Géographie physique et Quaternaire

Mapped patterns in sediment samples of modern pollen from southeastern Canada and northeastern United States
La distribution géographique d'échantillons polliniques dans le sud-est du Canada et le nord-est des États-Unis
Geographische Wiedergabe der Pollenverteilung im südöstlichen Kanada und den nord-östlichen Vereinigten Staaten

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Article abstract

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MAPPED PATTERNS IN SEDIMENT SAMPLES OF MODERN POLLEN FROM SOUTHEASTERN CANADA AND NORTHEASTERN UNITED STATES

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ABSTRACT Isopoll maps based on 173 modern-pollen samples illustrate the geographical patterns of 12 pollen types within a 600,000 sq. km area centered in southern Québec. The mapped patterns reflect several scales of vegetational pattern that ranges from the major regional change between conifer-hardwood forest and boreal forest down to the minor local differences in vegetation between nearby sites. *Picea* and other arboreal pollen types are most representative of the regional patterns, whereas Cyperaceae and Ericaceae pollen often vary markedly between adjacent sites. Further analysis of these pollen data explored how much differences in sediment type and variations in analyst practices among the samples can affect the sensitivity of the pollen data to certain of the vegetational patterns. The set of 173 samples was divided into three subsets, two of which differ in sediment types and two of which differ in analyst practices. The distributions of pollen types are then correlated between the contrasting subsets, and their principal components are compared. These results show that only small differences exist among the subsets in their portrayal of the major vegetational patterns, but marked differences appear in the record of certain minor patterns.

RÉSUMÉ *La distribution géographique d'échantillons polliniques dans le sud-est du Canada et le nord-est des États-Unis.* La distribution géographique des pourcentages polliniques de 12 taxons à l'intérieur d'une aire de 600 000 km² centrée sur le Québec méridional est présentée à l'aide de cartes isopolles dressées à partir de 173 spectres polliniques contemporains. Cette cartographie reflète la distribution des éléments de la végétation à différentes échelles: *Picea* et d'autres espèces arborescentes traduisent surtout des tendances régionales, tandis que les Cypéracées et les Éricacées varient beaucoup entre des stations voisines. Une analyse plus poussée de cette banque de données polliniques révèle les variations causées par le type de sédiment analysé ou par les différentes pratiques des analystes, et leur influence sur l'aptitude des spectres polliniques à refléter la distribution actuelle de la végétation. Cette analyse a été faite en divisant les données en trois populations dont deux diffèrent par le type de sédiment et deux autres par les analyses effectuées. La corrélation entre les distributions des types polliniques a été, par la suite, calculée pour chaque paire de populations, et étudiée par l'analyse des composantes principales. Les résultats indiquent que les gradients majeurs de la distribution de la végétation sont bien traduits. Toutefois, on note de grandes différences lorsqu'on étudie certaines distributions mineures.

ZUSAMMENFASSUNG *Geographische Wiedergabe der Pollenverteilung im südöstlichen Kanada und den nordöstlichen Vereinigten Staaten.* Isopoll-Karten, die, die Ergebnisse von 173 heutigen Pollenproben darstellen, illustrieren die geopgraphische Verteilung von 12 Pollentypen innerhalb einer 600000 km² umfassenden Fläche, deren Zentrum sich im südlichen Québec befinet. Die dargestellten Pollenverteilungen spiegeln die Verteilung der verschiedenen Elemente der Vegetation auf regionaler sowie auf localer Basis wider. Picea, und andere baumartige Pollen zeigen hauptsächlich regionale Tendenzen an, wogegen Cyperaceae und Ericaceae oft grosse Unterschiede zwischen benachbarten Gegenden anzeigen. Eine weitere Analyse der Pollenverteilung zeigt Unterschiede die durch verschiedene untersuchte Sedimenttypen und die Verschiedenheit der Arbeitsweise der Forscher verursacht wurden, und den Einfluss dieser auf die Fähigkeit der Pollenmuster die Verteilung der Vegetation wahrheitsgemäss wiederzugeben. Die Ergebnisse der 173 Proben wurden in drei Gruppen aufgeteilt, von denen zwei sich im Sedimenttyp unterscheiden und zwei in der Arbeitsweise der Forscher. Die Verteilung der Pollentypen wurde dann zwischen kontrastierenden Gruppen in Beziehung gebracht und die Hauptbestandteile verglichen. Die Resultate zeigen, dass es nur kleine Unterschiede zwischen den Gruppen gibt, wenn es sich um die Wiedergabe der Hauptvegetationslinien handelt, aber bemerkbare Unterschiede kommen in der Wiedergabe von weniger bedeutenden Modellen vor.

INTRODUCTION

Since the pioneering work by AUER (1930) and BOWMAN (1931), southern Québec has been an area of intensive palynological investigation. Potzger completed several studies there in the 1950's (POTZGER, 1953; POTZGER and COURTEMANCHE, 1954; 1956 a,b), and most recently RICHARD (1971; 1973 a,b,c; 1975 a,b,c), MOTT (1976, 1977), TERASMAE and ANDERSON (1970), and VINCENT (1973) have described the pollen data from several radiocarbon-dated cores.

As part of this work, data from numerous samples of modern pollen have been published, and DAVIS (1967) and DAVIS and WEBB (1975) have included Potzger's data along with those of other analysts in summaries of the modern distribution of pollen types in eastern North America. These summaries aid the broad-scale interpretation of pollen diagrams; but, in light of RICHARD's (1976) description of 56 new samples, a detailed mapping of the modern data from this area should refine the interpretation of the diagrams there. These maps, in addition, may help in reconstructing the environment of the final phase of the basal zone of high spruce *(Picea)* pollen in many North American pollen diagrams. This zone frequently has a slight peak in fir *(Abies)* pollen that could indicate a vegetation similar to the forests wide-spread along the eastern part of the St. Lawrence River.

By following the approach of WEBB (1974 a,b) and BIRKS et al. (1975), we present isopoll maps and a principal components analysis of the major pollen types from a 600,000 sq. km. area centered in southern Québec. The isopoll maps include details smoothed out by the contours on the small-scale maps of DAVIS and WEBB (1975) and also show the distribution of several herb pollen types that DAVIS and WEBB (1975) did not map. The principal components analysis summarizes the information on the maps by showing the geographical distribution of the major groups of covarying pollen types.

In addition to this basic description of the modern pollen data, we stratified the main data set of 173 samples into three subsets. These subsets contain firstly either the uppermost samples from peats or the surface samples from lake sediments and secondly either a sample set produced by only one analyst or sample sets from several analysts. Comparisons were then made between the contrasting subsets in order to see what effects the differences in sampling have on the ability of pollen data to record the major vegetational patterns.

THE REGIONAL VEGETATION PATTERNS

Three major vegetational patterns provide three separate vegetational contrasts for the pollen data to record

in both the large data set and its subsets. These three patterns are: 1) the contrast between the boreal forest in the north and the conifer-hardwood forest in the south; 2) the east-west gradient from higher abundances of pine trees in the northwest to higher abundances of fir trees in the central and eastern regions (HALLIDAY and BROWN, 1943); and 3) the high density of cultivated land along the St. Lawrence River Valley and the dominance of forests to the north and the southeast.

THE DATA EXAMINED

From the studies of DAVIS and WEBB (1975) and RICHARD (1976), a data set of 173 samples was assembled with all samples lying between 43° and 51° N and between 61° and 77° W (Fig. 1). The samples were collected from both peat and lake sediments and were analyzed by twenty different palynologists between 1931 and 1976.

From among these 173 samples, three subsets were extracted. The first (Fig. 2a) consists of 73 samples mostly from bogs. These samples were published in 13 papers cited in DAVIS and WEBB (1975). The second subset (Fig. 2b) includes 42 lake-sediment samples that were published in ten studies cited in DAVIS and WEBB (1975). The third subset (Fig. 2c) consists of 56 samples from mosses (mostly *Sphagnum*) that were collected from peat bogs and from floating mats at the edge of lakes by RICHARD (1976).

METHODS

BASIC PLAN

Isopoll maps and principal components analysis describe the distribution of the pollen data within the total data set of 173 samples. This data set was then stratified by sediment type and by analyst practice, and the similarity in pollen distribution between the contrasting subsets was measured. Because the same patterns in the regional vegetation exist in the areas under comparison, the pollen distributions should be highly correlated, unless biased by the contrasting sampling practices between the subsets. High correlations for the pollen types or principal components between the first and second subsets will therefore reveal only a small biasing due to sediment-type differences, and high correlations between the first and third subsets will permit similar conclusions concerning the effect of analyst-practice differences.

PREPARATION AND MAPPING OF POLLEN DATA

We divided the pollen types in each of the data sets into three groups — 1) arboreal pollen, 2) herb pollen,
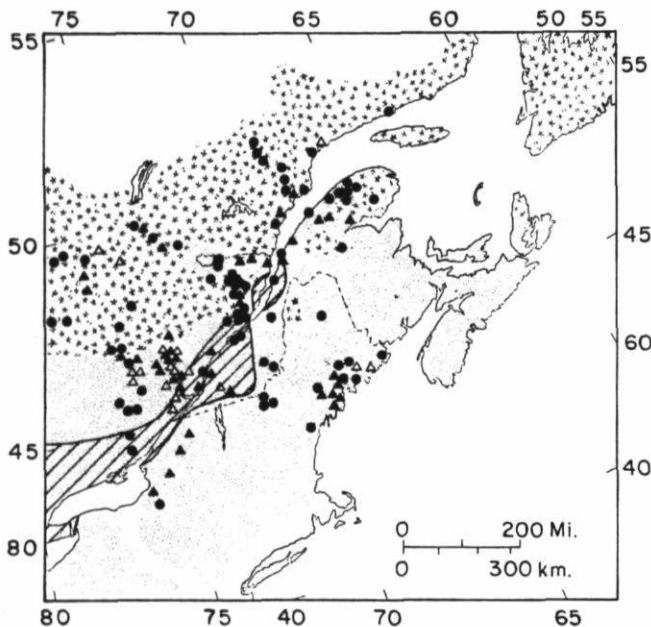
FIGURE 1. Location of the sample sites in the study area. Some sites represent more than one sample. Solid triangles: sites with arboreal pollen data only; open triangles: sites with herb counts but no separation of Compositae pollen types; black dots: sites with counts for all standard tree and herb pollen types; stippled pattern: area of mixed conifer-harwood forest; stars: position of the boreal forest (DAVIS and WEBB, 1975); Cross-hatched area along the St. Lawrence River represent over 60% cultivated land (Oxford World Atlas, 1973).

Localisation des sites échantillonnés. Certains sites comprennent plus d'un échantillon. Triangles noirs: la somme pollinique ne comprend que les arbres; triangles blancs: la somme pollinique comprend aussi le pollen des herbacées mais sans distinction des types de Composées; points noirs: la somme pollinique comprend les arbres, arbustes et herbes couramment identifiés. Le figuré en pointillé représente la région de forêt mixte et les étoiles, la forêt boréale (DAVIS et WEBB, 1975). La zone hachurée identifie une région où plus de 60% de la superficie est cultivée (Oxford World Atlas, 1973).

and 3) Cyperaceae and Ericaceae pollen — and used a different pollen sum in order to calculate the pollen percentages for each group. Only arboreal pollen types were included in the sum used to calculate their percentages. The percentages for herb pollen types were based on a sum of total terrestrial pollen excluding spores, aquatics, Cyperaceae, and Ericaceae pollen. These latter two pollen types were excluded because of their local occurrence in bog samples but were included in the pollen sum when their own percentages were calculated.

Of the 25 arboreal pollen types identified in the area by RICHARD (1976), only *Picea* (spruce), *Abies* (fir),

Pinus (pine), *Betula* (birch), *Fagus* (beech), *Tsuga* (hemlock), *Acer* (maple), *Ulmus* (elm), *Quercus* (oak), and *Alnus* (alder) were mapped. Because of the relatively low values of *Fagus*, *Tsuga*, and *Acer*, these three pollen types were summed together and mapped as one group.

Consistent distinctions among *Pinus* types were only made within RICHARD's (1976) data set and therefore maps for *Pinus strobus* (white pine) and other-*Pinus* could only be produced from his data. No comparisons of these maps were possible with similar maps from the other two data sets.

Four maps of herb pollen types were produced. These include maps for Gramineae (grass), *Ambrosia* (ragweed), Compositae (including *Artemisia* and *Ambrosia*), and total herbs (excluding aquatics, Cyperaceae, and Ericaceae). The *Ambrosia* map was based only on data from 103 sites. The Compositae map was produced in order to include the data from an additional 12 samples in which *Ambrosia* and *Artemisia* were included in the category Compositae. The map of total-herb pollen summarizes the data from all herb types, but even its contours are based on only 125 samples because no herb counts were recorded at 48 samples.

A SYMAP computer program (DUDNIK, 1971) was used in order to map and contour the pollen distribution of each of the pollen types. WEBB and McANDREWS (1976) describe the features of this program.

NUMERICAL METHODS

As in previous studies (WEBB, 1974a, b; BIRKS *et al.*, 1975), principal components analysis was used in order to extract groups of covarying pollen types (principal components) from each of the sets of pollen samples. These components were then mapped in order to illustrate the spatial distribution of each of the groups. ANDERSON (1958), MORRISON (1967), and KUTZBACH (1967) describe this technique; and COLE (1969), WEBB (1974, a,b), BRUBAKER (1975), and BIRKS *et al.* (1975) illustrate its use in interpreting spatially arrayed pollen data.

Comparisons between maps in different data sets were made using Pearson product-moment correlation coefficients (ROBINSON and BRYSON, 1957; J. DAVIS, 1973). These coefficients yield a consistent numerical measure of similarity between maps and allow ordering of the pollen types by the amount of similarity that they show. Further analysis of the data is required, however, if probablistic arguments are to be developed using these coefficients. Because the location of the samples does not coincide between the pairs of subsets, the correlations are based on the interpolated values of a given pollen type or a given principal component at 170 points within the area of overlap between the subsets.
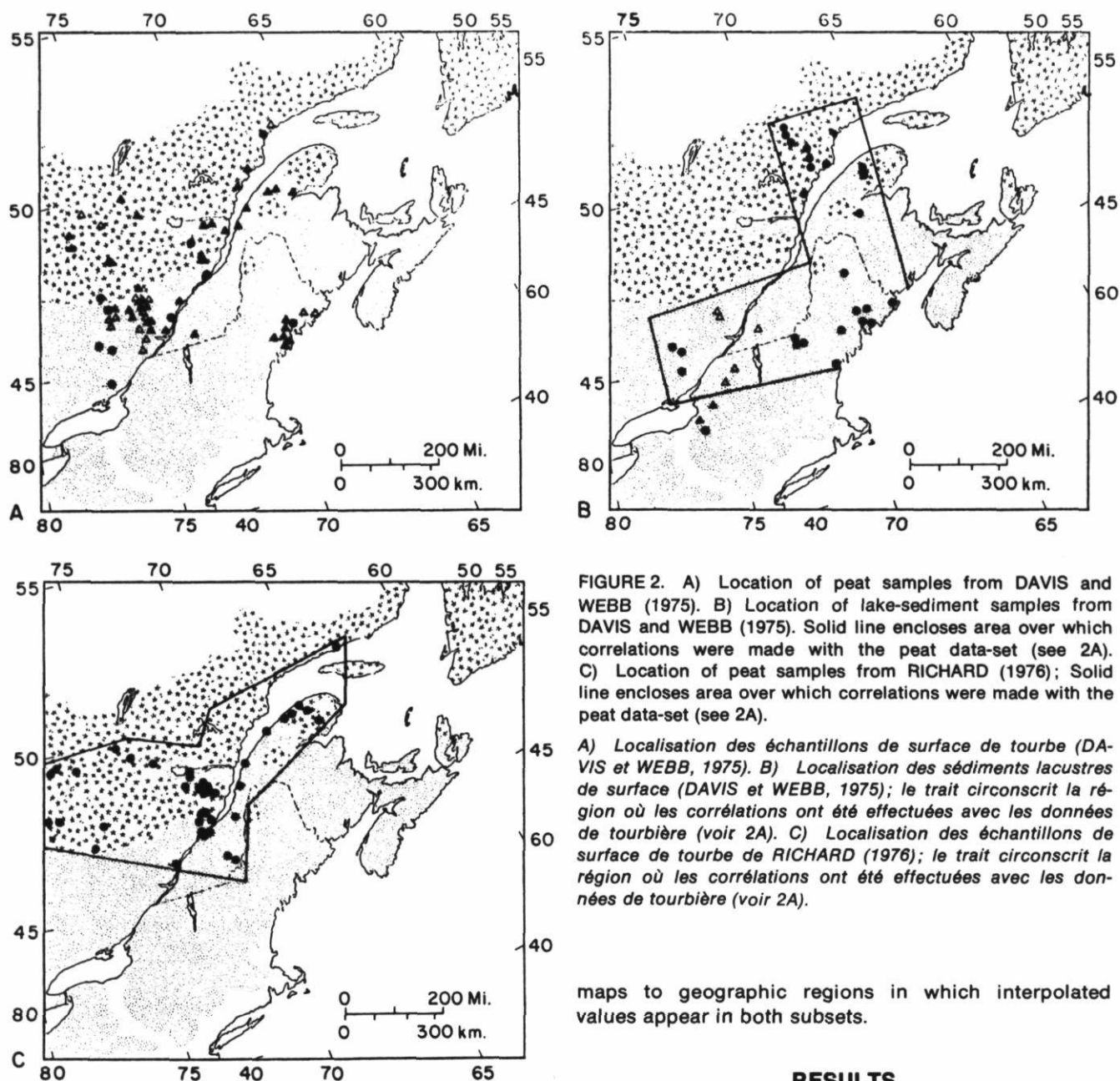
FIGURE 2. A) Location of peat samples from DAVIS and WEBB (1975). B) Location of lake-sediment samples from DAVIS and WEBB (1975). Solid line encloses area over which correlations were made with the peat data-set (see 2A). C) Location of peat samples from RICHARD (1976); Solid line encloses area over which correlations were made with the peat data-set (see 2A).

A) Localisation des échantillons de surface de tourbe (DA-VIS et WEBB, 1975). B) Localisation des sédiments lacustres de surface (DAVIS et WEBB, 1975); le trait circonscrit la région où les corrélations ont été effectuées avec les données de tourbière (voir 2A). C) Localisation des échantillons de surface de tourbe de RICHARD (1976); le trait circonscrit la région où les corrélations ont été effectuées avec les données de tourbière (voir 2A).

maps to geographic regions in which interpolated values appear in both subsets.

RESULTS

ISOPOLL MAPS

The SYMAP program interpolated these values at the grid points.

In the actual comparisons, we were forced by the geographical arrangement of the samples to select two subsets within the bog data, one overlapping Richard's data set and the other overlapping the lake data (Fig. 2). This selection restricts comparisons between

Figures 3-7 present isopoll maps of the major pollen types with the more northern types shown first. *Picea* (Fig. 3a) is the dominant pollen type in the north and its values decrease toward the south except for a slight increase in values near Lake Ontario and along the Maine coast. *Pinus* (Fig. 3b) also has high values in the north, but these are confined mainly to the northwest in contrast to *Abies* (Fig. 4a) whose high values are in the east and west-central areas.
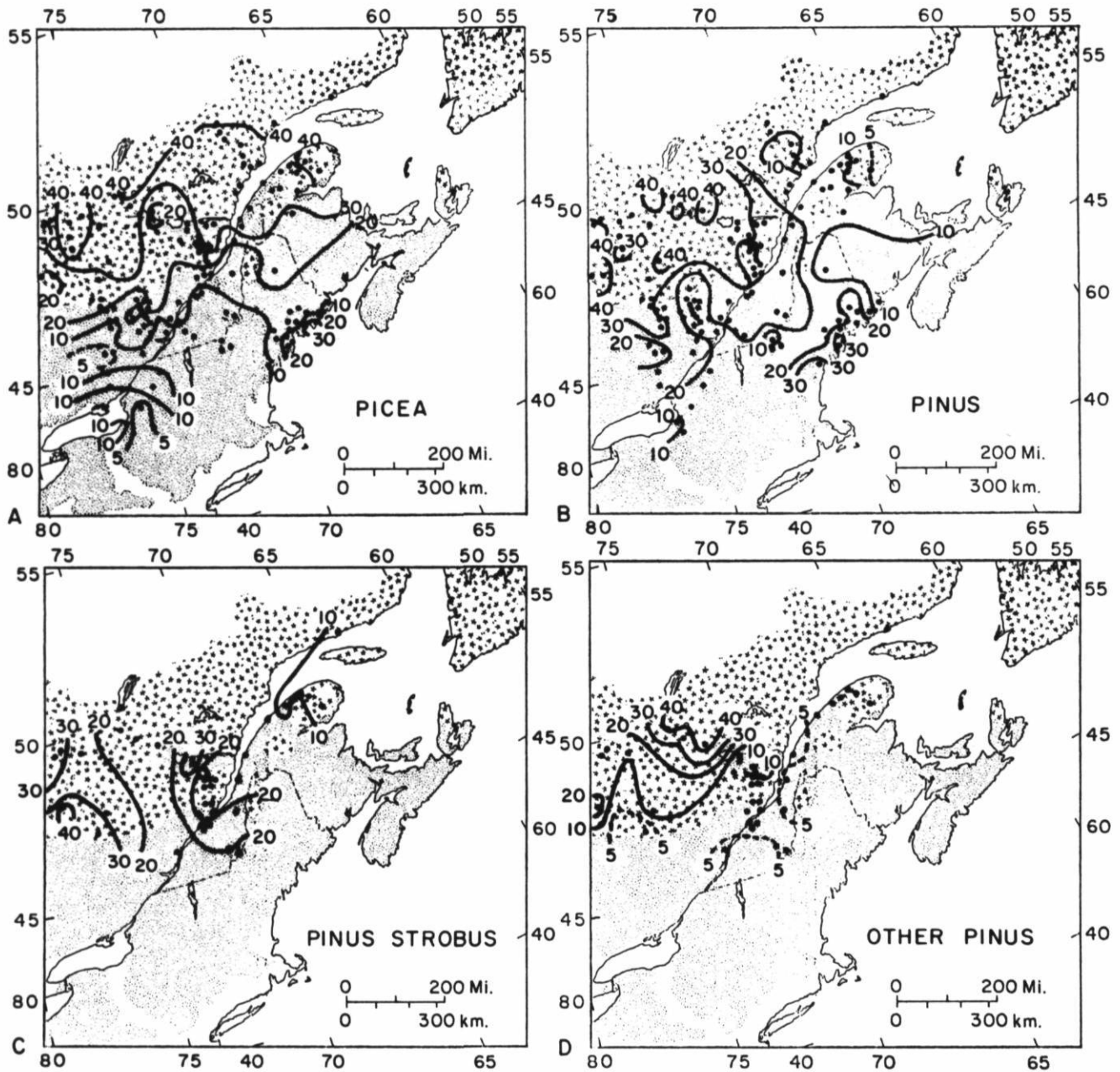
FIGURE 3. Isopoll maps for a) spruce, b) pine, c) white pine, and d) other pine pollen. For key to stippled and starred regions, see Figure 1.

Cartes isopolles: a) épinette; b) pin; c) pin blanc; d) autres pins. Voir légende de la figure 1.

When Pinus is split into two groups (Fig. 3 c,d), Pinus strobus-type and other-Pinus, a north-south gradient appears on the map of other-Pinus. Pinus strobus-type shows a bimodal distribution with high values both in the north-west and in the central region around the mouth of the St. Lawrence.

Betula (Fig. 4b) has its highest values in the central and southern part of the study area, just to the east of the high values of Quercus (Fig. 5a) and Ulmus (Fig. 5b) pollen and to the north of Fagus-plus-Tsuga-plus-Acer (Fig. 5c) pollen. Figure 5d is a sum of the other three maps in Figure 5 plus the values of Juglans, Carya, and Fraxinus pollen. This grouping of pollen types from "southern trees" shows a steep gradient of decreasing values toward the north and east and has low values in the south only where Betula or Pinus pollen
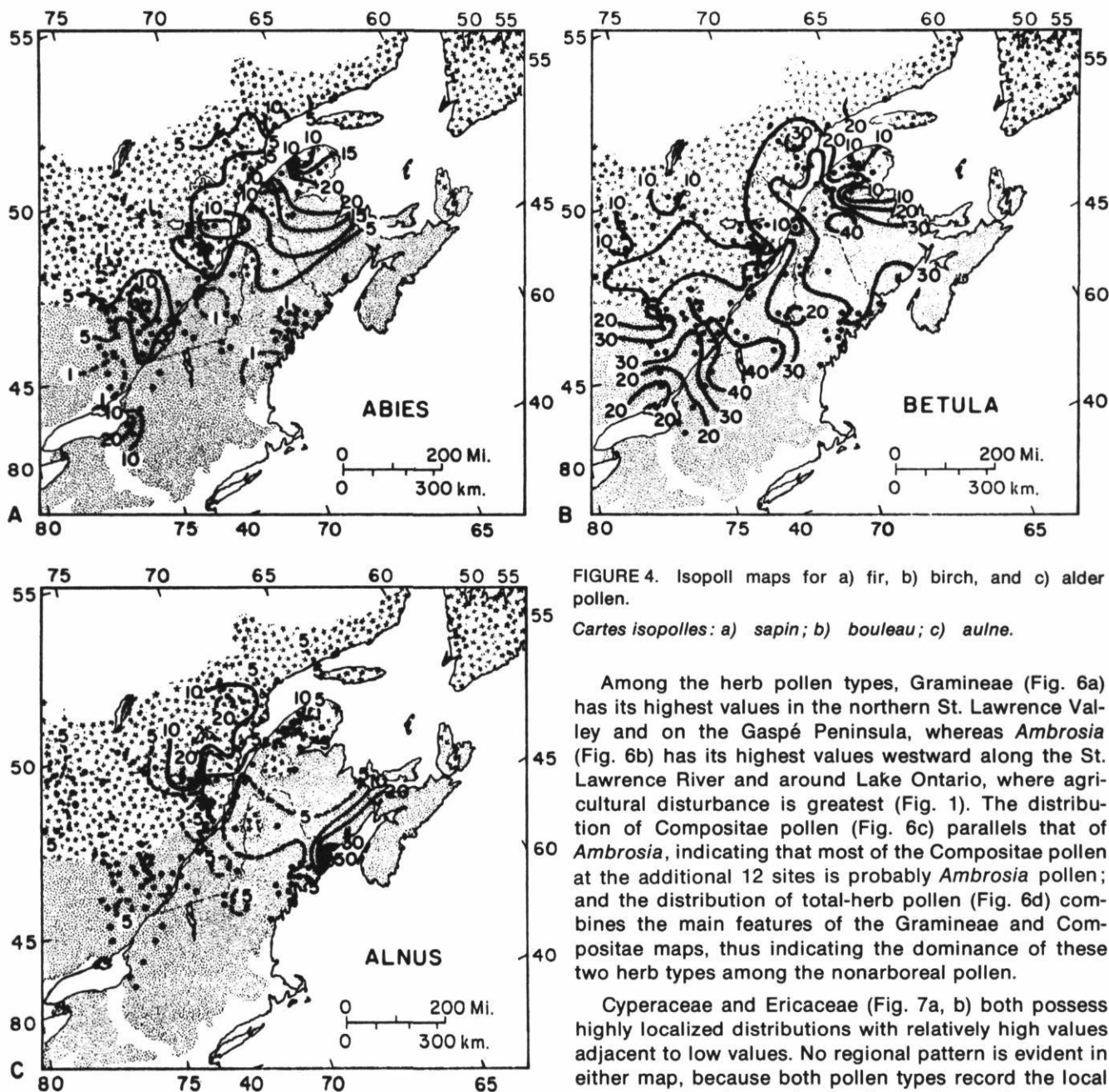
FIGURE 4. Isopoll maps for a) fir, b) birch, and c) alder pollen.

Cartes isopolles: a) sapin; b) bouleau; c) aulne.

Among the herb pollen types, Gramineae (Fig. 6a) has its highest values in the northern St. Lawrence Valley and on the Gaspé Peninsula, whereas *Ambrosia* (Fig. 6b) has its highest values westward along the St. Lawrence River and around Lake Ontario, where agricultural disturbance is greatest (Fig. 1). The distribution of Compositae pollen (Fig. 6c) parallels that of *Ambrosia*, indicating that most of the Compositae pollen at the additional 12 sites is probably *Ambrosia* pollen; and the distribution of total-herb pollen (Fig. 6d) combines the main features of the Gramineae and Compositae maps, thus indicating the dominance of these two herb types among the nonarboreal pollen.

Cyperaceae and Ericaceae (Fig. 7a, b) both possess highly localized distributions with relatively high values adjacent to low values. No regional pattern is evident in either map, because both pollen types record the local presence of sedge or heath plants at a particular site.

The maps thus show that the three main vegetational patterns described in the introduction influence the distribution of most of the pollen types. The north-south gradient from the boreal forest to the conifer-hardwood forest is represented in seven of the maps of arboreal pollen types, and the northwest to east and west-central differences show up in the distribution of *Pinus* and *Abies* pollen. High herb values occur where the land is cultivated, but no broad-scale patterns were evident on the maps for *Alnus*, Cyperaceae, and Ericaceae.

have high values. A clear division therefore exists between the basically northern pollen types (*Picea, Pinus,* and *Abies*) and the southern pollen types shown in Figure 5d.

Alnus (Fig. 4c) was the only shrub pollen type mapped and has values above five percent scattered throughout the study area. The highest value for *Alnus* pollen occurs at one site along the Maine coast, where alder is an important successional shrub in deforested terrain (DAVIS and WEBB, 1975).
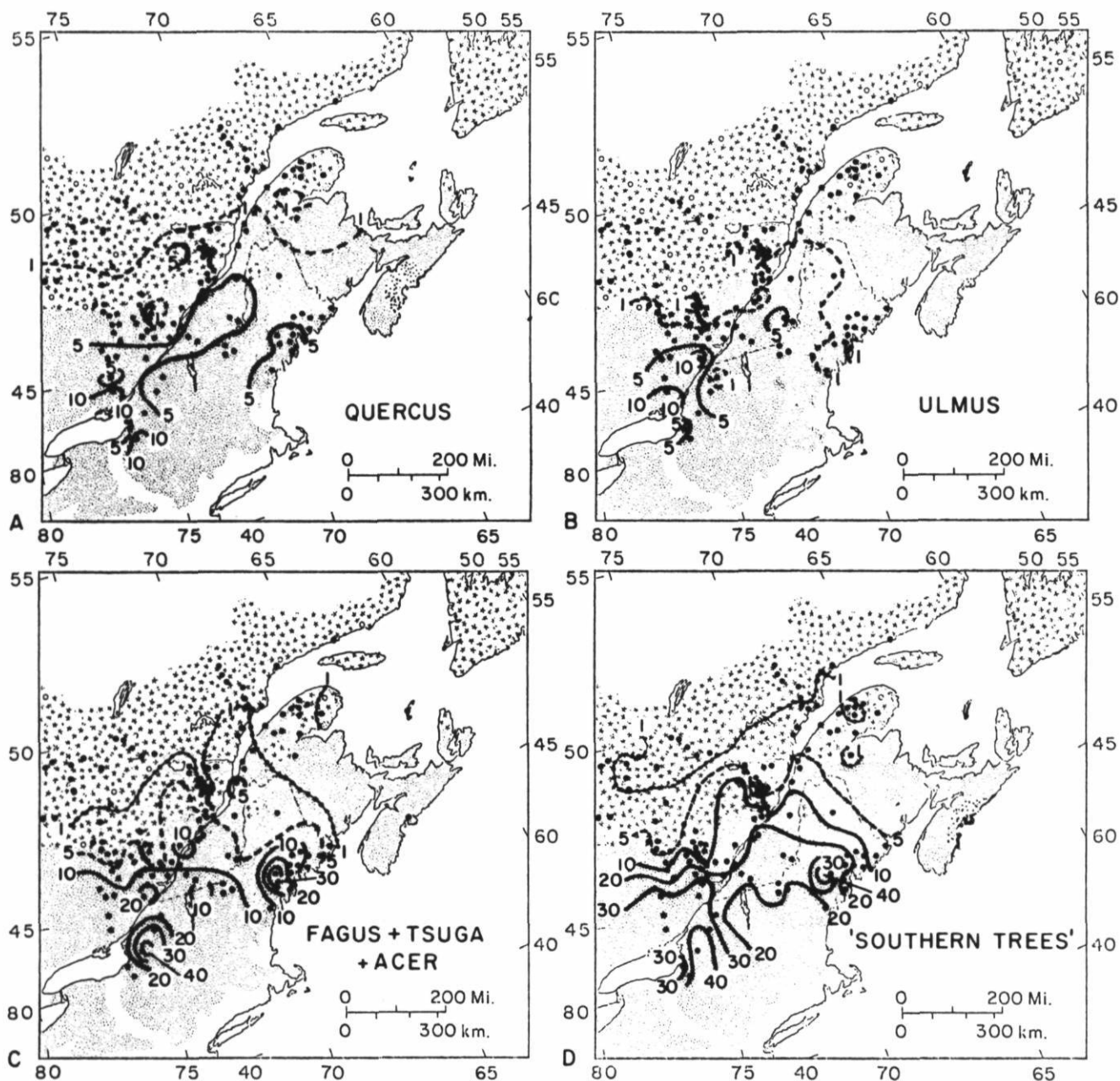
FIGURE 5. Isopoll maps for a) oak, b) elm, c) beech-plus-hemlock-plus-maple, and d) "southern trees" pollen.

Cartes isopolles: a) chêne; b) orme; c) ensemble hêtre-pruche-érable; d) essences méridionales.

COMPARISON OF THE SUBSETS

Table I shows the means and standard deviations for each of the major pollen types that were mapped. In all three subsets, *Betula, Picea,* and *Pinus* pollen are the dominant types, whereas, *Tsuga, Alnus, Ambrosia,* Gramineae, Cyperaceae, and Ericaceae differ considerably in their mean abundances among these subsets. The best comparison among the subsets, however,

comes from correlating the mapped patterns and contrasting the principal components. The visual correlation possible for *Picea* pollen (Fig. 8) is summarized by the correlation coefficients in Table II, which gives the correlations between Figures 8a and 8b and between Figures 8a and 8c.

Picea along with "southern trees" pollen (*Quercus + Ulmus + Fagus + Tsuga + Acer + Carya + Juglans +*
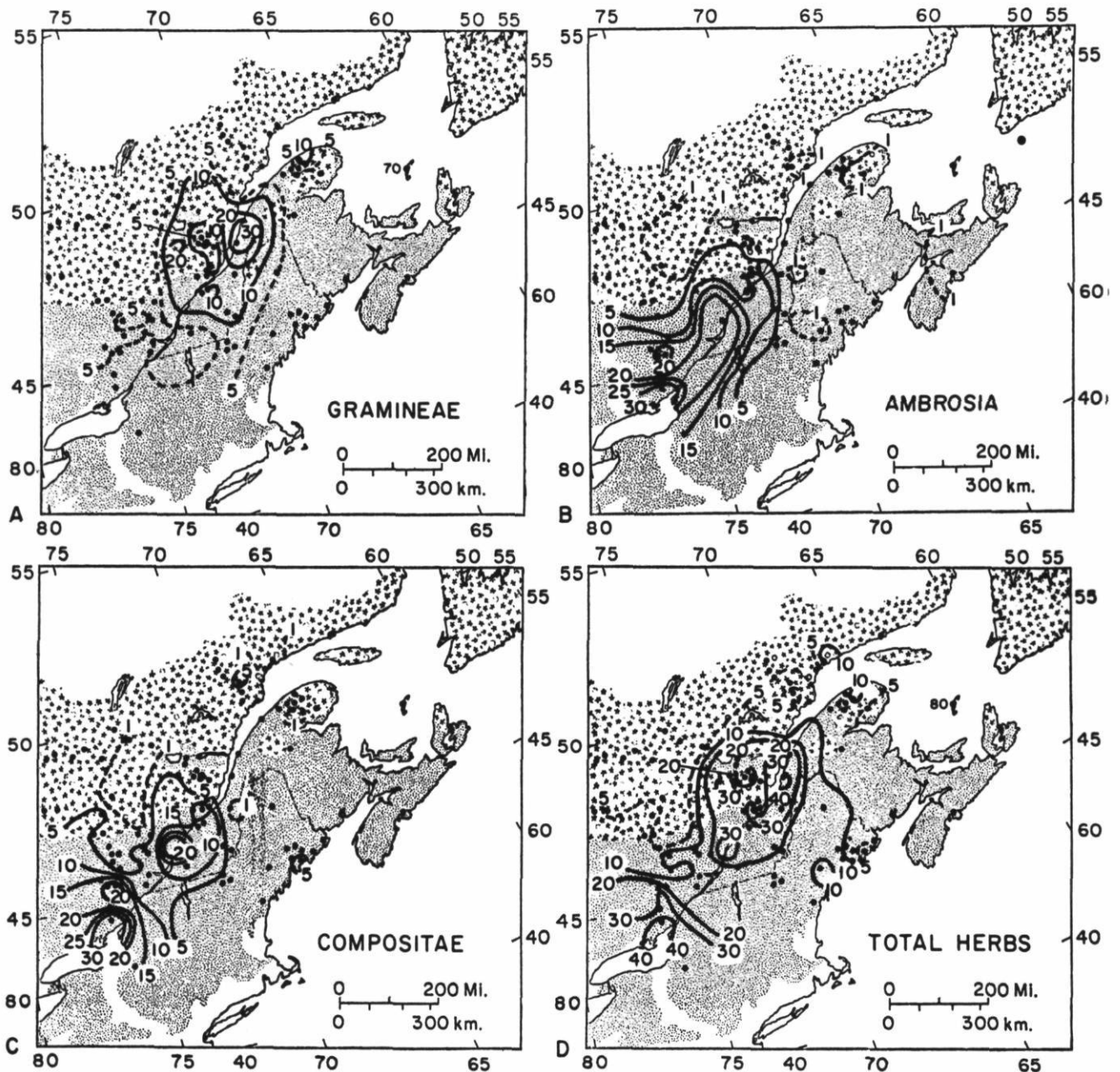
FIGURE 6. Isopoll maps for a) grass, b) ragweed, c) total Composite family, and d) total herb pollen.

Cartes isopolles: a) Graminées; b) ambroisie; c) Composées; d) ensemble des plantes herbacées.

Fraxinus) are the arboreal pollen groups that show the highest correlations between the contrasted subsets (Table II). These high correlations indicate the prominance in all three subsets of the vegetational gradient from the boreal forest in the north to the conifer-hardwood forest in the south. Despite the differences in analytical practices and in the sediment types among the three subsets of pollen samples, all three are similarly sensitive to this pattern.

Compared to the previous group of pollen types, the patterns of *Betula*, *Abies*, and *Pinus* pollen have generally lower correlations between the subsets and therefore show greater sensivity to the differences among the subsets. The lower correlations occur in part because
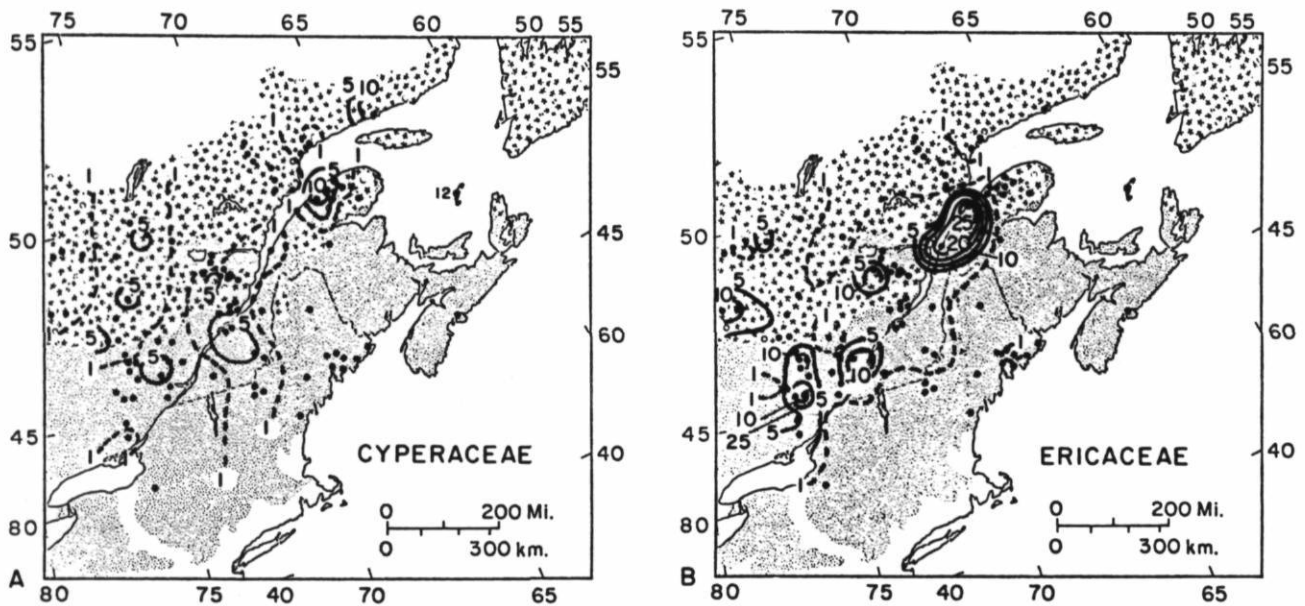
FIGURE 7. Isopoll maps for a) sedge and b) heath pollen.   *Cartes isopolles: a) Cypéracées; b) Éricacées.*

Betula, Abies, and *Pinus* pollen respond to a less strong vegetational signal than the first group. The "noise" generated by sampling differences between the subsets can thus have a relatively larger role in influencing the spatial distribution of these pollen types.

The restricted area of overlap between the lake and peat subsets, however, is the main factor causing the extremely low correlation for *Pinus* pollen between these subsets. Inspection of *Pinus* maps from these two subsets reveals that the area of overlap (Fig. 2) contains no major gradient in *Pinus* percentages. (Note the low mean-value for *Pinus* pollen in the lake data set, Table I) Were the north-western region included in the study area (Fig. 2), the correlations for *Pinus* pollen would probably be higher.

TABLE I

Means (m) and Standard Deviations (s.d.) of the Pollen Types

| Pollen Type	Total Data Set		Peat Data Set		Lake Data Set		Richard Data Set	
	m	s.d.	m	s.d.	m	s.d.	m	s.d.
Picea	24.2	16.4	24.0	16.1	18.7	14.9	28.3	17.1
Abies	7.1	8.8	9.7	10.7	3.9	6.2	6.3	6.6
Pinus	21.5	12.8	22.2	11.9	14.4	9.2	25.8	13.9
Betula	27.5	14.7	29.8	15.1	32.9	13.8	20.6	12.1
Fagus	1.6	2.4	1.3	1.8	2.8	3.9	1.0	1.2
Tsuga	2.9	5.6	3.6	6.7	5.0	6.1	0.4	0.9
Acer	1.2	1.7	0.8	1.4	1.7	1.7	1.4	1.9
Quercus	2.6	3.0	2.7	3.1	3.6	3.6	1.9	2.3
Ulmus	1.4	2.8	1.4	2.7	2.1	3.8	1.0	1.6
Alnus	5.1	7.5	1.6	2.5	7.6	10.1	7.6	7.9
Ambrosia	5.2	7.1	15.4	15.7	3.5	3.6	4.4	4.8
Compositae	6.0	7.3	8.1	11.7	4.8	4.7	5.6	5.3
Gramineae	6.4	9.8	3.5	3.3	3.1	2.4	10.0	13.3
Total Herbs	15.0	14.7	13.2	15.0	11.1	6.9	18.3	17.4
Cyperaceae	2.7	5.7	.8	1.4	.6	1.0	5.0	7.7
Ericaceae	2.9	7.7	6.2	12.4	.2	.5	2.9	6.3
Total no. of samples	173		73		42		58	
No. samples with Ambrosia	103		10		35		58	
No. samples with herbs	125		30		37		58	
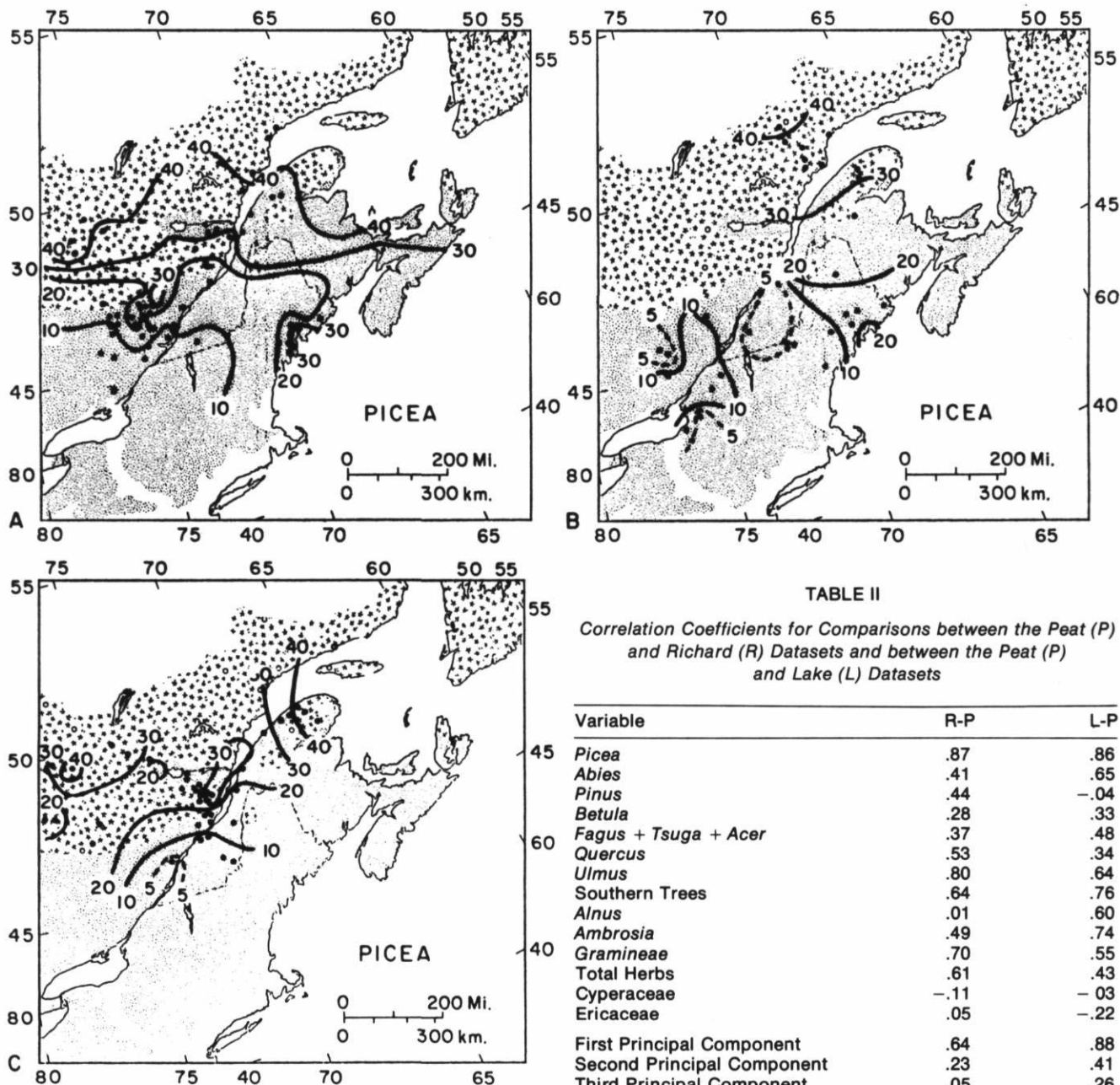
FIGURE 8. Isopoll maps for spruce pollen from a) the peat data-set (Fig. 2A), b) the lake data-set (Fig. 2B), and c) the Richard data-set (Fig. 2C).

Cartes isopolles de l'épinette provenant des données suivantes: a) tourbières (fig. 2A); b) lacs (fig. 2B); c) Richard (fig. 2C).

TABLE II

Correlation Coefficients for Comparisons between the Peat (P) and Richard (R) Datasets and between the Peat (P) and Lake (L) Datasets

Variable	R-P	L-P
Picea	.87	.86
Abies	.41	.65
Pinus	.44	−.04
Betula	.28	.33
Fagus + Tsuga + Acer	.37	.48
Quercus	.53	.34
Ulmus	.80	.64
Southern Trees	.64	.76
Alnus	.01	.60
Ambrosia	.49	.74
Gramineae	.70	.55
Total Herbs	.61	.43
Cyperaceae	−.11	− 03
Ericaceae	.05	−.22
First Principal Component	.64	.88
Second Principal Component	.23	.41
Third Principal Component	.05	.26

The correlations for *Alnus* pollen are moderate to low and vary between the two comparisons (Table II). The small correlations probably result from the localized distribution of *Alnus* and its preference for growing on damp or disturbed ground. The high mean value for

Alnus among the lake samples (Table I) is partially attributable to one site with 56 percent *Alnus* pollen due to local disturbance by fire (R. B. Davis, pers. comm.).

The distributions of terrestrial herb pollen types correlate well between the different subsets and indicate the common influence of agriculture and disturbance on the abundance of these pollen types. Low correlations exist for Cyperaceae and Ericaceae pollen, however, because plants producing these pollen types grow on wet ground and in bogs. The distribution of both of

these pollen types therefore depends upon the type of sediments sampled and the particular location of the individual samples within each sampling site.

PRINCIPAL COMPONENTS ANALYSIS

We used principal components analysis in order to identify the major groups of covarying pollen types among the ten arboreal pollen types that were mapped in each of the data sets. For this analysis, *Fagus, Tsuga*, and *Acer* were entered as separate variables, but only the category of total *Pinus* was used. This section describes the results of this analysis on the large data set and on each of the three subsets and also presents maps derived from analysis of the large data set.

The first three principal components accounted for betweeen 61 and 68 percent of the total variance in each of the data sets (Table III), and the first two components showed a clear separation of the pollen types into ecologically meaningful groups. Some meaning was evident in each of the third components, but no meaning could be attached to the grouping of pollen types in the other seven components.

In each of the data sets, the first principal component shows from 33-39 percent of the total variance to be associated with a linking together of *Picea* and *Abies* in opposition to *Acer, Fagus, Tsuga, Quercus*, and *Ulmus* (Table II). The high correlation between the maps of the individual pollen types in this component contributes directly to the high correlation between the mapped patterns of the first principal components (Table II). A strong north-south gradient exists in the geographical distribution of this principal component (Fig. 9a). It therefore reflects the major differences in vegetational composition between the boreal forest in the north and

the conifer-hardwood forest in the south. The composition of the first component is also quite similar among the subsets. The differences in sampling methods that distinguish the subsets, therefore, have little effect on the importance of this vegetational pattern in each of the subsets.

The second principal component from each of the four data sets shows the high negative value for *Pinus* pollen, which is contrasted with high positive values for *Betula* and/or *Abies* pollen (Table III). This component is sensitive to differences in composition within two different sectors of the boreal forest and northern conifer-hardwood forest. The region of negative component scores results from high values of *Pinus* pollen in the northwest, whereas the positive scores are associated with high values of *Betula* and/or *Abies* pollen in the central and eastern regions (Fig. 9b). Greater compositional differences occur among the three second components from the subsets than among the three first components (Table III). These differences result in moderate to low correlations between the mapped patterns of the second components (Table II).

Although little correlation exists between the mapped patterns for the third principal components (Table III), these components all account for about ten percent of the total variance and share a common high positive weighting of *Alnus* pollen in opposition to high negative values of *Fagus, Tsuga, Abies*, or *Picea* pollen. The high weighting of *Alnus* in each of the third principal components is in part a residual effect because *Alnus* was poorly represented in the first two components of each of the data sets.

In summary, the principal component analyses show a gradation in similarity among the components from

TABLE III

Loadings for the First Three Principal Components

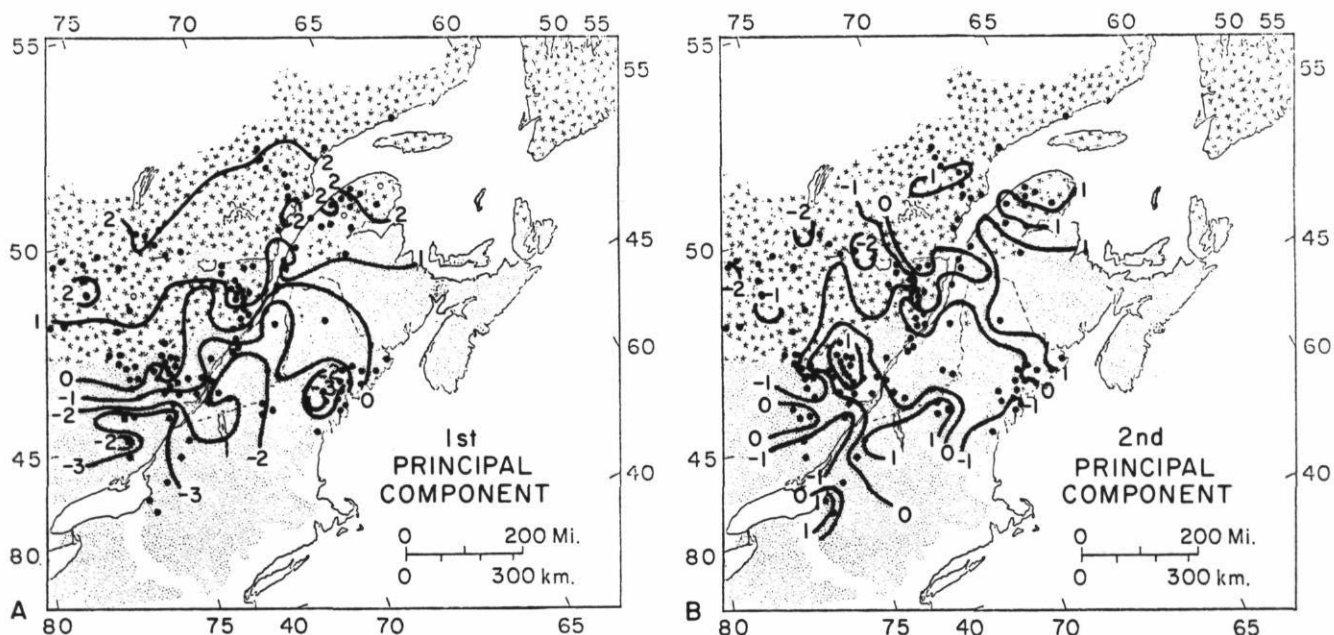|	First Principal Component				Second Principal Component				Third Principal Component			
	Total	Peat	Lake	Richard	Total	Peat	Lake	Richard	Total	Peat	Lake	Richard
Picea	.43	.40	.44	.39	−.09	−.23	−.19	.07	−.15	.08	−.22	−.39
Abies	.22	.25	.23	.17	.39	.36	.11	.57	−.32	−.04	−.61	−.17
Pinus	.08	.02	−.12	.02	−.68	−.60	−.60	−.70	.04	.23	.07	−.02
Betula	−.24	−.19	.01	−.34	.52	.57	.61	.30	.16	−.11	.23	.11
Fagus	−.38	−.36	−.36	−.36	.03	−.18	.15	.17	−.39	−.46	−.35	−.22
Tsuga	−.30	−.21	−.39	−.34	−.06	−.18	−.18	−.06	−.52	−.66	−.13	−.06
Acer	−.37	−.38	−.37	−.41	.08	.16	.33	.10	.19	.27	−.13	−.12
Quercus	−.42	−.46	−.36	−.42	−.22	−.19	−.18	−.16	.13	.13	.34	.03
Ulmus	−.38	−.42	−.36	−.33	−.13	−.02	.02	.02	.13	.30	−.06	−.02
Alnus	.07	−.19	.23	.09	.12	.08	.12	.15	.60	.33	.50	.86
Variance (%)	33	33	36	39	15	16	17	17	13	15	13	12

FIGURE 9. Contoured maps of the component scores from the total data-set for a) the first principal component, and b) the second principal component.

Cartes isolignes des résultats de l'analyse en composantes principales effectuée sur l'ensemble des données; a) première composante; b) deuxième composante.

closely similar mapped patterns for the first principal components to the generally dissimilar patterns for the third and higher numbered principal components. The strong difference in vegetational composition from the boreal forest to the conifer-hardwood forest shows up in the four first components, the east-west difference in composition between the greater prominence of pine in the northwest and the greater prominence of birch or fir in the central and eastern regions appears in the four second components. These results illustrate the strong influence of the major patterns in the regional vegetation in determining the distribution of pollen data and also show that this influence prevails despite the noise introduced by differences in both sediment types and analyst practices.

DISCUSSION

Like the pollen data from lake sediments in northern Wisconsin (WEBB, 1974b) and in lower Michigan (WEBB, 1974a), the maps and principal components analysis in this study show that the division between the major vegetational regions is most important in determining the major patterns of variation within the pollen data. Whereas these previous studies illustrated the differences in the pollen rain between the deciduous forest and the conifer-hardwood forest, our results depict the differences between the conifer-hardwood forest and the boreal forest. Although some of these pollen differ-

ences were evident in the maps of DAVIS and WEBB (1975), Figures 3-7 show the changes in more detail and include maps of the herb pollen types. Our maps thus aid the interpretation of certain zones in the fossil diagrams from this area southward to Georgia.

In addition to the basic description of the data, our results showed that the major vegetational patterns appear in equal prominence and with similar composition within each of the subsets (Fig. 9; Table III). They all possess similar first principal components and basically similar second principal components. Although differences appear among the maps of herb types from the different subsets, their samples are comparable in their ability to record the major forest patterns among the arboreal pollen types. Placing these different types of samples together in one large data set is therefore meaningful and does not represent a case of adding "apples and oranges" (*i.e.*, noncomparable entities) together. This statement is especially true for lake sediment samples and peat samples when the latter samples are taken on almost bare *Sphagnum* mats in an open part of a bog (RICHARD, 1976).

The similarity between bog and lake samples is worth demonstrating in light of recent experimental work indicating major differences between bogs and lakes in how pollen accumulates within their sediments. For many lakes, a significant fraction of their pollen is washed in by streams rather than being blown in from the

atmosphere (PECK, 1973; BONNY, 1976). Once in the lake, the pollen moves about within the basin and can be redeposited several times before being buried permanently in the lake muds (M. DAVIS, 1973). Bogs, however, accumulate most of their pollen from the atmosphere and can have a significant local input from plants growing on the peat. Despite these differences in pollen accumulation, our results show that the uppermost sediments from bogs and lakes contain similar records of the regional vegetation. A comparison of the results of PRENTICE (1978) with those of AARIO (1940) yields a similar conclusion.

When the records from moss polsters within upland (*i.e.* not wet-land) plant communities are compared to samples from lake sediments, however, large differences appear which indicate that these two types of samples are noncomparable (RITCHIE, 1974). Ritchie's results from the Mackenzie Delta show that the regional vegetational patterns were not as clearly expressed in the polster data as they were in the lake-sediment data and that the polster data showed large inter-sample differences within each vegetational region. These differences occur because upland moss-polsters accumulate their pollen from a much smaller area than that from which lake samples gain their pollen. The pollen data from moss polsters are therefore best used for recording local patterns within forests (ANDERSEN, 1970) and other plant communities (JANSSEN, 1966) and for interpreting fossil data obtained from small hollows within forests (IVERSEN, 1969). Only when several moss polsters collected over a large area (*ca.* 20-100 sq. km.) are added together will they give a record of the vegetation comparable to that produced in the pollen data from lake sediments.

For the broad-scale vegetational patterns presented in our study, POTZGER's samples (1953) yield a similar record to that of RICHARD's (1976). For detailed consideration of certain pollen types, however, Richard's data have information that is not in Potzger's data (*e.g.*, Fig. 3c, d). Fine-scale distinctions are therefore possible with Richard's samples that cannot be made with less detailed pollen counts.

More comparisons from other areas are needed between data sets differing in their sample type and sampling procedures. If the differing samples are located in pairs within the study area and if forest-inventory information is compiled, then these studies will show what biases result from each sample type or from each sampling procedure. These studies will also show which sources of variation need to be controlled in order to improve the record of particular features in the vegetation (WEBB *et al.*, in press). Although our study showed that the differences among the subsets only minorly affected the pollen records of the major patterns in the vegetation, understanding these differences may be

quite important when pollen data are used to represent intermediate- to fine-scale variations in the forests. Further studies are needed in order to elucidate this point.

ACKNOWLEDGEMENTS

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