ml of peat. See Fig. II-4 for abbreviations.

Mariana Lakes Macrofossils
%Freq.



Sphagnum and ericaceous fragments, remain dominant, with minor oscillations for 100 cm. In the most recent twenty centimeters of peat, the most frequent macrofossil component is ericads (36%). At the present time monocots are absent, while bryophytes (Sphagnum, Pleurozium), and ericads are the peat forming species.

Site 8 (Fig. II-9)

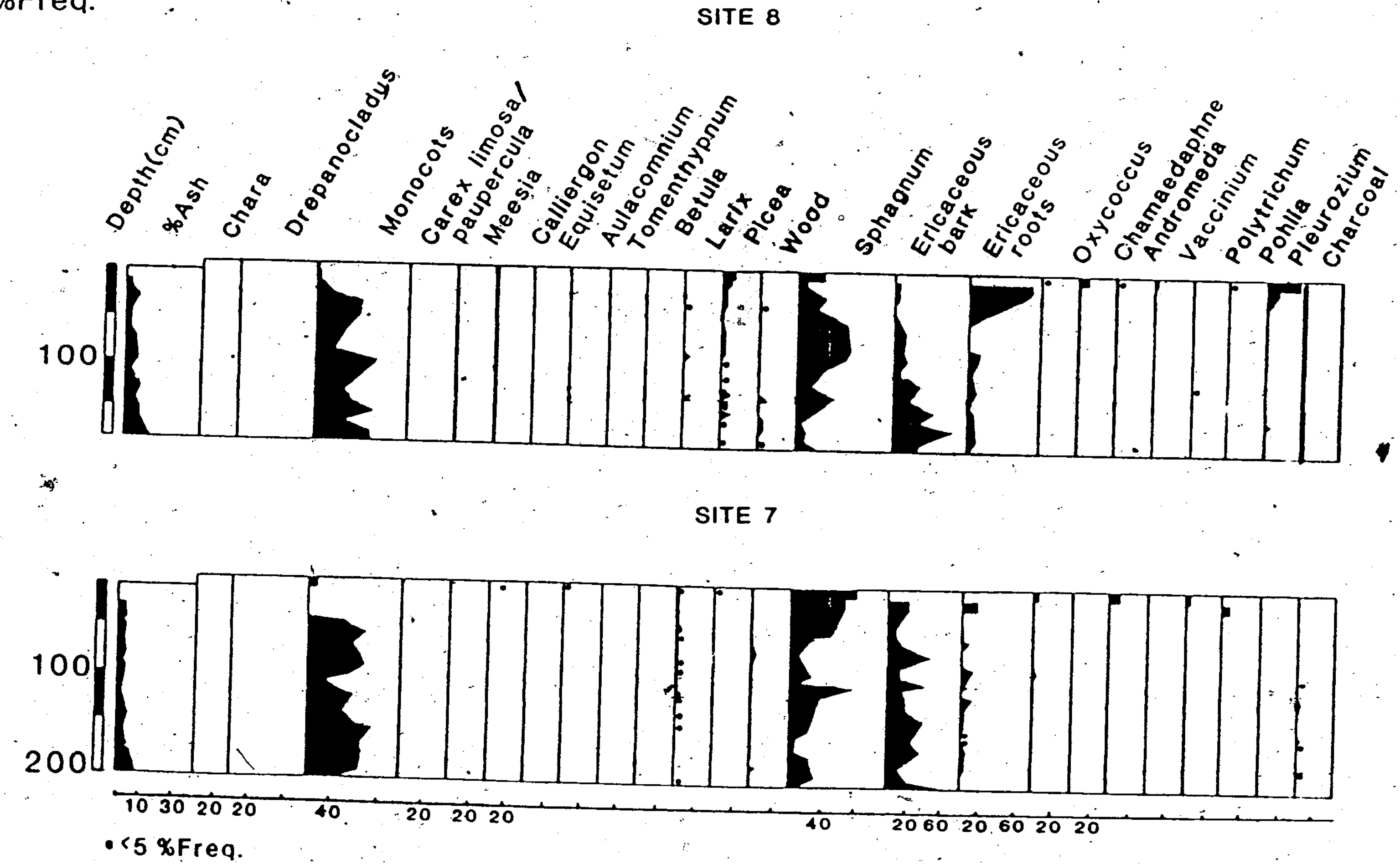
Peat accumulation at site 8 begins with assemblages similar to sites 10 and 16. Monocots are abundant (60%). Ericaceous shrubs (23%) and Sphagnum (15%) are common and some Picea (1%) is present. For the first 60 cm of peat accumulation, the peat forming assemblage oscillates between an ericad-monocot assemblage and a monocot-ericad one. Sphagnum is dominant briefly from 130-121 cm and is associated with a 10% rise in Picea and the appearance of Larix. Increases in both ericaceous shrubs and monocots bring site 8 temporarily back to a monocot-ericad dominant assemblage. At 100 cm, Sphagnum occurs and remains the predominant macrofossil for the next 59 cm. A high percentage of monocots and 3% frequency of Picea is associated with the Sphagnum dominance. At 41 cm, Sphagnum begins to decline and is replaced by ericads. Following this period, Sphagnum again increases, monocots rapidly decline, and site 8 remains as a Picea covered, ericaceous-Sphagnum community.

Site 7 (Fig. II-9)

Peat formation at site 7 begins with an ericad assemblage having a high percentage of monocots and a low percentage of Sphagnum. After peat becomes established, monocots form the dominant component, with Sphagnum and ericads as subdominants. As with previous sites, site 7 goes through a period of Sphagnum dominance (109 cm to 93 cm). Again this stage is only temporary, as Sphagnum declines from 67% to 8%, monocots rise to 46%, and ericads increase to 43%. The peat forming assemblage remains monocot-ericaceous for the next 53 cm, when Sphagnum once again becomes dominant, forming the Sphagnum-ericaceous shrub cap that is present on the site today.

Fig. II-9. Macrofossil stratigraphy of Mariana Lakes Sphagnum islands sites 8 and 7. Data is presented as percent frequency of number of stems/ml of peat. See Fig. II-4 for abbreviations.

Mariana Lakes Macrofossils
%Freq.



Additional *Sphagnum* Islands Cores (Sites 13,1) See Appendix II.

Ericads form a major component of the basal macrofossils at site 13 and 1. *Sphagnum* is not initially present at site 1, but comprises 30% of the basal macrofossils at site 13. The relative percentage of *Sphagnum* increases through both profiles, becoming dominant (92%) at 100 cm (site 1) and 140 cm (site 13). Both sites continue to be *Sphagnum* dominated to the present surface. Two wood inclusions occur at site 13. A layer of wood macrofossils occurs from 116-124 cm and a layer of *Larix* needles from 50-70 cm.

Accumulation Diagrams

Macrofossil Influx (Sites 12 (lake basin),15 (upper fen), and 10 (*Sphagnum* island))

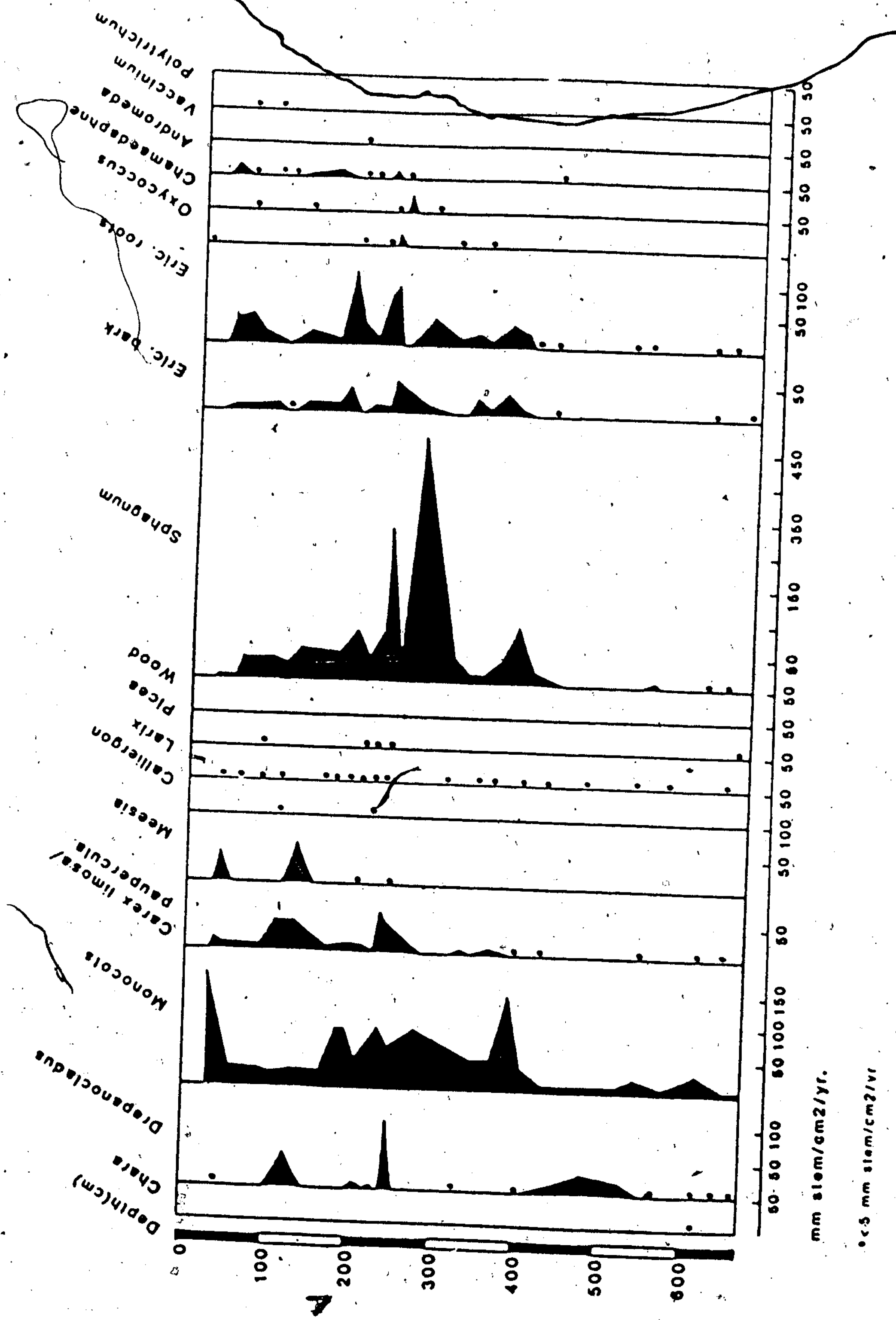
It can be seen from Fig. II-10 that peat accumulation at site 12 is initally low. Data presented as percent frequency (Fig. II-4) has exaggerated the relative amounts of *Drepanocladus*, monocots, *Carex limosa*, and ericaceous bark in the limnic and *Drepanocladus* stages. Significant accumulation rates begin subsequent to the *Drepanocladus* stage, with major contributions coming from monocots (29-50, 190-300, and 385-400 cm), *Sphagnum* (230-240, and 250-300 cm) and from ericaceous roots (180-190, and 220-240 cm).

The macrofossil accumulation diagram of fen site 15 (Fig. II-11) is not significantly different from the percentage (Fig. II-7) diagram. The major difference is a period of monocot accumulation that occurred from 193-200 cm. At site 10, (Fig. II-12) the macrofossil accumulation diagram differs only slightly from the percentage diagram. The monocot contribution is slightly overrepresented in the percentage diagram. The high correlation between the two diagrams is due to a constant deposition rate.

Peat Influx Rates

Fig. II-13 is a summary of the total peat influx rates for nine peat cores reflecting periods of increased production or decomposition. As the accuracy of the accumulation rates is dependant upon the chronology and that the maximum number of radio carbon dates per core is six, it should be understood that these graphs are estimates.

Fig. II-10. Macrofossil influx (mm stem/ cm^2 peat/yr) of lake basin site 12 at Mariana Lakes.



Mariana Lakes

Macrofossil Influx
Site 12

Fig. II-11. Macrofossil influx (mm stem/cm^2 peat/yr) of upper fen site 15.

Mariana Lakes

Macrofossil Influx

Site 15

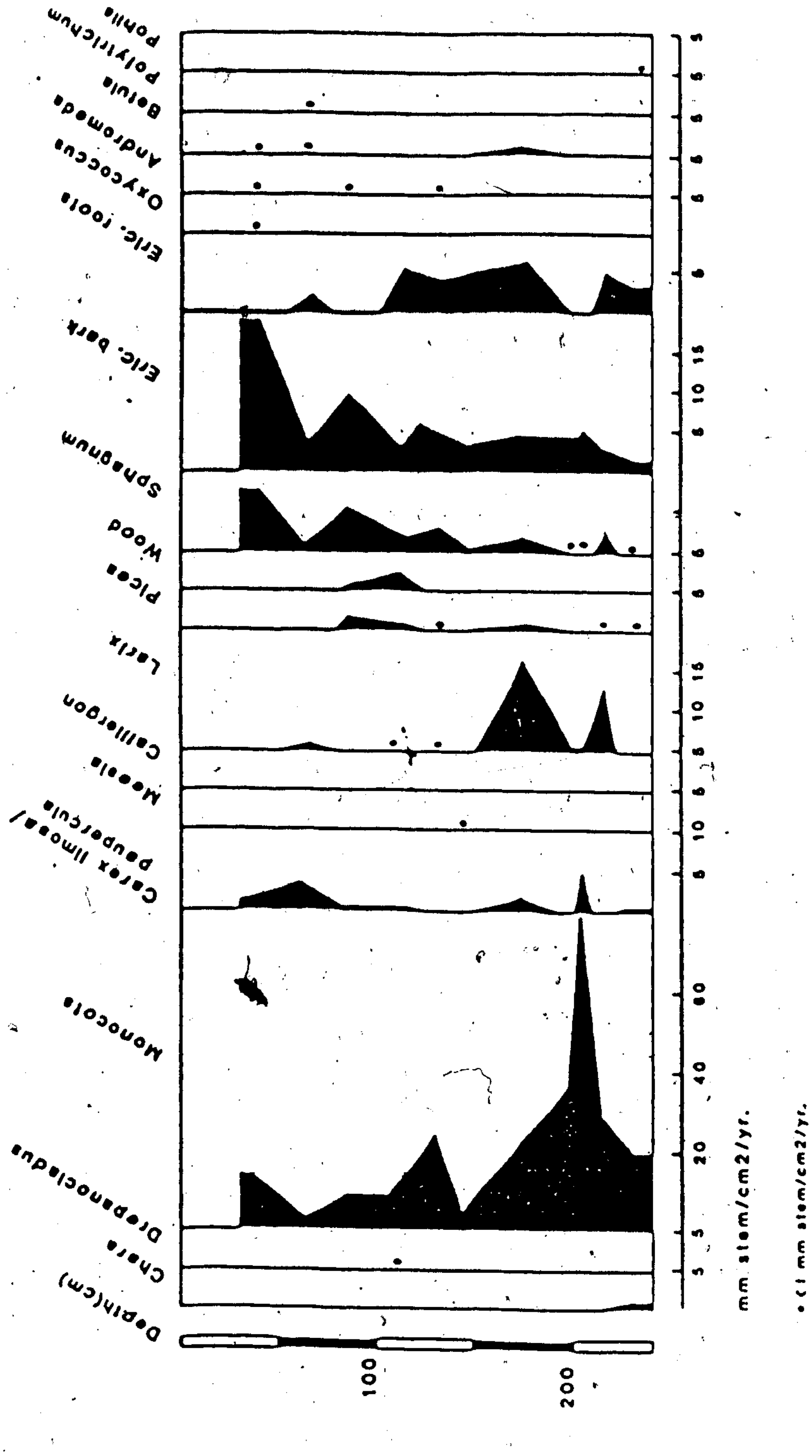


Fig. II-12. Macrofossil influx (mm stem/cm^2 peat/yr. of sphagnum island site 10.

Mariana Lakes

Macrofossil Influx
Site 10

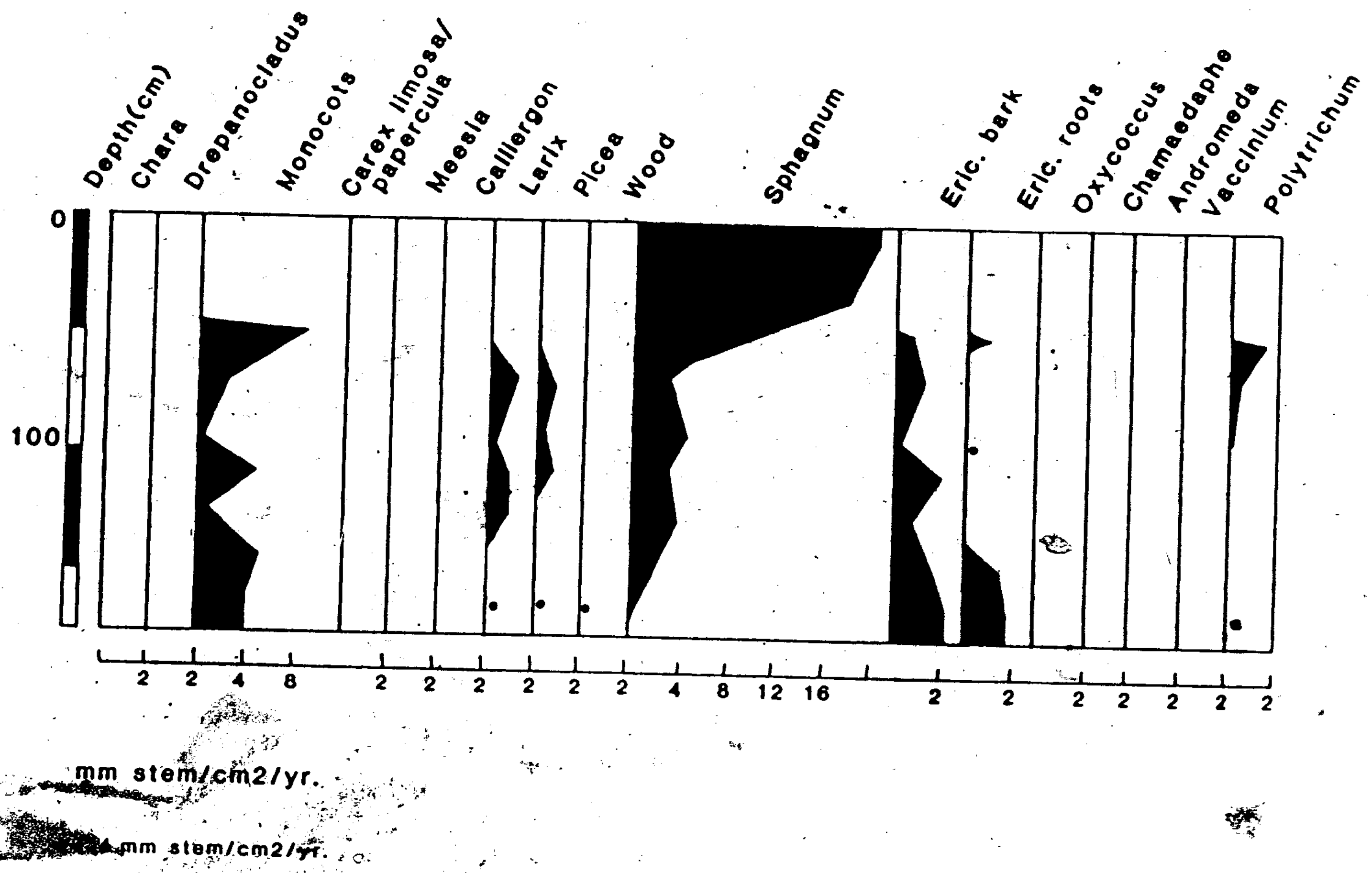
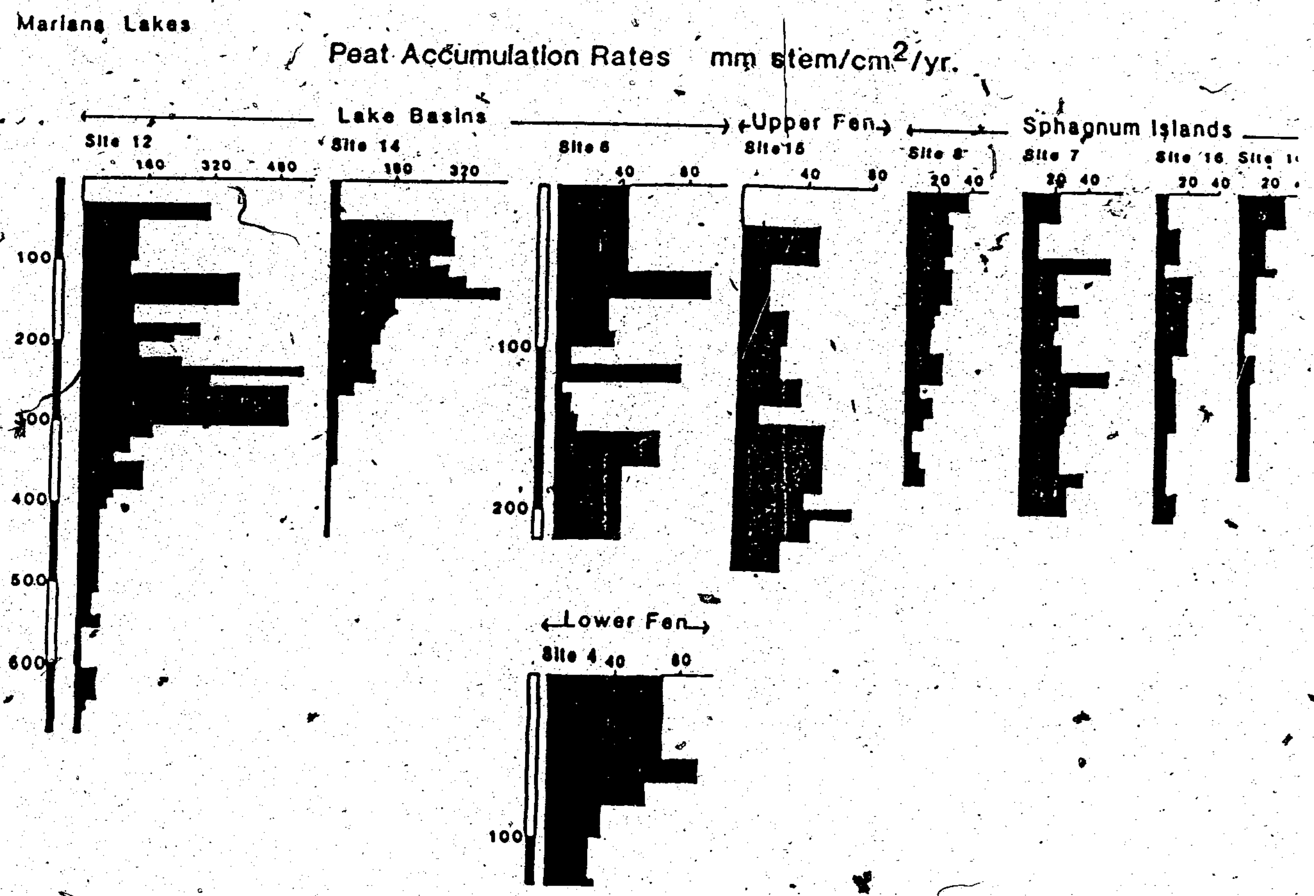


Fig. II-13. Peat influx rates (mm stem/cm^2 peat/yr) for all cores at Mariana Lakes. Sites are grouped according to lake basin, upper fen, lower fen and forested Sphagnum island areas.


Mariana Lakes
Peat Accumulation Rates mm stem/cm²/yr.
Lake Basins
Upper Fen
Sphagnum Islands
Lower Fen
Site 12
Site 14
Site 6
Site 15
Site 8
Site 7
Site 16
Site 1
Site 4
160
320
480
40
80
20
100
200
300
400
500
600

Lake Basin Sites (12,14,6)

Peat accumulation in the lake basin cores (sites 12, 14) is low throughout the limnic and Drepanocladus stages. Sphagnum, monocots and ericads contribute significantly to the accumulation. Macrofossil accumulation significantly increases to 530 [illegible]em/cm²/yr subsequent to the Drepanocladus stage. Peat accumulation at site [illegible]er (40-80 mm stem²/yr) than sites 12 and 14. Large fluctuations occur in the deposition rates that are associated with monocot macrofossils.

Upper and Lower Fen Sites

Peat accumulation in the fen sites (15,4) is one tenth of that in the lake basins (40-60 mm stem/cm²/yr). Fluctuations are more prevalent and are associated with increases in monocot and ericad macrofossil concentrations.

Sphagnum Island Sites (8,7,16,10)

Accumulation rates on the Sphagnum islands are the lowest at 10-54 mm stem/cm²/yr. Site 7 has a peak accumulation from 40-50 cm, 68-77 cm, and 109-120 cm, due to an increase in monocots. Sphagnum island sites 10 and 16 have low and stable accumulation rates.

Peat Stratigraphy - Macrofossil Assemblages

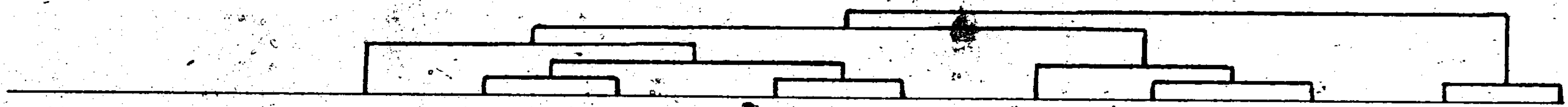
Twenty five macrofossil species in one hundred and thiry six peat samples were hierarchically arranged by *Twinspan* into ten macrofossil assemblages (Table II-7). The primary division is largely based on the presence/absence of algal detritus and Drepanocladus sp. Subsequent divisions are based on the amounts of Sphagnum , monocots, Picea mariana and Carex limosa/paupercula.

The first assemblage is group S1, having a high percentage of Sphagnum (50-70%) content. Mean peat calcium ion content for this group is 2195 mg/Kg. This assemblage constitutes surface and subsurface Sphagnum peats removed from sites 14, 17, and 10.

Table II-7. Twinspan generated association table for 25 macrofossils species in 10 macrofossil groups. Numbers are mean frequency values on a scale of 1 to 8; * = <0.1.

+ = Species names are given to these based on surface vegetation.

+ + = Drepanocladus spp. consists of D. aduncus, D. exannulatus, D. fluitans, D. lapponicus, D. vernicosus. Sphagnum spp. consists of S. angustifolium, S. contortum, S. fallax, S. jensenii, S. magellanicum, S. majus, S. obtusum, S. platyphyllum, S. subsecundum, S. teres, S. warnstorfii and the groups Acutifolia and Cuspidata.



Twinspan Groups	S1	S2	MS3	ME4	MC15	LS6	LM7	DM8	D9	L10
+ +Drepanocladus spp.						0.4	0.3	2.5	6.0	2.2
Chara sp.										1.0
Algal detritus										4.8
+ +Sphagnum spp.	6.8	4.3	2.6	1.2	0.3	2.3	0.9	1.8	1.1	1.4
Larix laricina		0.8	0.4	0.3	0.5	0.8	0.6	1.2	0.7	0.2
Monocots		3.5	4.6	4.6	3.0	3.9	5.5	3.8	3.3	2.8
Tomenthypnum nitens				•						
Pleurozium schreberi			•	•					•	
+Ericaceous bark	0.8	2.3	2.4	2.3	3.3	1.5	1.5	1.5	0.3	0.8
+Picea mariana		1.2	0.9	0.6	1.3	0.2	0.3	•		0.2
Pohlia nutans	0.4			•	0.5		0.2			
+Ericaceous roots	1.8	0.8	2.1	1.3	1.0	2.8	1.2	1.0	0.3	
Charcoal		•	•	0.1	0.5		0.8	•		
Polytrichum strictum		•	•	•				•		•
Wood		•	•	0.7	2.0	•		0.5		•
Calliergon stramineum				•	0.5	•		•		•
Aulacomnium palustre						•	•			
+Betula sp.			•			0.1	•	•		
+Vaccinium vitis-idaca						•				
+Chamaedaphne calyculata						0.2		0.2		
+Oxycoccus microcarpus			•			0.3		0.2		•
+Equisetum fluviatile								•		
+Andromeda polifolia		•		•		0.5	0.3	0.4		
Meesia triquetra						0.3	0.7	0.5		•
+Carex limosa/paupercul.		•	•	•	1.8	1.5	2.8	2.2	0.3	1.0
No. of samples	1	20	27	22	4	28	10	15	7	5
Peat Calcium mg/Kg	2195	3671	6046	7317	11538	10439	11022	10705	10327	8228
St. Dev.	-	432	1987	4073	3948	2082	6289	2774	2363	4491

Table II-8. Twinspan generated association table of 25 macrofossil species in 10 macrofossil groups. Numbers are mean frequency values on a scale of 1 to 8; • = <0.1

Group S2 has a slightly lower Sphagnum content (30%) than S1, with moderate (5-45%) amounts of monocots. Picea mariana, ericaceous bark and ericaceous roots form a large component of the assemblage. Mean calcium ion content for this assemblage is 3761 mg/Kg. S2 is predominant in the Sphagnum island cores, 7,8, and 10, but is also present in cores 12,14,15 and 16.

Monocots are predominant (45%)in macrofossil assemblage MS3. Sphagnum is still present (15%) as well as ericaceous roots, bark, and Picea mariana. Calcium ion content of the peat averages 6046 mg/Kg. Group MS3 is wetter and more minerotrophic than S2 and represents the more minerotrophic peat forming communities from the Sphagnum island cores (10,8,7,) and more oligotrophic phases of site 16, site 4 and site 5.

Monocots dominate (45%) in assemblage ME4, but with a higher percentage of ericaceous shrubs, a lower (0-15%) percentage of Sphagnum and the occasional appearance of Carex limosa/paupercula, and Calliergon. This assemblage is characteristic of minerotrophic shrubby sedge fens. ME4 forms the basal peat forming community at site 8,10, and 16 and the less minerotrophic portions of cores 15, and 6. Mean peat calcium ion content is 7317 mg/Kg.

Group MC15 has few occurrences of wood or Picea needles, but frequent low (2%) occurrences of Larix needles. Ericads are abundant, as well as Sphagnum, and monocots. Minerotrophic indicators such as Meesia triquetra, Drepanocladus ,Betula, and Carex limosa/paupercula have sporadic appearances. This is a small, restricted species assemblage common to only four peat samples. Modern analogues are likely to be located at site 6 where the extant vegetation has high coverage of monocots, ericaceous shrubs, and Larix laricina. Peat group MC15 has a higher mean calcium ion content of 11538 mg/Kg than group ME4.

Macrofossil assemblage LS6 is identified by moderate (15%) Sphagnum cover in association with Carex limosa and Larix laricina. Monocots and ericaceous shrubs are prevalent, with Meesia triquetra and Drepanocladus. This assemblage represents Sphagnum hummock communities within the ionically richer areas of the fen. Group LS6 has peat calcium ion content of 10439 mg/Kg.

Assemblage LM7 has substantially less Sphagnum (5%) and more monocots (60%) than LS6. Carex limosa/paupercula, Larix laricina, Meesia triquetra, and Drepanocladus continue to remain as important associates. This assemblage appears to have its modern analogue in the lawn communities of the more minerotrophic Sphagnum-sedge fens. Peat calcium ion content remains high in LM7 at 11022 mg/Kg.

High (30-40%) percentages of monocots, and moderate (15-30%) percentages of Drepanocladus and Carex limosa characterize macrofossil assemblage DM8. Sphagnum is present in low amounts (0-5%) as well as Larix laricina and Meesia triquetra. Calcium ion content of the peats in DM8 average 10705 mg/Kg. This assemblage originates from wetter and more minerotrophic conditions than assemblages LS6 and LM7. DM8 was also found above and below D9, the Drepanocladus stages of sites 12 and 14.

D9 macrofossil assemblage is distinct as it has a high (45-75%) percentage of Drepanocladus macrofossils. Monocots are still prevalent (5-30%) and Sphagnum is extremely low (0-5%). Mean peat calcium ion content is 10327 mg/Kg. This assemblage has its origins in floating Drepanocladus mats which formed around the periphery of the lakes.

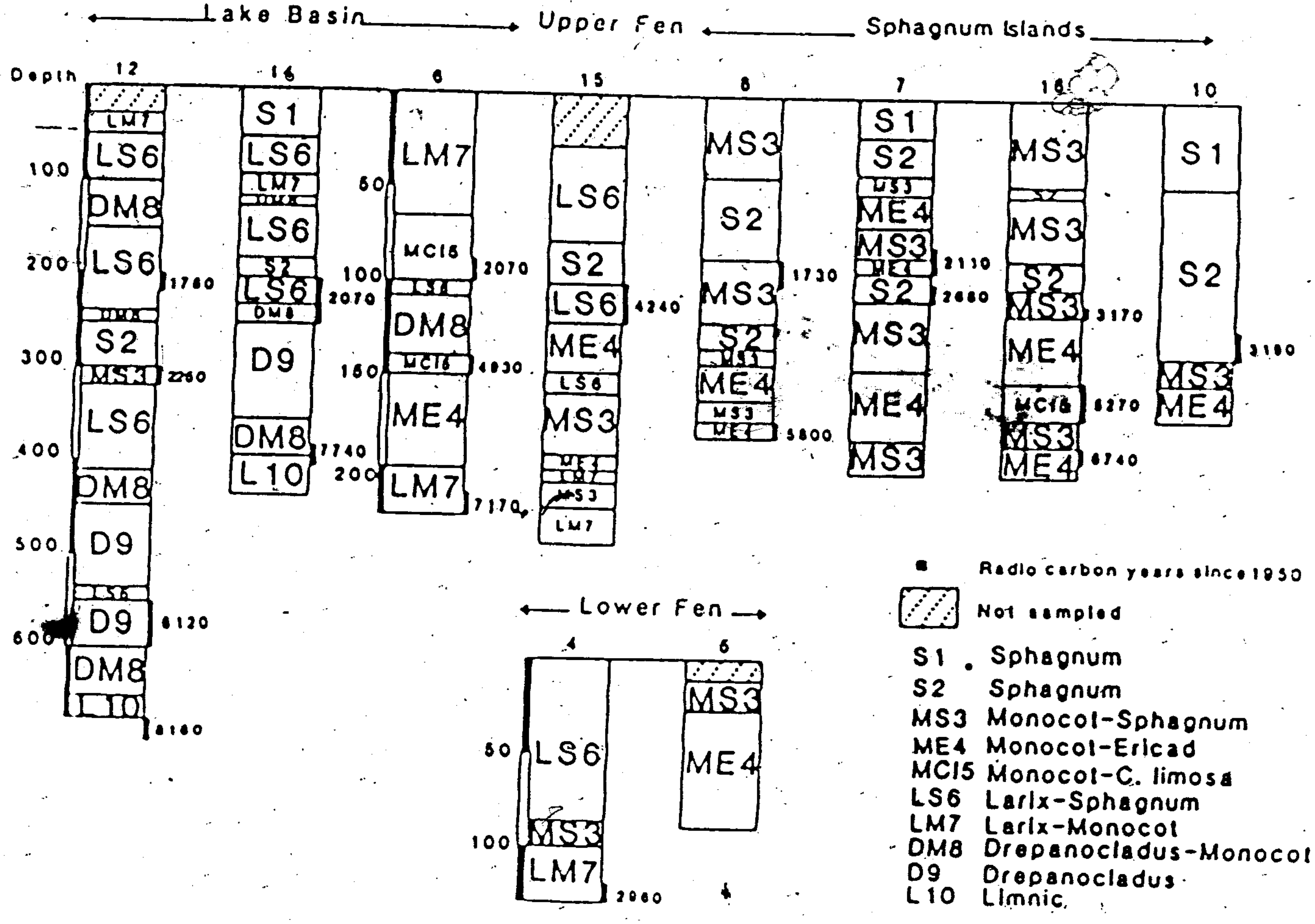
L10 is a small group of peat samples which contain very few macrofossils. These samples were located at the base of sites 12 and 14. Macrofossils consist of Sphagnum, Chara, monocots, and algal detritus. Due to the finely stratified nature of the substratum and the presence of Chara oospores this assemblage has been interpreted as limnic in origin, with calcium ion contents of 8228 mg/Kg.

The macrofossil assemblages generated by Twinspan follow both a minerotrophic (see Table II-7) and moisture gradient (see below) . Figure II-14 presents a summary of macrofossil assemblages for the ten analyzed cores.

Fig. II-14. Classification of macrofossil assemblages of ten of the sixteen peat cores for Mariana Lakes. Peat cores are grouped according to lake basin, upper fen, lower fen, and Sphagnum island areas. Radiocarbon years since 1950 are indicated for each core. Assemblages classified by *Twinspan* are based on major macrofossil components (see Table II-7).

Mariana Lakes

TWINSPAN MACROFOSSIL CLASSIFICATION



E. DISCUSSION

Lake Basins (Sites 12,14,6)

Sites 12 and 14

Sites 12 and 14 surrounding the northwest lake, have the wettest and most calcium rich peat profiles, beginning with L10 limnic sediment group and ending with either LM7 or S1. The stratigraphy of sites 12 and 14 suggest a classical hydrosere or terrestrialization process, whereby lake basins are quickly colonized by algae, zooplankton (Everett, 1983), and aquatic plants. At sites 12 and 14, the early lake species were Chara, Drepanocladus, monocots and algae (L10). Later, infilling occurred, and floating mats of Drepanocladus, sedges, Sphagnum, and ericaceous shrubs formed (D9). The floating mats provided structural support, promoting an increase in Sphagnum production. This resulted in a vegetation change towards a Sphagnum-sedge fen (LS6). Sphagnum dominance followed, with coalescence of the Sphagnum hummocks (S2). Reappearance of Drepanocladus, Meesia, and Calliergon (DM8) in the macrofossil record, and an associated decline in Sphagnum suggests that minerotrophy increased and the system changed from an ionically poor Sphagnum dominated peatland to a more ionically rich monocot-Sphagnum dominated poor fen. Minor oscillations in monocot, ericad, and Sphagnum abundance in this last stage are likely due to alternating patterns of the Sphagnum lawns and hollows as Sphagnum lawns shift and pools coalesce (Foster et al., 1983).

Site 6 (surrounding the larger northeastern lake)

Early peat development at site 6 (Fig. II-2) began in a drier, more nutrient poor environment than sites 12 and 14, as indicated by the macrofossil group LM7. This area may have began as a sedge dominated marsh, a monocot community which is prevalent on inundated shorelines today. Gradually the site was invaded by ericaceous shrubs Larix, and Picea, and became drier with less mineral influence (ME4). Renewed flooding occurred, tree cover diminished and monocots increased (DM8). At present, the surface water at site 6 moves in channels around shrub and ericad covered mounds. Fluctuating percentages of ericads, wood, and monocots in the peat profile have reflected shifting drainage patterns in this area.

Upper Fen (Site 15)

The peat profiles from the upper fen area indicate that they were originally positioned in a watertrack and overtime have remained under minerotrophic (ground water) influence. The area originated in a basal peat forming community of Larix, monocots and ericads (LM7). For a period of time the area became drier, and less minerotrophically influenced, as indicated by the presence of ME4, MS3, and S2 macrofossil groups. Continual ground water input is suggested by the periodic re-occurrence of LS6.

Lower Fen (Sites 4,5)

Only minor changes in the macrofossil assemblages have occurred in the lower fen sites following peat initiation. Site 4 began as a sedge community similar to the basal community at site 6 (LM7). Fluctuating minerotrophic influences have occurred, indicated by the presence of ionically poor MS3 peat followed by ionically rich LS6 peat. Peat development at site 5 began in the dry,ionically poor macrofossil group ME4. Recent expansion of Sphagnum in the MS3 peat group is likely due to the isolating effect of the accumulating peat.

Sphagnum Islands (Sites 10,16,8,7,)

Site 10

Three stages of peatland development are present at site 10 (Fig. II-8). The first stage is a ionically poor monocot-ericad peat (ME4), with a low abundance of wood and Sphagnum. The second stage is a deep section of peat consisting of Sphagnum-monocot peat (S2) with many wood inclusions. The third stage is Sphagnum (S1) dominated.

Site 16

The developmental history of site 16 is complex. Macrofossils of the basal peat are predominantly of monocots and ericads with wood inclusions (ME4). Subsequent strata oscillate back and forth between monocot-ericad peat assemblages and monocot-Sphagnum assemblages (ME4 and MS3) The developmental history of site 16 suggests alternating minerotrophic and ombrotrophic influences. Site 16 is an ecotonal community lying between a fluctuating water track community at site 15, and an fluctuating Sphagnum island community at site 10.

Site 8

Basal peat formation at site 8 began as a Carex, Picea and ericad shrub community (ME4). It underwent a period of Sphagnum dominance (S2) that was very transitory in nature, and reverted quickly back to a more ionically rich peat (MS3). The second section of Sphagnum dominance (S2)is more extensive and ends with a gradual increase in monocots, indicating renewed minerotrophy. Site 8 appears to have maintained its ombrotrophic conditions, as a recent expansion of ericads and Sphagnum has occurred. Surface physiognomy at site 8 suggests that this site is not hydrologically isolated. Therefore, the complex history of site 8 is probably due to its tenuous hydrological profile, and it is easily influenced by hydrological conditions in the adjacent watertracks.

Site 7

Although site 7 initially developed on a dry, monocot, Sphagnum, and ericad covered site, it was quickly inundated resulting with a ME4 peat group. As with site 8, it was influenced by a period of high Sphagnum abundance (S2). Following this phase, site 7 reverted back (ME4,MS3), suggesting fluctuating mineral influences. More recently at 44 cm, site 7 has developed into an open Sphagnum and shrub covered bog.

Summary - Macrofossil Assemblages and Peatland Development

Comparison of the ten macrofossil classification profiles suggest three stages of peatland development. Lake basin cores have the wettest most ionic peat profiles. Early terrestrialization stages are the wet minerotrophic L10, D9, and DM8 peat assemblages. Late terrestrialization stages are the drier minerotrophic LM7, LS6, and MC15 peat assemblages. Open fen cores (upper and lower), are intermediate in position. Initial peat assemblages are either LM7 or ME4, progressing to drier more oligotrophic MS3, S2 peat assemblages. Forested Sphagnum islands sites have the driest, most oligotrophic peat profiles. Peat profiles begin with MS3, ME4 peat assemblages, succeeding to S2 and S1 assemblages. Site 10 has the most stable peat profile indicating gradual progression from peat assemblage ME4 to assemblage S1.

Environmental Reconstructions

A model of peatland genesis and development in continental western Canada.

Paleo-pH

The ecological relationship between mire vegetation and environmental gradients has been documented in peatland literature since the 1920's (Glaser 1982, Jeglum 1971, Reinikainen et al. 1984, Sjors 1952, Vitt and Slack 1984, Waughman 1980). Species specific quantitative data for mire vegetation has been recently undertaken by only a few authors (Jeglum 1971, Janssens and Glaser 1986, Vitt and Slack 1984, and Andrus 1974). With the acquisition of species specific data it is possible to utilize macrofossil data to quantify past environmental conditions.

PH inferences based on diatom autecology have been used by limnologists since the 1930's to reconstruct the pH history and acidification of lakes (Battarbee 1984, Davis and Anderson 1985, Renberg and Hellberg 1982, Webb and Clark 1977). PH inferences are supported by quantitative relationships between present environmental conditions and associated diatom communities, that are expressed as an index or multiple linear regression equation. Reconstructions determined by diatom occurrences are known to have standard errors of between *ca* 0.25 and 0.5 pH units, the lowest being calculated by multiple regressions on individual taxa or on their principal components (Battarbee 1984, Davis and Anderson 1985).

Due to the low number of macrofossil groups present in the peat cores at Mariana Lakes, multiple regression on individual taxa was chosen as the best method for pH reconstruction. Weighted percent cover values of 60 vegetation plots and associated pH values were used to calculate the linear regression equation. By applying the regression equation to weighted macrofossil density values, inferred pH was calculated (See methods for details). The relationship between observed pH values of the 60 surface vegetation plots and their predicted pH values using the regression equation shows a high correlation of r=.86.

Paleo-pH details for the Mariana Lake macrofossil cores are shown in Fig. II-15.

Lake Basin Cores (Sites 12,14,6)

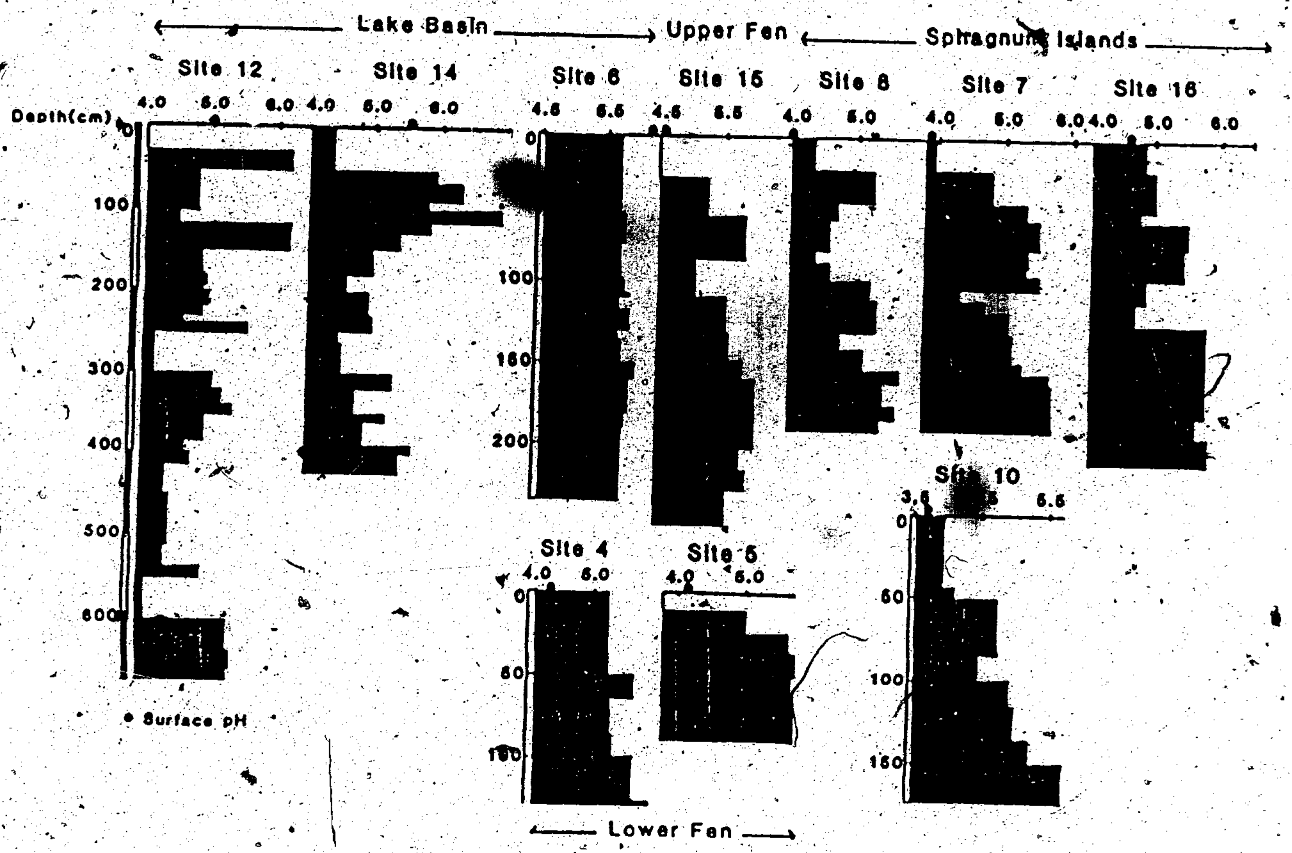
Inferred pH profiles of sites 12 and 14 describe the original paleo-pH as being between 5.35 and 5.60. In both cores, pH decreases through the floating mat stage to a pH of 4.5 and is followed by periods of increased minerotrophy in the LS6 and DM8 peat macrofossil community groups (Fig. II-14). Lowest paleo-pH values are found in the S1 and S2 peat macrofossil groups. Directly contrasting to sites 12 and 14 is site 6. The inferred pH profile at site 6 is stable, beginning and ending with a paleo-pH of 5.75.

Open Fen (Upper and Lower) Cores (Sites 15,4,5)

Site 15 has a pH profile that is distinctly different from sites 4 and 5. At site 15, paleo-pH increases from an initial pH of 5.75 to a paleo-pH of 6.0, followed by a decline in paleo-pH to 5.10, corresponding to macrofossil community S2 (Fig. II-14). Paleo-pH increases in the next stratum (LS6), but declines to 5.25 near the surface horizons. Inferred pH profiles of sites 4 and 5 are relatively stable and similar to that of site 6. Site 4 shows a slight pH reduction from the initial pH of 5.80 to a final pH of 5.15. Inferred pH at site 5 undergoes a more dramatic pH reduction corresponding to the bryostratigraphic change from macrofossil community ME4 to MS3.

Fig. II-15. Environmental reconstruction. Paleo-pH of surface waters at Mariana Lakes. Peat cores are grouped according to lake basin, upper fen, lower fen, and *Sphagnum* island areas (see methods). Present surface pH is indicated for each core(O).

Mariana Lakes Paleo-pH



[illegible]m Island Cores(Sites 10,16,8,7,)

The pH profile of site 10 describes a gradual decline from an initial pH of 5.75 to a final pH of 3.90. Inferred pH profiles of sites 7,8, and 16 are similar, showing initial paleo-pH values of about 5.75, declining to a paleo-pH of between 4.3 and 4.8. As with previous cores, low paleo-pH values correspond to S2 macrofossil peat communities (Fig. II-14). All three cores experience a period of renewed mineralization which increased the paleo-pH to approx. 5.25, followed by a rapid decline in pH through the more recent surface horizons.

Summary

The peatland at Mariana Lakes has from its initiation been an ionically poor fen, with a pH of about 5.75. Natural acidification took place in the <u>Drepanocladus</u> mat communities surrounding the lake basins. Glime <u>et</u> <u>al.</u> (1982) reports that <u>Drepanocladus</u> <u>vernicosus</u> and D. <u>revolvens</u> have the ability to significantly reduce pH values through cation exchange. Subsequent to the development of the poor fen community, changes in water chemistry have resulted in periods of acidification and mineralization. The inferred pH profiles suggest that lake basin sites (12 and 14) are the most minerotrophic and have been vegetatively the most sensitive to changes in water chemistry.

Fen communities in the upper reaches of the peatland were also sensitive to changes in water chemistry (site 15), whereas fen communities in the lower reaches (sites 4,5) were less sensitive. Low surface pH and calcium concentration at these sites suggest that most ions have been previously removed by filtration before surface waters reached these lower sites. Site 6 has an extremely stable inferred pH profile. The high surface pH of this site (6.34) suggests that site 6 is receiving additional ground water flow. A constant supply of mineral-enriched ground water flow could account for the stable profile that site 6 experiences.

All <u>Sphagnum</u> island cores with the exception of site 10, have an inferred pH profile that indicates changes in water chemistry. Sites 7,8, and 16 appear not to be as hydrologically isolated as site 10 and are therefore more sensitive to changes in water chemistry. Basal paleo-pH values in these cores are all about 5.75, but renewed minerotrophic conditions do not exceed a paleo-pH of 5.5. This is in direct contrast to the lake basin and fen cores and may indicate a time period when these sites had achieved a tenuous hydrological isolation. Site 10 has an inferred pH profile that describes the gradual removal of a Sphagnum island from ground water influence.

Problems with Inferred pH

The application of pH reconstruction utilizing fossil macrophytes has some inherent problems. The use of an absolute counting technique to acquire macrofossil density data has resulted in the overrepresentation of monocots due to their sheathing growth form and large underground root production. This has led to an exaggeration in the amount of monocots found in the fen assemblages, resulting in a disparity between inferred pH of the first peat horizion at site 12, 4 and 5, and the surface water pH (See Fig. II-15).

Hummocks are micro-ecoystems having unique water chemistry and vegetation. When describing water chemistry conditions using vegetative characteristics, only the flarks should be sampled. The hummock effect is seen at site 14 where the first peat horizion was located within a hummock community. The inferred pH of this horizon is much lower than the actual surface water chemistry. This situation is similar for site 6.

In order to calculate an accurate multiple linear regression equation, a large data base covering a wide amplitude of variation is required. In this study, insufficient data was available to accurately describe the full range of environmental conditions found within Drepanocladus communities. This resulted in an extremely low inferred pH (4.10) for the floating mat Drepanocladus communities at sites 12 and 14. A pH of 5.0 to 5.9 is a more commonly accepted pH value for Drepanocladus dominated communities (Jeglum 1971, Janssens 1983c).

Relationship of peat assemblages to modern day plant associations.

Percentage cover values of the extant vegetation were placed within the peat macrofossil data and ordinated using *Twinspan*, in order to assess the relationship between peat assemblages and extant plant associations. Results are given in Table II-8. The third column contains the *Twinspan* classification of the extant vegetation with the peat macrofossils, and the fourth column contains the first subsurface peat assemblage. This chart indicates that the extant vegetation of the lake basin and fen sites do not bear a close relationship to their first subsurface macrofossil assemblage. Forested Sphagnum island sites have a much closer relationship. This is due to the abundance of monocots in the fen communities, their sheathing growth form, the abundance of persistent subterranean parts and the absolute method by which the original data was obtained.

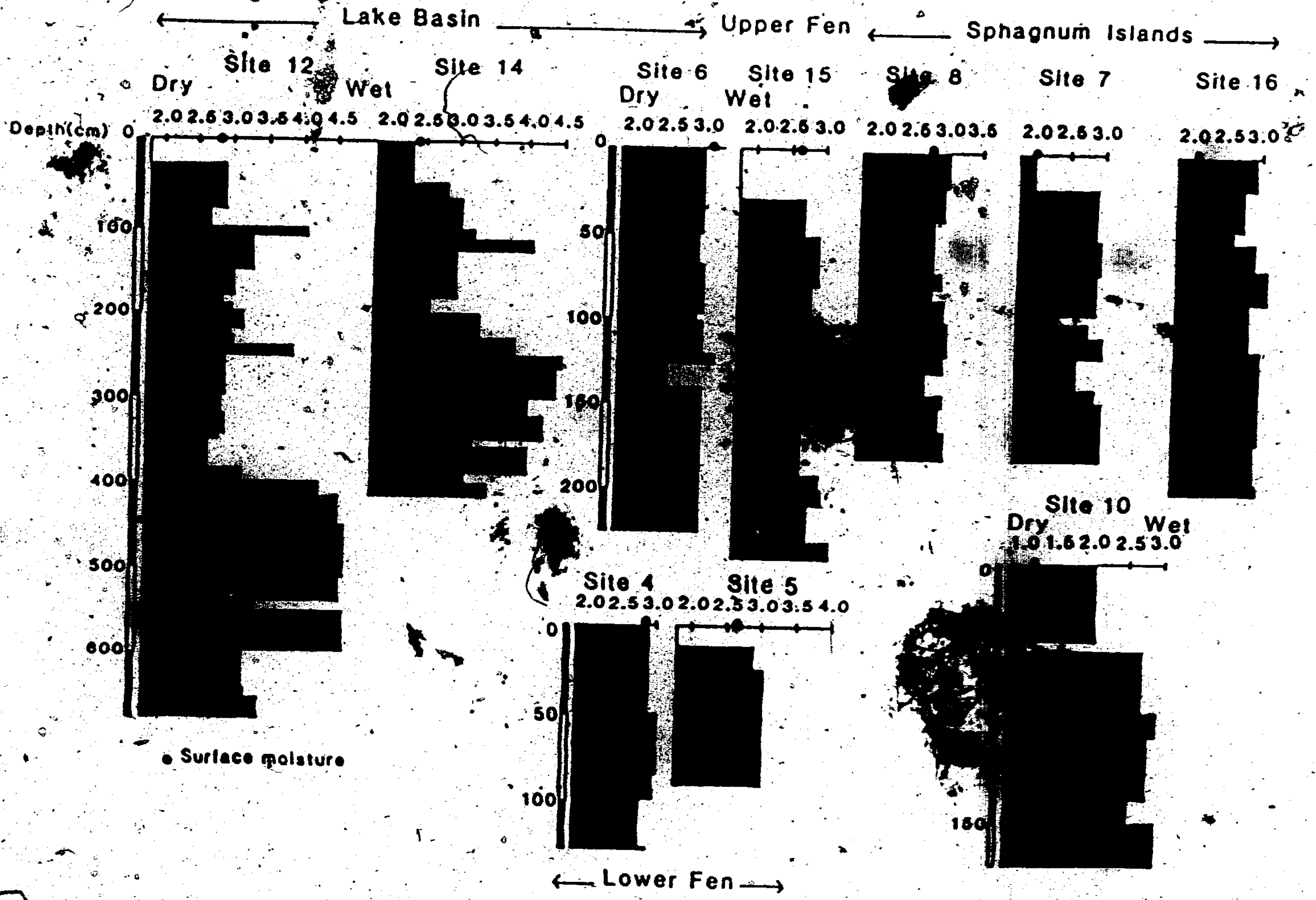
Paleo-Moisture

The paleo-moisture profiles based on a moisture index, (See Methods) (Fig. II-16) show that lake basin sites (12 and 14) [illegible] the wettest moisture profile, particularly through the floating mat stages. Upon enclosure of the floating mat and the development of the poor fen (LS6), these sites became significantly drier. Peaks in the inferred moisture profiles in these cores beyond the poor fen stage are due to the presence of Drepanocladus or Sphagnum angustifolium. Site 6 has a constant moisture profile, except for a particularly dry strata at 126-140 cm. Lower fen sites 4 and 5 have stable moisture profiles at a moisture index of 2.75-3.00. The Sphagnum island cores have a more stable paleo-moisture profile than that of the lake basin cores (sites 12 and 14). Moisture conditions tend to remain around a moisture index of between 2.75 and 3.0. Major moisture reductions in site 7 and site 10 correspond to macrofossil changes from S2, a Sphagnum peat community, to S1 (Fig. II-14).

F. CONCLUSIONS

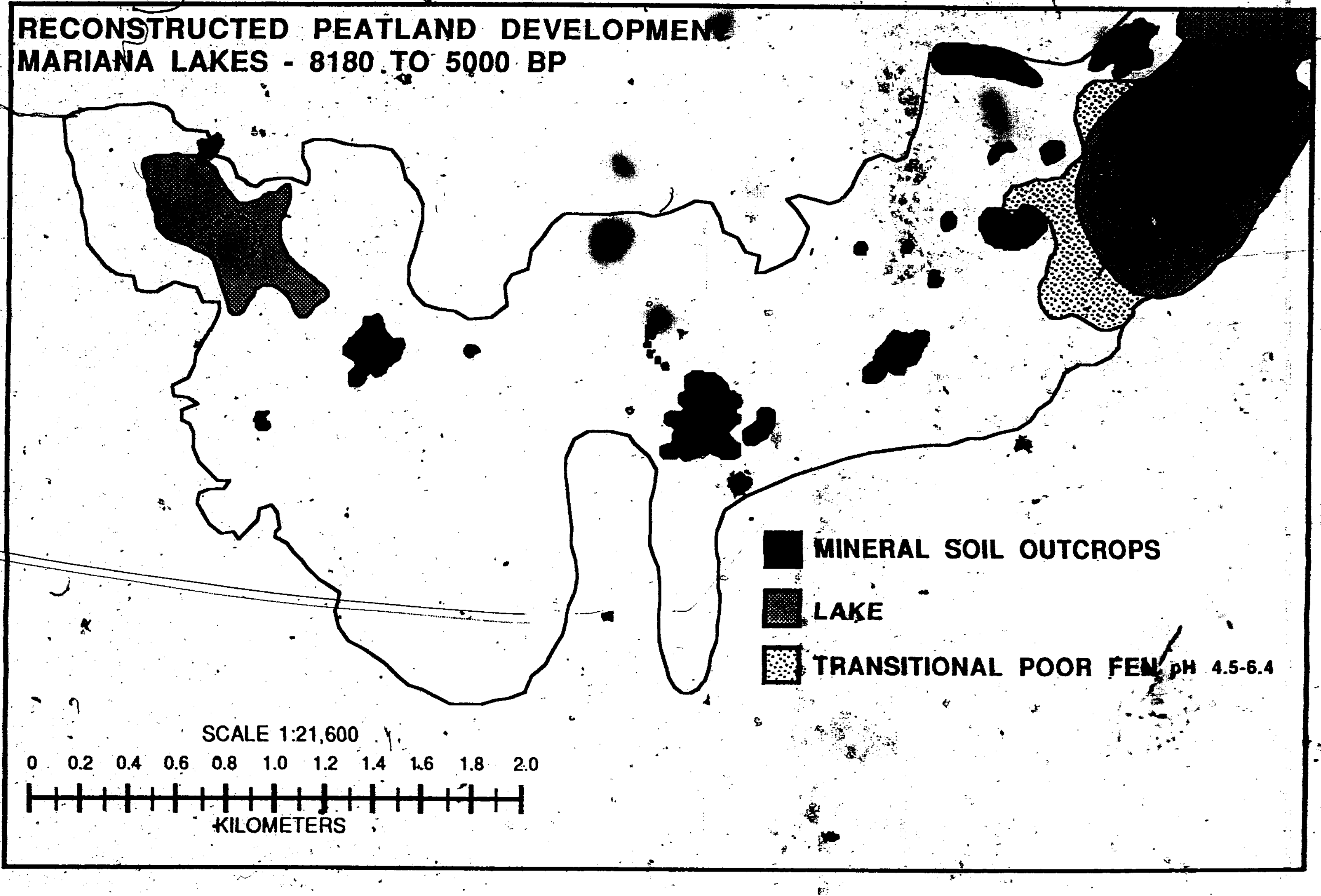
Both processes of peatland formation, terrestrialization and paludification have occurred at Mariana Lakes (Figs. II 17-20). Earliest peat formation began in the northwest lake basin at 8180 and the northeast basin around 7170 BP and followed a classical hydroseral

Fig. II-16. Environmental reconstruction. Paleo-moisture at Mariana Lakes. Cores are grouped according to lake basin, upper fen, lower fen, and <u>Sphagnum</u> island areas. Present surface moisture conditions are indicated ( ) for each core. Moisture is based on a 1-5 scale (see methods).



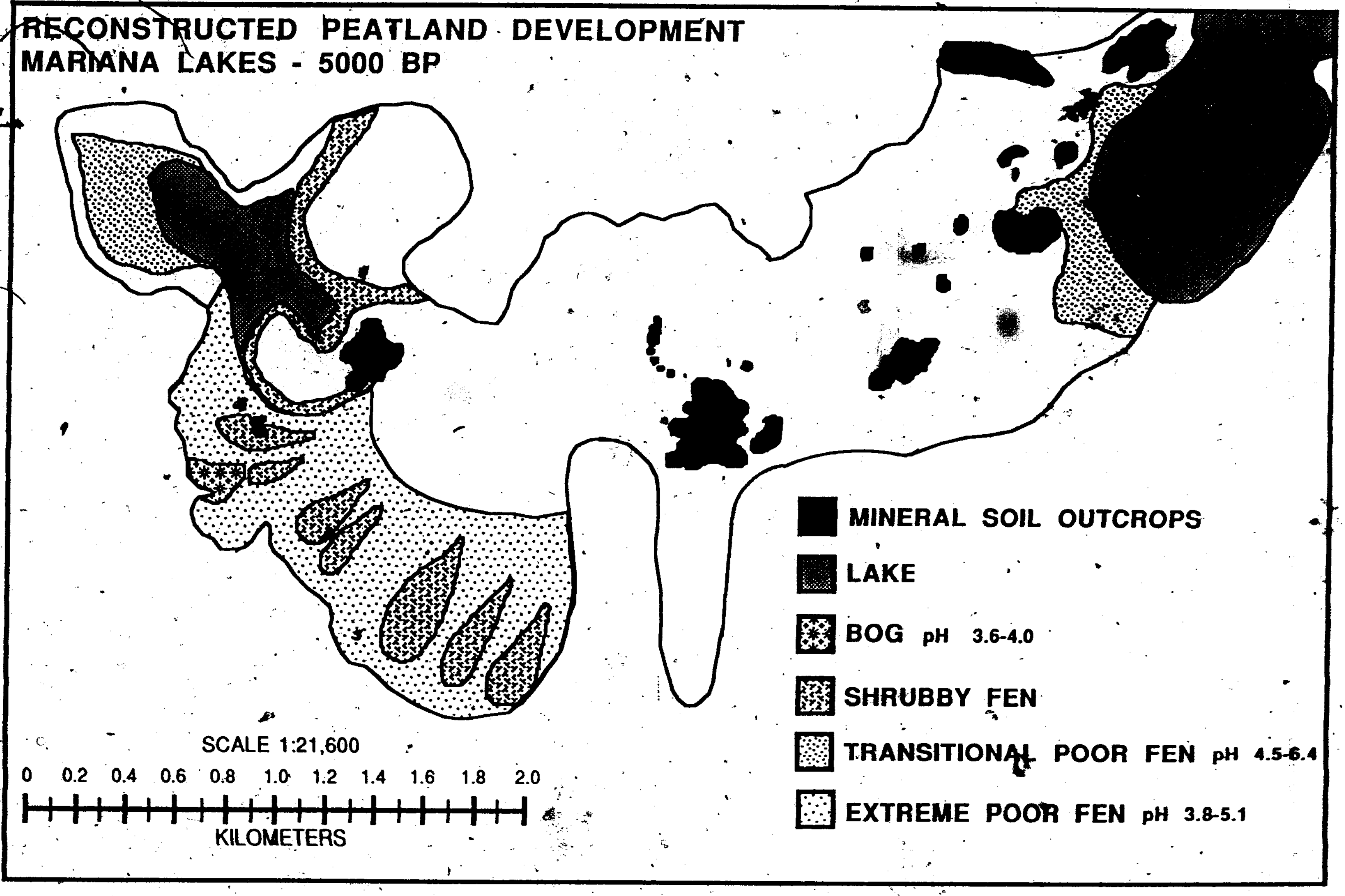
Mariana Lakes Paleo-Moisture

Fig. II-17. Model of peatland development at Mariana Lakes. Reconstruction from 8180 BP to 5000 BP.



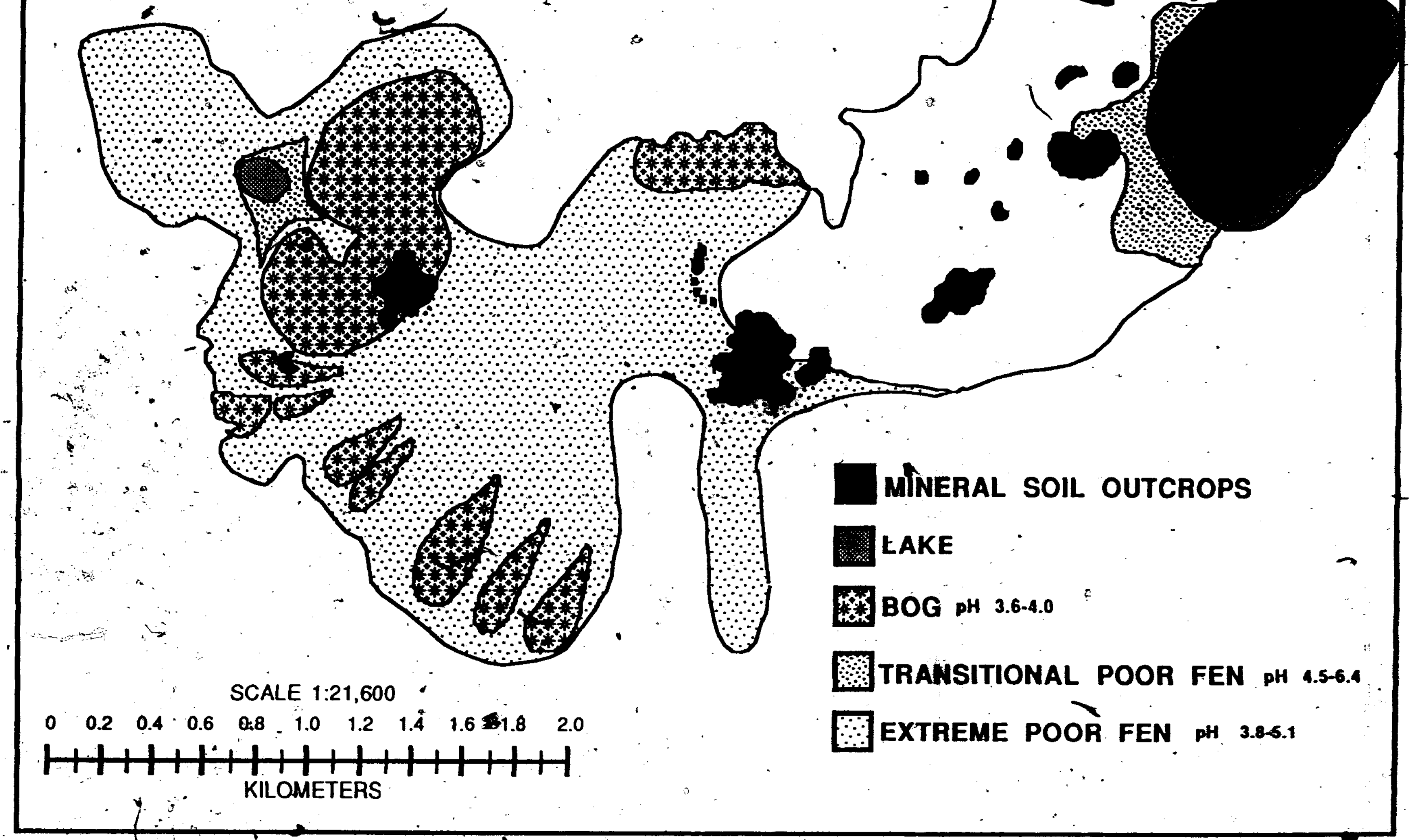
RECONSTRUCTED PEATLAND DEVELOPMENT
MARIANA LAKES - 8180 TO 5000 BP

Fig. II-18. Model of peatland development at Mariana Lakes. Reconstruction at 5000 BP.



RECONSTRUCTED PEATLAND DEVELOPMENT
MARIANA LAKES - 5000 BP

Fig. II-19. Model of peatland development at Mariana Lakes. Reconstruction at 3000 BP.



RECONSTRUCTED PEATLAND DEVELOPMENT
MARIANA LAKES - 3000 BP

Fig. II-20. Model of peatland development at Mariana Lakes. Present day mire types. Compare with Fig. II-2 for further details.

RECONSTRUCTED PEATLAND DEVELOPMENT
MARIANA LAKES - PRESENT

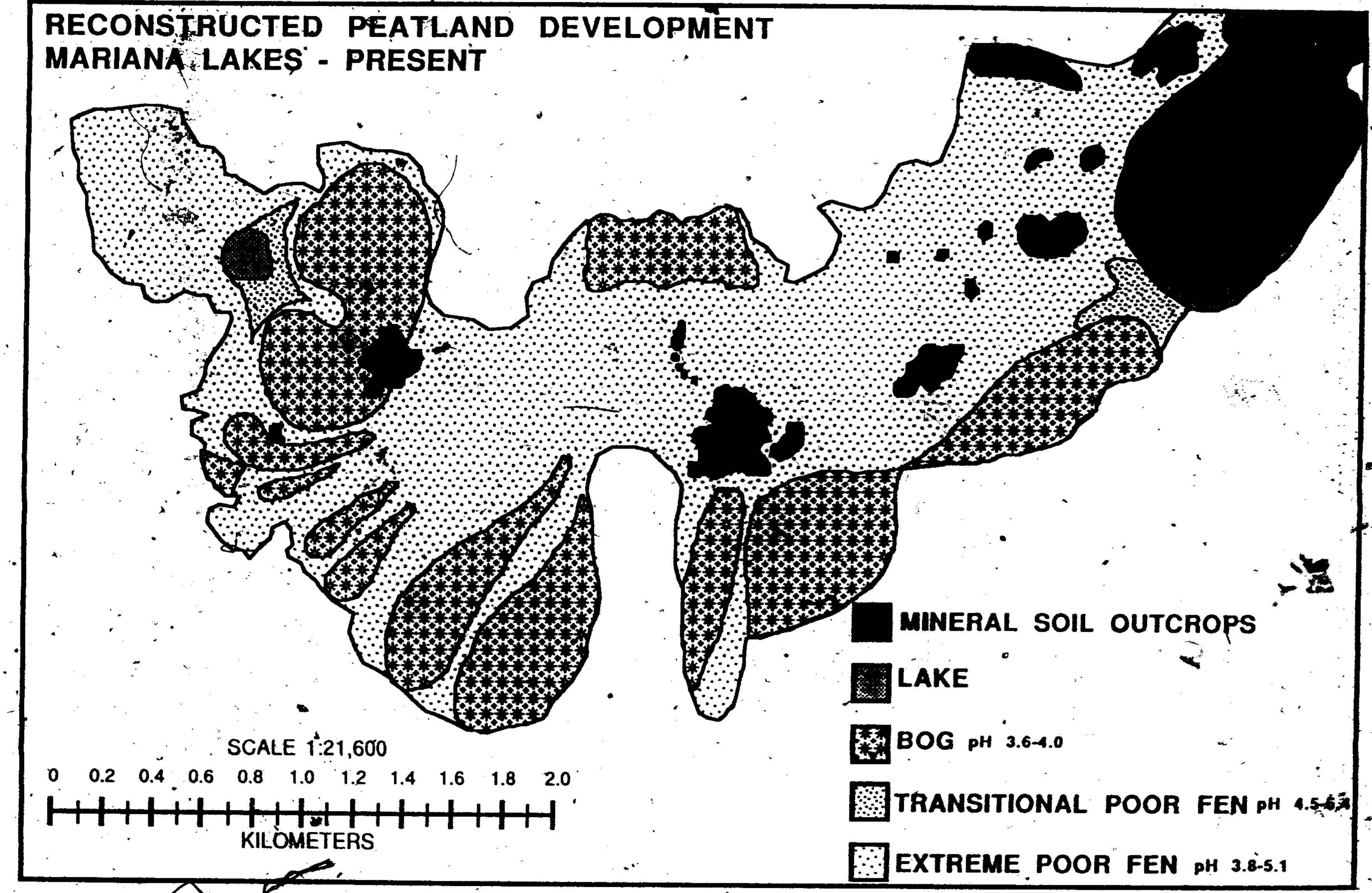


Table II-8. The relationship of the surface vegetation releves at each site, to the first subsurface peat sample. Refer to Fig. II-4 for abbreviations of category classes.

Vegetative Landform Category	Site Number	Surface Releves Twinspan Class	First Subsurface Twinspan Class
Lake Basin and Open Fen	12	S1	LM7
	14	S2	S1
	6	LS6	LS6
	15	S2	LS6
	4	S2	LS6
	5	S2	MS3
Sphagnum Islands	8	S2	S2
	7	S2	S1
	16	S2	MS3
	10	S1	S1

succession resembling those outlined by Everett (1983), Heinselman (1970) and Sjors (1960). Autogenic infilling of the lake basin produced a floating mat, that upon enclosure, isolation, and natural acidification developed into a poor fen. Allogenic paludification of the upper fen began between 5800 BP and 5130 BP, subsequent to terrestrialization of the lake basins, and progressed in a downslope direction towards the mire outlet (Figs. II 17-20). By 2960 BP the entire drainage path was completed paludified.

Plant macrofossils, *Twinspan* classification of macrofossil assemblages, and inferred reconstruction profiles describe the developmental history of the present day surface features. The lake basin areas are the most minerotrophic from the time of initiation to the present. Minerotrophic, highly ionic conditions are expressed as high paleo-pH values of 6.0 and 6.9. Accumulation diagrams indicate that these areas have high production and low decomposition, which is indicative of a high water table with high moisture conditions. Paleo-moisture profiles suggest that these areas were wetter than the <u>Sphagnum</u> islands, particularly in the upper strata of the cores. The northwest basin evolved in a former proglacial lake with succession toward a <u>Sphagnum</u> dominated poor fen. It is located at the upper end of the drainage basin, and has remained within minerotrophic overland flow, and has therefore been sensitive to changes in hydrology and water chemistry. The macrofossil history, inferred reconstructions, peat accumulation diagrams, and *Twinspan* classification, all express a dynamically unstable, wet, and relatively minerotrophic peat forming community.

The peatland area near the shore of the northeastern lake has evolved from a lakeshore sedge swamp into one dominated by <u>Picea</u>, <u>Larix</u>, shrubs and sedges. Peat accumulation rates have been high but erratic, while moisture conditions and water chemi[illegible] have remained stable. As former-lake levels dropped, this area became exposed to waterflow from an adjacent drainage basin. This water source is enriched with mineral ions, and has provided the area with a continous supply of moisture and nutrients. The macrofossil profile expresses minor shifts in the drainage patterns, and is not related to any major climatic or hydrological events.

The upper fen site has a peat profile that suggest early development in a watertrack with groundwater influence. No change has occurred and it remains within the present watertrack. *Twinspan* and peat accumulation profiles indicate that the fen area was both richer and wetter than the *Sphagnum* islands. Adjacent *Sphagnum* islands, experience a correlating sequence of vegetational and environmental changes to that of the fen. This suggests a close hydrological relationship exists between these areas. Lower fen sites have been recently been paludified. Early peat forming assemblages had high amounts of ericaceous shrubs, *Larix* and monocots. As these site became wetter, monocot increased and *Larix* and ericads decreased. With the accumulation of sufficient peat material to isolate the surface vegetation from the underlying mineral soils, these sites experiencee a increase in *Sphagnum* and a corresponding drop in the paleo-pH.

On *Sphagnum* island sites, early peat forming vegetation was dominated by monocots and ericads, with a moisture index of 2.9, a paleo-pH of 5.75, and a low peat accumulation rate. Some island sites experienced a gradual removal from ground water influence, and a corresponding succession to *Sphagnum* dominance. Other sites appear to be hydrologically unstable, occupying ecotonal positions between *Sphagnum* islands and adjacents fens, or they experienced a close hydrological relationship to the adjacent fen.

Correlation of regional climatic changes documented in paleoecological studies, with changes in peat stratigraphy.

According to paleoecological studies there have been two major climatic events that have occurred since deglaciation in Alberta. The first is the mid holocene climatic optimum that appears to have been a time transgressive event of increased summer temperatures (Schweger, unpublished). Dated pollen cores from lakes in Alberta give a varying account for the climatic optimum; 9,000-6,000 BP at Wabamum Lake (Hickman *et al.* 1984), from 9,500 to 5,000 BP at Mary Gregg Lake (Bombin 1982), and 8,000 BP at Lake Isle (Hickman and Klarer 1981). Schweger (Unpublished) gives a blanket figure of 9,300 to 5,600 BP for the climatic optimum in Alberta. During this time period at Mariana Lakes, only the lake basins were accumulating peat. Lowered lake levels during the warm dry interval could account for the transitions from a limnic sedimentation stage to the floating mat stage. The shore area of the northeastern lake evolved during this interval from a sedge swamp community into a drier ericad, Larix, and Picea community. The second major climatic event was the shift from the altithermal into modern climatic conditions which brought about an increase in precipitation or a decrease in evapotranspiration. Pollen core evidence suggests that this transition was also time transgressive and took place in Alberta at Hastings Lake from 5555-4460 BP (Hickman and Forbes 1981), at Baptiste Lake at 4600 BP (Hickman et al. 1978) and at Elk Island National Park at 4000-4200 BP (Vance 1979). A climatic change to cooler and wetter conditions would have brought increased water flow to Mariana Lakes resulting in the initiation of the paludification process. Periods of extensive paludification and peat inception have been reported between 5000-3800 BP for peatlands in northern Quebec (Payette 1984), and of 3500 BP, 2400 BP, and 700 BP for all of Canada (Nichols 1969).

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LITERATURE CITED

1. Andrus, R.E., 1974. The Sphagna of New York State. State University of New York College of Environmental Science and Forestry. Ph.D. Thesis.
2. Andrus, R.E., 1986. Some aspects of <u>Sphagnum</u> ecology. Can. J. Bot. 64:416-426.
3. Alberta Environment, Climate of Alberta, Report for 1982. Tables of Temperature, Precipitation and Sunshine.
4. Battarbee, R.W. 1972. Preliminary studies of Lough Neah sediments II. Diatom analysis from the uppermost sediment. In: Quaternary Plant Ecology. H.J.B. Birks and R.G. West (eds.). Blackwell, London pp. 279-288.
5. Battarbee, R.W. 1984. Diatom analysis and the acidification of lakes. Phil. Trans. R. Soc. Lond. B 305:451-477.
6. Birks, H.J.B. and H.H. Birks. 1980. Quaternary Palaecology. Edward Arnold, London.
7. Bombin, E.R. 1982. Holocene paleolimnology of Mary Gregg Lake, Foothills of Alberta Rocky Mountains, Canada. University of Alberta. M.Sc. Thesis.
8. Damman, A.W.H. 1978. Distribution and movement of elements in ombrotrophic peat bogs. Oikos 30:480-495.
9. Damman, A.W.H. 1978. Ecological and floristic trends in ombrotrophic peat bogs of eastern North America. Colloques phytosociologiques VII. Sols tourbeux, Lille:61-79.
10. Damman, A.W.H. 1986. Hydrology, development, and biogeochemistry of ombrogenous peat bogs with special reference to nutrient relocation in a western Newfoundland bog. Can. J. Bot. 64:384-394.
11. Davis, R.B., and D.S. Anderson. 1985. Methods of pH calibration of sedimentary diatom remains for reconstructing history of pH in lakes. Hydrobiologia 120:69-87.
12. Everett, K.R. 1983. Histosols. In: Pedogenesis and Soil Taxonomy. II. The Soil Orders. Wilding, L.P., N.E. Smeck, and G.F. Hall (eds.). Elsevier, Amsterdam. pp. 1-53.
13. Fisheries and Environment Canada, Atmospheric Environment Service. Monthly Record Meterological Observations in Western Canada. 1977-1982. Downsview, Ont.
14. Foster, D.R. 1984. The dynamics of <u>Sphagnum</u> in forest and peatland communities in Southeastern Labrador, Canada. Arctic 37:133-140.
15. Glaser, P.H. 1983. Vegetation patterns in the north Black River peatland, northern Minnesota. Can. J. Bot. 61:2085-2102.
16. Glaser, P.H., G.A. Wheeler, E. Gorham, and H.E. Wright Jr. 1981. The patterned mires of the Red Lake Peatland, northern Minnesota: Vegetation, water chemistry, and landforms. J. Ecol. 69:575-599.
17. Glime, J.M., R.G. Wetzel, and B.J. Kennedy. 1982. The effects of bryophytes of succession from alkaline marsh to <u>Sphagnum</u> bog. American Midland Naturalist 108:209-223.

18. Gorham, E. 1956. The ionic composition of some bog and fen waters in the English Lake district. J. Ecol. 44:142-152.

19. Gorham, E. 1957. The development of peatlands. Quarterly Reviews of Biology 32:145-166.

20. Hackbarth, D.A. and N.Nastasa. 1979. The Hydrogeology of the Athabasca Oil Sands Area, Alberta. Alberta Research Council Bulletin #38.

21. Heinselman, M.L. 1970. Landscape evolution, peatland types, and the environment in the Agassiz Peatland Natural Area. Ecol. Monogr. 40:235-261.

22. Hickman, M., D.M. Klarer, C. Schweger and T. Habgood. 1978. The paleoenvironmental history of Baptiste Lake, Alberta. Alberta Environmental Report Water Quality Section.

23. Hickman, M., and D.M. Klarer. 1981. Paleolimnology of Isle Lake Alberta. Canada. Including sediment chemistry, pigments and diatom stratigraphy. Arch. Hydrobiol. 91:490-508.

24. Hickman, M., and J.R. Forbes. 1981. Paleolimnology of two shallow lakes in Central Alberta. Int. Revue ges Hydrobiol. 66:836-888.

25. Hickman, M., C.E. Schweger, and T. Habgood. 1984. Lake Wabamum, Alta.; a paleoenvironmental study. Can. J. Bot. 62:1438-1465.

26. Hill, M.O. 1979a. DECORANA-A FORTRAN program for detrended correspondence analysis and reciprocal averging. Ecology and Systematics, Cornell University, Ithaca.

27. Hill, M.O. 1979b. TWINSPAN-A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of individuals and attributes. Ecology and Systematics, Cornell University, Ithaca.

28. Horton, D.G., D.H. Vitt, and N.G. Slack. 1979. Habitats of circumboreal-subartic Sphagna: I. A quantitative analysis of review of species in the Caribou Mtns., northern Alberta. Can. J. Bot. 57:2283-2317.

29. Ireland, R.R. 1982. Moss Flora of the Maritime Provinces. National Museum of Natural Sciences

30. Janssens, J.A. 1983. A quantitative method for stratigraphic analysis of bryophytes in holocene peat. J. Ecol. 71:189-196.

31. Janssens, J.A. 1983c. Past and extant distribution of <u>Drepanocladus</u> in North America, with notes on the differentiation of fossil fragments. J. Hattori Bot. Lab. 55: 251-298.

32. Janssens, J.A., and P.H. Glaser. 1986. The bryophyte flora and major peat-forming mosses at Red Lake peatland, Minnesota. Can. J. Bot. 64:427-442.

33. Jeglum, J.K. 1971. Plant indicators of pH and water level in peatlands at Candle Lake, Saskatchewan. Can. J. Bot. 49:1661-1676.

34. Karlin, E.F. and L.C. Bliss. 1984. Variation in substrate chemistry along microtopographical and water chemistry gradients in peatlands. Can. J. Bot. 62:142-153.

35. Kratz, T.K., and C.B. DeWitt. 1986. Internal factors controlling peatland-lake ecosystem development. Ecology 67:100-107.

36. MacIsaac, D. Crow Lake Study Area, Northeastern Alberta. A Biophysical Inventory. Alberta Energy and Natural Resources Natural Areas Technical Report #16.

37. Moss, H.E. 1983. Flora of Alberta. 2nd ed. Edited by John G. Packer. University of Toronto Press, Toronto.

38. Nichols, H. 1969. Chronology of peat growth in Canada. Paleogeogr., Paleoecol. 6:61-65.

39. Ozoray, G.F. and A.T. Lytviak. 1980. Hydrogeology of the Pelican-Algar Lake Area, Alberta. Alberta Research Council, Earth Sciences Report 80-1.

40. Payette, S. 1984. Peat inception and climatic change in no[illegible] [illegible]ebec, Canada. In: N.A. Morner and W. Karlen (eds.), Climatic Changes on a [illegible] to Millennial Bas[illegible] D. Reidel Publishing Co. pp.173-179.

41. Pennington, W. and M.J. Sackin. 1975. An application of principal components analysis to the zonation of two Late Devensian profiles. New Phytol. 75:419-543.

42. Powell, J.M. and D.C. MacIver. 1978. Maps of selected climatic parameters for the Prairie Provinces, May to Sept. 1961-1970. Fisheries and Environment Canada, Canadian Forestry Service, Northern Forest Research Centre. Information Report NOR-X-206.

43. Reinikainen, A., T. Lindholm and H. Vasander. 1984. Ecological variation of mire site types in the ~~small~~ kettle-hole mire Heinisuo, southern Finland. Ann. Bot. Fenn. 21:79-101.

44. Renberg, I. and T. Hellberg. 1982. The pH history of lakes in southwestern Sweden, as calculated from the subfossil diatom flora of the sediments. Ambio 11:30-33.

45. Rowe, J.S. 1972. Forest Regions of Canada. Dept. of the Environment, Canadian Forestry Service. Ottawa. Publ. No. 1300.

46. Schuster, R.M. 1966. Boreal Hepaticeae of Minnesota. University of Notre Dame Press, Notre Dame.

47. Schweger, C.E. Unpublished. A critical appraisal of the altithermal and its role in archaeology. University of Alberta, Edmonton, Alberta.

48. Sjors, H. 1950. Regional studies in North Swedish mire vegetation. Bot. Not. 1950:173-222.

49. Sjors, H. 1952. On the relation between vegetation and electrolytes in North Swedish mire waters. Oikos. 2(1950):241-258.

50. Sjors, H. 1961. Forest and peatland at Hawley Lake, northern Ontario. Bull. Nat. Mus. Canada 171:1-31.

51. Sjors, H. 1983. Mires of Sweden. In: Ecosystems of the World. Mires: Swamp, Bog, Fen, and Moor. A.J.P Gore (ed.). Elsevier Scientific Publishing Co., New York. pp. 69-92.

52. Slack, N.G., D.H. Vitt, and D.G. Horton. 1980. Vegetation gradients of minerotrophically rich fens in western Alberta. Can. J. Bot. 58:330-350.

53. Stainton, M.P., M.J. Capel and F.A.J. Armstrong. 1977. The Chemical Analysis of Fresh Water Fisheries and Environment Canada. Miscellaneous Special Publication No. 25. 2nd

ed.

54. Strong, W.L. and K.R. Leggat. 1981. Ecoregions of Alberta. Alberta Energy and Natural Resources. Resource Evaluation and Planning Division.

55. Tallis, J.H. 1983. Changes in Wetland Communities. In: Ecosystems of the World. Mires: Swamp, Bog, Fen, and Moor. A.J. Gore (ed.). Elsevier Scientific Publishing Co., New York. pp. 311-344.

56. Taylor, T.M.C. 1983. The Sedge Family of British Columbia. Provincial Museum Handbook #43.

57. Vance, R.E. 1979. Late Holocene paleoecology of the Aspen Parkland regions of western Canada. M.A. thesis, Department of Anthropology, University of Alberta, Edmonton.

58. Vitt, D.H., H.P. Achuff, and R.E. Andrus. 1975. The vegetation and chemical properties of patterned fens in the Swan Hills, north central Alberta. Can. J. Bot. 53:2776-2795.

59. Vitt, D.H. and R.E. Andrus. 1977. The genus Sphagnum in Alberta. Can. J. Bot. 55:331-357.

60. Vitt, D.H., and S. Bayley. 1984. The vegetation and water chemistry of four oligotrophic basin mires in northwestern Ontario. Can. J. Bot. 62:1485-1500.

61. Vitt, D.H., D.G. Horton, and N. Malmer. Unpublished. Peatland complexes of the Ft.McMurray area, northeastern Alberta: vegetation, water chemistry, and landscape gradients.

62. Vitt, D.H., and N.G. Slack. 1975. An analysis of the vegetation of Sphagnum dominated kettle-hole bogs in relation to environmental gradients. Can. J. Bot. 53:332-359.

63. Vitt, D.H., and N.G. Slack. 1984. Niche diversification of Sphagnum relative to environmental factors in northern Minnesota peatlands. Can. J. Bot. 62:1409-1430. Ann. N.Y. Acad. Sci. 288:93-118.

64. Walter, H. 1979. Vegetation of the Earth and Ecological Systems of the Geo-biosphere. Springer-Verlag, New York.

65. Waughman, G.J. 1980. Chemical aspects of the ecology of some south German peatlands. J. Ecol. 68:1025-1046.

66. Webb, T., III and D.R. Clark. 1977. Calibrating micropaleontological data in climatic terms: a critical review. Annals New York Acad. Sci. 288:93-118.

67. Wynnyk, R., J.D. Lindsay, P.K. Heringa, and W. Odynsky. 1963. Research Council of Alberta. Preliminary Soil Survey Report #64-1. Map sheets 830, 83P, 73M.

68. Zoltai, S.C. and F.C. Pollett. Wetlands in Canada: Their Classification, Distribution, and Use. In: Ecosystems of the World. Mires: Swamp, Bog, Fen and Moor. A.J.P. Gore (ed.). Elsevier Scientific Publishing Co. New York. pp.245-268.

III. PEAT CHEMISTRY

A. INTRODUCTION

[1] The relationship between peatland vegetation and water chemistry has been studied by many authors, notably: Sjors (1952), Gorham (1956),(1984), Heinselman (1970), Glaser (1983), and Comeau and Bellamy (1986), resulting in the conclusion that peatlands occupy a bimodal distribution along a water chemistry gradient (Sjors 1950, Gorham 1956, Gorham and Pearsall, 1956). Bogs are ombrotrophic peatlands that receive their mineral supply from precipitation only and are situated at the lower end of the gradient, while rich fens receiving large amounts of calcium and magnesium through groundwater supply are located at the highest end of the gradient. Water chemistry and vegetational gradients also exist within individual mires (Glaser 1983, Glaser *et al*. 1981, Damman 1986). In continental North America where large ombrotrophic peatlands do not form, water chemistry and vegetation gradients are associated with unique vegetational landforms. In the Black River and Red Lake peatlands of northern Minnesota these landforms take the shape of raised *Sphagnum* crests, watertracks, and ovoid *Sphagnum* islands (Glaser 1983).

Peat is an accumulation of undecomposed mire vegetation. Due to its physical properties, peat can sequestre cations, particularily *Sphagnum* peat which has a large cation exchange capacity. Surface peat chemistry has been considered by some to better reflect ionic and nutrient concentrations in the mire due to the seasonal variability found in surface water chemistry (Damman 1978, Karlin and Bliss 1984), and the accumulating effects that flowing water can create (Pakarinen and Tolonen 1977b).

Peat stratigraphy and peat chemistry in combination can be used to determine the developmental history of a peatland. Peat macrofossils describe the vegetational changes, while peat chemistry reveals chemical and hydrological changes. Most peat chemistry studies have focused on establishing a relationship between surface waters and surface peats (Pakarinen and Tolonen 1977b, Damman 1978), between mire plants and peat (Malmer and

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[1] A version of this chapter has been submitted for publication. B. Nicholson and D.H. Vitt. 1988. Journal of Ecology.

Sjors 1955, Stanek et al 1977, Lembrechts and Vanderborght 1985, Giller and Wheeler 1986), or to assess trace metal deposition (Sillanpaa 1972, Pakarinen and Tolonen 1977a). Few studies have been done utilizing peat chemistry to establish hydrology and water chemistry changes associated with peatland development (Zoltai and Johnson 1985), particularily in defining the chemical change between minerotrophic and ombrotrophic peats (Chapman 1964, Mornsjo 1968, Tallis 1973, Gorham et al. 1984).

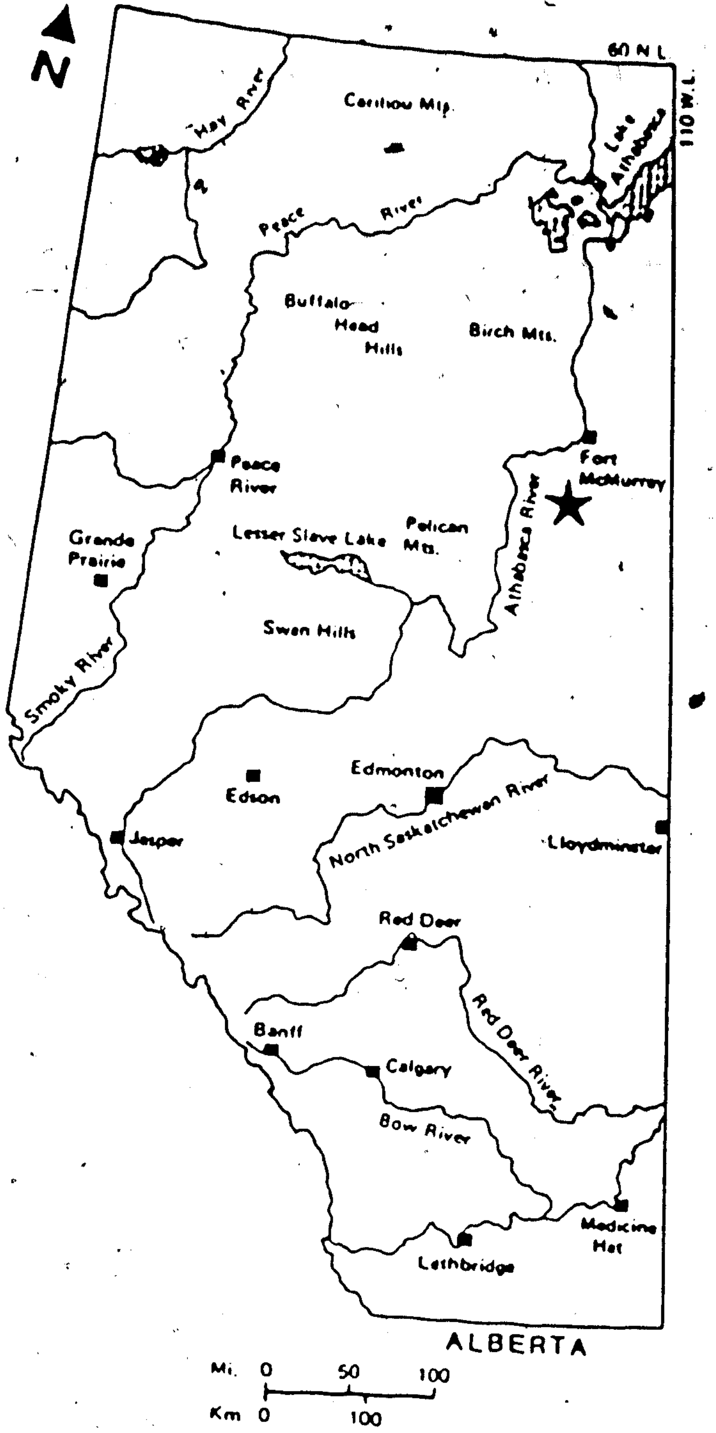
A continental peatland complex with varied vegetational landforms was studied to determine the developmental history of the peatland, and to relate the surface physiognomy to peatland development. As part of this study, peat chemistry was used to determine the influence of water chemistry on peatland vegetation and landform formation. Particular emphasis was directed towards establishing the presence of ombrotrophic conditions of the forested Sphagnum islands and documenting within the peat chemistry profile a stratigraphic boundary between ombrotrophic and minerotrophic peats.

B. STUDY AREA

The study area (Fig. III-1) is a peatland complex, located 100 Km southwest of Ft. McMurray in northern Alberta at 55°54' N latitude and 112°04' W longitude. The peatland is situated on a broad upland plateau, the Stoney Mountain Uplands, elevated 180 m above the surrounding area. Situated within the peatland complex is an east-west drainage divide. The study site is an 6.88 square kilometer mire located at the eastern head of the drainage divide. Water from this mire enters a large unnamed tributary of the House River. The Stoney Mountain Uplands is a physiographic feature formed by glacial till overlaying a minor rise in the sedimentary bedrock (Hackbarth and Nastasa 1979). The glacial till is non calcareous consisting of bedrock blocks, gravel, sand, and some clay (Ozoray and Lytviak 1980).

Climate for the area is type VIII, boreal cold temperate (Walter 1979), with short winter days and long summer days. During the winter the region is dominated by cold dry Arctic air masses (Strong and Leggat 1981). During the summer months the mid-Albertan storm track brings excessive precipitation (>400 mm) to the area.

Fig. III-1. Map of Alberta, Canada, with the Mariana Lakes study area shown by a star.



Mariana Lakes Peatland

Regional upland vegetation is Boreal Mixedwood (Rowe 1972). Well drained sites have an association of *Populus tremuloidies*, *P. balsamifera*, *Betula papyrifera*, *Betula neoalaskana*, *P. glauca*, and *Abies balsamea*. On sandy soils *Pinus banksiana* can be found while *Picea mariana* and *Larix laricina* occupy lower basins and catchment areas. This area is in the Continental High Boreal wetland region, (Zoltai and Pollett 1983), characterized by peat plateaus, palsas, and fens.

Immediately surrounding Mariana Lakes study site, is an extensive system of discontinuous mires. Outlined in Figure III-2 is the study site, a complex fen. Light shaded zones delimit the extent of the fen. Converging flow paths indicate that drainage is to the northeast. Mineral soil ridges (darkest shading) appear sporadically within the peatland and along the mire edge. Four tear drop shaped, and two ovoid shaped *Picea mariana*- *Sphagnum* dominated islands, (medium shading) are situated within the western section of the fen. The vegetation of these islands is dominated by a thick *Picea mariana* cover, with an understory shrub cover of *Chamaedaphne calyculata*, *Ledum groenlandicum*, *Vaccinium vitis-idaea*, *Oxycoccus microcarpus*, and *Rubus chamaemorus*. Bryophyte cover is dominated by *Sphagnum fuscum*, *S. angustifolium*, *S. magellanicum*, and *Pleurozium schreberi*. The fen portion of the mire (lightest shading), contains watertracks, and covers 3.69 square kilometers. It is dominated by *Andromeda polifolia*, *Betula glandulifera*, *Carex aquatilis*, *C. limosa*, *C. chordorrhiza*, *Sphagnum angustifolium*, *S. magellanicum*, *S. fallax*, and *S. subsecundum*. A scattered cover of *Menyanthes trifoliata*, *Sphagnum majus*, *Scheuchzeria palustris* is also present with individuals of *Equisetum fluviatile*, *Drepanocladus lapponicus*, *D. exannulatus*, and *Meesia triquetra* at the richer sites.

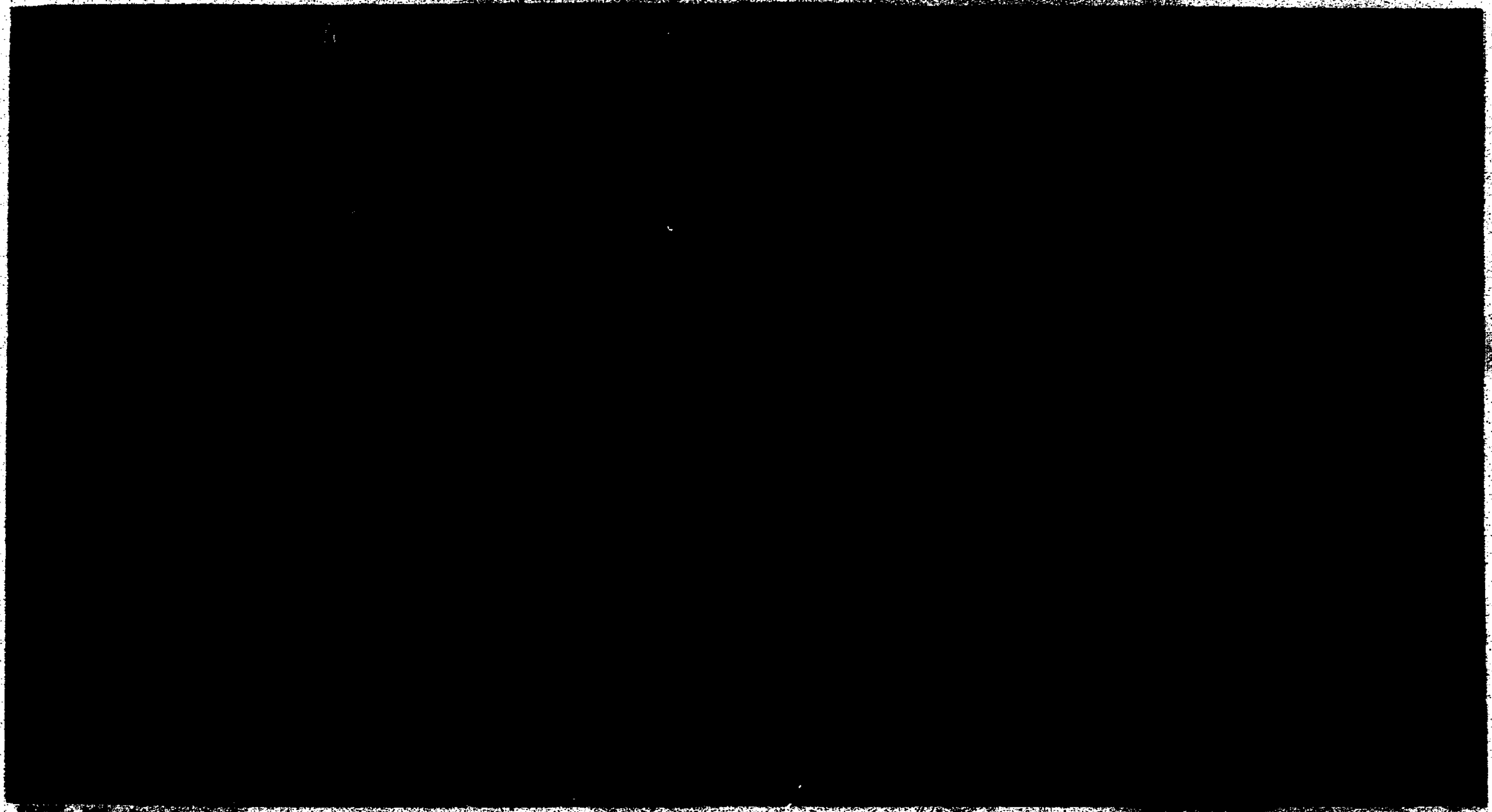
C. METHODS

Coring sites were selected on the basis of landform features as determined by air photo interpretation. Coring sites form two transects. The first transect traverses the upper portion of the peatland and includes all landform features, while the second follows the long axis of the mire to the outlet at the western lake (Fig. III-2). Site selection included

Fig. III-2. Map of Mariana Lakes study area with landform features. Site locations (numbers 1-16) are shown. The mire is divided into three main areas: upper fen (UF), lower fen (LF), and forested *Sphagnum* islands (FS). Arrows indicate direction of water flow.

Mariana Lakes Study Area

Site Location and Landform Features



WT–Watertrack
FS–Forested Sphagnum Islands
UF–Upper Fen
LF–Lower Fen
⟶ Direction of Waterflow

duplication of the three major landforms (upper fen, lower fen, and forested Sphagnum islands).

Surface water samples were removed from natural depressions on July 25, 1984, May 24, 1985, and August 17, 1985 in acid washed linear polyethylene bottles and analyzed for pH, electrical conductivity, and major ions. PH measurements were taken directly in the field using an electromate pH meter. Conductivity was analyzed at 25°C and corrected for hydrogen ions using Sjors (1952) method. Water samples used for ion concentrations were filtered, preserved with 1 ml of 4 N HCl, and analyzed by an inductively coupled argon plasma spectrophotometer.

Duplicate peat cores were removed with a 5 cm modified Mcauley peat sampler. Peat stratigraphy was determined in the field on the basis of botanical composition and state of decomposition. Estimates of the percentage of Sphagnum , sedges, brown mosses, wood, ericaceous shrubs, and the Von Post scale of decomposition was made for each stratum. In one core a 5 cm section of each stratum was removed for bulk density and peat chemistry. The second core was kept intact by storing it in a half section of 2 m polyvinylchloride pipe, wrapped in cellulose acetate. This core was used for macrofossil analyses and radiocarbon dating.

Peat samples removed for bulk density and peat chemistry were weighed and air dried. A mortar and pestle were used to finely grind the samples. Subsamples of 0.2 to 0.3 g were dry ashed in a muffle furnace at 550°C for 16 hours. Ash residue was digested with 3 ml of 1.5 N HCl, 1 ml of concentrated HNO3, and evaporated. A further 3 ml of 1.5 N HCl and 5 ml of distilled water was added to the dried salt. Solutions were filtered through Whatman #42 paper, volumetrically adjusted to 25 ml and stored in 30 ml polyethylene bottles. Ion concentrations were determined on an inductively coupled argon plasma spectrophotometer. Ion concentrations are calculated in mg/Kg.

Peat samples used for macrofossil analysis were wrapped in a layer of cellulose acetate and volumetrically measured using Janssens (1983) displacement technique. Each sample was soaked for 3 days in 75% aqueous Areosol OT solution to allow for complete dispersion of the organic material. Samples were sieved in a 500 um soil sieve and spiked with 0.5 g (958.88 ± 52.32) of poppy seeds. Every macrofossil in a 1 % subsample was tabulated, measured, and identified. Stems were measured on all bryophyte species whereas for monocots (parallel veined, graminoids), ericaceous shrub leaves and wood, all identifiable portions were counted. For Picea and Larix needles were measured and counted. Macrofossil density was calculated as mm stem/ml peat. Percent frequency of each macrofossil species was calculated as a proportion of the total mm stem/ml of peat.

Stand groups were ordinated with Decorana (Hill 1979a), a detrended correspondence analysis. Twinspan, a polythetic devisive reciprocal averaging program (Hill, 1979b) was used to relate surface vegetation to surface water chemistry, and to obtain peat macrofossil classes. Based on the *Twinspan* macrofossil classification, peat cores were subdivided into two major peat types (open fen and forested Sphagnum islands). A non-parametric median test, the Mann-Whitney U was used to determine significant differences in peat physical parameters, ion concentrations, and macrofossil classes between the two peat types.

D. RESULTS

Surface vegetation was subdivided by Twinspan into four vegetation types; these are related to water chemistry in Table III-1 and surface landforms in Fig. III-3. Forested Sphagnum islands have the lowest pH (3.6-4.5), and conductivity (0-25 uS/cm). Calcium and magnesium contents are low at 1.1-2.4 mg/l and 0.2-0.6 mg/l respectively. Open fen sites containing Sphagnum fallax are ionically poor having pH values between 3.8 mg/l and 4.2 mg/l with conductivity values of 31.8-41.6 uS/cm. Calcium concentrations are between 1.2 mg/l and 2.7 mg/l. Magnesium concentrations are between 0.4 mg/l and 0.8 mg/l. Fen sites containing Carex chordorrhiza are more ionically rich having pH values between 4.5 and 5.4, conductivity values between 0 and 62.8 uS/cm, calcium ion contents of 1.4-3.6 mg/l, and magnesium values of 0.4-1.0 mg/l. The two forested Betula sites (11,6) are more minerotrophic, receiving additional nutrient sources. Site 11 receives additional drainage from the small easternly lake and site 6 receives additional flow through another ground water

Fig. III-3. Releves of the surface vegetation positioned by *Decorana* ordination showing the relationship between physiographic-vegetation units and surface water chemistry. Eigen values for the first two axis are included (Eig).

Mariana Lakes

Surface Water Chemistry and Decorana Physiographic Types

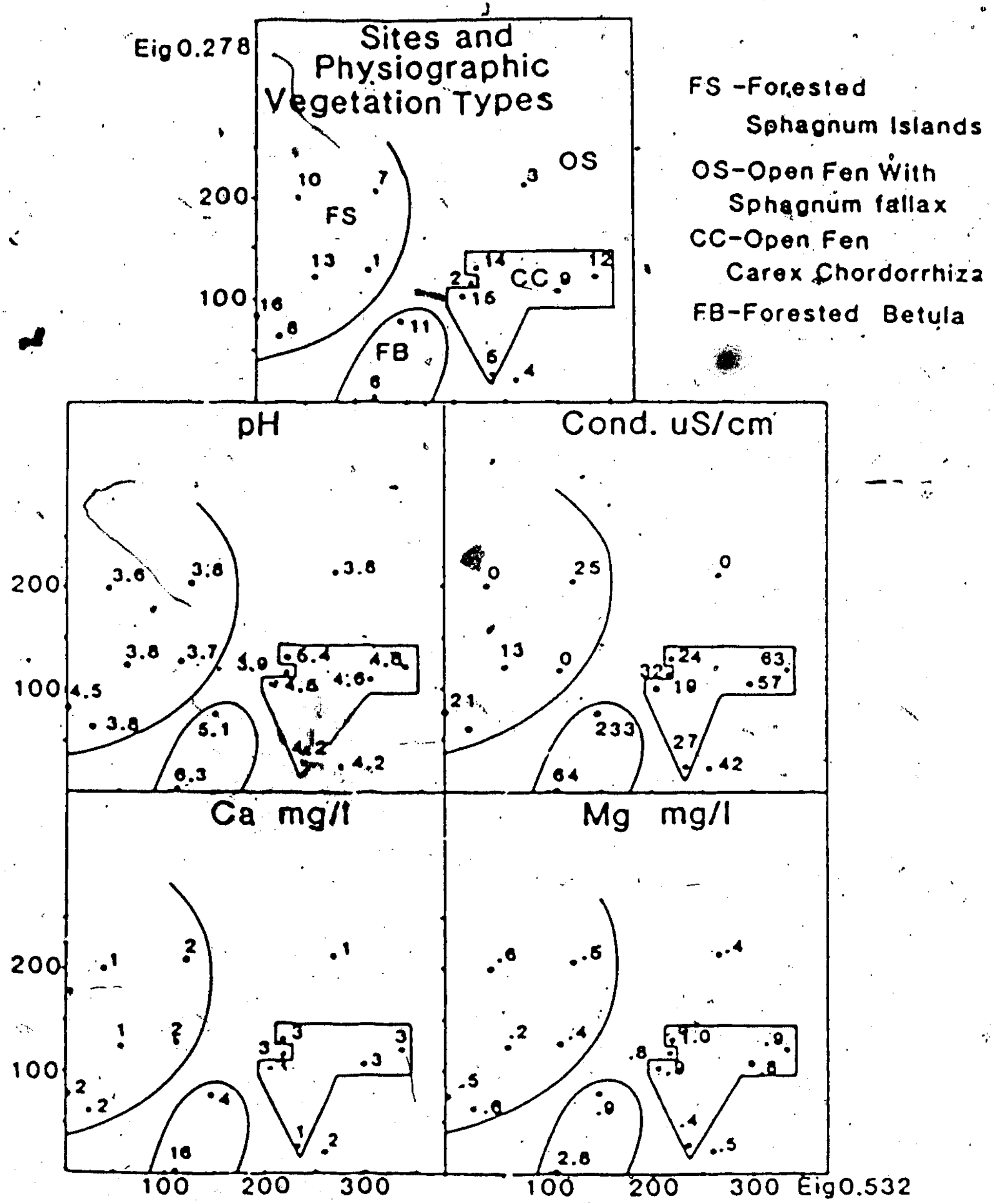


Table III-1. Surface water chemistry at Mariana Lakes. Ion values are given in mg/l, with sample size (n) and standard deviations.

Table III-1. Mariana Lakes Surface Water Chemistry (mg/l)

Site	Ca	Mg	Na	K	Al	Fe	Mn	Zn	S	P	(n)
1	1.63	0.43	0.91	0.44	0.04	0.39	0.04	0.05	0.45	0.07	3
stdev	.702	.062	1.55	.622	.032	.199	.016	.032	.035	.035	
2	2.65	0.75	0.96	1.06	0.03	0.53	0.06	0.09	0.54	0.04	3
stdev	1.14	.190	.797	1.14	.038	.172	.015	.055	.155	.033	
3	1.24	0.40	0.47	0.48	0.03	0.37	0.05	0.04	0.28	0.0	3
stdev	.461	.066	.808	.315	.026	.107	.032	.015	.038	0	
4	1.83	0.53	0.57	0.10	0.05	0.51	0.07	0.04	0.21	0.02	2
stdev	1.33	.219	.806	.099	.028	.177	0	.007	.141	.028	
5	1.40	0.38	1.10	0.65	0.05	0.48	0.06	0.07	0.24	0.03	2
stdev	.671	.050	1.03	.169	.007	.198	.007	.028	.014	.028	
6	15.6	2.76	1.22	0.08	0	2.22	0.23	0.03	0.23	0	1
stdev	0	0	0	0	0	0	0	0	0	0	
7	2.43	0.51	1.33	0.97	0.21	0.75	0.04	0.22	0.73	0.08	3
stdev	.955	.080	1.54	.600	.021	.114	.005	.262	.180	.101	
8	1.52	0.59	1.06	0.65	0.10	0.33	0.05	0.05	0.50	0.43	3
stdev	.537	.325	1.22	.539	.060	.093	.006	.023	.263	.454	
9	2.71	0.79	1.06	0.26	0	0.30	0.05	0.54	0.28	0.01	3
stdev	.771	.104	1.21	.170	0	.210	.010	.906	1.22	.003	
10	1.12	0.57	0.97	1.03	0.03	0.28	0.23	0.53	0.34	0.66	3
stdev	.481	.773	1.18	.442	.036	.135	.006	.814	.069	.917	
11	3.38	0.92	1.87	0.84	0.17	0.28	0.02	0.22	0.27	0.01	3
stdev	.962	.161	3.03	1.23	.029	.065	.007	.361	.140	.017	
12	3.47	0.89	1.26	0.37	0	0.62	0.04	0.18	0.26	0.01	3
stdev	2.00	.137	1.42	.400	0	.284	.021	.274	.036	.006	
13	0.92	0.22	0.62	0.29	0.02	0.69	0.02	0.03	0.43	0	2
stdev	.735	.035	.869	.276	.022	.169	.007	0	.042	0	
14	3.63	1.04	0.75	0.06	0	0.36	0.11	0.10	0.18	0	2
stdev	.459	.063	1.06	.085	0	.141	.049	.136	.092	0	
15	2.80	0.94	.250	0.28	0	0.60	0.06	0.06	0.28	0.07	2
stdev	1.09	.262	.042	.057	0	.361	.007	.007	.035	.035	
16	1.62	0.53	0.21	0.14	0	0.34	0.02	0.04	0.28	0.06	2
stdev	.332	.057	.106	.198	0	.127	0	0	.078	0	

Table III-2. Surface water chemistry at Mariana Lakes. PH and corrected conductivity values with associated sample size (n) and standard deviation. Conductivity values were taken at 25°C and corrected for hydrogen ion concentration (Sjors 1952).

Table III-2
Mariana Lakes Surface Water Chemistry

Site	Mean pH	Hydrogen Ion Standard Deviation	Corrected Conductivity uS/cm	Standard Deviation	(n)
1	3.74	.0000413	0	0	3
2	3.90	.0000739	31.8	32.5	3
3	3.81	.0000578	0	17.3	3
4	4.20	.0000183	41.6	30.0	2
5	4.17	.0000022	27.1	19.4	2
6	6.34	.0	64.0	14.7	1
7	3.82	.0000534	25.5	4.3	3
8	3.76	.0000534	7.7	8.6	3
9	4.65	.0000097	57.4	30.9	3
10	3.63	.0001600	0	0	3
11	5.12	.0000039	232.7	296.0	3
12	4.83	.0000217	62.8	55.2	3
13	3.77	0	13.5	3.2	2
14	5.40	.0000014	23.9	1.5	2
15	4.55	0	19.5	1.8	2
16	4.50	.0000041	21.2	2.5	2

Conductivity was measured at 25°C and corrected for hydrogen ion concentration (Sjors 1952).

source. These sites have the highest pH and conductivity values in the mire (pH 5.12, cond. 232 uS/cm; pH 6.34 cond. 64 uS/cm) and have an calcium and magnesium content of 3.4-15.6 mg/l and 0.9-2.8 mg/l respectively

Macrofossil analysis

The bulk of the macrofossil analysis has been presented in a previous paper (Chapter 2). Our interpretation of the data presented in that paper is as follows. Results of the Twinspan classification of peat macrofossils are presented in Fig. III-4. Peat macrofossil classification follows ionic and moisture gradients (Table III-3), and in the forested Sphagnum peats is positively correlated to calcium (r=.5568) and magnesium (r=.4281) (Table III-4). Peat development at Mariana Lakes initiated in former lake basins at site 12 and site 14. Floating mats (L9) of Drepanocladus formed, causing infilling of the lake basins. Peat that developed subsequent to the floating mat stage is high in Sphagnum (Table III-3) and Larix both of which indicate initiation of poor fen vegetation. Macrofossil changes in the upper portions of site 12 and site 14 cores suggest shifts in the local patternation of Sphagnum lawns and pools. Early peat development at site 6 began in macrofossil class LM7, an assemblage high in sedges. Gradually the site was invaded by ericads, Larix, Picea, and developed into macrofossil class ME4. Renewed flooding occurred resulting in an increase in monocots (DM8, MC15). Surface water flow at site 6 presently moves in channels around shrub and ericad covered mounds. Changes in macrofossil classes at site 6 throughout the peat profile reflects shifting drainage patterns in this area. In upper fen site 15, peat development began with an assemblage high in Larix and monocots (LM7). Early in the peat profile, Sphagnum and monocots form important components of the macrofossil assemblages (MS3, ME4). Interspersed with Sphagnum dominanting (S2) peat classes is the peat class LS6, a class containing Drepanocladus, a minerotrophic indicator. The peat profile at site 15 indicates that this site was originally positioned in a poor fen watertrack and has remained under minerotrophic (ground water) influence. Lower fen sites 4 and 5 have a similar developmental pattern to upper fen site 15. Site 4 initiated in a monocot assemblage (LM7), while site 5 has

Fig. III-4. Classification of macrofossil assemblages for ten of the sixteen peat cores at Mariana Lakes. Peat cores are grouped according to lake basin, upper fen, lower fen, and Sphagnum island areas. Radiocarbon years since 1950 are indicated for each core. Assemblages classified by *Twinspan* are named according to the main macrofossil components.

TWINSPAN MACROFOSSIL CLASSIFICATION

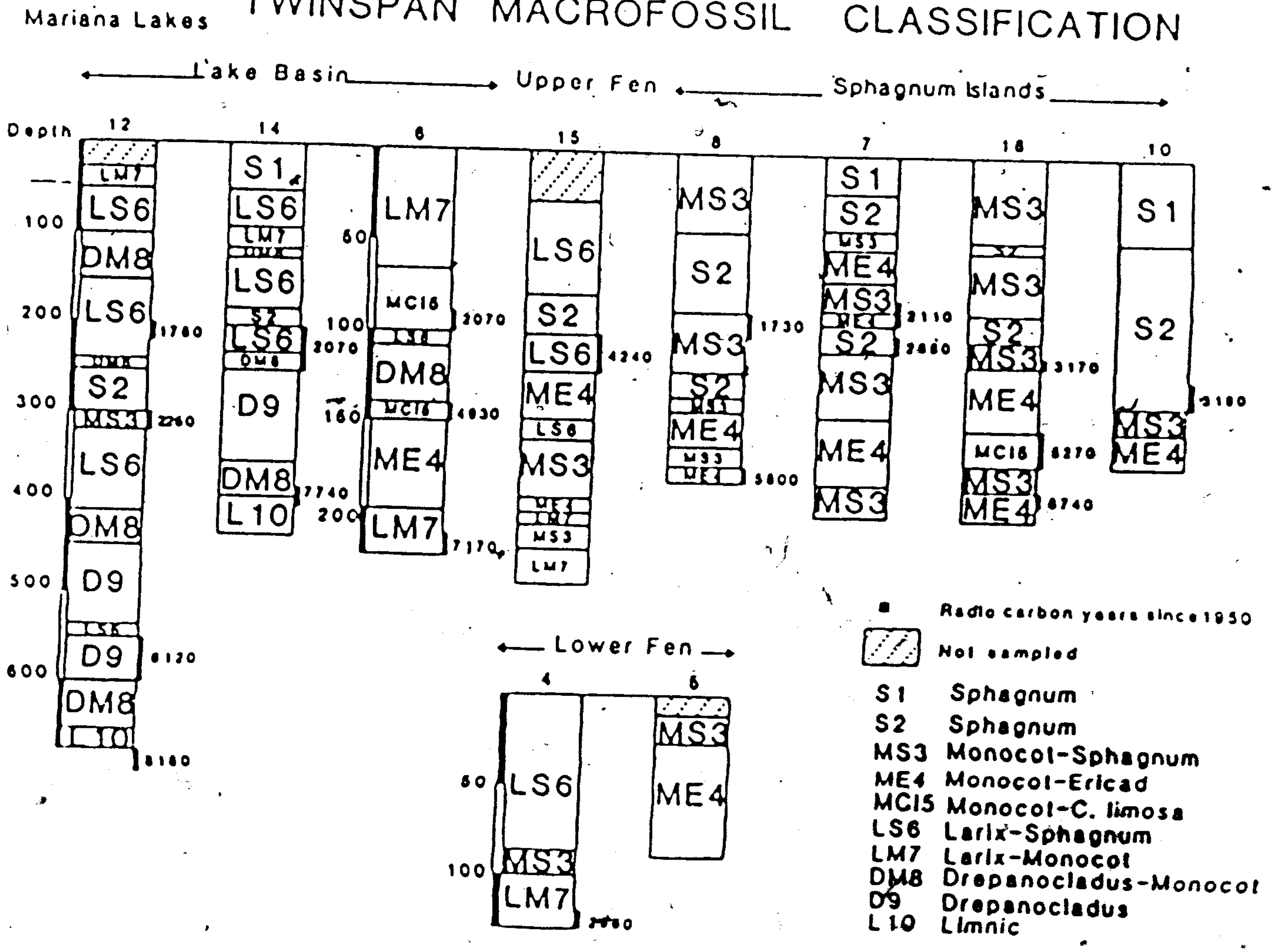
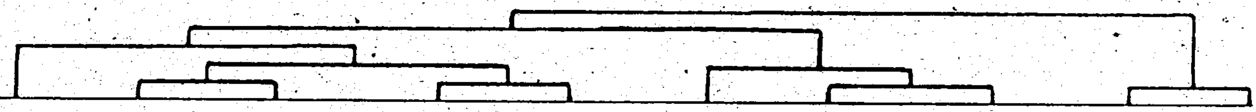


Table III-3. Twinspan generated association table for 25 macrofossil species in 10 macrofossil groups. Numbers are mean frequency values on a scale of 1 to 8; * = <0.1.

\+ species names are given to these based on surface vegetation

\+ + Drepanocladus spp., consists of D. aduncus, D. exannulatus, D. fluitans, D. lapponicus, D. vernicosus. Sphagnum spp. consists of S. angustifolium, S. contortum, S. fallax, S. jensenii, S. magellanicum, S. majus, S. obtusum, S. platyphyllum, S. subsecundum, S. teres, S. warnstorfii, and the groups Acutifolia and Cuspidata.



Twinspan Groups	S1	S2	MS3	ME4	MC15	LS6	LM7	DM8	D9	L10
++Drepanocladus spp.						0.4	0.3	2.5	6.0	2.2
Chara sp.										1.0
Algal detritus										4.8
++Sphagnum spp.	6.8	4.3	2.6	1.2	0.3	2.3	0.9	1.8	1.1	1.4
Larix laricina		0.8	0.4	0.3	0.5	0.8	0.6	1.2	0.7	0.2
Monocots		3.5	4.6	4.6	3.0	3.9	5.5	3.8	3.3	2.8
Tomenthypnum nitens				•						
Pleurozium schreberi			•	•						
+Ericaceous bark	0.8	2.3	2.4	2.3	3.3	1.5	1.5	1.5	0.3	0.8
+Picea mariana		1.2	0.9	0.6	1.3	0.2	0.3	•		0.2
Pohlia nutans	0.4			•	0.5		0.2			
+Ericaceous roots	1.8	0.8	2.1	1.3	1.0	2.8	1.2	1.0	0.3	
Charcoal		•	•	0.1	0.5		0.8	•		
Polytrichum strictum		•	•	•				•		•
Wood		•	•	0.7	2.0	•		0.5		•
Calliergon stramineum				•	0.5	•		•		•
Aulacomnium palustre						•	•			
+Betula sp.			•			0.1	•	•		
+Vaccinium vitis-idaea						•				
+Chamaedaphne calyculata						0.2		0.2		
+Oxycoccus microcarpus			•			0.3		0.2		•
+Equisetum fluviatile								•		
+Andromeda polifolia		•		•		0.5	0.3	0.4		
Meesia triquetra						0.3	0.7	0.5		•
+Carex limosa/paupercul.		•	•	•	1.8	1.5	2.8	2.2	0.3	1.0
No. of samples	1	20	27	22	4	28	10	15	7	5
Peat Calcium mg/Kg	2195	3671	6046	7317	11538	9439	11022	10705	10327	8228
St. Dev.		432	1987	4073	3948	2782	6289	2774	2363	4491

Table II-8. Twinspan generated association table of 25 macrofossil species in 10 macrofossil groups. Numbers are mean frequency values on a scale of 1 to 8; • = <0.1

its origins in macrofossil class ME4. Both sites experience recent increases in Sphagnum (MS3) due to increased isolation from the underlying mineral soils by the accumulating peat. Peat development at the forested Sphagnum island sites began with either peat class MS3 or ME4, assemblages which are distinctly different from basal peats present in the upper and lower fen sites. Sphagnum is a more significant component of the peat assemblages. Peat profiles indicate that site 10 has the most stable macrofossil history describing gradual progression from peat macrofossil assemblage ME4 to S1. Sites 8,7, and 16 have fluctuating macrofossil profiles indicating fluctuating mineral influences.

Peat Analysis

Physical Properties

Percentage Ash

Percentage ash contents of the first subsurface peat horizon is highest at site 6 (38%), the most minerotrophic site. Fen sites are intermediate (Fig. III-5) from 3.5% to 9%, and forested Sphagnum islands have the lowest subsurface ash contents from 3.5% to 1%. Fen sites have peat profiles that tend to increase in % ash with depth (r= .2644, sig .01)(Table III-4). Site 6 has a dramatic increase in ash near the peat surface, while site 15 has a stable ash profile. Percentage ash in forested Sphagnum peats are not correlated with peat depth (Table III-4). A significant difference in ash contents was found to occur between subsurface forested Sphagnum peats and fen peats. Fen peats have an average ash content of 12.38 %, while forested Sphagnum peats contain only 4.29 %. No correlation was found to occur between macrofossil class and % ash.

Bulk Density

The bulk density of the first subsurface peat horizon (Fig. III-6) does not appear to bear any relationship to landform features. Site 15 has the highest bulk density (0.44 g/cm^3, followed closely by site 16 with 0.29 g/cm^3, and site 10 at 0.24 g/cm^3.

Fig. III-5. Physical properties. Percentage ash (g/g) in peat cores at Mariana Lakes. Peat cores are organized into upper fen, lower fen and <u>Sphagnum</u> island areas.

C

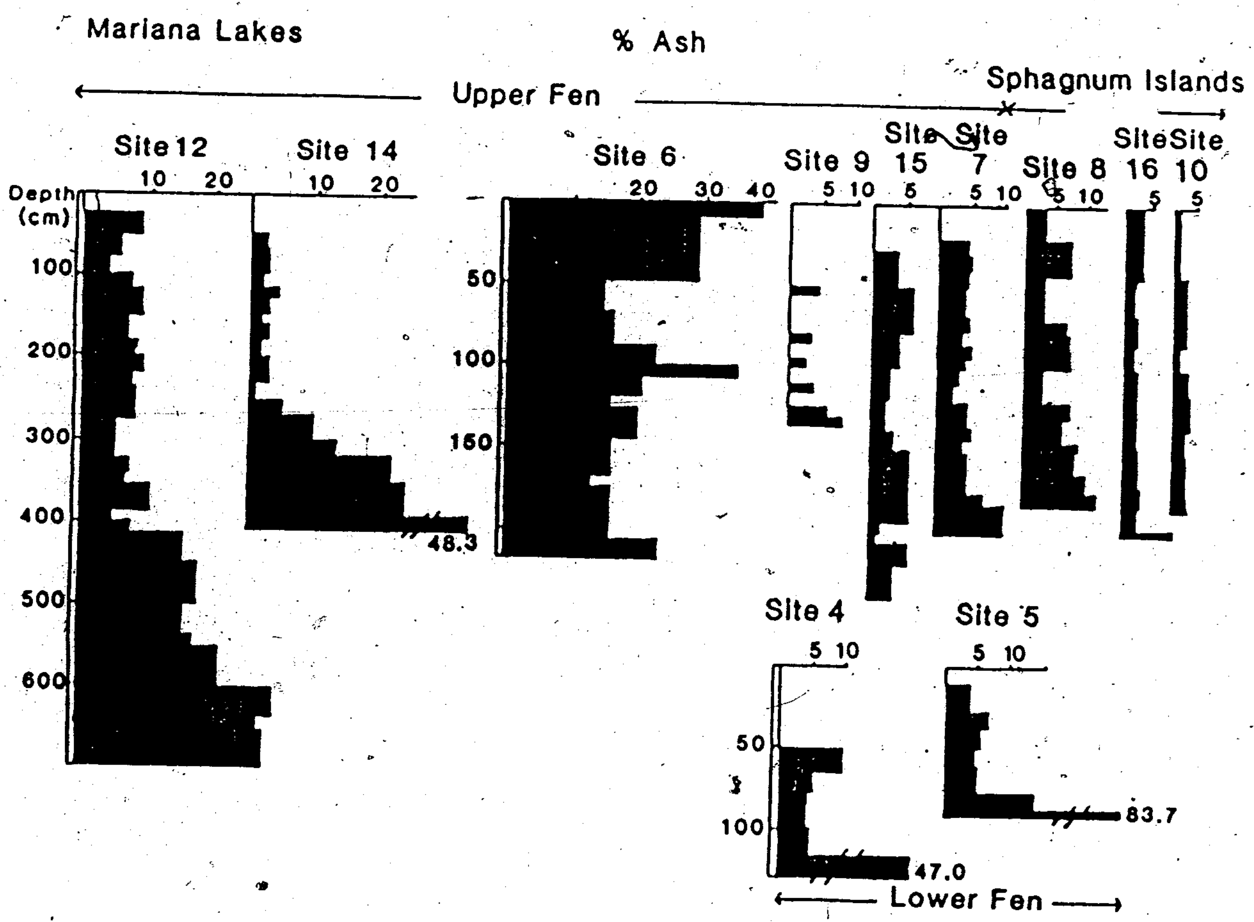

Mariana Lakes
% Ash
Upper Fen
Sphagnum Islands
Site 12
Site 14
Site 6
Site 9
Site 15
Site 7
Site 8
Site 16
Site 10
Depth (cm)
10
20
30
40
5
50
100
150
200
300
400
500
600
48.3
Site 4
Site 5
47.0
83.7
Lower Fen

Fig. III-6. Physical properties. Bulk density measurements (g/cm^3) in peat cores at Mariana Lakes. Peat cores are organized into upper fen, lower fen, and <u>Sphagnum</u> island areas.

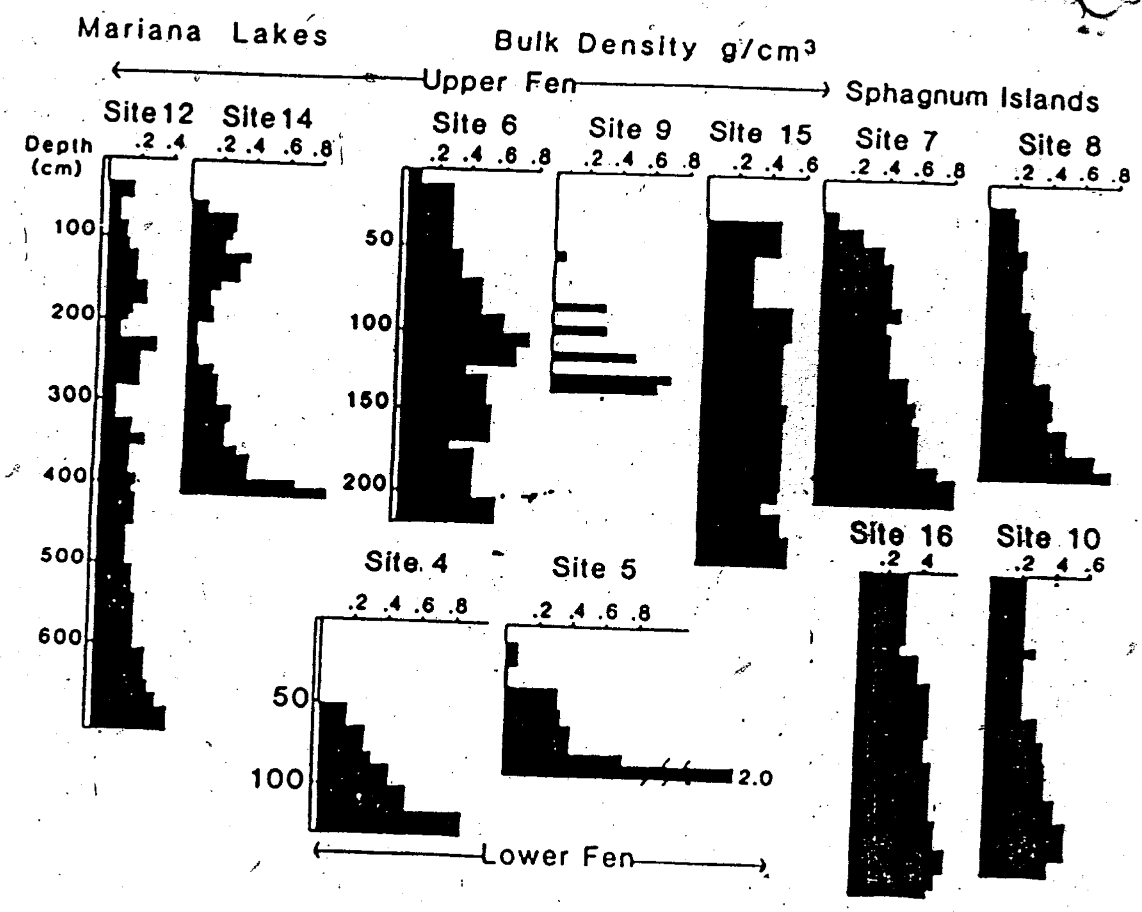

Mariana Lakes
Bulk Density g/cm3
Upper Fen
Sphagnum Islands
Depth (cm)
100
200
300
400
500
600
Site 12
.2 .4
Site 14
.2 .4 .6 .8
Site 6
.2 .4 .6 .8
50
100
150
200
Site 9
.2 .4 .6 .8
Site 15
.2 .4 .6
Site 7
.2 .4 .6 .8
Site 8
.2 .4 .6 .8
Site 16
.2 .4
Site 10
.2 .4 .6
Site 4
.2 .4 .6 .8
50
100
Site 5
.2 .4 .6 .8
2.0
Lower Fen

Table III-4. Correlation matrix of peat chemistry and physical properties for the forested Sphagnum island cores. Elements are (mg/kg) Calcium, magnesium, potassium, aluminum, lead, copper, iron, manganese, zinc, nickle, sulfur, potassium. Physical properties are percentage ash (g/g), bulk density (g/cm^3), depth (cm), and macrofossil classification.

Table III-4.
Correlation Matrix Forested Sphagnum Islands

	CA	MG	NA	K	AL	TI	PB	CU	FE	MN
MG	.8968**									
NA	.1981	.3326*								
K	.2784	.4758**	.7422**							
AL	.7638**	.6978**	.2274	.4267*						
TI	.6249**	.4337**	.0256	.1588	.7494**					
PB	.3494*	.4290**	-.0126	.3498*	.5145**	.2491				
CU	.3558*	.2431	-.0098	.1707	.2399	.3967*	.2207			
FE	.7079**	.7201**	.2253	.4221*	.6912**	.4790**	.4735**	.4700**		
MN	.3523*	.6028**	.3022	.5548**	.2128	-.2056	.4487**	.1279	.5550**	
ZN	.2193	.2442	.0876	.1102	.0947	.1643	.2182	.1730	.1309	.1624
NI	.5786**	.6273**	.2800	.5736**	.6901**	.4328**	.6066**	.5239**	.7607**	.5979
S	.7782**	.6928**	.0865	.2911	.6513**	.7026**	.3241	.6270**	.7318**	.2248
P	.1233	.3623*	.1994	.4694**	.2252	-.0949	.4797**	-.1407	.1900	.5488**
ASH	.4815**	.5909**	.1521	.4945**	.4968**	.2631	.4890**	.4379**	.7687**	.6265**
DB	.7472**	.5160**	-.0440	.0880	.7426**	.8643**	.2519	.3800*	.5057**	-.1206
DEPTH	.6498**	.4080*	-.0702	-.0020	.5242**	.7741**	.0259	.5135**	.5143**	-.1852
MACRO	.5568**	.4281**	-.0222	.1205	.4672**	.5707**	.1218	.3427*	.3398*	-.0097

	ZN	NI	S	P	ASH	DB	DEPTH
NI	0.853						
S	.2583	.5471**					
P	-.0428	.3980*	-.0666				
ASH	.1292	.6669**	.6217**	.1942			
DB	.0992	.3751*	.7325**	-.1233	.2790		
DEPTH	.1703	.2446	.8082**	-.4440**	.3225	.8086**	
MACRO	.1487	.2396	.7004**	.0436	.2505	.6252**	.5749**

Spearman coefficients * - SIGNIF. at .01 ** - SIGNIF. at .001

Intermediate in position are sites 12,14,4,7,and 8 with bulk densities of 0.10-0.16 g/cm³. Sites 6, 9, and 5 have the lowest bulk densities, less than 0.10 g/cm³. Statistical analysis reveals that within the two peat types, fen and forested Sphagnum , the forested Sphagnum peats have a slightly higher bulk density (0.462 g/cm³ versus 0.334 g/cm³). Bulk density was found to be strongly correlated to peat depth (r=.8086, sig .001) (Table III-4) and macrofossil content (r=.6252, sig .001) on forested Sphagnum islands, and ash (r=.2782, sig.01) in fen cores (Table III-5).

Element Chemistry

Calcium

Calcium element content in the first subsurface peat horizon at Mariana Lakes forms a decreasing gradient from minerotrophic fen site 6 (17,400 mg/Kg); to upper fen sites 12,14,15, and 9 (9,000-13,500 mg/Kg); to lower fen sites 4 and 5 (2,000-5,000 mg/Kg); and to forested Sphagnum island sites 7,8,16,10 (3,000-3,200 mg/Kg). Calcium element profiles (Fig. III-7) describe three trends in calcium element accumulation. Sites 12, 15, and 6 have calcium ion profiles that are fluctuating but remain relatively stable. Sites 14 and 9 have profiles which indicate gradual enrichment upwards. Sites 4,5,7,8,16,and 10 (lower fen and forested Sphagnum) have profiles which indicate a gradual decline upwards in calcium content. Calcium contents between subsurface fen and forested Sphagnum peats were found to be significantly different (Table III-6). Fen peats contained 9399 mg/Kg of calcium, while forested Sphagnum peats contain an average of 5046 mg/Kg. Within forested Sphagnum island peat cores calcium elememt contents are positively correlated with depth (r=.6498, sig. .001)(Table III-4), % Ash (r=.4815, sig. .001), bulk density (r=.7472, sig. .001), magnesium (r=.8968, sig. .001), and macrofossil classfication (r=.5568, sig. .001). In fen cores calcium is correlated to magnesium (r=.2989, sig. .01), and % ash (r=.2788, sig. .01) (Table III-5).

Fig. III-7. Peat chemistry. Elemental calcium (mg/kg) content in peat cores at Mariana Lakes. Peat cores are organized into upper fen, lower fen, and Sphagnum island areas.

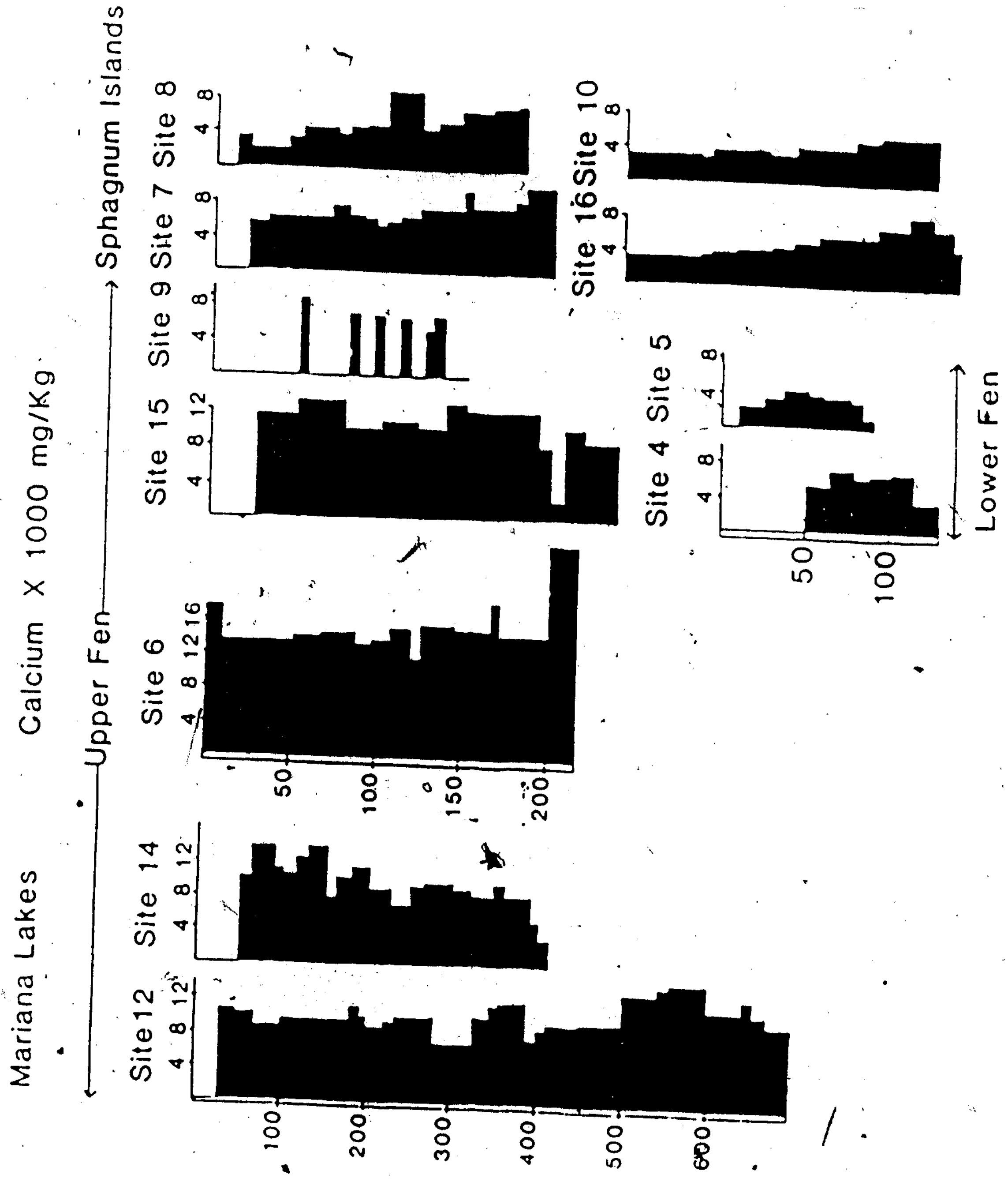

Mariana Lakes
Calcium X 1000 mg/Kg
Upper Fen
Sphagnum Islands
Lower Fen
Site 12
4 8 12
100
200
300
400
500
600
Site 14
4 8 12
Site 6
4 8 12 16
50
100
150
200
Site 15
4 8 12
Site 9
4 8
Site 7
4 8
Site 8
4 8
Site 16
4 8
Site 10
4 8
Site 4
4 8
Site 5
4 8
50
100

Table III-5. Correlation matrix of peat chemistry and physical properties for fen cores. Elements are (mg/kg) calcium, magnesium, potassium, aluminum, lead, copper, iron, manganese, zinc, nickle, sulfur, and potassium. Physical properties are percentage (g/g) ash, bulk density (g/cm^3), depth (cm), and macrofossil classification.

Table III-5.
Correlation Matrix Fen

	CA	MG	NA	K	AL	TI	PB	CU	FE	MN
MG	.2989*									
NA	-.0651	.0648								
K	-.1111	.0586	.7711**							
AL	-.0980	.0917	.3561**	.7082**						
TI	-.0556	-.2003	.0886	.2692*	.6422**					
PB	.2468	-.0051	.3921**	.6005**	.6408**	.2819*				
CU	.1052	-.3786**	.3965**	.2925*	.2652*	.4467**	.3585**			
FE	.0167	.1180	.3562**	.5508**	.5961**	.2504	.4007**	.2141		
MN	.5551**	.1309	.2433	.3434**	.1811	.0964	.4923**	.2272	.1596	
ZN	-.0283	-.0541	.2085	.3352*	.1951	.1174	.2934*	.1117	.1633	.2347
NI	.1830	.1050	.4752**	.7421**	.6849**	.2819*	.7327**	.3653**	.4488**	.5568**
S	.5209**	.1430	.3048*	.4789**	.4767**	.2271	.5656**	.2771*	.3775**	.5833**
P	.2627*	-.4182**	.1521	.2819*	.0804	.1047	.4055**	.2711*	.1587	.4726**
ASH	.2788*	.1492	.3201*	.5860**	.5308*	.0289	.6729**	.0714	.3891**	.5359**
DB	.1692	-.1955	.0407	.1843	.4993**	.4562**	.4518**	.2710*	.2876*	-.0575
DEPTH	.0263	.4144**	.0871	.1530	.2245	.0605	.0379	-.0427	-.0275	.1603
MACRO	.1827	.1204	-.0978	.0776	.1159	.0676	.1194	.0491	-.0402	.2053

	ZN	NI	S	P	ASH	DB	DEPTH
NI	.4256**						
S	.3128*	.6662**					
P	.3079*	.4359**	.3177*				
ASH	.4825**	.6627**	.6386**	.2626*			
DB	-.0659	.2300	.4642**	.0586	.2782*		
DEPTH	.1458	.2446	.3618**	-.4446**	.2644*	.0505	
MACRO	-.0130	.2880*	.2996*	.1005	.1566	-.1450	.2934*

Spearman Coefficients * - SIGNIF. at .01 ** - SIGNIF. at .001

Table III-6. Mann-Whitney U test comparing peat chemistry and physical properties of forested *Sphagnum* island cores to fen cores. (N)=sample size.

Table III-6. Mann-Whitney U Test

ION		Mean	Standard Deviation	T value	2 Tail Prob.
CA	Islands	5663.2	1837.9	-6.87	0.000
	Fen	9702.5	3906.4		
MG	Islands	498.3	153.2	-10.38	0.000
	Fen	934.9	272.9		
Na	Islands	130.8	42.1	-1.30	0.196
	Fen	148.9	93.2		
K	Islands	140.0	61.2	-3.16	0.002
	Fen	345.6	456.1		
AL	Islands	1486.0	799.7	-2.32	0.022
	Fen	2307.1	2419.8		
TI	Islands	22.8	12.0	0.76	0.449
	Fen	21.0	13.4		
PB	Islands	3.0	3.2	-3.62	0.000
	Fen	6.3	5.9		
CU	Islands	6.1	2.6	-2.01	0.047
	Fen	7.4	3.9		
FE	Islands	1855.8	1453.9	-0.56	0.578
	Fen	2016.3	1700.2		
MN	Islands	32.7	12.9	-3.60	0.000
	Fen	108.7	148.6		
ZN	Islands	439.3	186.5	2.58	0.011
	Fen	319.0	297.1		
NI	Islands	4.4	2.6	-3.17	0.002
	Fen	6.8	4.9		
S	Islands	794.1	671.7	-3.01	0.003
	Fen	2140.9	2140.9		
P	Islands	355.3	152.3	-2.77	0.006
	Fen	954.3	1521.9		
Ash	Islands	4.3	2.6	-4.03	0.000
	Fen	12.4	14.0		
DB	Islands	0.4	0.2	2.51	0.013
	Fen	0.3	0.2		

Magnesium

Magnesium contents of the first subsurface peat horizon (Fig. III-8) also follows a gradient which corresponds to landform features. Upper fen sites have the highest magnesium contents (1,000-1,300 mg/Kg), lower fen sites are significantly lower in magnesium (650-700 mg/Kg) and forested Sphagnum islands have the lowest magnesium contents (300-620 mg/Kg). Magnesium is strongly correlated to calcium, both in surface waters and subsurface peats (Tables III-1 and III-3). Magnesium profiles fall into three categories, stable, increasing or declining. Fen sites tend to have stable but fluctuating magnesium profiles. Site 6 has a magnesium profile that is distinctly enriched in the surface horizons. Forested sphagnum sites (plus site 5) display a slight and gradual decline in magnesium towards the peat surface. The Mann-Whitney U test indicates that there is a significant difference (Table III-4) between subsurface fen peats and forested Sphagnum peats. Forested Sphagnum peats have magnesium concentrations of 498.31 mg/Kg while subsurface fen peats contain 934.98 mg/Kg. Correlation studies indicate that magnesium is correlated to depth (r=.4144, sig. .001) in the fen cores. Magnesium content in forested Sphagnum cores was correlated with % ash (r=.5909, sig. .001) and bulk density (r=.5160, sig. .001), depth (r=.4080, sig. .01), and macrophytes (r=.4281, sig. .001).

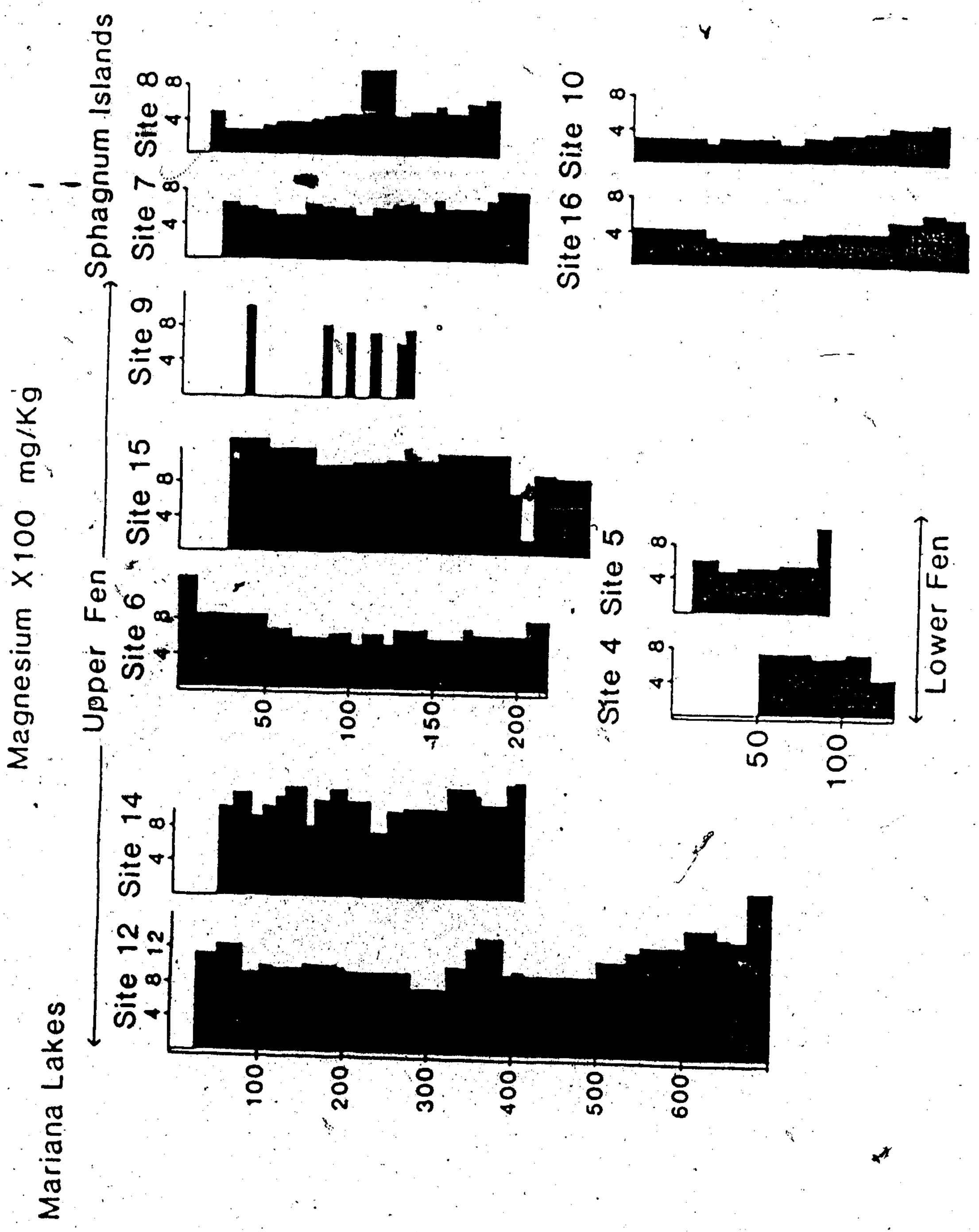
E. DISCUSSION

Physical Properties

% Ash

Percentage ash is a measure of the total elemental content of the peat and is dependant upon the botanical origin of the peat (Chapman 1964, Mornsjo 1968), the decomposition of the peat and subsequent nutrient release, the mobility of the ions, the water source (minerotrophic versus ombrotrophic), the presence of volcanic ash (Zoltai and Johnson 1985), and contamination by wind blown particles (Chapman 1964). At

Fig. III-8. Peat chemistry. Elemental magnesium (mg/Kg) content in peat cores at Mariana Lakes. Peat cores are organized into upper fen, lower fen, and Sphagnum island areas.


Magnesium X100 mg/Kg
Mariana Lakes
Upper Fen
Sphagnum Islands
Lower Fen
Site 12
4 8 12
Site 14
4 8
Site 6
4 8
Site 15
4 8
Site 9
4 8
Site 7
4 8
Site 8
4 8
Site 16
4 8
Site 10
4 8
Site 4
4 8
Site 5
4 8
100 200 300 400 500 600
50 100 150 200
50 100

Mariana Lakes % ash follows a minerotrophic-ombrotrophic gradient, that is not dependant upon botanical orign, as indicated by the nonsignificant correlation between macrofossil class and % ash (Table III-3). Elemental composition of peat is dependant upon translocation and accumulation of elements (Damman 1978). Ash contents at site 6 are extremely high, reflecting both a strong hydrological flow and an ionically rich water source. Forested Sphagnum island sites have % ash contents that correspond with published values for ombrotrophic peats (Chapman 1964, Mornsjo 1968), and reflect not only ionically poor nutrient source but translocation of minerals away from hydrologically high areas of the peatland. Fen sites are intermediate in % ash, reflecting an ionically poor water source, strong hydrological flows and accumulation from the higher forested Sphagnum islands and surrounding uplands.

Within the peat cores, % ash was found to increase with peat depth at the fen sites only. This is related to either state of decomposition, contamination by mineral soil grains, compaction, or basin morphology. Sites 12 and 14 have large ash accumulations in the lower peat horizons. This accumulation is not reflected in bulk density profiles and is therefore not due to compaction, nor decomposition. Percentage ash in these lower horizons decreases dramatically at the macrofossil change from a floating Drepanocladus mat to Sphagnum dominated poor fen. This indicates that high ash content in the lower horizons was due to basin morphology. Mineral ions from overland flow deposited in the lake basin, which subsided upon the enclosure of the lake basin and development of fen vegetation. Increase in % ash with depth at fen sites 9,4,5 appears to be related to decomposition (bulk density) and mineral soil contamination in the lowest peat horizons.

Bulk Density

Bulk density is the ratio of peat weight to volume, and indicates the density or porosity of the material. Bulk density is dependant upon botancial origin, state of decomposition, and compaction (Damman 1978, Zoltai and Johnson 1985). Bulk density measurements in peats at Mariana Lakes, agree with those reported by Zoltai and Johnson (1985) for another Alberta peatland. Bulk density measurements at Mariana

Lakes do not follow a minerotrophic-ombrotrophic gradient and were not found to be related to landform features. However they are related within peat cores to macrofossil class and peat depth (compaction). Forested Sphagnum peats had higher bulk density values than fen peats. This is in direct contrast to results reported by Zoltai and Johnson (1985) and Karlin and Bliss (1984). In these studies a comparison was made between forested Sphagnum peats and brown moss dominated fen peats, where brown mosses have a significant influence on bulk density. In addition, the fen vegetation at Mariana Lakes is floating and becomes compacted as much as 10 cm during dry periods. Lower bulk density values at the fen sites is due to the combined effect of bouyancy and lack of wood.

Element Chemistry

Chemical analysis of peat stratigraphy can be difficult to interpret, due to the multitude of factors which affect the chemical composition of the peat. In addition to water source and flow rate, direction of flow plays an important role in determining the amount of ions retained in the peat. Damman (1978), found that through leaching and relocation 50 % of the calcium and magnesium that is aerially deposited in ombrotrophic peats are retained. Other factors which influence peat chemistry include plant uptake, redox changes, and surface enrichment due to capillary flow (Damman 1986). The cation exchange complex of Sphagnum strongly binds divalent cations such as calcium and magnesium, resulting in the retention of these ions (Malmer and Sjors 1955, Yefimov and Yefimova 1973, Damman 1978, Hemmond 1980, Lembrechts and Vanderborght 1985, Damman 1986). Magnesium and calcium ion gradients have been documented between ombrotrophic and minerotrophic peats (Malmer and Sjors 1955, Stanek et al. 1977, Lembrechts and Vanderborght 1985, Giller and Wheeler 1986). Peat chemistry profiles, particularily calcium and magnesium have been used by researchers to gain an understanding into peatland development by comparing vegetation changes occurring during peat development with changes in peat chemistry (Chapman 1964, Mornsjo 1968, Tallis 1973, Zoltai and Johnson 1984).

Calcium

Calcium follows an ionic gradient in the surface peats at Mariana Lakes that corresponds to landform features and surface hydrology. Calcium values in the forested Sphagnum peats (3,000-3,200 mg/Kg) correspond to calcium values of 2,500-4,400 mg/Kg recorded for Sphagnum ombrotrophic bogs by Gorham (1956) and less than those recorded on Sphagnum bog islands by Zoltai and Johnson (1985) with 4,125-5,550 mg/Kg. Stanek et al. (1977) reported 4,370 mg/Kg of calcium in northern Ontario bog peats and 11,080 mg/Kg in fen peats. Calcium profiles which are stable (sites 12,15,6) describe a continuous deposition of calcium ions. Sites 14 and 9 have profiles with a gradual increase upwards in ion accumulation probably due to increased water flow. Lower fen sites 4 and 5 tend to have calcium ion profiles that become reduced in calcium towards the peat surface. Lower fen sites are gradually being removed from calcium ion influence by paludification (Chapter 2). Forested Sphagnum islands have basal calcium ion contents similar to basal sediments of fen sites 15 and 9, however, they experience a gradual decline in calcium ion content towards the peat surface. Calcium ion reduction suggests a change in hydrology at these sites. The surfaces of the forested Sphagnum islands are raised 15 cm from the fen surface, and as such form local discharge areas where precipitation is shed from the islands into the surrounding fen. From this study it is impossible to identify whether low calcium contents of the island peat is due to leaching and translocation into the adjacent fen or from gradual removal of the Sphagnum islands from minerotrophic water flow. Calcium profiles from British and European studies describe gradual calcium ion decline as the peatlands developed from a minerotrophic soil water regime to an ombrotrophic one. Some of the European cores indicate that ombrotrophic conditions existed right from the time of peat initiation (Chapman 1964, Tallis 1973). At Mariana Lakes calcium ion content in the peats is correlated to the peat classification. In some peatlands peat chemistry is not correlated with macrofossil type due to either flooding (Mornsjo 1968) or a tenuous hydrological profile (Zoltai and Johnson 1985), which causes ombrotrophic peats to become marinated by mineral enriched waters. At Mariana Lakes this is reflected to some extent in the fen peat profiles as calcium ion contents of the S2 macrofossil class is not always significantly lowered.

Three of the sites, sites 15,16, and 10, form a transect from one of the forested Sphagnum island into an adjacent watertrack. The sites are separated by 20 m intervals. Figure III-9 outlines the calcium ion contents of the peat and places the three cores at their respective heights above the water table. From this transect the deficiency of calcium ions in the forested Sphagnum island cores is readily apparent. Calcium ion contents in the fen peats of watertrack site 15 are approximately 10-12,000 g/Kg while calcium ions in the forested Sphagnum peats are less than 5,000 g/Kg. From this graph a relationship is seen between peat macrofossil classification and calcium ion content. In the forested Sphagnum island cores the calcium ion content rises toward the bottom with a corresponding change in macrofossil class. In the fen core the macrofossil classes are higher and calcium ion content more variable.

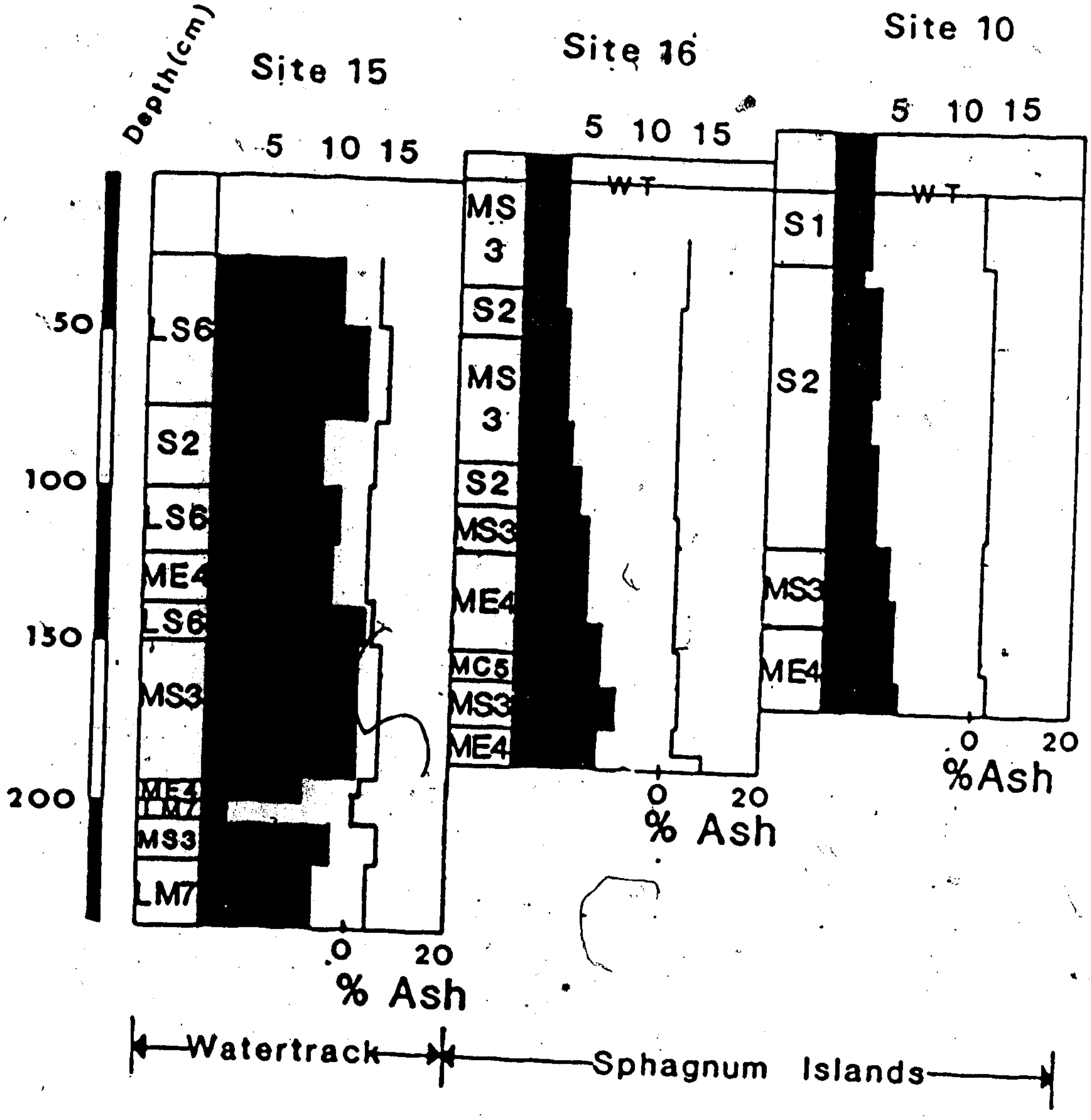
Magnesium

Magnesium values in surface peats at Mariana Lakes are similar to those reported by Malmer and Sjors (1955), Stanek et al. (1977), and Karlin and Bliss (1984). Forested Sphagnum islands at Mariana contain 300-640 mg/Kg of magnesium. Malmer and Sjors (1955) reported 2200 mg/Kg of magnesium in bog hummocks and poor fens, while Zoltai and Johnson (1985) averaged 814 mg/Kg on the forested bog islands. In northern Ontario, bogs average 690 mg/Kg of magnesium. Fen peats at Mariana averaged 640-700 mg/Kg in the lower fen sites and 1500-1300 mg/Kg in the upper fen sites. This compares favorably to 1945-3400 mg/Kg of magnesium Karlin and Bliss (1984) found in weakly minerotrophic Alberta peats, and the 2636 mg/Kg magnesium found in fen peats by Zoltai and Johnson (1985). Magnesium profiles reflect trends previously discussed with calcium. Fen sites have stable profiles indicating continuous magnesium enrichment through increased water flow. Forested Sphagnum islands have profiles that decline in magnesium concentration towards the peat surface and suggest that a hydrological change

Fig. III-9. Peat chemistry. Elemental calcium (mg/kg) content in cores forming a transect, taken from a watertrack onto an adjacent forested *Sphagnum* island. Cores are separated at 20 m intervals. Macrofossil classification is indicated on the left side of each core. Depth of water table (WT) is indicated at the top of each core, and percentage ash in each horizon is indicated by the black vertical line to the right of each core.

Mariana Lakes

Calcium X 1000 mg/Kg



WT-Water table

from recharge to discharge has occurred, resulting in the removal of Sphagnum islands from direct water flow and the leaching of minerals from the peat profile. Magnesium profiles in publications (Chapman 1964, Mornsjo 1968, Tallis 1973) have less amplitude, but show similar trends as compared to calcium.

F. CONCLUSION

Based on our previous work (Chapter 2), we conclude that peatland development at Mariana Lakes has occurred in two stages. The first began at 8180 BP and was completed when the infilling of former lake basins by a floating Drepanocladus mat, resulted in a Sphagnum dominated poor fen. The second stage occurred more recently at 2960 BP and resulted in paludification of adjacent upland soils by the poor fen. Within the peatland, water flow areas developed carrying overland runoff through the mire. Vegetation within the flow areas received mineral enriched waters and accumulated higher amounts of mineral ions. On adjacent slightly higher mineral ridges and in lowland areas not directly influenced by water flow, paludification resulted in drier more ionically poor environments. Forested Sphagnum islands developed in these hydrologically isolated regions. Surface water chemistry, vegetation, and peat chemistry profiles suggest that the forested Sphagnum islands have become ombrotrophic. In the process of ombrotrophic development, the Sphagnum islands have formed local discharge areas. Peat chemistry profiles describe gradual mineral ion reduction as a result of leaching from the discharge zones, and as a result of removal from ground water flow. At Mariana Lakes there is no distinct stratigraphic boundary between minerotrophic and ombrotrophic peats as described in Chapman (1964), Mornsjo (1968), Tallis (1973), and Zoltai and Johnson (1985). This system has not evolved from a concave basin mire into a convex domed ombrotrophic peatland in a region suitable for ombrotrophic peat development. Basin development at Mariana has resulted in a gently sloping poor fen. Areas that were initially removed from direct ground water influence have developed into expanding ombrotrophic Sphagnum islands. Thus while the surface features have a distinct ombrotrophic-minerotrophic boundary, the stratigraphy does not indicate a distinct boundary but a gradual transition from a mineral poor environment to ombrotrophy.

Acknowledgments

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LITERATURE CITED

1. Chapman, S.B. 1964. The ecology of Coom Rigg Moss, Northumberland. II The chemistry of peat profiles and the development of the bog system. J. Ecol. 52:315-323.

2. Comeau, P.L. and D.J. Bellamy. 1986. An ecological interpretation of the chemistry of mire waters from selected sites in eastern Canada. Can. J. Bot. 64:2576-2581.

3. Damman, A.W.H. 1978. Ecological and floristic trends in ombrotrophic peat bogs of eastern North America. Colloques phytosociologiques VII. Sols tourbeux, Lille:61-79.

4. Damman, A.W.H. 1986. Hydrology, development and biogeochemistry of ombrogenous peat bogs with special reference to nutrient relocation in a western Newfoundland bog. Can. J. Bot. 64:384-394.

5. Giller, K.E. and B.D. Wheeler. 19[illegible] Peat and peatwater chemistry of a flood-plain fen in Broadland, Norfolk. U.K. Fres[illegible]er Biology 16:99-114.

6. Glaser, P.H. 1983. Vegetation p[illegible] the North Black River peatland, northern Minnesota. Can. J. Bot. 61:208[illegible]

7. Glaser, P.H., G.A. Wheeler, E. Gorham and H. E. Wright Jr. 1981. The pattern mires of the Red Lake Peatland, northern Minnesota: Vegetation, water chemistry and landforms. J. Ecol. 69:575-599.

8. Gorham, E. 1956. The ionic composition of some bog and fen waters in the English Lake District. J. Ecol. 44:142-152.

9. Gorham, E., S.J. Eisenreich, J. Ford, and M.V. Santelmann. 1984. The chemistry of bog waters. In: Chemical Processes in Lakes, W. Stumm, ed. Wiley, N.Y. pp. 339-363.

10. Gorham, E. and W.H. Pearsall. 1956. Acidity, specific conductivity and calcium content of some bog and fen waters in northern Britian. J. Ecol. 44:129-141.

11. Hackbarth , D.A. and N. Natasa. 1979. The hydrologeology of the Athabasca Oil Sands Area, Alberta. Alberta Research Council Bulletin #38.

12. Heinselman, M.L. 1970. Landscape evolution, peatland types, and the environment in the Agassiz Peatlands Natural Area. Ecol. Monogr. 40:235-261.

13. Hemmond, H.F. 1980. Biogeochemistry of Thoreau's Bog, Concord, Mass. Ecol. Monogr. 50:507-526.

14. Hill, M.O. 1979a DECORANA-A FORTRAN program for detrended correspondence anaylsis and reciprocal averaging. Ecology and Systematics, Cornell University, Ithaca.

15. Hill, M.O. 1979b. TWINSPAN-A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of individuals and attributes. Ecology and Systematics, Cornell University, Ithaca.

16. Janssens, J.A. 1983. A quantitative method for strategraphic analysis of bryophytes in holocene peat. J. Ecol. 71:189-196.

17. Karlin, E.F., and L.C. Bliss. 1984. Variation in substrate chemistry along microtopigraphical and water-chemistry gradients in peatlands. Can. J. Bot. 62:142-153.

18. Lembrechts, J.F.M. and O.L.J. Vanderborght. 1985. Mineral content of Sphagnum mosses in Belgium bog ecosystems. J. Envir. Qual. 14:217-223.

19. Malmer, N. and H. Sjors. 1955. Some determinations of elementary constituents in mire plants and peats. Bot. Notiser 108:46-80.

20. Mornsjo, T. 1968. Stratigraphical and chemical studies on two peatlands in Scania, South Sweden. Bot. Notiser 121:343-360.

21. Nicholson, B., and D.H. Vitt 1988. Peatland Development at Mariana Lakes, a northern Alberta complex mire.

22. Ozoray, G.F. and A.T. Lytviak. Hydrogeology of the Pelican-Algar Lake Area, Alberta. Alberta Research Council, Earth Sciences Report 80-1. 1980.

23. Pakarinen, P. and K. Tolonen. 1977a. Distribution of lead in Sphagnum fuscum profiles in Finland. Oikos 28:69-73.

24. Pakarinen, P. and K. Tolonen. 1977b. Nutrient contents of Sphagnum mosses in relation to bog water chemistry in northern Finland. Lindbergia 4:27-33.

25. Rowe, J.S. Forest Regions of Canada. Dept. of the Environment. Canadian Forestry Service. Ottawa. 1972. Publ. No. 1400, 172 p.

26. Sillanpaa, M. 1972. Distribution of trace elements in peat profiles. Proc. 4th Int. Peat Congress, Outaniemi, Finland. 1972. 5:185-191.

27. Sjors, H. 1952. On the relation between vegetation and electrolytes in North Swedish mire waters. Oikos 2 (1950):241-258.

28. Stanek, W., J.K. Jeglum, and L. Orloci. 1977. Comparisons of peatland types using macronutrient contents of peat. Vegetatio 33:163-173.

29. Strong, W.L. and K.R. Leggat. Ecoregions of Alberta. Alberta Energy and Natural Resources. Resource Evaluation and Planning Division. 1981.

30. Tallis, J.H. 1973. The terrestrialization of lake basins in north Cheshire, with special reference to the development of a schwingmoor structure. J. Ecol. 61:537-567.

31. Yefimov, V. N. and Z. S. Yefimova. 1973. Chemical composition of bog water in the northwestern part of European USSR. Soviet Soils 11:27-36.

32. Walter, H. Vegetation of the Earth and Ecological Systems of the Geo-biosphere. Springer-Verlag, 1979. New York.

33. Wilson, K.A. and A.H. Fitter. 1984. The role of phosphorus in vegetational differentiation in a small valley mire. J. Ecol. 72:463-473.

34. Zoltai, S.C. and J.D. Johnson. 1985. Development of a treed bog island in a minerotrophic fen. Can. J. Bot. 63:1076-1085.

35. Zoltai, S.C. and F.C. Pollett. 1983. Wetlands in Canada: Their Classification, Distribution, and Use. Environment Canada. Ecosystems of the World. Mires: Swamp, Bog, Fen, and Moor. A.J.P. Gore (ed.). Elsevier Scientific Publishing Co., New York. pp. 245-268.

IV. CONCLUSION

Both processes of peat formation, terrestrialization and paludification have occurred at Mariana Lakes. Earliest peat formation began in the lake basins at 8180 and 7740 BP and followed the classical hydroseral succession outlined by Sjors(1961), Heinselamn(1970), and Everett(1983). Autogenic infilling of the lake basins produced a floating mat, that upon enclosure and acidification developed into a poor fen. Allogenic paludification took place subsequent to terrestrialization of the lake basins and progressed in a downslope direction towards the mire outlet. Water flow paths developed early carrying ionically richer mineral soil runoff across the mire. Minerotrophic fen vegetation grew within the flow paths. On adjacent slightly higher mineral ridges and in lowland areas not directly influenced by water flow, paludification resulted in slightly drier more ionically poor environments. Forested Sphagnum islands have developed in these hydrologically isolated regions. Present surface physiognomy relates to water flow paths that were established early in mire formation. Lake basin sites 12 and 14 receive overland flow form adjacent mineral ridges. Minerotrophic site 6 receives additional mineral from another drainage basin. Site 11 receives discharge from the small westerly lake. Sites 9 and 15 are situated within a major flow path (watertracks) and are receiving some mineral enrichment. Sites 2,3,4,5 are situated within a major flow path but are receiving mineral poor water. Sites 1,13,7,8,16,10 are situated in hydrologically high areas not directly influenced by ground water flow. Allogenic factors contributing to the peatland development at Mariana Lakes are the mid Holocene climatic optimum, which occurred during terrestrializtion of the lake basins(Hickman and Klarer 1981, Bombin 1982, Hickman et al. 1984, Schweger unpublished), and the shift in climate from the altithermal into modern climatic conditions. This initiated the paludification process.

During the development of the ombrotrophic forested Sphagnum islands a change in hydrology occurred resulting in the formation of local discharge zones. Peat chemistry profiles describe mineral ion reduction on the Sphagnum islands resulting from the removal of the islands from ground water flow and the effects of leaching from the discharge zones.

LITERATURE CITED

1. Bombin, E.R. 1982. Holocene paleolimnology of Mary Greg Lake, Foothills of Alberta Rocky Mountains, Canada. University of Alberta, M.Sc. Thesis.
2. Everett, K,R. 1983. Histosols. In: Pedogenesis and Soil Taxonomy. II. The Soil Orders. Wilding, L.P., N.E. Smeck, and G.F. Hall(eds.). Elsevier, Amsterdam. pp 1-53.
3. Heinselman, M.L. 1970. Landscape evolution, peatland types, and the environment in the Agassiz Peatland Natural Area. Ecological Monographs 40:235-261.
4. Hickman, M., and D.M. Klarer. 1981. Paleolimnology of Isle Lake Alberta, Canada. Including sediment chemistry, pigments and diatom stratigraphy. Arch. Hydrobiol. 9:490-508.
5. Hickman, M., C.E. Schweger, and T. Habgood. 1984. Lake Wabamum, Alta:a paleoenvironmental study. Can. J. Bot. 62:1438-1465.
6. Schweger, C.E. Unpublished. A critical appraisal of the altithermal and its role in archaeology. University of Alberta.
7. Sjors, H. 1961. Forest and peatland at Hawley Lake, northern Ontario. Bull. Nat. Mus. Canada. 171:1-31.

V. Appendix I

Peat stratigraphy of additional Sphagnum Island Cores (sites 13,1) determined using a relative method. Values are percent frequency of total macrofossils.

Depth	Monocots	Larix	Sphagnum	Ericads	Picea	Wood	Andromeda
Site 13							
20-37	4		90	5	1		*
37-59	35	1	59	2	2	1	
59-70	5	88	2	5			
70-87	5		94	1	*		
87-100	5	*	70	30	*		*
100-116	*	*	94	1	*		
116-124	1	*	1			98	
124-131	*	*	60	35	*		
131-140	1		92	5	*		
140-150	2		30	38	10		
Site 1							
50-65	1	*	98	1			
65-80	20	*	79	1	*		
80-95	1		98	1	*		
95-100	5	*	92	3	*		
100-125	10		50	40	*		
140-155	50		20	30	*		
155-162	50		10	40	*		

*=<5% Macofossil Frequency

VI: Appendix II

Peat stratigraphy of additional fen cores (sites 9,2,3), determined using a relative method. Values are percent frequency of total macrofossils.

Depth(cm)	Monocots	Larix	Sphagnum	Ericads	Picea	Wood	Andromeda
Site 9							
25-40	10		60	30			
40-45	10		75	15			
45-50	5		70	25	5		
50-55	25		25	50			
55-65	5		75	20			
65-70	40		10	50			
70-80	40	10	5	60			
80-95	20		10	70			
95-110	20		10	70			
110-125	50			50			
125-140	40			60			
Site 2							
50-65	20		30	50			
65-80	30		20	50			
80-100	35		5	60			
100-121	35		5	60			
121-144	50		20	30			
144-150	20		30	50			
150-170	35		35	30			
170-178	50		30	20			
178-189	30		20	50			
189-200	5		90	5			

200-215	45		10	45		
215-230	25	*	5	55	5	10
230-245	45		15	40	*	
245-260	50		5	40	5	*
260-279	30		*	70		
279-285	25		*	75		
285-300	10		*	90		
300-320	5		*	95	*	

Depth(cm)	Monocots	Larix	Sphagnum	Ericads	Picea	Wood	Andromeda
Site 3							
25-30	50		40	10			*
30-35	50		30	20			
35-40	70		20	10			*
40-45	30		65	5			
45-50	25		65	10			
50-65	20		75	5			
65-80	15		84	1			*
80-95	10		90	*			*
95-100	10		40	50			
100-142	60		10	30			
142-150	60		10	30			
150-192	85		5	10			
192-200	80		10	10			
200-208	60		30	10			*
208-224	90		*	10			
224-248	70		*	30			

* = <5% Macrofossil Frequency