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POSTGLACIAL VEGETATIONAL CHANGES IN THE EASTERN BALTIC COASTAL ZONE OF POLAND

Postglacjalne przemiany szaty roślinnej wschodniej części polskiego pobrzeża Bałtyku

ABSTRACT. The postglacial vegetational history of the environs of Lake Żarnowiec has been reconstructed on the basis of the pollen analysis of three profiles from this area. 8 regional pollen assemblage zones are described; they were synchronized with the aid of 21 ^{14}C dates. The profiles cover the period from about 11 000 years BP to the present day. The results from the Late Holocene have been correlated with archaeological data; this has enabled the phases of settlement in this area to be identified. Macrofossil analysis has allowed the local plant history of the sedimentation basins studied to be reconstructed; the information from localities situated in the Lake Żarnowiec channel have thrown new light on the history of this lake.

CONTENTS

INTRODUCTION

Palaeobotanical studies of the eastern Baltic coastal zone of Poland, as of the whole of Pomerania, started long before the Second World War. Nevertheless, compared to other regions of Poland, the plant history of this area is little known. Above all, there is a shortage of data obtained using modern methods which enable better understanding of changes in the vegetation and of the part played by man in its transformation over the last few thousand years.

Of the pre-war studies supplying data on the history of forests, one may mention the papers by Dobrzyński (1937); Paszewski (1928, 1934) and Thomaschewski (1929, 1930). In these studies, only a small number of sporomorphs were counted and pollen of herbs and certain shrubs were not identified. The post-war works of Ołtuszewski (1948), and Ołtuszewski

& Borówko (1954) are of a similar value. A considerable amount of information is contained in the papers by Szafrański (1961), dealing with the Staniszewska Upland, and by Zachowicz (1976), describing localities from Lake Druzno and the Vistula Lagoon. These latter two areas, however, present geobotanical problems different from those of the Lake Żarnowiec area.

As regards the regional plant history, the locality in the Słowiński National Park described by Tobolski (in preparation) is expected to show many similarities to the material discussed in this study. The work published so far by Tobolski (1975 a, b, c, 1979) deals mainly with the very specific problem of the origin of the fossil soils occurring on the Łeba spit, and provides interesting information on the plant history of this area.

There is hardly any information on the Late Glacial in the study area. Few data are available in the works done on neighbouring areas (Tobolski 1975 b; Zachowicz 1976); particularly valuable are the finds of Dryas flora described by Nathorst (1892, 1894).

In the light of data provided by the literature quoted above, this area fully deserves detailed palaeobotanical investigation. An additional point in favour of this area is the fact that recession of the ice-sheet in this part of the Baltic coastal zone was delayed. In consequence, the plant history of this area may be different from that of neighbouring regions.

The aim of this work was to study the postglacial changes in the vegetation of the eastern Baltic coastal zone of Poland. A further aim was to attempt the reconstruction of local vegetational changes, and of the history of the sedimentation basins from which the material for this study is derived.

The localities discussed in this dissertation have been included as type localities to the International Geological Correlation Programme IGCP subproject No. 158 B: "Paleohydrological changes in the temperate zone in the last 15 000 years — lake and mire environments" (Berglund & Digerfeldt 1975; Berglund 1979).

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DESCRIPTION OF THE STUDY AREA

Physiography

According to the physical-geographical classification of Poland (Kondracki 1978), the study area belongs to the Żarnowiec Upland mesoregion and is part of the Koszalin coastal zone. The region is hypsometrically well-defined — in places the height exceeds 100 m a. s. l. To the south and west it borders on the Reda-Łeba ice-marginal valley, while the Płutnica valley forms its eastern boundary. To the north, it reaches as far as the extensive Przymorskie Błota

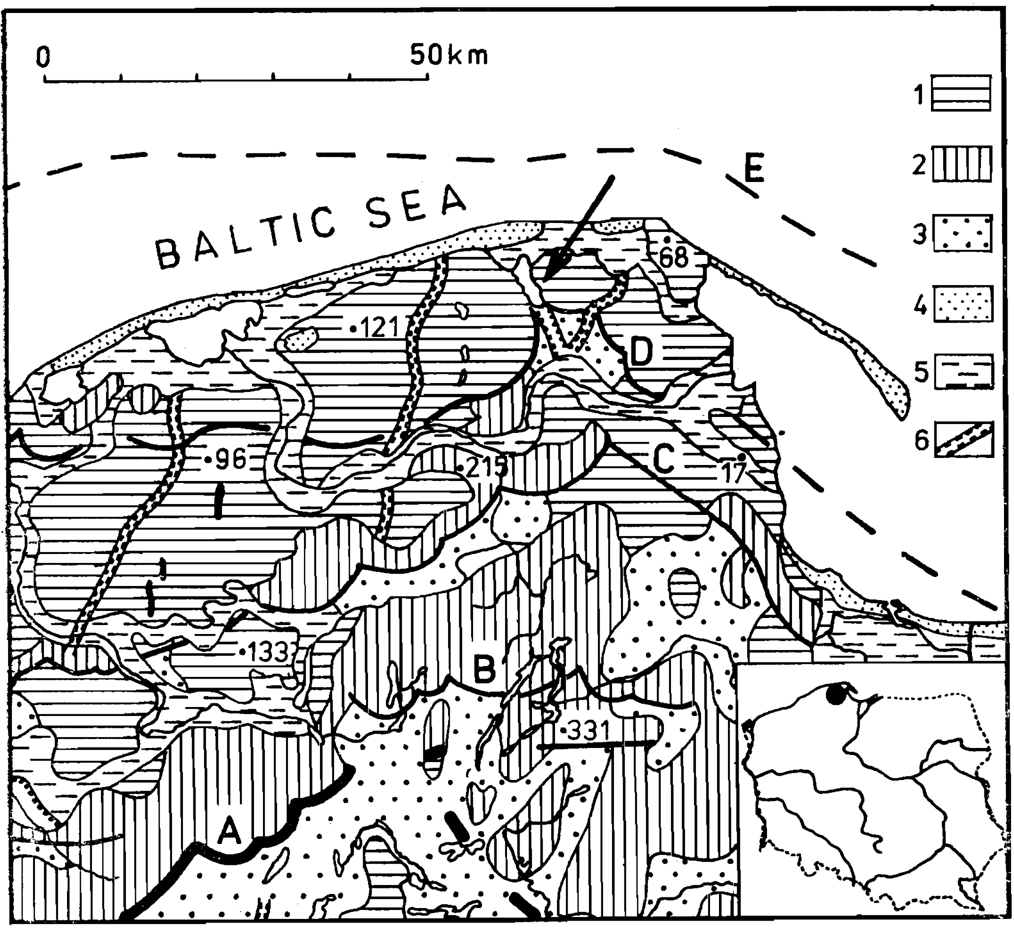

Fig. 1. A geomorphological outline of the recession stages of the last ice-sheet in the eastern part of Western Pomerania (after Liedtke 1975). 1 — flat or undulating landscape; 2 — hummocky moraine landscape; 3 — outwash plain; 4 — inland dunes, blown sand areas, high shore dunes; 5 — bogs; 6 — main subglacial channels. Stages and phases in the recession of the ice-sheet: A — Pomeranian stage; B — Szczecin phase (Kashubo-Warmian); C — Koszalin phase; D — Gardno phase (Copenhagen); E — Bornholm phase. The arrow indicates Lake Żarnowiec

marshes which are part of the Słowiński coastal belt. Lake Żarnowiec lies in the east of the region. According to other classifications, this area is part of the Kashubian coastal zone (Augustowski 1969, 1974) or the Kashubian Upland (Bartkowski 1968).

The landscape of this area was shaped by the action of the Vistulian ice-sheet and its melt waters. The Żarnowiec Upland is one of those areas which remained longest under the direct influence of the glaciation. Even during the Gardno phase (Roszko 1968), a large part of this area was within the range of the ice-sheet's activity. It should be added that this phase can be identified with the Copenhagen phase (Liedtke 1975) running through the island of Rügen, Zeeland (south-west of Copenhagen) and south-eastern Scania (Fig. 1). In comparison with the rest of Poland, the recession of the ice-sheet was long delayed, and this undoubtedly left its mark on the plant history of the area.

An important aspect of the relief of this area is the occurrence of hills which arose as a result of the dissection of Pleistocene plateaux by deep ice-marginal valleys. Worthy of attention is differentiated topography of edge zones of the ice-marginal valleys and channels, especially in the Lake Żarnowiec channel. The hills are fairly flat-topped, as they were formed from flat or slightly undulating ground moraine. Other glacial forms are less well-represented in this area. Only the outwash plain of the Piaśnica river occupies a fairly large area in the south-eastern part of the Żarnowiec Upland (Augustowski 1969, 1974).

Geology and soils

The Żarnowiec Upland is covered with Quaternary formations. Their distribution depends on the configuration of older geological formations. The ground moraine hills are mostly till and loamy sands, while the Piaśnica outwash plain is of outwashed sands and gravels. The Lake Żarnowiec channel, which cuts across the Upland, and the ice-marginal valleys bordering it are filled with Holocene formations: peats and river deposits (Augustowski 1969, 1974).

The soil cover of this area is closely associated with the deposits of the Upland, river valley bottoms and lake channels; it is also associated with the relief of the area (Fig. 2). Brown soils (more rarely, pseudopodsols) formed from clays and sands occur on the hills. These soils retain considerable quantities of moisture and contain quite a lot of humus substance. In the neighbourhood of Lake Żarnowiec they do not contain any calcium carbonate; they are leached and acidic. Greater mosaic of soils occur around the edges of hills, on poorer sandy formations. Hydrogenic peat and bog soils are to be found in the ice-marginal valleys and channels. The Piaśnica outwash plain is a large area of poor sandy soils made up of unconsolidated sands (Augustowski 1969; Witek et al. 1974). Their mosaic-like distribution is the result of varying thickness of outwash plain sands which are covered in a number of places by patches of till.

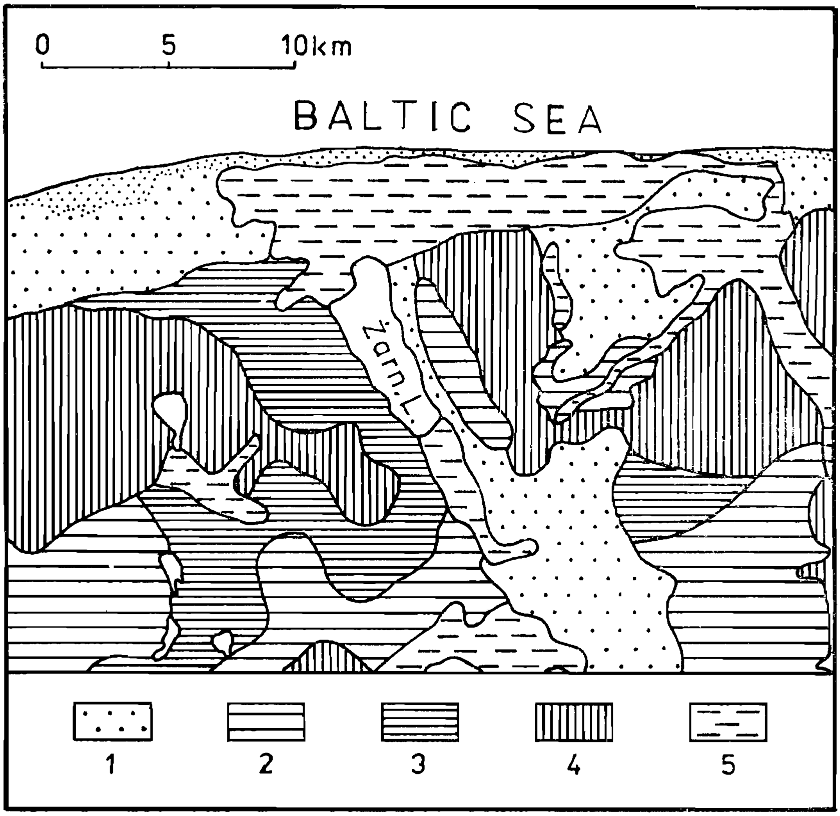

Fig. 2. Distribution of the most important soil types (after Polish Soil Map; Scale 1: 300 000). 1 — podsols formed from unconsolidated sands; 2 — podsols formed from slightly clayey sands; 3 — podsols formed from clayey sands; 4 — light and medium soils formed from boulder clays, and sands overlying clay and loam; 5 — peaty soils formed from low-moor peats

Climate

The climate of the Żarnowiec Upland is directly influenced by the proximity of the Baltic Sea (Fig. 3). The humidity of the air is relatively high, summers are cool and winters mild. All this delays the growing season by about two weeks in comparison with central Poland. Strong winds are frequent in the coastal zone. Taking the year as a whole, the prevailing winds in this area are from the north and north-west. However, in spring and summer, which are the most important seasons for pollen studies because the production of sporomorphs is greatest at this time, southerly and south-westerly winds prevail (Kwiecień & Taranowska 1974).

Present-day vegetation

According to the geobotanical classification by Szafer (1972 a), this area is part of the Baltic Division, Subdivision of the Belt of Maritime Plains and Pomeranian Uplands, Region of the Baltic Coast. However, the working classification compiled for the distribution of type localities for the programme IGCP 158 B designates this area as the Baltic Coastal zone within the region of Western Pomerania (Ralska-Jasiewiczowa 1982).

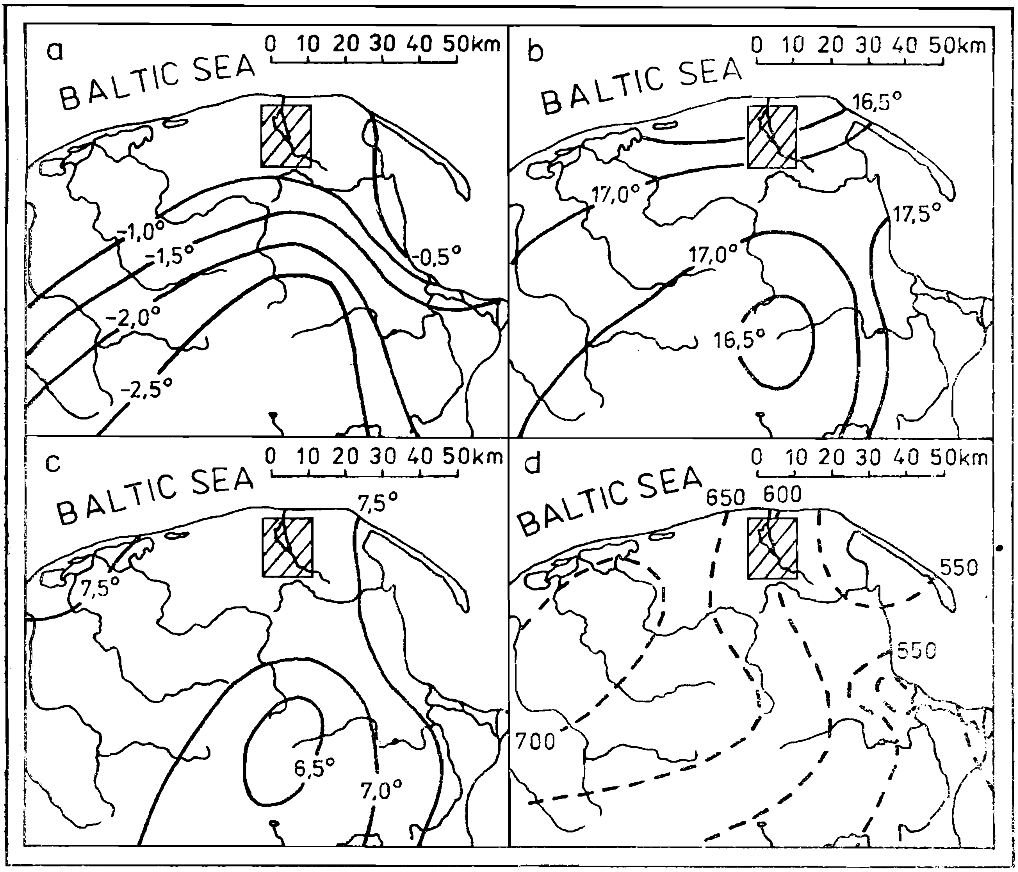

Fig. 3. Selected climatic data: a — January isotherms; b — July isotherms; c — annual isotherms; d — annual rainfall (after Kwiecień & Taranowska 1974)

The maritime climate of the zone has affected the nature of the vegetation, a characteristic feature of the latter being the occurrence of the Atlantic element (s. l.) in the flora (Czeczott 1926; Czubiński 1950; Szafer 1972 b).

The vegetation of this area comprises mainly forest and peat-bogs (Fig. 4). Its present-day state is largely a result of human activities. The forest cover has been seriously reduced and major negative changes have taken place in its structure and species content. The peat-bogs in the ice-marginal valleys and lake channels have been drained and are being farmed.

Low moor communities are of prime importance in the peat-bog vegetation. Small patches of raised bogs, the remnants of a once much larger area, are

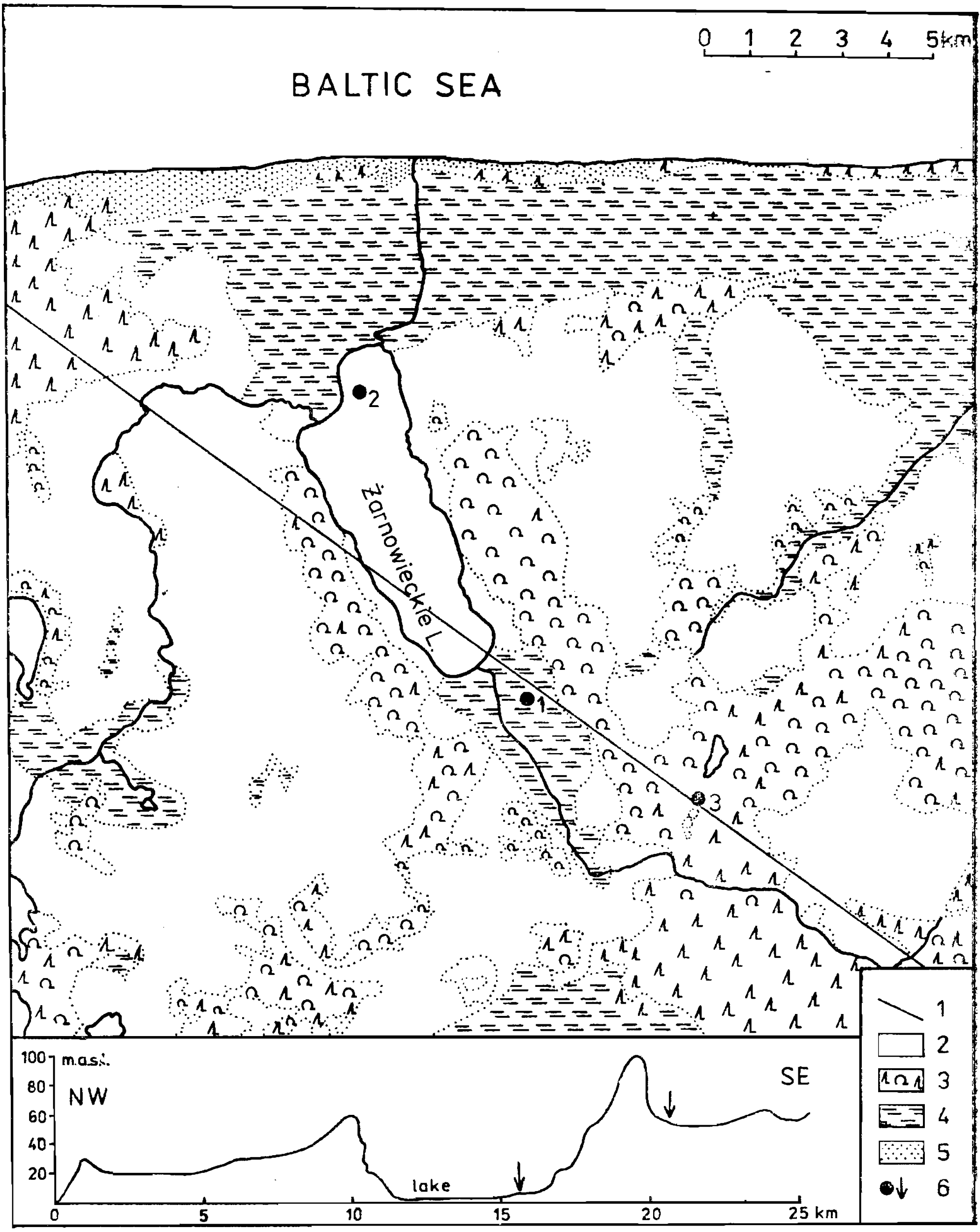

Fig. 4. A. Sketch map showing the vegetation of the study area and the position of the localities. a — morphological cross-section NW-SE; b — deforested areas (pasture and arable land); c — forests; d — peat-bogs; e — coastal sand dunes; f — positions of localities: 1 — profile Żar/76, 2 — profile J. Żar/78, 3 — profile P. Darż/78. B. Morphological cross-section along line a

found mainly in the eastern part of the Błota Przymorskie marshes. It is still possible to find dwindling patches of Atlantic-type heath moors with *Erica tetralix* (Czubiński 1950; Herbichowa 1979); this type of community reaches the easternmost limits of its range here.

Beech is by far the most common tree in the forests. *Luzulo-Fagetum*, an acid beech forests is the dominant community on the flat hills of ground moraine and on sand-clay formations. Patches of more fertile beech forests (*Melico-Fagetum*) are much rarer and cover the edges of uplands showing diversified relief. Beech is often present together with oak in mixed acidophilous woodland (*Fago-Quercetum*). These communities occur on the upland, generally on a sandy substrate, on the undulating ground moraine. Oak-hornbeam forests (*Stellario-Carpinetum*) occupy only a small area, though these remnants suggest that their occurrence in the past was much more extensive. The present distribution of oak-hornbeam forests is mainly along river terraces and at the foot of slopes. Small patches of *Fraxino-Ulmetum*, though much damaged, have survived in the river valleys and the Lake Żarnowiec channel. Alder swamps are also rare (Dąbrowski 1978). Of the pine communities, *Vaccinio myrtilli-Pinetum* s. l. occurs over a fairly large area in the south-eastern part of the Piaśnica outwash plain. *Empetro nigri-Pinetum* is found on sandy spit formations in the coastal zone, whereas *Leucobryo-Pinetum* occurs north-west of Lake Żarnowiec; old specimens of oak trees still exist in this latter community (Wojterski 1964). *Pino-Quercetum* is present mostly in the transition zone between the outwash plain and the upland on the sandier soils of the ground moraine (Dąbrowski 1978).

The study area lies beyond the natural range of spruce (Szafer 1972 b; Środoń 1967), although it is quite numerous where it has been introduced during afforestation.

METHODS

Collection of material

Material from the peat-bogs was collected during 1975—78 using a Russian 'Instorf' corer 10 cm in diameter. Two profiles were taken simultaneously from each locality. One was to be used for palynological investigations and ^{14}C-dating, the other for macrofossil and chemical analyses of sediments. Bottom sediments from northern part of Lake Żarnowiec were sampled using a Boros sampler; however, because of technical difficulties, it was impossible to preserve the continuity of the material. The topmost section of the sediments (37 - 125 cm) was collected using a 5 cm diameter plastic tube as they were insufficiently consolidated to be collected with heavier equipment.

The distribution of the profiles and their symbols are given in the caption to Fig. 4.

Laboratory methods and presentation of results

Pollen analysis

Samples for pollen analysis were taken from the cores at 5 cm intervals with a 1 cm^3 sampler. After heating in 10% KOH on a water bath for 1 hour, the samples were prepared by acetolysis. Material containing silica was left in cold hydrofluoric acid 24 - 48 hours, after which it was rinsed with 10% HCL and then acetolysed. Calcium carbonate was removed with 10% HCL.

Tablets containing *Lycopodium* spores were used to calculate the absolute number of sporomorphs per cm^3 of sediment (Stockmarr 1971, 1973). In most cases, two tablets were used for each sample. The following two principles were observed during the pollen count:

1) the count covered the whole cover-slip area, and in most cases, at least two preparations were used;

2) 1000 tree-pollen grains was the accepted minimum number of sporomorphs counted. Where the number of pollen grains was very low, and also in Late Glacial spectra, 1000 pollen grains of AP +NAP were counted.

The results of pollen analysis are presented in percentage diagrams (Figs. 12 a, 13, 16, 18), concentration diagrams (Figs. 14, 17, 19) and influx diagrams (Figs. 15, 20)[1].

The basis for calculating the percentage diagrams is the sum AP +NAP = = 100% in part A, and the sum AP = 100% in part B which was constructed in order to eliminate the pollen of local herbs. The sum AP includes the pollen of shrubs, whereas the sum NAP excludes the pollen of aquatic and telmatic plants, and spores.

Influx diagrams were compiled only for radiocarbon-dated portion of peat deposits. As dates for the top and bottom of the profiles are unavailable, the sedimentation rate was not calculated, and thus, neither was the pollen influx for this part of the material.

Macrofossil analysis and description of sediments

Samples intended for macrofossil analysis were as a rule 5 cm sections of cores, except in cases where the stratification of deposits called for sections of different lengths. The method of preparation depended on the type of sediment and the degree of its decomposition. Samples of peat were left in water containing HNO_3 for 24 - 48 hours. Some samples required gentle heating to achieve full desintegration of sediment.

A small number of samples from the Żar/76 profile was boiled with added KOH. Calcium carbonate was removed with 10% HCL. All samples were rinsed on a double sieve of mesh sizes 0·43 and 0·2 mm.

The number of identified macrofossils is shown in Figs. 12 b, 21, 22 and 23. Because of the differing volumes of samples, the number of macrofossils is

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[1] The tables of pollen values are in the library of the University of Gdańsk. Figs. 12-23 under the cover.

given in the diagrams as the number per 100 cm³ of deposit (per 200 cm³ in the case of the Żar/75 profile). The estimated number of identified mosses, wood fragments and other tissues is given on a 5-point scale: +: up to 10%, 1: 11-25%, 2: 26-50%, 3: 51-75%, 4: 76-100%. When determining the quantities of tissues, the material left on the sieve was used, and the results were then checked against data obtained using the microscope-percentage method (Maciak & Liwski 1970). A few tissues which occurred in small quantities could not be identified.

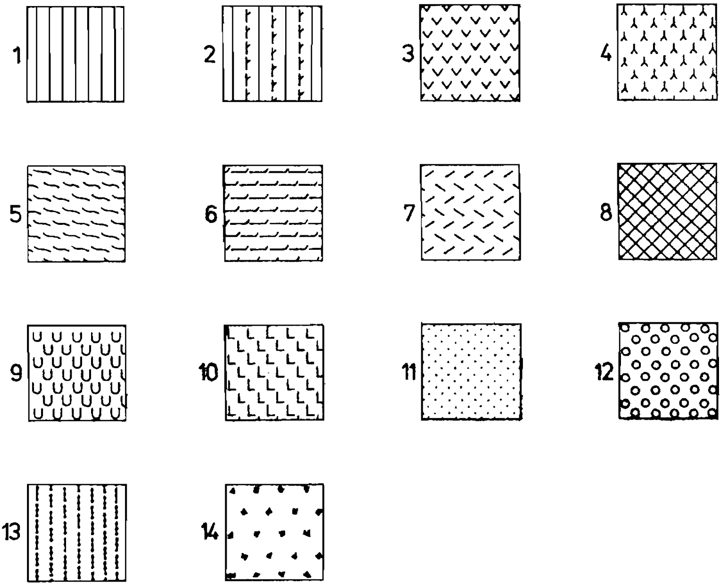

Fig. 5. Symbols used in stratygraphic columns. 1 — *Carex* peat; 2 — *Phragmites* peat; 3 — lignous peat; 4 — *Ericaceae* peat; 5 — moss peat; 6 — *Sphagnum* peat; 7 — detritus gyttja; 9 — calcareous gyttja; 10 — silt and clay; 11 — sand; 12 — gravel; 13 — *Cladium* peat; 14 — charcoal

The sediments have been described using a simplified version of Troels-Smith's system (1955). The accuracy of the macroscopic characterization was corrected using microscopic methods. Fig. 5 gives the sediment symbols.

Chemical analyses of sediments

The following chemical and physical analyses of the sediments were carried out. Samples were dried at 105°C (dry weight) and then ignited at 550°C. The raw ash so obtained was macerated with HCL; as a result, the silica content of the sample could be calculated (Maciak & Liwski 1970). Calcium carbonate was determined by Scheibler's methods, pH potentiometrically in distilled water. Because of the varying time and conditions of samples storage, the wet density of the sediments was not taken into consideration; the percentage of components is given with respect to the sediment dry weight. The results of these analyses are included in the macrofossil diagrams (Figs. 21, 22, 23).

DESCRIPTION OF LOCALITIES AND SEDIMENTS

The localities were chosen in such a way that the pollen material would be representative of the history of both the local and regional vegetation (Fig. 4). So, the localities themselves differ with respect to the size of the sedimentation basins and the topography of the terrain. The relief determines to what extent the peat-bog or lake is protected from the possibility of long-distance pollen dispersal.

The Lake Żarnowiec channel

The Lake Żarnowiec channel is a deep incision into the surface of the moraine upland. It is some 13 km long, and 3·5 km broad at its widest point. The northern part of the channel is occupied by Lake Żarnowiec, and the southern part by low moors. The moraine hills surrounding the channel reach a height of 100 m above sea level and are to a large extent wooded. Their slopes have been dissected by erosion gullies at whose outlets alluvial fans of considerable proportions have been formed. The microclimate of the valley is undoubtedly affected by the fact that it is open to the sea and to the extensive peat-bog system of the Nizina Karwieńska lowland.

Lake Żarnowiec is a channel lake of glacial origin (Kondracki 1978); it is an inflow-outflow lake (Fig. 4). The depth of the lake (Fig. 6) and the type and thickness of the bottom sediments show great differentiation. There is a considerable thickness of calcareous gyttja (of varying calcium carbonate content) which reaches about 20 m in the central part of the lake (Więckowski et al. 1973). Under the gyttja there is a thick layer of sand and gravel. In the more shallow northern part of the lake, and also in its western part there is peat interbedding. No organic sediments occur in the southern and south-eastern parts. In these places the lake bottom is covered with sand only (Dokumentacja wierceń geologicznych — Geological drilling records 1973, 1979), because organic deposits are removed by the action of the river Piaśnica which flows through the lake, and by strong wave action.

The vegetation of Lake Żarnowiec indicates that it is a mesotrophic lake with a strongly eutrophic littoral zone (Ozimek & Pieczyńska MS). The littoral of the northern part of the lake is wide and shows great species diversity. There occur here both macrophytes with floating leaves (*Nymphaea alba*, *Polygonum amphibium*) and submerged macrophytes (*Potamogeton perfoliatus*, *P. pectinatus*, *P. gramineus*, *P. rutilus*, accompanied by specimens of the genera *Chara* and *Nitella*). *Myriophyllum spicatum* and *Elodea canadensis* are also common. In the greater depths, beyond the zone occupied by the above-mentioned plants, filamentous algae are mostly found, among them, numerous examples of the genus *Spirogyra*. Reed associations are best developed in the northern part of the lake. The dominating species here include *Phragmites communis*, and *Schoenoplectus lacustris*; less common are *Typha angustifolia*, *Acorus cal-*

amus, *Eleocharis palustris*, *Iris pseudoacorus*, *Glyceria aquatica* and *Carex hudsoni* (Ozimek & Pieczyńska MS).

Material for palaeobotanical investigation was taken from the lake (locality 2) about 400 m from the western shore and almost 1·5 km from the northern shore (Figs. 4, 6). The depth of water at this point is 2 m.

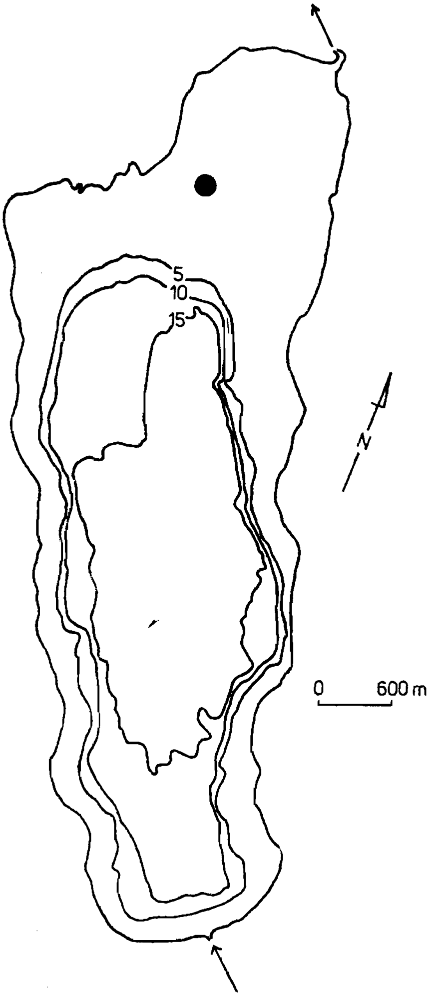

Fig. 6. Bathymetric sketch of Lake Żarnowiec. The dot indicates the spot from which profile J. Żar/78 was taken

Locality 2, profile J. Żar/78

Layer No.	Depth (cm)	
1	36-45	brown sand with mollusc shells Ga & Gs 2,5, Dg 1,5, Gg +, Dl & Dh +, Ld+, [part. test. mol. 3], nig 2, elas 0, strf 0, sicc 2.

Layer No.	Depth (cm)	
2	45-52	brown detritus gyttja with mollusc shells, Ld 4, Ga & Gs +, Dl & Dh +, [part. test. mol. & test. mol. 4], nig 2, elas 0, strf 0, sicc 2, lim. sup. 0.
3	52-57	dark brown detritus gyttja, Ld 4, Ga & Gs +, Dl & Dh +, Dg +, [part. test. mol. +], nig 3, elas 0, strf 1, sicc 2, lim. sup. 0.
4	57-67	dark grey calcareous gyttja, Lc 3, Ld 1, As +, [part. test. mol. & test. mol. +], nig 2, elas 0, strf 1, sicc 2, lim. sup. 0.
5	67-103	light grey calcareous gyttja, Lc 4, Ld +, As +, [part. test. mol. & test. mol. +], nig 1, elas 0, strf 1, sicc 2, lim. sup. 0.
6	103-107	dark grey calcareous gyttja, Lc 3, Ld 1, As +, [part. test. mol. & test. mol. +], nig 2, elas 0, strf 1, sicc 2, lim. sup. 0.
7	107-118	ligth grey calcareous gyttja, Lc 4, Ld +, As +, [part. test. mol. +], nig 1, elas 0, strf 1, sicc 2, lim. sup. 0.
8	118-125	dark brown calcareous detritus gyttja, Lc 2, Ld 2, [part. test. mol. & test. mol. +], nig 2, elas 0, strf 1, sicc 2, lim. sup. 0.
9	146-196	dark brown *Cladium-Phragmites* peat, Th^3 (Cladii) 2, Th^3 (Phra) 2, Dh +, elas 2, strf 0, sicc 2, humo 3 (H_8).
10	208-233	dark brown *Cladium* peat, Th^3 (Cladii) 3, Th^3 (Phra) 1, Dh +, nig 3, elas 2, strf 0, sicc 2, lim. sup. 0, humo 3 (H_8).
11	233-258	ligth grey calcareous gyttja, Lc 3, Dl & Dh 1, Ld +, Dg +, [test. mol. +], nig 1, elas 0, strf 1, sicc 2, lim. sup. 3.
12	290-298	light grey calcareous gyttja with mosses, Lc 2, Tb^1 2, Ld +, Dg +, [test. mol. +], nig 1, elas 0, strf 1, sicc 2.
13	298-332	light grey calcareous gyttja with mosses, Lc 3, Tb^1 1, [test. mol. +], Ld +, Dl & Dh +, Dg +, nig 1, elas 0, strf 1, sicc 2, lim. sup. 0.
14	332-340	grey calcareous gyttja with clay, Lc 3, As & Ag 1, Ga & Gs +, Ld +, Dg +, Dl & Dh +, [test. mol +], nig 1, elas 0, strf 1, sicc 2, lim. sup. 0.
15	360-410	grey clayey calcareous gyttja, Lc 2, As & Ag 2, Ga & Gs +, Ld +, Dg +, Dl & Dh +, nig 2, elas 0, strf 1, sicc 2.
16	420-700	grey coarse-grained sand, Ga & Gs 4, Gg +.

The surface of the peat-bog in the southern part of the Lake Żarnowiec channel has been almost completely destroyed by the construction work in progress there. Before 1976, this area was one of meadows and pastures, criss-crossed by drainage ditches and with rectangular patches of *Salix cinerea* and *S. aurita* scrub in between. The floristic content of this scrub suggested that it represented various stages of a secondary succession arising after shallow peat-cutting. Evidence for this may be the existing variety of species from swamp, scrub and meadow communities. Among the meadow vegetation, prevalent were communities which are part of the *Cirsio-Polygonetum* association, in which *Cirsium oleraceum* and *Polygonum bistorta* were dominant. Swamp and low moor species were present in the numerous drainage ditches and pits left after peat-cutting, and in their immediate neighbourhood.

Material for palaeobotanical investigation was taken from a locality some 2 km from the southern shore of the lake (locality 1, Fig. 4), and gave the following two profiles:

Locality 1, profile Żar/75

Layer No.	Depth (cm)	
1	450-455	dark brown silt with plant detritus, As & Ag 2, Dg 1, Dl & Dh 1, Ga & Gs +, Lc +, [part. test. mol. +].
2	455-485	dark brown sandy silt with plant detritus, As & Ag 2, Ga & Gs 1, Dg 1, Dl & Dh +, Lc +.
3	485-500	grey clayey sand with plant detritus, Ga & Gs 3, Dg 1, Dl & Dh +, Lc +.

Locality 1, profile Żar/76

Layer No.	Depth (cm)	
1	0-20	brown dried-up *Carex* peat, Th^2 4, nig 3, elas 1, strf 0, sicc 1, humo 2 (H_5).
2	20-65	dark brown fibrous felted *Carex-Phragmites* peat, Th^2 2, Th^2 (Phra) 2, Dh +, nig 3, elas 2, strf 0, sicc 2, lim. sup. 0, humo 2 (H_5).
3	65-135	dark brown fibrous *Cladium* peat, Th^2 (Cladii) 3, Th^2 (Phra) 1, Dh +, nig 3, elas 2, strf 0, sicc 2, humo 2 (H_5).
4	135-295	dark brown *Phragmites-Cladium* peat, Th^3 (Phra) 2, Th^3 (Cladii) 2, Dh +, nig 3, elas 2, strf 0, sicc 2, lim. sup. 0, humo 3 (H_8).
5	295-355	dark brown fibrous *Cladium* peat, Th^3 (Cladii) 3, Th^3 (Phra) 1, Dh +, nig 3, elas 2, strf 0, sicc 2, lim. sup. 0, humo 3 (H_8).

Layer No.	Depth (cm)	
6	355 - 395	dark brown slightly fibrous *Carex*-moss peat with wood fragments, Th^3 2, Tb^3 1, Dl 1, nig 3, elas 2, strf 0, sicc 2, lim. sup. 0, humo 3 (H_8).
7	395 - 400	light beige sand, Ga & Gs 2, Gg 1, Dg 1, Ag +, Ld +, nig 1, elas 0, strf 0, sicc 3, lim. sup. 3.
8	400 - 448	light yellow sand, Ga & Gs 4, Gg +, Dg +, Dl & Dh +, nig 1, elas 0, strf 0, sicc 3, lim. sup. 0.
9	448 - 450	dark brown calcareous gyttja, Lc 2, Ld 2, Ag +, Ga & Gs +, nig 3, elas 0, strf 0, sicc 3, lim. sup. 2.

Locality 1, profile Żar/76 (additional samples)

Layer No.	Depth (cm)	
1	400 - 428	ligth beige sand, Ga & Gs 3, Gg 1, Ag +, Dl & Dh +, Dg +, Ld +, nig 1, elas 0, strf 0, sicc 3, (425-428 cm: greater detritus content, sand with Fe stains).
2	428 - 431	dark brown detritus gyttja, Ld 1, Dg 1, Dl & Dh 1, Ga & Gs 1, Ag +, Lc +, nig 3, elas 0, strf 0, sicc 2, lim. sup. 3.
3	431 - 449	brown silt, Lc 1, Ld 1, Dg 1, As 1, Dl & Dh +, nig 2, elas 0, strf 0, sicc 2, lim. sup. 1.
4	449 - 450	dark grey clayey sand, Ga & Gs 2, Ag 1, Dg 1, As +, Lc +, Ld +, nig 3, elas 0, strf 0, sicc 3, lim. sup. 1.

Darżlubie Forest

Locality 3 lies on the upland (Fig. 5). Material for palaeobotanical investigation was taken from a small peat-bog in the Lake Dobre channel, about 1 km south-west of that lake. The channel is some 100 m wide at this point; its slopes are fairly steep and are covered with forest, mostly pine. The characteristics of this sedimentation basin are highly suitable for a study of the local plant history. Wet meadow communities of the order *Molinietalia* are now found on the surface of the peat-bog. These meadows arose as a result of the transformation of a low moor which had some features of a transition bog. This is indicated by the fact that species typical of low moors (e. g. *Carex fusca*, *C. flava*) and of transition bogs (e. g. *Comarum palustre*, *Hydrocotyle vulgaris*, *Viola palustris*, *Eriophorum angustifolium*, *Sphagnum palustre*, *Sph. apiculatum* and *Aulacomium palustre*) occur side by side. Occasionally, one may come across raised bog species such as *Drosera rotundifolia*. Reed species including *Phragmites communis*, *Carex rostrata* and *Glyceria plicata* are dominant in the drainage ditches which criss-cross the bog.

Locality 3, profile P. Darż/78

Layer No.	Depth (cm)	
1	0-25	dark brown felted *Carex* peat with some sand, Th^1 3, Ga & Gs 1, Dl & Dh +, [anth. +], nig 3, elas 1, strf 0, sicc 1, humo 1 (H_3).
2	25-170	brown felted *Carex* peat, Th^1 3, Th^1 (Phra) 1, Tb^1 +, Dl & Dh +, [anth. +], nig 2, elas 1, strf 0, sicc 2, lim. sup. 0, humo 1 (H_3).
3	170-225	brown *Carex-Phragmites* peat, much compressed, Th^1 2, Th^1 (Phra) 2, Dl & Dh +, Ga & Gs +, nig 3, elas 1, strf 0, sicc 2, lim. sup. 0, humo 1 (H_3).
4	225-292	dark brown *Carex* peat, much compressed, Th^1 4, Th^1 (Phra) +, Tb^1 +, Dl & Dh +, nig 3, elas 1, strf 0, sicc 2, lim. sup. 0, humo 1 (H_3).
5	292-308	light brown fibrous *Sphagnum* peat, Tb^1 (Sphag) 3, Tl^1 (Ericac) 1, Th^1 +, Dl & Dh +, nig 2, elas 2, strf 0, sicc 2, lim. sup. 1, humo 1 (H_3).
6	308-320	dark brown *Ericaceae-Carex* peat, Tl^1 (Ericac)2, Th^1 1, Tb^1 1, Dl & Dh +, nig 3, elas 2, strf 0, sicc 2, lim. sup. 0, humo 1 (H_4).
7	320-335	dark brown fibrous *Phragmites* peat, Th^2 2, Th^2 (Cladii) 1, Th^2 (Dryopt)1, Tb^2 +, Dl & Dh +, nig 3, elas 2, strf 0, sicc 2, lim. sup. 0, humo 2 (H_5).
8	335-360	dark brown moss peat, Tb^1 3, Th^1 1, Dl & Dh +, nig 3, elas 2, strf 1, sicc 2, lim. sup. 0, humo 1 (H_4).
9	360-374	dark brown fibrous *Carex* peat, Th^2 3, Tb^2 1, Dl & Dh +, nig 3, elas 1, strf 0, sicc 2, lim. sup. 1, humo 2 (H_6). *Betula* wood at 365 cm.
10	374-382	dark brown, lamellar, detritus gyttja, Ld 3, Dl & Dh 1, Dg +, nig 3, elas 2, strf 3, sicc 2, humo 3 (H_8).
11	382-391	light grey calcareous gyttja, Lc 4, Ld +, Dg +, Dl & Dh +, nig 1, elas 0, strf 1, sicc 2, lim. sup. 1.
12	391-397	yellow fine- and medium-grained sand, Ga & Gs 4, Ld +, nig 1, elas 0, strf 0, sicc 2, lim. sup. 1.
13	397-400	Coarse-grained sand, Ga & Gs 3, Gg 1, Ld +, nig 1, elas 0, strf 0, sicc 2, lim. sup. 0.

RADIOCARBON DATING

Dating was carried out in the ^{14}C laboratory of the Silesian Polytechnic in Gliwice. Sample ages were calculated assuming the half-life of the ^{14}C isotope to be $t_{\frac{1}{2}} = 5568$ years. No correction was made for past changes in its concentration.

Sample No.	Sample code	Depth (cm)	Laboratory number	Age (years BP)
1	Żar/76	45 - 50	Gd-685	2400 ±60
2	Żar/76	107 - 112	Gd-598	3230 ±70
3	Żar/76	142 - 152	Gd-1030	4035 ±60
4	Żar/76	191 - 200	Gd-595	5460 ±60
5	Żar/76	245 - 250	Gd-686	6635 ±100
6	Żar/76	288 - 298	Gd-596	8090 ±70
7	Żar/76	343 - 352	Gd-1029	9065 ±70
8	Żar/76	387 - 397	Gd-1031	10 130 ±120
9	P. Darż/78	23 - 33	Gd-1032	1125 ±55
10	P. Darż/78	87 - 98	Gd-599	2310 ±65
11	P. Darż/78	113 - 123	Gd-1033	2770 ±60
12	P. Darż/78	183 - 193	Gd-1058	4035 ±65
13	P. Darż/78	201 - 205	Gd-1124	5057 ±75
14	P. Darż/78	220 - 225	Gd-1125	6775 ±115
15	P. Darż/78	253 - 263	Gd-625	7895 ±110
16	P. Darż/78	303 - 313	Gd-1113	8780 ±85
17	P. Darż/78	303 - 313	Gd-626	8885 ±95
18	P. Darż/78	327 - 332	Gd-1126	9165 ±110
19	P. Darż/78	332 - 337	Gd-1154	8995 ±85
20	P. Darż/78	350 - 358	Gd-1059	9080 ±85
21	P. Darż/78	375 - 381	Gd-1060	9840 ±115

When calculating the sedimentation rate, the mean age of samples 16 and 17 (8830 ±65 BP) was used. Sample 18 was not taken into consideration.

ACCUMULATION RATE OF PEAT DEPOSITS

The accumulation rate is a characteristic property of a deposit, and depends on a number of primary factors such as the type of plant community involved in its formation, climate, humidity etc. In fossil deposits, the original thickness alters as a result of secondary factors which cause the subsidence of the surface. Most important in this process are: time, the overall thickness of deposits, their substrate, hydrology and the degree of decomposition of the peat itself. The action of each factor varies, depending on the type of sediment (Ilnicki 1972).

The accumulation rate is the basis upon which pollen influx diagrams are constructed and macrofossil diagrams interpreted. Its value has been calculated for successive sections of the profiles by dividing their lengths by the number of years during which they were deposited (Birks & Mathews 1978; Fredskild 1973; Hicks 1976). Fig 7 shows the sedimentation rate curves for profiles Żar/76 and P. Darż/78.

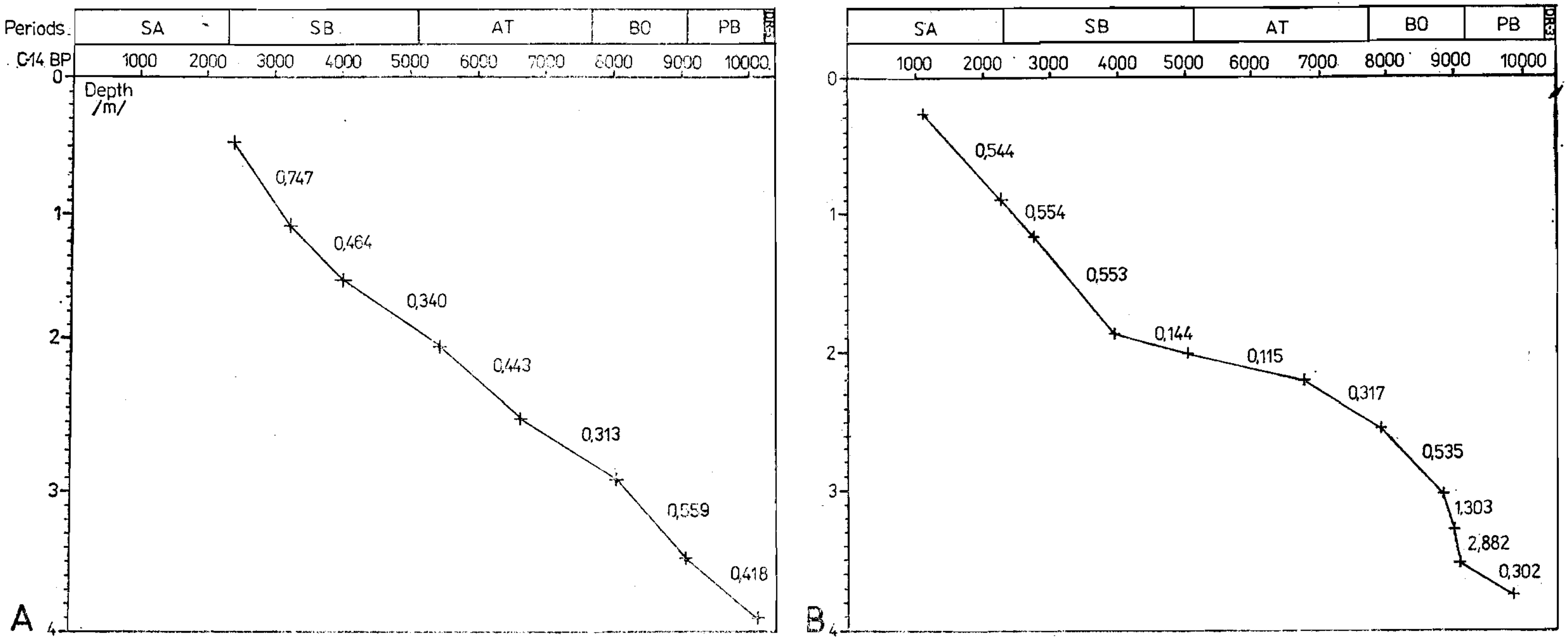

Fig. 7. Graph showing the accumulation rate of peat-bog sediments: A — peat-bog near Lake Żarnowiec (profile Żar/76); B — peat-bog in Darżlubie Forest (profile P. Darż/78). The accumulation rate is given in mm/year

It is characteristic of profile Żar/76 that the rate of sedimentation is relatively even. This fact corresponds to the results of macrofossil analysis (Fig. 21) which show that reed-swamp communities of *Phragmitetea*, indicating the high water table, have existed throughout practically the whole period of the bog's development.

The accumulation rate of sediments demonstrated by profile P. Darż/78 took a different course. The various profile sections are markedly differentiated: this is a consequence of the type of plant community existing at a given time, and the hydrological conditions under which accumulation took place. It has been calculated that the accumulation rate was fastest when mosses prevailed in the communities (1·3-2·9 mm/year), and slowest when the communities comprised mainly aquatic species such as *Potamogeton*, *Sparganium*, *Characeae* (0·115 mm/year).

In the topmost sections of both profiles, the accumulation rate was found to be reduced. This is indicated by the substantially increased concentrations of sporomorphs per cm^3 of material (Figs. 14 and 19). This is probably the effect of drainage work carried out earlier (see Ilnicki 1972).

PLANT HISTORY OF THE LAKE ŻARNOWIEC AREA

Notes on the occurrence of some interesting species

Musci

Meesea longiseta Hedw. Remains of this moss are quite numerous in one sample (300-308 cm) from the Darżlubie Forest profile. In this deposit it is accompanied by *Sphagnum apiculatum*, *S. palustre* and *Oxycoccus quadripetalus* remains. The present range of *Meesea longiseta* coincides with the distribution of peat-bogs in the Holarctic (Jasnowski 1957). It is a very rare species in Poland. Small quantities occur occasionally in Quaternary peats (Jasnowski loc. cit.). Wasylikowa (1964) has reported it in the Oldest Dryas sediments from the locality at Witów.

Pteridophyta

Selaginellaceae

Selaginella selaginoides L. Macro- and microspores of this species occur abundantly in samples of Younger Dryas sediments from profiles Żar/75 and Żar/76, and sporadically in the sediments of Lake Żarnowiec (J. Żar/78). This is a calciphilous plant, not tolerating shade found in damp habitats in tundra vegetation. At present, it has arctic-alpine distribution (Hultén 1950). In Late Glacial sediments from Poland, it occurs mainly as single spores. A high percentage of *S. selaginoides* from the Younger Dryas has been reported from the Cracow area (Mamakowa 1970).

Angiospermae

Betulaceae

Betula sect. *nanae*. *Betula* t. *nana* pollen grains were identified morphologically (Tarasmaë 1951). Because of the considerable destruction of material and the various methods of maceration used before acetolysis (depending on the type of sediment), statistical methods have not been used here. *Betula nana* pollen was not counted in diagram Żar/76: its presence in this material was merely confirmed. Among the macrofossils some *B. nana* leaf fragments were found, also some scales and dozens of nutlets which have a very wide base and very narrow wings. They were most numerous in profile Żar/75. Small *Betula* nutlets with a fairly narrow base, in shape approaching that of *B. humilis* fruits, were classified as *Betula* sect. *nanae* (profile Żar/76, 355-365 cm). All *Betula* nutlets and scales were drawn and measured. However, the biometrical method (Białobrzeska & Truchanowiczówna 1960) could not be fully applied because the remains were damaged. *Betula nana* is a boreal-montane species (Hultén 1950) and a typical component of the so-called "Dryas flora" (Iversen 1954, 1973) and has been observed in many Glacial and Late Glacial localities in Europe.

Caprifoliaceae

Lonicera periclymenum L. The diagrams show that single pollen grains of *L. periclymenum* occur a few times in Subboreal and Subatlantic sediments. It is a subatlantic species (Czubiński 1950), like *Hedera helix* indicating the increasingly maritime nature of the climate (Iversen 1960). At present, its range extends no farther east than the Vistula Spit (Hantz 1979).

Cyperaceae

Carex aquatilis Wahlenb. Single nutlets identified as *Carex* t. *aquatilis* or *C.* cf. *aquatilis* have been found in a number of samples from the Younger Dryas in profiles Żar/75 and Żar/76. The accuracy of identification was checked against both present-day and fossil reference material. However, as the utriculi, vital for identification in this case, were missing (Wasylikowa 1964), it was not possible to exclude *Carex rigida* Goed. (*C. bigelowii* Torr.).

At present, *Carex aquatilis* s. l. occurs in the boreal zone (Hultén 1964). During the Pleniglacial and Late Glacial it was common in plant communities of damp habitats and shallow water as is indicated by numerous localities in Europe where *C. aquatilis* was found in the Vistulian Glaciation floras (Wasylikowa 1964 and literature quoted there).

Cladium mariscus L. Numerous pollen grains and large quantities of fruits and tissues of this pseudoatlantic species (Czubiński 1950) were found in profiles from all the localities. The first *Cladium* pollen appeared in the bottom sediments of Lake Żarnowiec already in the Preboreal period. However, *Cladium* reed-swamps only began to develop at the start of the Boreal period. Most of the identified *Cladium* remains are from this period. *Cladium* pollen occurs in a great variety of shapes. Apart from the characteristic pollen grains having a narrow finger-like projection at one end, there were many grains less extended and even ovate. In this case, the diagnostic feature was the very delicate structure of the grains, and also the number and shape of the lacunae

(Faegri & Iversen 1975). Reference preparations of present-day specimens, and the paper of Kac, Kac and Skobeeva (1977) were used in the identification of tissues from vegetative parts.

Investigations carried out so far on subfossil communities in north-eastern Poland indicate that in the past *Cladium* communities were very widely distributed (Herbichowa 1975; Jasnowski 1962; Latałowa unpubl.; Tobolski — oral information; Żelazna 1979). The present scarcity of *Cladium mariscus* communities is due to the drainage of the bogs and probably also to the deteriorating climate.

Ericaceae

Arctostaphylos alpina L. One seed was found in the 475-485 cm sample from profile Żar/75, in Younger Dryas sediments. *Arctostaphylos alpina* is a heliophyte of circumpolar distribution and arctic-alpine range (Hultén 1964). Iversen (1954, 1973) mentions this species as a component of Late Glacial flora, especially characteristic of the Younger Dryas.

Myricaceae

Myrica gale L. Pollen grains occur most often in the diagram from the peat-bog near Lake Żarnowiec, but only sporadically in the other diagrams. The first grains appeared as late as the Subboreal period. The shape of the curve suggests that pollen was not transported from a long distance, possibly from the system of peat-bogs to the north of Lake Żarnowiec, where it is still common today. Because of the difficulties involved in correctly identifying the pollen of this species, especially in material as highly corroded as profile Żar/75, it is possible that some of the pollen grains have been identified incorrectly. Some of them were very well preserved and had all the essential diagnostic features (Jentys-Szaferowa 1929). *Myrica gale* is classified as a pseudo-atlantic species (Czubiński 1950).

Polygonàceae

Rumex acetosa type and *R. acetosella* type. Pollen grains from both these types have been identified (see. e. g. Ralska-Jasiewiczowa 1981). The accuracy of identification depended on the state of preservation of the material, so for this reason some of the pollen grains were classified only as the *acetosa/acetosella* type. A common curve was drawn in the diagrams.

Rosaceae

Dryas octopetala L. This species is represented only by a small leaf fragment found in sample 475-485 cm from the Younger Dryas in profile Żar/75. This fragment was identified by its characteristic shape, curling of the leaf edge and its venation. This heliophilous and calciphilous species, a typical component of Dryas floras, occurred on richly calcareous Late Glacial soils (Iversen 1954, 1973). Remains of *Dryas octopetala* have been reported from a number of localities in Poland.

Umbelliferae

Hydrocotyle vulgaris L. Numerous fruits and pollen grains were found in sediments from the peat-bogs in Darżlubie Forest and near Lake Żarnowiec.

They occur in both profiles in the second half of the Subboreal period, and again in the upper sections of the diagrams from the Subatlantic period. *Hydrocotyle vulgaris* is a subatlantic plant common in Pomerania (Czubiński 1950).

Zoning of pollen diagrams

The biostratigraphic zonation system applied to the diagrams in the thesis is based on the sporomorph content of the various profile sections. This zonation consists of pollen assemblage zones (**Birks & Berglund 1979; West 1970**) which are named after the species dominating or characteristic of a given section of the diagram. In the diagrams only the zone numbers are given. This zonation attempts to distinguish easily recognizable units; excessive fragmentation of the diagrams is thus avoided.

In order to facilitate comparison with other pollen diagrams from Poland the climatic-vegetational periods of the Blytt-Sernander system are also used. They are treated here as chronostratigraphic units (**Faegri & Iversen 1975**) with time boundaries defined according to the approximate conventional radiocarbon dates taken from the paper by Środoń (1972). The only change that has been made to this zonation system is the insertion of a transition period DR-3/PB.

Description of pollen assemblage zones

The pollen assemblage zones (PAZ) show great similarities in all the diagrams and they can probably be applied regionally. The description of the assemblage zones contains features common to all the diagrams. The differences in percentage pollen values and in the pollen influx from the various taxa are the consequence of the different habitat conditions and the different morphometry of the basins in various localities. These percentage differences are set out in Table 1.

Pinus-Juniperus-herbs pollen assemblage zone (1)

Diagrams Żar/75, Żar/76, J. Żar/78.

In diagrams Żar/75 and Żar/76, characteristic are the high pollen values of NAP (means 53·3%, 57·5%), *Juniperus* (means 3·4%, 4·4%) and other heliophytes like *Artemisia* (max. 4·5%), *Selaginella selaginoides* (max. 4·8%), ***Betula nana*, *Chenopodiaceae*** and ***Empetrum*. *Helianthemum*, *Saxifraga*** t. ***nivalis*, *S*.** t. ***oppositifolia*, *Ephedra*** cf. ***distachya*** and ***E*.** t. ***fragilis*** appear with low frequencies. These species are less well represented in diagram Żar/76.

In the diagram of bottom sediments J. Żar/78 (locality 2), the ***Pinus-Juniperus*-herbs** assemblage zone is characterized by higher pollen values of ***Betula*** and ***Pinus*** and lower NAP (31·4%) than is the case in the diagrams discussed

Table 1

Mean and maximum pollen percentage values of selected genera in distinguished pollen assemblage zones. Basis of calculations: a — for 1 and 2 PAZ AP+NAP = 100%, b — for 3-8 PAZ AP = 100%

Pollen Assemblage Zones (PAZ)	Locality 1 — Żar/75 Żar/76			Locality 2 — J. Żar/78			Locality 3 — P.Darż/78		
		mean%	max.%		mean%	max.%		mean%	max.%
1. *Pinus-Juniperus*-herbs	Depth: 500-450 cm Żar/75								
	Pinus	29·3	37·0						
	Betula	11·6	16·5						
	Juniperus	3·4	5·4						
	NAP	53·3	58·2						
	Artemisia	2·4	4·5						
	Depth: 445—430 cm Żar/76			Depth: 409—322 cm					
	Pinus	23·9	28·5	*Pinus*	37·6	54·4			
	Betula	11·2	12·6	*Betula*	18·8	38·9			
	Juniperus	4·4	6·1	*Juniperus*	8·7	13·9			
	NAP	57·5	60·0	NAP	31·4	43·6			
	Artemisia	3·4	4·5	*Artemisia*	2·0	4·0			
2. *Juniperus-Pinus-Betula*	Depth: 402-392 cm			Depth: 322-312 cm			Depth: 389-377 cm		
	Pinus	31·8	41·8	*Pinus*	26·6	29·3	*Pinus*	22·8	29·3
	Betula	15·6	18·5	*Betula*	32·0	33·5	*Betula*	23·1	30·4
	Juniperus	6·1	6·6	*Juniperus*	20·5	24·1	*Juniperus*	14·2	20·1
	NAP	49·4	54·4	NAP	17·1	19·1	NAP	37·6	47·2
3. *Pinus-Betula* 3a. *Pinus-Betula-Filipendula*	Depth: 392-380 cm			Depth: 312-293 cm					
	Pinus	72·6	75·8	*Pinus*	50·7	57·7			
	Betula	24·5	27·0	*Betula*	36·1	38·5			
	NAP	18·6	19·6	NAP	16·5	21·3			

	Depth: 380-367 cm						Depth: 377-357 cm		
3b. *Betula-*	*Pinus*	56·3	58·7				*Pinus*	62·3	67·9
	Betula	42·8	45·5				*Betula*	35·6	40·4
-Empetrum	NAP	20·7	27·0				NAP	19·4	24·8
	Empetrum	7·9	15·7						
	Depth: 367-353 cm			Depth: 255-236 cm					
3c. *Pinus*	*Pinus*	65·8	70·5	*Pinus*	67·7	78·5			
	Betula	32·8	42·3	*Betula*	28·7	39·1			
	NAP	22·2	29·8	NAP	16·1	27·8			
	Depth: 353-307 cm			Depth: 236-178 cm			Depth: 357-275 cm		
	Pinus	80·7	87·6	*Pinus*	72·8	85·3	*Pinus*	61·7	78·4
	Betula	12·3	21·7	*Betula*	18·2	32·5	*Betula*	26·7	42·0
4a. *Corylus*	*Corylus*	5·2	8·1	*Corylus*	5·8	10·7	*Corylus*	8·6	27·2
	Ulmus	1·1	1·7	*Ulmus*	1·3	2·0	*Ulmus*	1·0	4·5
4. *Corylus-Pinus*									
	Depth: 307-272 cm			Depth: 236-157 cm			Depth: 275-252 cm		
4b. *Corylus-*	*Pinus*	81·0	89·3	*Pinus*	82·9	85·0	*Pinus*	53·6	55·5
	Betula	5·3	7·7	*Betula*	6·7	8·1	*Betula*	16·3	19·4
-Alnus	*Corylus*	8·2	11·0	*Corylus*	5·1	6·4	*Corylus*	24·2	27·9
	Alnus	2·7	4·5	*Alnus*	2·4	3·4	*Alnus*	1·3	4·1
	Depth: 272-200 cm						Depth: 252-198 cm		
	Pinus	76·6	86·7				*Pinus*	55·7	70·3
	Tilia	2·8	6·8				*Tilia*	2·5	3·6
5. *Tilia-Ulmus-Pinus*	*Ulmus*	2·6	4·4				*Ulmus*	3·6	5·3
	Quercus	1·9	7·8				*Quercus*	4·9	15·8
	Alnus	5·8	8·7				*Alnus*	8·9	14·2
	Corylus	4·7	7·1				*Corylus*	11·9	14·9

Pollen Assemblage Zones (PAZ)	Locality 1 — Żar/75 Żar/76	mean%	max.%	Locality 2 — J. Żar/78	mean%	max.%	Locality 3 — P.Darż/78	mean%	max.%
6. *Quercus-Corylus*.	Depth: 200-72 cm			Depth: 123-45 cm			Depth: 198-123 cm		
	Pinus	48·3	66·7	*Pinus*	12·5	23·2	*Pinus*	14·9	31·8
	Tilia	3·6	8·4	*Tilia*	2·8	4·5	*Tilia*	3·0	3·8
	Ulmus	2·8	6·8	*Ulmus*	3·7	7·6	*Ulmus*	1·6	4·1
	Quercus	8·3	14·2	*Quercus*	15·9	23·5	*Quercus*	31·9	43·3
	Alnus	16·1	37·2	*Alnus*	31·9	48·8	*Alnus*	15·6	29·8
	Corylus	10·1	14·5	*Corylus*	17·2	22·6	*Corylus*	20·6	29·0
7. *Quercus-Carpinus*	Depth: 72-0 cm						Depth: 123-32 cm		
	Pinus	53·2	63·4				*Pinus*	32·4	55·3
	Tilia	0·3	0·7				*Tilia*	0·6	2·4
	Ulmus	0·5	1·3				*Ulmus*	0·4	1·0
	Quercus	7·3	13·1				*Quercus*	13·9	21·3
	Corylus	5·2	10·7				*Corylus*	5·4	14·2
	Carpinus	2·6	4·5				*Carpinus*	11·1	25·2
	Fagus	0·2	0·7				*Fagus*	0·7	1·5
8. *Pinus-Fagus-Juniperus*							Depth: 32-0 cm		
							Pinus	44·8	57·3
							Quercus	11·8	17·8
							Carpinus	7·8	21·4
							Fagus	3·1	5·4
							Juniperus	1·7	2·3

above. Heliophytes reach maximum frequencies (***Betula nana*** 3·3%, ***Artemisia*** 4·0%, ***Juniperus*** 13·9%, ***Chenopodiaceae*** 1·3%). ***Empetrum nigrum*** s. l., ***Helianthemum***, ***Selaginella selaginoides***, ***Saxifraga*** t. ***oppositifolia*** and ***S.*** t. ***nivalis*** occur less frequently.

The upper boundary, which can be defined only on the basis of diagram J. Żar/78 is placed where the *Juniperus* curve rises. This zone may be identified with the Younger Dryas.

Juniperus-Pinus-Betula pollen assemblage zone (2)

Diagrams Żar/76, J. Żar/78. P. Darż/78.

This zone contains a *Juniperus* pollen maximum which in these profiles reaches 6·6%, 24·1% and 20·1% AP+NAP respectively. These maxima are accompanied by fairly high percentage values of NAP, ***Salix*** and ***Artemisia*** pollen. The upper boundary is placed where the ***Juniperus*** pollen value falls along with that of NAP, and where the ***Betula*** and ***Pinus*** pollen curves rise abruptly. This boundary has been dated in diagram Żar/76 at 10 130 ±120 BP and in diagram P. Darż/78 at 9840 ±115 BP.

Pinus-Betula pollen assemblage zone (3)

Diagrams Żar/76, J. Żar/78, P. Darż/78.

This zone is represented by high pollen values of ***Pinus*** and ***Betula***, and fairly high values of heliophytes such as ***Populus***, ***Salix***, ***Betula nana*** and ***Artemisia***. The upper boundary is placed at the point where *Corylus* pollen exceeds 1%. This boundary is synchronous in diagrams Żar/76 and P. Darż/78 and falls at around 9100 BP.

Three subzones can be distinguished in the diagram from the Lake Żarnowiec peat-bog. Traces of these subzones are also present in diagram J. Żar/78.

Pinus-Betula-Filipendula pollen assemblage subzone (3a)

The *Pinus* pollen curve rises, the *Betula* curve also rises though to a much lesser extent; NAP falls. Among the herbs, ***Filipendula*** is of great importance. The upper boundary is placed where the percentage of ***Pinus*** pollen decreases and that of ***Betula*** increases.

Betula-Empetrum pollen assemblage subzone (3b)

The frequency of ***Betula*** pollen is high; that of ***Pinus*** is lower compared with subzone 3a. Herb pollen increases somewhat, and ***Empetrum*** reaches its maximum frequency of 15·7%. The upper boundary is where the ***Pinus*** pollen value increases and the ***Betula*** pollen value falls.

Pinus pollen assemblage subzone (3c)

The *Pinus* pollen value shows a tendency to rise, *Betula*, to fall. An exception to this is the sample from 360 cm in which the *Pinus* pollen value again falls. A high frequency of *Ericaceae* is characteristic of this subzone.

Corylus-Pinus pollen assemblage zone (4)

Diagrams Żar/76, P. Darż/78, partially J. Żar/78.

The *Corylus* pollen value increases to reach its first postglacial maximum. This is accompanied by a high frequency of *Pinus* pollen (mean 80·9%, 57·7% AP), increasing *Ulmus* and the presence of *Quercus*. Low herb pollen values appear in all diagrams. In the upper part of the zone the percentage of *Alnus* pollen increases, thus the zone can be subdivided into *Corylus* (4a) and *Corylus-Alnus* (4b) assemblage subzones. The upper boundary is at the decrease of *Corylus* pollen values.

Dating: Żar/76: c. 9100-8340 BP; P. Darż/78: c. 9100-7740 BP.

Tilia-Ulmus-Pinus pollen assemblage zone (5)

Diagrams Żar/76, P. Darż/78.

Pollen values of *Tilia*, *Quercus* and *Fraxinus* increase while those of *Pinus* decrease. The upper boundary is at the point where *Quercus* and *Corylus* pollen values rise sharply.

Dating: Żar/76: c. 8340-5580 BP; P. Darż/78: 7740-4700 BP.

Quercus-Corylus pollen assemblage zone (6)

Diagrams Żar/76, J. Żar/78, P. Darż/78.

This zone is distinguished in all diagrams by maximum percentage pollen values of *Quercus* (max. 14·2%, 23·5%, 43·3% AP) and a second *Corylus* maximum. *Pinus* values (mean 48·3%, 12·5%, 14·9% AP) are low, but *Ulmus*, *Tilia* and *Fraxinus* pollen values remain high. The upper boundary is placed where *Quercus* and *Corylus* pollen values fall and *Carpinus* values rise.

Dating: Żar/76: c. 5580-2740 BP; P. Darż/78: c. 4700-2840 BP.

Quercus-Carpinus pollen assemblage zone (7)

Diagrams Żar/76, P. Darż/78.

In this zone, *Carpinus* reaches high pollen values (Żar/76: mean 2·6% AP; P. Darż/78: mean 11·1%, max. 25·2% AP). Characteristic of this zone are also the fairly high frequencies of *Quercus* (Żar/76: mean 7·3% AP; P. Darż/78: mean 13·9% AP). The frequency of *Corylus* is low, while that of *Ulmus*, *Tilia* and *Fraxinus* dwindles to practically zero. However, *Betula* and *Pinus* pollen values show a distinct increase. The upper boundary, delimited only in diagram P. Darż/78 as parts of the material were missing from the remaining profiles, is where *Carpinus* decreases rapidly and *Fagus* pollen values rise.

Dating: Żar/76: c. 2740 BP.—?; P. Darż/78: c. 2840-1200 BP.

Pinus-Fagus-Juniperus pollen assemblage zone (8)

Diagram P. Darż/78.

This zone can be distinguished only in diagram P. Darż/78. *Fagus* reaches its maximum frequency (mean 3·1% AP, max. 5·4% AP), *Pinus* shows a rapid increase (visible in part B of the diagram) and *Juniperus* appears (mean 1·7 %). There is a simultaneous reduction in pollen from edaphically more demanding broad-leaved trees such as hornbeam. Pollen from culture indicators reaches culminating values.

Dating: P. Darż/78: 1200 BP—?

Changes in the vegetation of the Lake Żarnowiec area as an interpretation of the pollen assemblage zones

Pinus-Juniperus-herbs. pollen assemblage zone (1)

This zone is characterized by considerable differences in pollen frequencies of the same taxa occurring in both diagrams from the peat-bog near Lake Żarnowiec (locality 1). A noteworthy feature of diagram Żar/75 is the occurrence of large quantities of rebedded sporomorphs (up to 46 % of the total AP +NAP.) Such great contamination could affect the true picture, as it is possible that some of the pollen washed in from older sediments was not eliminated. To a certain extent this elimination was possible because of the different colouration and appearance of the redeposited material. In the analogous section of profile Żar/76 rebedded sporomorphs appear only occasionally. Herb communities were dominant in the Lake Żarnowiec area; shrubs and dwarf shrubs such as *Juniperus*, *Salix* and *Betula nana* were also present.

In the pollen diagrams high pollen values are reached by heliophilous herbs such as *Artemisia*, *Chenopodiaceae*, *Selaginella selaginoides*. Other characteristic Dryas flora species (Iversen 1954, 1973) occur but sporadically: *Arctostaphylos alpina*, *Dryas octopetala* (macrofossils), *Helianthemum* sp., *Saxifraga* t. *nivalis*, *S.* t. *oppositifolia*; also *Sanguisorba minor*, *S. officinalis*, *Botrychium*, *Carex* t. *aquatilis*, *Potamogeton filiformis*, *Ephedra* cf. *distachya* and *E.* t. *fragilis*, which are usually found in Late Glacial sediments. The presence of these species is an indication of the importance of tundra communities in the Lake Żarnowiec channel. However, in drier habitats, perhaps on the slopes and tops of the hills, steppe-like communities flourished. In the diagrams, pine has rather higher pollen values than birch, though its low percentage values indicate the lesser importance of *Pinus* in plant communities. Fragments of *Pinus* bark found in the bottom part of profile Żar/76 are proof of its presence in situ. Morphology of a large part of the *Betula* pollen and macrofossil remains of *Betula* sect. *albae* are the evidence that the birch trees occurred in this area. Such remains are, however, far less frequent than those of *Betula nana*.

Typha latifolia pollen grains found in two samples from profile J. Żar/78 are worth noting. The pollen and fruit of *T. latifolia*, an indicator plant for the warmer periods of the Late Glacial (Iversen 1954), was found in Younger Dryas sediments from Lake Mikołajskie by Ralska-Jasiewiczowa (1966). This author explains the presence of this species (after Wasylikowa 1964) as the delayed reaction of aquatic plants towards a deteriorating climate. The high frequency of *Urtica* and *Filipendula* pollen in the Younger Dryas sediments of Lake Żarnowiec may be the result of the raising of the water level in the lake due to melting of the dead ice. The occurrence of both these plants was not restricted by thermal factors during the Younger Dryas; as the water level rose, new habitats for *Filipendula ulmaria* came into existence around the shores of the lake. The large quantities of *Urtica* pollen, as also the presence of *Epilobium* (often of the *Chamaenerion angustifolium* type-Casparie & v. Zeist 1960, after Ralska-Jasiewiczowa 1968) are thought to be the result of accelerated decay processes.

The lower NAP value in this part of diagram J. Żar/78 as compared with analogous zones of profiles Żar/75 and Żar/76 are the consequence of the characteristic difference arising between the spectra of lake and bog sediments; evidence for this may be found in studies of present-day pollen sedimentation (Aario 1940; Aletsee 1957 after Prentice 1978; Vuorela 1973). This difference is further emphasized by the large area of the lake (cf. Davis 1967; Pennington 1973). The vegetation of this zone distinguished in all the diagrams, can be interpreted as park-tundra such as has been described in other areas of northern Europe from the Younger Dryas (e. g. Berglund 1966; Iversen 1954, 1973; Ralska-Jasiewiczowa 1966; Wasylikowa 1964; Tobolski 1972).

Because of the presence of tundra species, the diagrams from the Lake Żarnowiec area may be related to those of north and north-west Europe (Berglund 1966; Iversen 1954, 1973; Robertsson 1969; van der Hammen 1952). The high values of *Juniperus* pollen accompanied by *Empetrum* (macroscopic remains in Żar/75) suggest a climate rather more maritime than that of central (Wasylikowa 1964) and north-eastern Poland (Ralska-Jasiewiczowa 1966).

Juniperus-Pinus-Betula pollen assemblage zone (2)

As the climate became warmer, the range of *Pinus* and *Betula* extended. The maximum pollen frequency of *Juniperus* indicates that juniper thickets were widespread. This is typical of areas immediately adjacent to the polar limit of the forest (van der Hammen 1952). The thickness of layer which belongs to this zone in the J. Żar/78 profile, greater than in the other diagrams, and the gradual decrease of *Juniperus* are certainly linked to the high sedimentation rate. The picture presented by the diagrams of this zone is characteristic for the Younger Dryas/Preboreal transition in north-western Europe where the effect of the maritime climate was marked (Berglund 1966; Digerfeldt 1972, 1977; Robertsson 1969) — according to Iversen (1954) this zone is often treated separately in vegetational history. The interpretation of this short phase in the postglacial forest successions and the role of *Juniperus* as indicator have been discussed extensively (i. a. Berglund 1966; van der Hammen 1952; Iversen 1954, 1973; Digerfeldt 1972; Vasari 1966; Robertsson 1969).

Pinus-Betula pollen assemblage zone (3)

This zone is not well represented in the P. Darż/78 and J. Żar/78 diagrams. In the diagrams of the bottom sediments of Lake Żarnowiec, the centre section of this zone (3b) is missing, while in the Darżlubie Forest profile it is much contracted as a result of the low sedimentation rate (Fig. 7B). A feature common to all the diagrams is the increasing dominance of *Pinus*, indicating the spread of pine forests, and also the large quantities of pollen from heliophytes. Among these, pollen from plants characteristic of the Late Glacial such as *Ephedra* cf. *distachya*, *Saxifraga* t. *nivalis*, *S.* t. *stellaris*, *Botrychium* etc. was occasionally found. This shows that habitats suitable for heliophytes managed to survive.

The diagram from the peat-bog near Lake Żarnowiec (Żar/76) provides more detailed information. Three pollen subzones were distinguished in this diagram:

Pinus-Betula-Filipendula pollen assemblage subzone (3a)

The increase of *Pinus* and *Betula* pollen values and the distinct decrease of NAP indicate that the climate, which had begun to improve in the *Juniperus-Pinus-Betula* PAZ, was continuing to get warmer. The relatively high amounts of *Filipendula* pollen (mean 3·7%, max. 4·0%) are also evidence of a climatic improvement. It was most probably at this time that *Pinus-Betula* forests began to spread over the study area.

Betula-Empetrum pollen assemblage subzone (3b)

Pinus decreases by around 20% while *Betula* increases by about the same amount. Simultaneously, *Empetrum nigrum* s. l. appears with a high frequency (max. 15·7%). This picture is typical for cool periods over areas affected by a maritime climate and occurs especially frequently in diagrams from the Younger Dryas in north-west Europe. It is linked on the one hand with the changes to a cooler climate, and on the other with the edaphic conditions obtaining towards the end of the Late Glacial, that is to say, with the start of soil leaching (Berglund 1966).

Behre (1967) has described analogous situation in diagrams from north-west Germany and suggests a climatic interpretation (deterioration) for these phenomena. Apart from the decrease of *Pinus* and the spread of *Betula* and *Empetrum* pollen, the disappearance of *Filipendula* pollen from the lower boundary of the subzone also indicates a deterioration of the climate in the Lake Żarnowiec area in the period represented by the *Betula-Empetrum* PASZ. Such an interpretation is supported by the discovery of a similar situation in the diagram from Orle, a locality some 15 km south of Lake Żarnowiec (Latałowa — unpubl.). In this diagram, the middle part of the Preboreal period shows a marked decrease in *Pinus* pollen of 30% and an increase of *Betula* pollen of 35%. These changes are accompanied by small quantities of *Juniperus*, *Empetrum* (0·3%) and *Artemisia* pollen; the decrease in *Filipendula* is quite distinct here. It thus seems that the forest communities at that time were becoming more open, *Betula* being dominant. *Empetrum* heath spread into suitable areas, especially those with a prevailing maritime climate.

Pinus pollen assemblage subzone (3c)

The increase of *Pinus* pollen and the gradual decrease of *Betula* pollen show that the climate again became warmer during this subzone. The regular appearance of *Ulmus* pollen is evidence for the initial spread of this tree. The nature of the heaths also changed, *Ericaceae* (*Calluna*) replacing *Empetrum*.

These three subzones and zone 2 are approximately equivalent to the Preboreal period and probably correspond to the climatic oscillations which took place at this period in north-west Europe (Behre 1967, 1978). According to the nomenclature proposed by Behre (1978), zone 2 and subzone 3a reflecting a climatic improvement are equivalent to the Friesland Oscillation, subzone 3b to the Youngest Dryas and 3c to the late Preboreal period. This is illustrated by the chronological table below:

K. E. Behre (1978)	Lake Żarnowiec area
Friesland oscillation 10 200-10 000 BP	*Junipers-Pinus-Betula* PAZ (2)>10 130 BP *Pinus-Betula-Filipendula* PASZ (3a) c.10 130-c.9800 BP
Youngest Dryas 10 000-9600 BP	*Betula-Empetrum* PASZ (3b) c.9800-9560 BP
Late Preboreal 9600-9000 BP	*Pinus* PASZ (3c) c.9560-9100 BP

Corylus-Pinus assemblage zone (4)

The most significant feature of this zone is the spread and first postglacial maximum of *Corylus*. The spread of *Corylus* as one of the succession stages in Holocene forest history is linked mainly to the fact that, as regards light requirements, it is a species competing with *Betula* and *Pinus* (Iversen 1960, 1973). A first *Corylus* pollen maximum during the Boreal period is wide spread phenomenon, although the percentage values depend on habitat conditions (Berglund 1966; Ralska-Jasiewiczowa 1966). In the Lake Żarnowiec channel profiles, these values are very low (Żar/76: max. 11% AP, J. Żar/78: max. 10·7% AP) and are typical of poor soils and cool habitats. Low *Corylus* values may be probably explained by the fact that the soils of the moraine upland surrounding the lake were intensively outwashed as a result of the steepness of the channel slopes; moreover, the microclimate of the channel, open to the north, was in all probability worse than that of the upland. Thus *Corylus* probably occupied only small areas, perhaps habitats at the foot of hills and in depressions in the channel slopes which were enriched with calcium carbonate leached from the upper parts of the slopes. *Ulmus* communities developed in similar, though more humid spots. The shores of the lake were a perfect habitat for *Alnus*, which began to spread during subzone 4b.

Diagram P. Darż/78 demonstrates that, in the Darżlubie Forest, conditions for the spread of forest communities differed. The relatively low values of *Pinus* pollen (mean 61·7% AP), in contrast with the high values of *Betula* pollen (mean 26·7% AP; max. 42% AP), and also the presence of *Populus* and a high percentage values of herbs indicate that in the first period of hazel expansion, lasting for some 100 years, open pine forests with birch and aspen were dominant. As *Ulmus* and *Quercus* pollen values increased, so did hazel, and the ligth-demanding trees mentioned earlier lost their significance. The *Corylus* pollen percentage, higher than in the diagrams from the Lake Żarnowiec channel, is on average 14% AP, and reaches a maximum of 27·9% in the second half of the zone, which is within the limits for spectra from outwash plains (Ralska-Jasiewiczowa 1966).

Tilia-Ulmus-Pinus pollen assemblage zone (5)

A characteristic feature of this zone is that broad-leaved species gradually replaced pine in more fertile habitats. Lime was quite distinctly dominant here and both *Tilia platyphyllos* and *T. cordata* pollen have been identified in all diagrams. During this zone, mixed woodland of lime and elm appeared in damp, fertile habitats, lime-oak forests in poorer habitats (Iversen 1960, 1973; Berglund 1966; Ralska-Jasiewiczowa 1966). *Alnus* communities continued to spread. The increasing importance of ash suggests that during this time, alluvial forests with elm and ash could have appeared in river valleys and at the foot of the upland surrounding the lake.

In this zone, *Hedera* and *Viscum* pollen appear in single finds, while *Picea* and *Carpinus* pollen are found regularly though with low frequencies. The continuous presence of *Calluna* pollen and *Pteridium* spores indicate the existence of habitats not occupied by deciduous woodland. Like *Corylus*, these plants probably grew along the forest edges, and could also have occurred in the undergrowth of more open pine forests and *Pinus-Quercus* communities.

The first signs of human activity appear in this zone; the progressive acidification of the soil is demonstrated by the presence of *Rumex acetosella* pollen.

Quercus-Corylus pollen assemblage zone (6)

The picture presented by all the diagrams in this zone is one of abundant growth of mixed deciduous forests. *Quercus* was absolutely dominant and had replaced *Pinus* even on the poor, sandy soils of the outwash plains. The pollen values of *Pinus* in the diagrams from the Darżlubie Forest and Lake Żarnowiec are 14·9% AP and 12·5% AP respectively, and point to the minimal significance of this species. *Pinus* shows a much higher frequency in the Żar/76 diagram, and this is probably linked to the selective decomposition of sporomorphs, mainly to the disadvantage of *Quercus*. In this case the influx diagram (Fig. 15) seems to give a more correct picture. Besides the undoubtedly dominant acidophilous, broad-leaved forests in this area, it is highly likely that mesophilous communities appeared; they could have occurred around the upland edges, now covered with patches of *Melico-Fagetum* (Dąbrowski 1978), or on outcrops of till in the Piaśnica outwash plain. Proof of this is the presence of *Mercurialis perennis* in all diagrams. This species is at present to be found i. a. in mesophilous beechwoods, and also occurs in other types of deciduous forest on fertile soils, especially in northern Europe (Danielsen 1970). Rich, mixed oakwoods containing also lime, elm and ash probably occupied the habitats at the foot of the upland slopes. *Carpinus* pollen appears with increasing regularity, although its significance in the study area is as yet minimal. Single finds of *Fagus* pollen show that this species was not present in the immediate neighbourhood of the localities.

The aboundant development of alder communities is characteristic for the first half of the Subboreal period (Firbas 1949, after Ralska-Jasiewiczowa 1966). The high percentage of *Alnus* pollen, especially from the Lake Żarnowiec profile could have resulted from a rise in the water level of the lake caused by the Littorina transgression phase, the effects of which are visible in the study area.

Myrica gale pollen appears as a curve in the Żar/76 diagram but only as single finds in the remaining profiles.

Human interference in the plant communities is manifested primarily by the decrease of *Ulmus* curve and the increase of *Corylus* pollen, and also by the increasing pollen frequency of culture indicators such as cereals.

Quercus-Carpinus pollen assemblage zone (7)

Important vegetational transformations took place during this zone. The decrease of *Quercus* and the almost complete disappearance of *Ulmus*, *Tilia* and *Fraxinus* pollen suggest a reduction in the area covered by mesophilous oakwoods and alluvial forests. The pollen values of all the trees and herbs clearly demonstrate the intensity of human interference; among the herbs, species indicative of human activities are of particular importance.

Deforestation is also indicated by increases in *Pinus* and *Betula* pollen values, especially distinct in the Darżlubie Forest diagram. During the time corresponding to the formation of this pollen zone, oak-hornbeam forests began to appear. Judging by the present distribution of forest habitats (Dąbrowski 1978, and oral information) and the soil and moisture conditions within the localities studied, it is probable that in the vicinity of Lake Żarnowiec oak-hornbeam communities grew only in the damp habitats at the foot of the upland; as the diagram shows, these communities were of limited importance. Quite different relationships obtained on the Piaśnica outwash plain. High frequencies of *Carpinus* pollen indicate the importance of hornbeam forests in this area. It is also probable that, unlike the Żarnowiec area, the dominant communities were hornbeam forests growing in fresh, warmer habitats. At present, they occur on the Piaśnica outwash plain in very small patches (**Dąbrowski** 1978), similarly as on the outwash plains in the Kashubian Lake District (M. **Herbich** & J. **Herbich**, 1982).

Pinus-Fagus-Juniperus pollen assemblage zone (8)

The features of this zone are characteristic of the most recent vegetational history, associated with a man-made landscape. Climatic changes, natural soil leaching (glacial-postglacial cycles, **Iversen** 1958), and also man's activities have impoverished the forest vegetation; species tolerating soil acidification such as pine, beech and oak have become dominant. At the same time, the spread of tillage has diminished the area of forests.

In the Darżlubie Forest diagram, the period of expansion of beech is distinctly marked, although its maximum pollen values indicate that it was relatively insignificant in the vicinity of the study area. This might be expected from the edaphic conditions existing here: unconsolidated sandy soils are dominant and support mainly pine and pine-oak forests.

At this time beech was dominant on the boulder clays of the moraine upland. As the upper sections of both diagrams from the Lake Żarnowiec channel are missing, only fragmentary data are available from the profile of the central part of Lake Żarnowiec (**Latałowa** 1977). The highest pollen percentage of *Fagus* in the spectra from this profiles was 4·6% AP +NAP. The most recent history of *Fagus* is provided by written data indicating the significant numbers of this tree in forest communities during the Middle Ages (**Dąbrowski** 1970, and literature contained therein).

Local and regional features of the diagrams from the Lake Żarnowiec area

A number of interesting problems dealing with the vegetational history of this area and their regional and local application emerge from a comparison of selected aspects of the palynological material set out here (Figs. 8 and 9). It must be emphasized once again that the diagrams presented in this study are of varying value for a number of reasons: the profile of the Lake Żarnowiec bottom sediments cannot be radiocarbon-dated, and some sections of this profile are missing; there was also considerable damage to and probably selective decomposition of sporomorphs from the peat-bog near Lake Żarnowiec. The variability of materials from the point of view of the size of the area represented in the diagrams and the conditions under which pollen sedimentation took place within the different localities are also of significance.

The following may be regarded as the most important regional features:

1. High frequencies of *Juniperus* pollen in all diagrams from the Lake Żarnowiec area in the *Juniperus-Pinus-Betula* PAZ. The *Juniperus* pollen curve

in some other diagrams from Western Pomerania is similar (Latałowa unpubl.; Drozdowski & Berglung 1974; Tobolski 1972).

2. It is probable that the cool climatic oscillation of the Preboreal (Youngest Dryas according to Behre, 1978) described here may have taken place over the whole region. Evidence for this may be the fact that similar conclusions can be drawn from sediments taken at Orle (Latałowa unpubl.).

3. It is generally accepted that the Quercetum mixtum maximum, connected with the rapid rise in the *Quercus* pollen curve, and the second postglacial *Corylus* maximum are synchronous in Pomerania, falling within the second half of the Atlantic period (Czubiński 1950). This criterion has hitherto been used as a basis for zonation of pollen diagrams from this region. In the light of the results obtained by the author, particularly the radiocarbon dates, this criterion should be revised.

The maximum frequency of broad-leaved trees, among which is a high percentage value of *Quercus* pollen, a low percentage value of *Pinus* pollen and also a low *Pinus* pollen influx, suggest the absolute domination of deciduous forests from c. 5600 (4700) BP to c. 2800 BP (*Quercus-Corylus* assemblage zone). This corresponds to the first part of the Subboreal period in the Blytt-Sernander system. Other diagrams from Western Pomerania also give low *Pinus* pollen percentages indicating that pine was uncommon in forest communities during that period (Tobolski 1975a; Zachowicz 1972). This picture is distinctly different from the one presented by the majority of diagrams from other parts of lowland Poland where the pollen percentage of *Pinus* remained high throughout the Holocene.

4. Another regional feature is the high pollen frequency of *Carpinus*, suggesting that predominantly hornbeam forests were common from c. 2800 BP to 1200 BP (*Quercus-Carpinus* PAZ). This is confirmed by material from adjacent areas where *Carpinus* pollen values reach similar values: 31·5% in the Bielawskie Błoto marsh (Ołtuszewski & Borówko 1954), 35·5% on the Staniszewska Upland (Szafrański 1961), 16% in the Czarne Bagno swamp (Ołtuszewski 1948) and around 15% of AP +NAP in Lake Druzno (Zachowicz 1976).

5. The late spread of *Fagus* over the study area during the early Middle Ages was undoubtedly of a regional nature.

The above-mentioned regional features to a greater or lesser extent underline the significance of the moist, maritime climate which at different periods has affected the vegetation. This is most readily apparent from the Late Glacial parts of the diagrams and the start of the Holocene; and later in pollen zones 6 and 7, which reflect the absolute domination of deciduous forests. The greater pollen frequency of *Hedera* than of *Viscum*, and the presence of *Lonicera periclymenum* pollen also point to the influence of a maritime climate (Iversen 1944).

The local features of the diagrams are related mainly to the numerical pollen representation of particular tree species and depend primarily on the habitat conditions obtaining in the nearest vicinity of the localities studied.

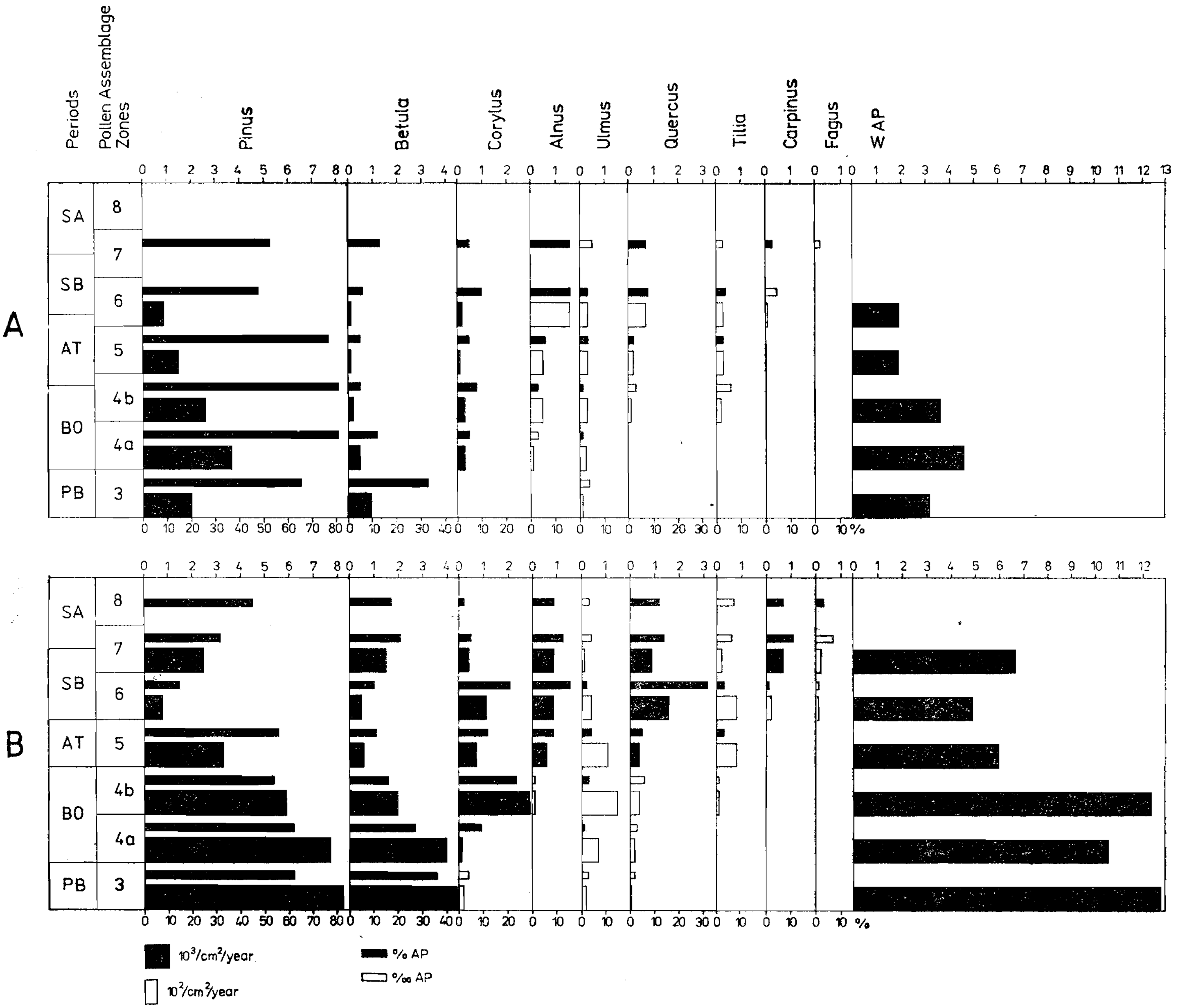

Fig. 8. Mean percentage pollen values and pollen influx in selected pollen assemblage zones. A — peat-bog near Lake Żarnowiec (Żar/76); B — peat-bog in Darżlubie Forest (P. Darż/78)

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The most important local features are probably: the high pollen frequency of *Alnus* in Lake Żarnowiec bottom sediments during the Subboreal period, the reason for this undoubtedly being the rise of the water table during the Littorina transgression; and, the overrepresentation of *Pinus* pollen in profile Żar/75. The metachronous boundaries of the *Tilia-Ulmus-Pinus* PAZ in diagrams Żar/76 and P. Darż/78 (Fig. 9) and the very low pollen frequency of *Carpinus* in the *Quercus-Carpinus* PAZ in the diagram from the Lake Żarnowiec peat-bog can be regarded as further local features. These differences may have been caused by the worse edaphic and microclimate conditions in the Lake Żarnowiec channel than on the upland. They may have restricted the occurrence of mesophilous species of trees such as *Ulmus*, *Tilia* and *Carpinus* in the immediate neighbourhood of the lake. Early human settlement in this area also negatively affected the growth of these trees. For other possible explanation see p. 216.

An especially local feature of the Darżlubie Forest diagram is the high pollen frequency and variety of herbs; this is derived from peat-bog vegetation and also from species growing in and around the edge of the nearby forest.

The comparison in Fig. 8 illustrates the much-discussed differences between the accumulation of pollen in large and small basins. The pollen influx in the Darżlubie Forest peat-bog was on average three times as great as that in the Lake Żarnowiec peat-bog, and this proportion remained practically constant during the various zones. The pollen influx of *Pinus* is about twice as great at the former locality as at the latter. This pollen was probably long-transported, hence the over-representation in the diagram from the Lake Żarnowiec bog. The greatest differences were observed in the pollen influx of *Quercus* in the material from both these bogs. It is about ten times lower in profile Żar/76. The extremely low pollen influx of *Quercus* is probably due to the selective decomposition of sporomorphs. Throughout nearly the whole profile, the material is badly preserved. Both types of pollen grain corrosion, as described by Havinga (1967), were observed. However, the more frequent type of pollen corrosion was the gradual thinning of the exine which *Quercus* pollen is particularly sensitive to. This is surely linked with the large fluctuations in water level in the reed-swamp communities which formed the peat deposits in this locality throughout almost the whole of the Holocene. The frequent fires on the bogs could also have been important; evidence for this is the regular occurrence of charred remains in the sediment.

There are no such disproportions in the diagrams as regards *Ulmus* and *Tilia* pollen which are more resistant to corrosion, despite the fact that these trees are as a rule less well-represented in the spectra than *Quercus* (Andersen 1970). Confirmation of selective corrosion are the diagrams showing the percentage and concentration of sporomorphs from the bottom sediments of Lake Żarnowiec, the diagrams of which should be similar to those from peat-bog (Żar/76), as they are both derived from the same basin. In the *Quercus-Corylus* PAZ of this profile there is a high frequency of broad-leaved trees, including *Quercus*, with a minimal frequency of *Pinus*.

The total pollen influx value during various zones is related to the presence of abundant pollen-producers like *Betula*, *Corylus* and especially *Pinus*. Hence the highest pollen influx occurred during the *Corylus-Pinus* PAZ.

Correlation of climatic-vegetational periods and pollen assemblage zones

The correlation of the pollen assemblage zones with the Blytt-Sernander's periods, and the relations between the diagrams from the three localities discussed here are presented in Fig. 9. This shows that most of the vegetational changes took place in synchronous stages. Most significant metachroneity is connected with the boundaries of the *Tilia-Ulmus-Pinus* PAZ. As discussed in the previous chapter, this fact may be linked to habitat differences in the vicinity of the localities. However, a more likely reason is the fact that precise dating of this part of the Darżlubie Forest profile was impossible. The sedimen-

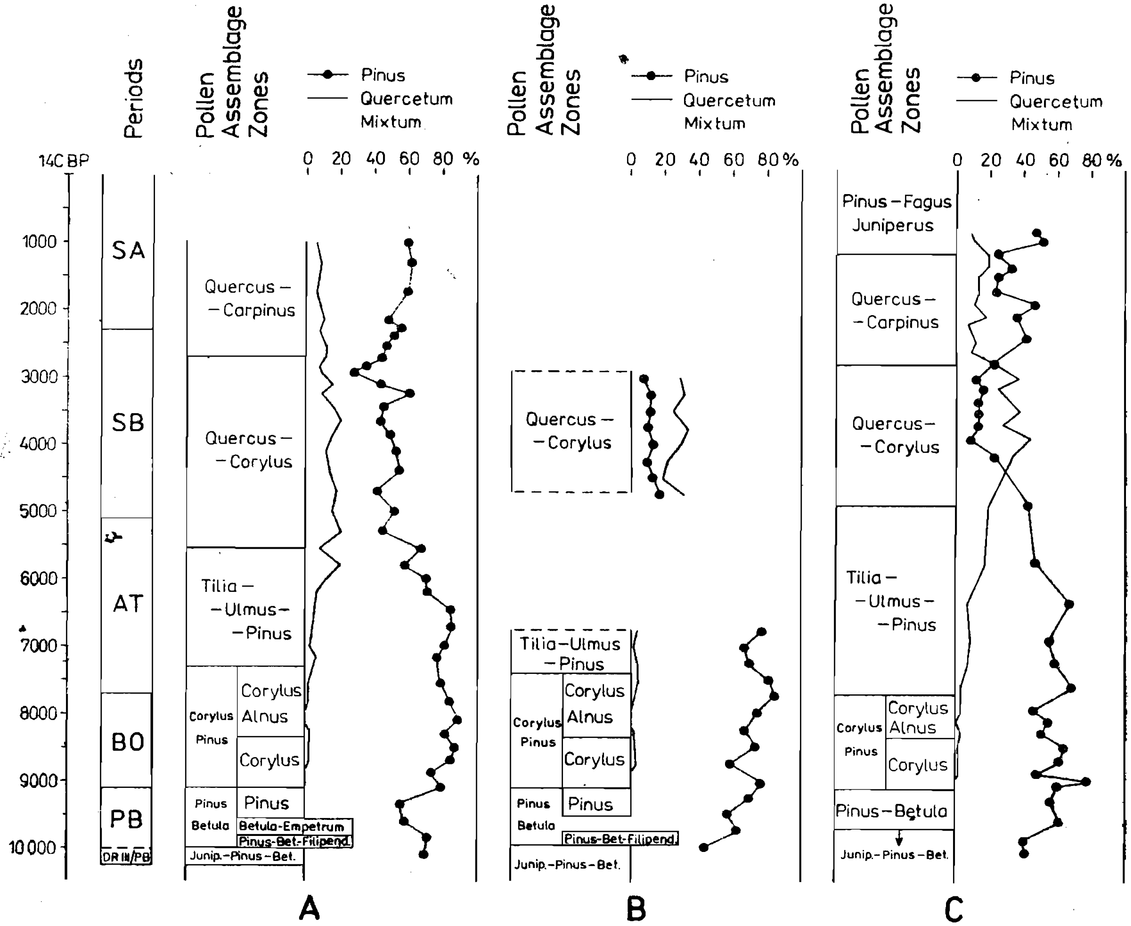

Fig. 9. Correlation of pollen assemblage zones with Blytt-Sernander periods. A — peat-bog near Lake Żarnowiec; B — Lake Żarnowiec (bottom sediments); C — peat-bog in Darżlubie Forest

tation rate (Fig. 7) shows that the tme span between samples from the boundary areas of PAZ 6 and 7 is around 400 years. Assuming that the boundaries between these zones are relatively synchronous, an attempt was made to correlate the boundaries of the Blytt-Sernander climatic-vegetational periods with the main changes in the pollen diagrams from the Lake Żarnowiec area.

SA
First slight rise in *Fagus* curve

SB
Quercus and *Corylus* curves rise

AT
Tilia starts to spread

BO
Corylus starts to spread; *Ulmus* curve rises

PB
Pinus curve rises rapidly; *Juniperus* falls

DR-3/PB
Percentage pollen values of *Pinus* rise; *Juniperus*
DR-3 curve rises sharply

The estimation of the absolute age at which the various tree species spread is helpful when dating fossil material palynologically. Thus the approximate age at which the most important trees spread over the study area is given on the basis of ^{14}C dates from profiles Żar/76 and P. Darż/78. Spreading was assumed to have started when pollen values of trees, whose pollen disperses well, reached 1% (*Corylus*, *Quercus*, *Alnus*), or when pollen curves rose steadily (*Ulmus*, *Tilia*, *Carpinus*, *Fagus*); AP = 100% constituted the basis for calculations: *Ulmus* — c. 9300 BP, *Corylus* — 9100-9000 BP, *Quercus* — c.8200-8000 BP, *Alnus* — c. 8300-8100 BP, *Tilia* — c. 8000-7700 BP, *Carpinus* — 4300-4000 BP, *Fagus* — 2100 BP.

Notes on the application of pollen concentration and influx methods to peat deposits

Data on the concentration and influx of sporomorphs have been obtained hitherto on the basis of the analysis of lake sediments. This method is rarely used for deposits (Hicks 1974, 1975, 1976) because of special problems involved in the interpretation of spectra obtained from peats (especially of low moor deposits) (Berglund 1979; Faegri & Iversen 1975; Rybničkova & Rybniček 1971).

Hicks (1974) emphasizes that sporomorph concentration in peat deposits reflects primarily the properties of and changes in the sediment itself, and only to a much lesser extent actual changes in the surrounding vegetation. The results obtained during this study fully confirm this. The sporomorph concentration diagram from the Darżlubie Forest (Figs. 19 and 19 a) illustrates this best. In this diagram there are sections in which the sporomorph concentration rises as a result of the low sedimentation rate (380-360 cm and 224-201 cm), surface subsidence after land reclamation (20-1 cm), and burning (95 cm). These values are only partially corrected in the influx diagram.

However, the concentration diagrams in this study contain important information necessary for the correct interpretation of the precentage diagrams particularly in sections showing rapid changes. Besides the pollen concentration diagram is useful in selecting samples for ^{14}C-dating (Fig. 19). It helps to delimit by means of dates sections of sediments which had accumulated at more or less the same rate. Significant changes in the sedimentation rate are expressed in the diagrams by changes in pollen concentration.

An instance of the importance of the influx diagrams is also the previously discussed case where the Żar/76 percentage diagram confirmed over-representation of pine pollen. This had been brought about chiefly by selective sporomorph decomposition (mainly oak pollen, Fig. 8).

The examples quoted above show that, though possibilities for using the pollen concentration and influx diagrams from peat deposits are limited, they do supply valuable information which aids the correct interpretation of the past vegetation.

THE IMPACT OF PREHISTORIC MAN ON THE VEGETATION

The development of prehistoric settlement

Our knowledge of the settlement history of the Lake Żarnowiec area is patchy. The Lake Żarnowiec channel has been studied precisely, starting from the Bronze Age (Szułdrzyński & Żurawski 1978), but the surrounding upland has been far less well documented. Only a small part of the archaeological data available concerns Neolithic and Mesolithic cultures. The reason for this is probably the lack of suitable studies (Fig. 10).

Because of its exceptionally favourable position, the Lake Żarnowiec channel had probably been penetrated by Mesolithic peoples. Finds from this period relating to the Maglemose culture come from both inland areas of Pomerania and along the Baltic coast (Szwed 1977). These people were hunters and gatherers. Certain archaeological information available from the vicinity of Lake Żarnowiec refers to the Late Neolithic settlement (Szułdrzyński & Żurawski 1978). During this period, the Funnel Beaker and Rzucewo cultures were of the greatest importance here, the latter developing from the Corded Ware culture (Godłowski & Kozłowski 1979). The Funnel Beaker people showed here a preference for animal husbandry over crop-raising; hunting and fishing were also very important. Settlements were established on ligth soils

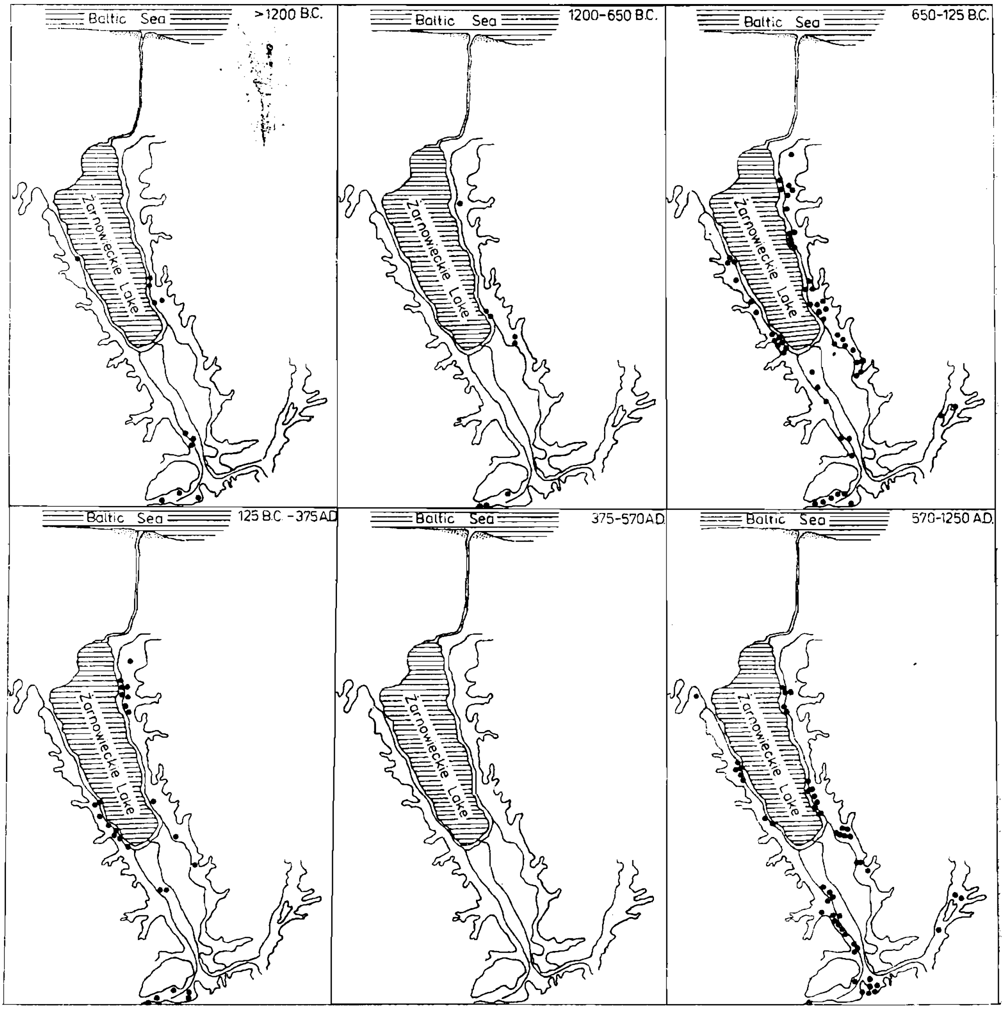

Fig. 10. Settlements in the Lake Żarnowiec area. A — Neolithic and Bronze I and II; B — Bronze III and IV (Lusatian culture); C — Hallstatt and Early and Middle La Tène (Lusatian and East Pomeranian cultures); D — Late La Tène and Roman periods (Oksywie and Wielbark cultures); E — Migration period; F — Early Middle Ages. (Map compiled by Szułdrzyński 1980)

near river valleys. People of the Rzucewo culture were highly specialized in fishing and hunting at sea, seals and porpoises being abundant at this time; agriculture was of secondary concern (Godłowski & Kozłowski 1979; Szwed 1977).

Settlement intensity during the early Bronze Age was not great. The number of archaeological finds increases along with the arrival of people of the Lusatian culture, who in this area retained distinctive features and are thus referred to as the Kashubian group of this culture (Godłowski & Kozłowski 1979; Łuka 1977). This group reached the high point of its development during periods IV and V of the Bronze Age. Settlement was then concentrated on lighter soils where, apart from animal breeding, shifting cultivation predominated. In this part of Pomerania the Lusatian culture reached its zenith in the early Iron Age (Hallstatt C). Settlement continued throughout this period and the consequent intensification of agriculture necessitated the utilization of the more fertile soils of the moraine uplands.

Further colonisation in the direction of the Darżlubie Forest took place during the Hallstatt D period, at which time the East Pomeranian culture achieved its culmination (Łuka 1977). The expansion of settlement on to the uplands was the result not only of a rapid increase in population but also of the deteriorating climate at the turn of the Subboreal and Subatlantic periods (Łuka 1977).

The number of East Pomeranian settlements declined considerably during the early and middle La Tène periods. This may be explained by the migration of part of the population to Wielkopolska (*Great Poland*) and the loosening of ties with Baltic tribes (Łuka 1977).

Furthermore, there are no sings of more intensive colonization during the period of domination by the Oksywie culture (late La Tène) or the Wielbark culture (period of Roman influence).

Colonization of Pomerania became much less intensive in the second half of the 5th century AD and especially during the 6th century. The great population migrations at this time were responsible for the decline here as in other parts of Europe (Migration period).

The next intensive settlement phase started in the early Middle Ages (c. 9th century). Four castles on the slopes surrounding the Lake Żarnowiec channel are from this period (material obtained from the Institute for the Conservation of Monuments, Gdańsk). Since that time, this area has been continuously utilized by man (Dąbrowski 1970).

Traces of settlement in the pollen diagrams

By comparing the percentage values of culture indicators with respect to time (Berglund 1969), seven periods of more intense agriculture (settlement phases) can be distinguished (Fig. 11). However, a graph like this contains only quantitative information. It says nothing about qualitative changes such as the highly significant relationship between the percentages of plants indicating various types of land use. Therefore, when deciding where the boundaries between settlement phases should run, use was made of the detailed information in the percentage diagram (Figs. 13 and 18). The plants taken to be culture indicators were identified with varying degrees of precision (i. e. species, genera, families, types). They may be found in both natural and anthropogenic communities, so the implications of their presence are not always unequivocal. They include:

— well-represented: *Artemisia*, *Calluna*, t.*Cannabis*/*Humulus*, *Centaurea cyanus*, *Cerealia*, *Chenopodiaceae*, *Juniperus*, *Melampyrum*, *Papilionaceae*, *Plantago lanceolata*, *P.* t. *maior*/*media*, *Polygonum*, *Pteridium*, *Rumex* t. *acetosa*/*acetosella*;

— singly represented: *Agrostemma*, *Centaurea jacea*, *Convolvulus arvensis*, *Fagopyrum*, *Linum usitatissimum*, *Papaver*, *Scleranthus*, *Spergula* cf. *arvensis*, *Stellaria media*.

The author presented a tentative outline of the settlement phases in an earlier article (Latałowa, in print). However, the lack of radiocarbon dates at

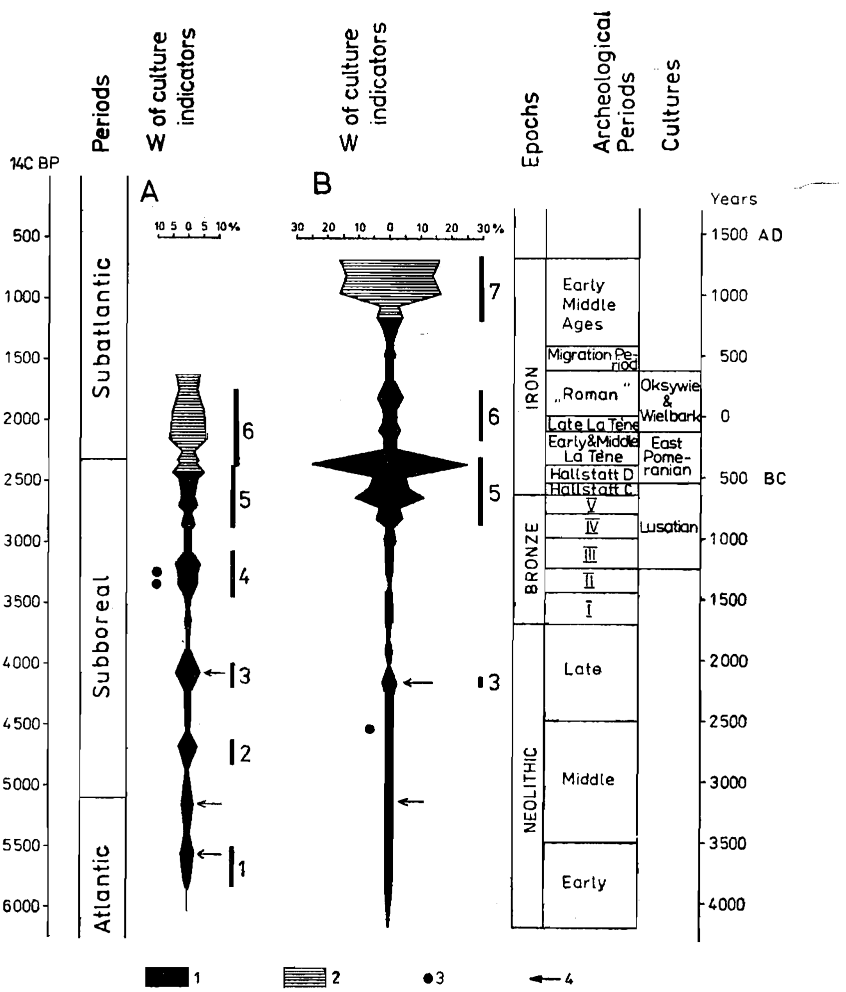

Fig. 11. Comparison of settlement phases distinguished in the peat-bog near Lake Żarnowiec (A) and in Darżlubie Forest (B) on the basis of the pollen sum of culture indicators and absolute dating. 1 — age calculations from ^{14}C-dating; 2 — approximate dating; 3 — first pollen grains of *Centaurea cyanus*; 4 — decreases of *Ulmus*. For explanations of settlement phases 1-7, see text

that stage of research seriously limited the possibility of the correlation of settlement phases with archaeological periods.

The chronological table compiled by Kostrzewski (1966) was used to relate these periods to the palynological results obtained here. This correlation is of necessity provisional as the periods embraced by the settlement phases are based on radiocarbon dates and not calendar dates. The differences in cultivation intensity and the qualitative changes brought about by these activities during the various phases are set out in Table 2.

Table 2

Mean percentage pollen values of *Plantago lanceolata, Cerealia* (incl. *Secale*) and *Secale* for settlement phases. + denotes the presence of single pollen grains

Settlement phases		1	2	3	4	5	6	7
Żar/76	*Plantago lanceolata*	+	—	0·6	0·5	0·6	0·9	—
	Cerealia	—	+	0·1	0·2	0·1	0·6	—
	Secale	—	—	—	0·1	—	0·3	—
P. Darż/78	*Plantago lanceolata*	—	—	+	—	0·6	0·4	0·9
	Cerealia	—	—	—	—	0·1	0·2	1·5
	Secale	—	—	—	—	+	0·1	0·9

An interesting feature of both diagrams is the early appearance of *Centaurea cyanus* in the Subboreal period (Fig. 11). The occurrence of this plant during the Holocene is connected mainly with the advanced stage of rye cultivation (Ralska-Jasiewiczowa 1968), although later studies have provided an increasing amount of data about earlier finds (cf. Danielsen 1970). *Centaurea cyanus* fruits have also been found in the Neolithic layer at Biskupin (Klichowska 1972).

The much-discussed, almost synchronous decrease of *Ulmus* pollen at the turn of the Atlantic and Subboreal periods (Iversen 1941, 1949, 1960, 1973; Tauber 1965; Troels-Smith 1960) is difficult to observe in the diagrams here. In the profile from the Lake Żarnowiec peat-bog, the first decline in percentage values of *Ulmus* pollen occurs in samples 205-201 cm together with the first occurrence of *Plantago lanceolata* pollen. On the basis of the sedimentation rate (Fig. 7 A), its age has been fixed at around 5500 BP: this coincides with the first settlement phase. The next fall in the *Ulmus* and *Tilia* curves appears in samples 185-180 cm (c. 5100 BP). The amount of *Rumex* t. *acetosa/acetosella* pollen increases distinctly in the NAP diagram: in the next sample (175 cm) the first pollen grain of *Cerealia* appears, accompanied by *Populus* pollen and a rise in the percentage pollen values of birch (2nd settlement phase). The first depression in the *Ulmus* curve in the Darżlubie Forest diagram is to be found in the sample adjacent to the level dated at 5075 ± 75 BP although the depression itself cannot be precisely dated because of the properties of the sediment. The decrease of elm at c. 4100 BP, synchronous in both diagrams is the third Neolithic settlement phase, which has all the features of "Land occupation" as described by Iversen (1941, 1973).

The evidence for the activities of Neolithic man in this area is supported by archaeological data according to which settlement at this time took place mainly in the Lake Żarnowiec channel, the surrounding upland remaining practically untouched. From the middle Neolithic (phase 2) onwards, grains of cereal pollen appear in diagram Żar/76, suggesting the beginnings of tillage, although animal husbandry was probably still of major importance.

The fourth settlement phase (II/III periods of the Bronze Age) was distinguishable only in diagram Żar/76. At this time pasture indicators (mostly *Plantago lanceolata*) prevailed over cereal pollen. *Secale* pollen appears for the first time in small quantities. High pollen values of *Rumex acetosa* and *R. acetosella* are evidence for the progressive acidification of the soil. Characteristic of this phase are the deep depressions in the pollen curves of all deciduous trees.

The expansion of the Lusatian (Kashubian group) and East Pomeranian cultures (settlement phases 5 and 6 respectively) is reflected in both diagrams. These cultures brought drastic changes in the forest communities, and contributed to the spread of hornbeam which, up to this time, had not been of any great importance. Direct evidence of forest burning is afforded by charred layers in the peat-bog deposits from Darżlubie Forest. The spectrum of one of this layer shows a large quantity of *Melampyrum* (21%) and *Papilionaceae* (9%) pollen (*Lotus*, *Lathyrus* and *Vicia* types); this was accompanied by a distinct though short-lived fall in the pollen values of acidophilus plants such as *Rumex*, *Ericaceae* and *Pteridium* (even though the presence of *Pteridium* is considered to be indicative of burned areas — Iversen 1973; Huttunen & Tolonen 1975). The disappearance of *Pteridium* spores should probably by linked to the fertilisation of the soil after fires.

Judging from the presence of cereal pollen and the rapid changes in the tree pollen curves in the Darżlubie Forest diagram, settlement at this time probably began to spread over the upland surrounding the lake. This is in accordance with the results of archaeological investigations (Łuka 1977). The prevalence of *Plantago lanceolata* pollen in phase 5 and the rise percentage values of *Cerealia* in phase 6 (Table 2) indicate the importance of pastoral farming to the Lusatians; with the arrival of the East Pomeranian culture agriculture began to develop more intensively.

Further effects of agricultural development in this area are evident from the Darżlubie Forest diagram. This intensive human activity (phases 5 and 6) was followed by a distinct regress. Cereal pollen curves disappear entirely, those of other culture indicators fall. The considerable rise in the pollen curves of *Carpinus* and other trees with high habitat requirements like *Tilia* and *Ulmus* is evidence for the regeneration of woodland in areas abandoned by man. An analogous situation occurs in a diagram from the Masurian Lake District (Ralska-Jasiewiczowa 1977). In the Darżlubie Forest profile this regress falls in the period 375-570 AD (Fig. 11), which in diagrams from Northern Europe, is interpreted as one of economic recession in the Migration period (Andersen 1978; Berglund 1969; Iversen 1973).

The last, 7th phase of settlement in the topmost part of the profile belongs undoubtedly to the early Middle Ages. Both its chronological position as well as the features of this part of the diagram point to this: cereal pollen reaches high values (*Secale* is very important), whereas in comparison with *Cerealia*, *Plantago lanceolata* pollen decreases. Acidophilous plants also reach their maximum, with *Rumex acetosella* and plants from sandy habitats e. g. *Scleranthus perennis* predominating. Worthy of mention among the weeds are the pollen curves of *Centaurea cyanus*, single grains of *Convolvulus arvensis*, *Agrostemma githago* and *Polygonum* t. *persicaria*. Apart from cereal pollen, the pollen of other cultivated plants such as *Linum usitatissimum* and *Fagopyrum* was noted in this part of the diagram (the importance of *Fagopyrum* pollen is exhaustively discussed by Mamakowa (1962). A final fall in the percentage pollen values of deciduous trees, and a rise in the pollen curves of pine, beech and heliophilous juniper (part B′ of the diagram) are the other significant features of this part of the diagram. The abundance of sand in the sediment is an indication of the eolian processes intensified as a result of deforestation.

A comparison of the effect of human activities during the various phases of settlement as ascertained on the basis of palynological material with archaeological data (Łuka 1977; Szułdrzyński & Żurawski 1978) gives good agreement. The pollen diagrams also confirm the importance of the Lake Żarnowiec channel as a settlement microregion up to and including the time of the East Pomeranian culture (Łuka 1977); this did not exclude the expansion of settlement on to the Darżlubie Forest from the Hallstatt period onwards. However, human economic activities did not really get started in the Darżlubie Forest until the early Middle Ages. It should be remembered, though, that the topmost parts of the profile are missing in material from this locality. This statement is made on the basis of the analysis of the upper parts of the diagram which shows that the area adjacent to the peat-bog was to a large extent deforested whereas at present it is overgrown with forest habitat (Fig. 5); also, according to information obtained from forestry records (Operaty leśne 1970, 1971), a large part of the currently existing woodland is on land once used for agriculture.

The impact of man on the forest vegetation with particular reference to hornbeam and beech history

During the early stages of settlement in this area, the forest vegetation and the soils, were not much affected by man's activities. Therefore, with decreasing human activities forest communities were able to regain their natural balance. Nevertheless, after each successive settlement phase, there were fewer trees of high edaphic requirements. It was the development of the Lusatian, and later the East Pomeranian cultures which, by intensive cultivation of land and expansion on the more fertile upland soils, brought about profound and irreversible changes in the forest vegetation of this area. By destroying the mixed oak forests, man enabled hornbeam to extend its range; this can be seen quite clearly in the Darżlubie Forest diagram. On the other hand, in the vicinity of Lake Żarnowiec, hornbeam was of little importance; this is obvious from the interrupted pollen curve and the low percentage values of *Carpinus* in profile Żar/76. It may be explained by the restricted area of suitable habitats as a consequence of both natural conditions and the early, intensive activities of man (high percentage pollen values of acidophilous plants). The minimal quantities of hornbeam pollen in the diagram from this locality are probably derived from the surrounding upland. This is corroborrated by the fact that hornbeam pollen occurred in layers in which the pollen values of culture indicators are high and the curves of other trees depressed. This change is associated with the decrease in pollen frequency of broad-leaved trees destroyed by man during land occupation, and with the better conditions for long distance dispersal of pollen after the removal of the woodland "filter" (see Ralska-Jasiewiczowa 1977; Tauber 1965). It is characteristic of layers in which the pollen values of hornbeam increase (beech pollen also increases somewhat) that the pollen curve for pine also rises distinctly, which could be a sign of deforestation.

Over a period of some 1500 years during which woodland approximating to oak-hornbeam forests have developing in the Darżlubie Forest area, the settlements phases are characterized by successive depressions in the hornbeam curve. As has also been observed in diagrams from other areas of Poland (Ralska-Jasiewiczowa 1964, 1966, 1968, 1977), this testifies to the felling and field cultivation of fertile habitats of hornbeam forests.

The short period of partial regeneration of forest communities was probably due to the decline in settlement during the Migration period, and precedes the last of the settlement phases described here. The destruction of oak-hornbeam forests and other deciduous woodlands at the time of the early Middle Ages, facilitated the expansion of beech.

Much has been written about the asynchronous spread of hornbeam and beech in Europe (Firbas 1949; Kubitzki 1961; Ralska-Jasiewiczowa 1977). This phenomenon can be also observed on the territory of Poland. In the west (Orwat 1958; Jasnowski 1962) beech established itself earlier or synchronously with hornbeam; in the Gardno-Łeba lowland (Ołtuszewski 1948) and Lake Gardno (Zachowicz 1972) their establishment was almost synchronous; but around Lake Żarnowiec, on the Bielawskie Błoto marshes (Ołtuszewski & Borówko 1954), the Staniszewska Upland (Szafrański 1961) and by the Vistula Lagoon (Redmann 1938; Zachowicz 1976) beech appeared only after the oak and hornbeam forests had been destroyed. Ralska-Jasiewiczowa (1968, 1977) and Tobolski (1975 a) have described the role of man in the spread of beech in Poland.

The current distribution of pine is also connected with human activities. The culminations of the *Pinus* pollen curve immediately after each deforestation are almost certainly due to the transport of pine pollen from distant areas, and are also evidence for the spread of pine on to degraded oak forests, and in the upper sections of the diagram, on to habitats formerly occupied by hornbeam.

The quantities of pollen of acidophilous plants increase with each succeeding settlement phase, thus demonstrating the progressive podsolisation of the soil. In accordance with the general climatic trends of the final period of the interglacial (Andersen 1961; Iversen 1958; Berglund 1969), this process was helped on by man himself: grazing and primitive forms of land cultivation accelerated the impoverishment of the rich soils of mesophilous deciduous forests and enabled podsolising species such as pine, and to a certain extent also beech, to spread.

DEVELOPMENT OF THE LOCAL VEGETATION

The interpretation of the history of sedimentation basins and their local vegetation is based mainly on macrofossil analysis and is supplemented by data from the pollen diagrams. Additionally, the principal physico-chemical properties of the sediments and diatom analysis of part of profile J. Żar/78 complete the information available. Macrofossil and diatom assemblage zones are distinguished on the basis of identified macroscopic remains and diatoms. As in the case of pollen assemblage zones, these zones are biostratigraphic units having characteristic combinations of fossil remains. Because of their polygenetic nature, they cannot be directly identified with given plant communities.

Lake Żarnowiec channel

Lake Żarnowiec (Fig. 22)

Macrofossil assemblage zones:

Characeae MAZ — JZ I (410-310 cm). This zone is dominated by *Characeae* oospores; together with these, a few remains of other aquatic plants are found, e. g. leaves of *Myriophyllum spicatum* f. *squamosum* and fragments of the mosses *Scorpidium scorpioides* and *Calliergon giganteum*.

Scorpidium scorpioides-Calliergon giganteum MAZ — JZ II (310-254 cm). The following mosses entirely dominate the zone: *Scorpidium scorpioides* (calciphilous) and *Calliergon giganteum* (calcium-tolerant).

Schoenoplectus-Phragmites MAZ — JZ III (254-240 cm). *Phragmites communis* tissues are dominant. Also found here are *Schoenoplectus lacustris* and *S. tabernaemontani* nutlets.

Cladium-Phragmites MAZ — JZ IV (240-145 cm). *Cladium mariscus* nutlets and tissues, and *Phragmites communis* tissues prevail. Numerous *Schoenoplectus tabernaemontani* nutlets and *Menyanthes trifoliata* seeds are also found in the upper part of the zone.

Characeae-Najas marina MAZ — JZ V (125-37 cm). Large numbers of *Characeae* oospores are characteristic. In the lower and upper parts of the zone they occur together with *Najas marina* fruits; in consequence of this, the zone can be divided into subzones;

Najas marina MASZ — JZ V a (125-100 cm). *Najas marina* fruits are dominant; there are relatively few *Characeae* oospores.

Characeae MASZ — JZ V b (100-55 cm). Only *Characeae* oospores are present in this section of the sediments.

Characeae-Najas marina-Schoenoplectus lacustris MASZ — JZ V c (55-37 cm). High numbers of *Characeae* and *Najas marina* remains. *Schoenoplectus lacustris* nutlets and the fruits of *Zannichellia* cf. *palustris* and *Ceratophyllum* cf. *demersum* are present in smaller quantities.

Diatom assemblage zones:

Campylodiscus clypeus-Anomoeneis sphoerophora v. *sculpta* DAZ — JZ 1 (123-120 cm). This zone is completely dominated by mesohalobous diatoms like *Campylodiscus clypeus*, *Anomoeneis sphoerophora* v. *sculpta*, *Amphora commutata* and *A. halsatica*.

Fragilaria-Achnanthes DAZ — JZ 2 (120-105 cm). Dominant in this zone are epiphytic and bottom fresh-water forms, among which the most numerous are *Fragilaria* species (*F. construens*) and *Achnanthes* species (*A. lanceolata*).

Stephanodiscus astraea-Epithemia sorex DAZ — JZ 3 (105-70 cm). This zone is dominated by plankton species, especially halophilous species (*Epithemia sorex*, *Stephanodiscus astraea*, *Cyclotella comta*, *Gomphonema intriatum*, *Cymbella affinis*).

Fragilaria-Epithemia turgida v. *granulata* DAZ — JZ 4 (70-45 cm). The percentage of epihytic forms such as *Fragilaria construens*, *F. brevistrata* and *Amphora ovalis* increases in this zone; *Epithemia turgida* v. *granulata* is common (up to 30%).

The water basin in the northern part of the present-day Lake Żarnowiec was probably formed during the Younger Dryas at the latest (*Characeae* MAZ — JZ 1). The sediment of this period is clayey calcareous gyttja, in which the calcium carbonate content distinctly increases towards the top of the profile. The silica content is about 30% of the dry weight. Among the macroscopic remains identified, the numerous calciphilous mosses are noteworthy; frequently occurring in an aquatic environment, they include *Scorpidium scorpioides*, *Drepanocladus fluitans* and *Calliergon giganteum*. Also were found vegetative remains of *Ceratophyllum* sp., seeds of *Potamogeton* sp., and fruits of *Hippuris*, as well as the scaly leaves of *Myriophyllum spicatum* f. *squamosum* (Aalto & Uusinoka 1978) characteristic of Late Glacial sediments. Substantial quantities of *Characeae* oospores and *Pediastrum boryanum* colonies testify to the high fertility of the water, this fertility being due to the considerable amounts of calcium carbonate in the substrate. The micro- and megaspores of *Selaginella selaginoides* and *Betula* sect. *nane* nutlets are derived from the damp habitats surrounding the lake.

In the DR-3/PB and Preboreal periods, this part of the lake began to dry out. This is manifested in an increase first in the numbers of calciphilous mosses (*Scorpidium scorpioides-Calliergon giganteum* MAZ — JZ II), and later in species currently found in reed-swamp communities (*Scirpo-Phragmitetum*) such as *Schoenoplectus lacustris*, *S. tabernaemontani*, *Typha latifolia* (pollen) and *Phragmites communis* (*Schoenoplectus-Phragmites* MAZ — JZ III). The low content of organic material in this sediment may be indicative of the initial and open nature of this community.

At the start of the Boreal period there was a rapid expansion of the reed-swamp community with dominant *Cladium mariscus* (*Cladium-Phragmites* MAZ — JZ IV). It was, probably similar to the present-day *Cladietum marisci* association (Jasnowski 1962; Rybníček 1973). The development of the *Cladium* reed-swamp, which included also *Phragmites communis*, continued until the beginning of the Atlantic period. Changes then took place which suggest that the water-level rose (the appearance of large quantities of *Schoenoplectus tabernaemontani* fruits, the increase in *Characeae* oospores), and possibly that the fertility of the water declined (numerous *Menyanthes trifoliata* seeds).

Most of the sediments deposited during the Atlantic period are missing from this profile. It is thus impossible to reconstruct completely the history of the lake, neither can an exhaustive interpretation of the Subboreal sediments be made.

The diatom analysis of the Subboreal part of the profile, carried out by Dr. B. Adamczak, indicates the influence of sea-water (possibly the result of ingression, Rosa 1963) in samples from depths of 123 and 120 cm (*Campylodiscus clypeus-Anomoeneis sphaerophora* v. *sculpta* DAZ — JZ 1). Mesohalobous diatoms (according to Kolbe's system of halobes, 1927) are present in large numbers, in fact 33·1-90·6% of the total number of specimens (Fig. 24)[1]. The absolutely dominant species here is *Campylodiscus clypeus* (71-87%), while *Anomoeneis sphaerophora* v. *sculpta* (22%) is of great importance in the next sample. Of the mesohalobous species, representatives of the genus *Amphora* (*A. commutata*, *A. halsatica*) are frequently encountered. Typically marine-euhalobous diatoms are represented by single forms of *Actinocyclus ehrenbergii* and *Cocconeis scutellum*. The mass occurrence of *Campylodiscus clypeus* and *Anomoeneis sphaerophora* v. *sculpta* is typical for a shallow coastal bay ("clypeus lagoon"), a characteristic transition zone between a deep Littorina bay or the open sea, and an independent, isolated body of water (Alhonen 1971). The small number of euhalobous diatoms characteristic of open-sea zones, especially the lack of *Coscinodiscus* species, suggests that the salinity of this water was low. The changes noted in further samples show that the water had become completely fresh and that this part of the lake had become shallower (*Fragilaria-Achnanthes* DAZ — JZ 2). Epiphytic and bottom diatoms are dominant:

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[1] Fig. 24 under the cover.

Amphora ovalis, *A. ovalis* v. *pediculus*, *Achnanthes clevei*, *A. lanceolata*, *A. lanceolata* v. *elliptica* *A. lanceolata* v. *rostrata*, and *Fragilaria* species. The considerable numbers of *Najas marina* fruits in the sediments are also an indication of the lake's shallowness. In samples from depths 105-70 cm (*Stephanodiscus astrea-Epithemia sorex* DAZ — JZ 3) there is a distinct increase in plankton species (*Stephanodiscus astrea*, *Cyclotella comta* and *C. comta* v. *radiosa*), which together make up about 40% of the total. Halophilous diatoms, especially *Epithemia sorex* (c. 30%), are also important here. The water level in the lake rose during this period. The lake again became shallower during phase 4 (70 cm) when the number of plankton fell rapidly and epiphytic forms increased in number. Diatoms are rare in the topmost samples. Worthy of mention among the macroscopic remains are the enormous numbers of *Characeae* oospores and fruits of *Najas marina*, *Zannichellia* cf. *palustris*, *Ceratophyllum* cf. *demersum*, *Potamogeton* sp., denoting the presence of the macrophytic association *Parvopotamogetono-Zannichellietum*, typical of shallow waters rich in calcium carbonate (Podbielkowski & Tomaszewicz 1979). Fairly large quantities of fine- and coarse-grained sand are found in the sediments, and pre-Quaternary spormorphs appear in the pollen diagram. This would suggest contamination with redeposited material. There is a clear hiatus in the topmost section of the profile: the missing sediments may have been washed out by the river flowing through the lake.

Peat-bog near Lake Żarnowiec (Fig. 21)

Macrofossil assemblage zones:

Selaginella-Betula nana MAZ — Z I (450-395 cm — profile Żar/75; 500-450 cm — profile Żar/76). Species typical of Late Glacial sediments are well represented in this zone. They include boreal-montane species such as *Selaginella selaginoides*, *Betula nana*, *Arctostaphylos alpina*, *Dryas octopetala*, and boreal species such as *Potamogeton filiformis* and *Empetrum nigrum*.

Sphagnum apiculatum-Carex lasiocarpa MAZ — Z II (395-350 cm). Remains of the following brown mosses occur in this zone: *Drepanocladus vernicosus*, *D. aduncus*, *Homalothecium nitens*; remains of the bog mosses *Sphagnum apiculatum*, *S. teres*, *S. fimbriatum*, *S. palustre*; nutlets of *Carex lasiocarpa* and *C. diandra*; *Empetrum nigrum* s. l. stones, *Betula* sect. *nanae* nutlets and scales, part of which show features of *Betula humilis*, also occur in the sediment.

Cladium-Phragmites MAZ — Z III (350-55 cm). Characteristic of this zone are the quantities of *Cladium* nutlets and tissues, and *Phragmites communis* tissues. *Carex* t. *flava/oederi*, *Schoenoplectus tabernaemontani* and *Eleocharis palustris* are present in much smaller amounts.

Carex rostrata-Eleocharis palustris MAZ — Z IV (55-25 cm). Dominant here are the fruits of *Eleocharis palustris* and nutlets of *Carex rostrata*; the fruits of *Hydrocotyle vulgaris*, *Juncus articulatus* and *Potentilla anserina* occur sporadically.

Hydrocotyle vulgaris-Potentilla anserina MAZ — Z V (25-0 cm). Fruits of

Hydrocotyle vulgaris, *Juncus articulatus* and *Potentilla anserina* are quite numerous in this zone. Sedge radicelles and *Gramineae* tissues are the most common tissues.

The succession at this locality was started during the Younger Dryas by typical Late Glacial pionier communities (*Selaginella-Betula nana* MAZ — Z I). These communities are similar to those occurring in present-day tundra or alpine vegetation (see Lye 1975), although there are some fundamental differences between these types of communities (Iversen 1973). The characteristic features of these pioneer communities can be examined in the bottom sections of profile Żar/76 and diagram Żar/75. Among the macrofossils many remains of plants having varying water-table requirements occur simultaneously. The following aquatic organisms have been identified: *Potamogeton filiformis*, *Sparganium minimum*, *Myriophyllum spicatum* f. *squamosum*, *Characeae*, *Batrachium* sp., and the boreal-montane species of water snail *Gyraulus acronicus* (det. A. Dzięczkowski). Mire vegetation is numerously represented by remains of *Menyanthes trifoliata*, *Betula nana*, *Selaginella selaginoides* and *Empetrum nigrum* s. l. Besides these, fragments of *Arctostaphylos alpina* and *Dryas octopetala* were found. Bark and wood fragments of pine and fruits of *Betula* sect. *albae* show that single tree specimens were growing on the incipient peat-bog. These plant species, having different ecological requirements, demonstrate the wide variety of habitats and the mosaic-like vegetation.

Another characteristic of these communities is the simultaneous occurrence of calciphytes like *Selaginella selaginoides*, *Scorpidum scorpioides* and *Dryas octopetala* with plants which are today found in acid habitats, such as *Empetrum nigrum* and *Betula nana*. This has often been observed in Late Glacial sediments (e.g.Ralska-Jasiewiczowa 1980).

A transition bog (*Sphagnum apiculatum-Carex lasiocarpa* MAZ — Z II) was formed during the Preboreal period. Brown mosses such as *Drepanocladus vernicosus*, *D. aduncus*, *Paludella squarrosa*, *Homalothecium nitens*, peat mosses such as *Sphagnum apiculatum*, *S. teres*, *S. fimbriatum*, *S. palustre*, sedges *Carex lasiocarpa*, *C.* cf. *diandra* and *Viola palustris* are present, so this section of the sediment can be classified as being of the Bryalo-parvocaricioni genus (Tołpa et al. 1967); nowadays, these species are found in communities of the class *Scheuchzerio-Caricetea fuscae* and the orders *Caricetalia fuscae* and *C. davalianae*. Willows and dwarf birches also grew on the peat-bog; among the *Betula* sect, *nanae* fruits, nutlets resembling those of *B. humilis* were found apart from typical *B. nana* nutlets. *Empetrum nigrum* stones are present throughout this section of the profile, so it is clear that crowberry must have been growing on the peat-bog.

Reed-swamp communities (*Cladium-Phragmites* MAZ — Z III) began to spread at the start of the Boreal period, probably as a result of the rise in the water table. Here, by far the commonest macrofossils are fruits and tissues of *Cladium mariscus* and vegetative fragments of *Phragmites communis*. Along with these, nutlets of *Carex* t. *flava/oederi*, *Eleocharis palustris* and *Schoeno-*

plectus tabernaemontani occur. It is highly likely that this community resembled the *Cladietum marisci* association occurring today (Jasnowski 1962; Rybniček 1973). It developed on the one and a half metre thick layer of transition bog which was devoid of calcium carbonate. *Cladium mariscus* communities were dominant practically to the end of the Subboreal period. Only at a depth of 120-100 cm a few species from the *Scheuchzerio-Caricetea fuscae* class appear: *Hydrocotyle vulgaris*, *Juncus articulatus*, *Ranunculus flammula* and *Eriophorum* sp. The presence of these plants suggests that the habitat conditions on the bog had altered, possibly as a result of fires (numerous charred herb remains).

The plant succesion was later continued by communities from the *Scheuchzerio-Caricetea fuscae* class. At first, when the water table was high, swamp species dominated (*Carex rostrata-Eleocharis palustris* MAZ — Z IV). These included *Carex rostrata* and *Eleocharis palustris*, together with a few fruits and tissues of other members of the *Phragmitetea* class: *Cladium mariscus*, *Phragmites communis*, *Schoenoplectus tabernaemontani*. Remains of plants typical of low-sedge, acid meadows (*Hydrocotyle vulgaris*, *Juncus articulatus*, *Potentilla anserina*) occur in small quantities. Among the seeds and fruits identified, there are a number of species probably connected with human activities such as *Chenopodium album*, *Rumex acetosella*, *Polygonum nodosum* and *P. persicaria*. In the topmost part of the profile (*Hydrocotyle vulgaris-Potentilla anserina* MAZ — Z V), swamp plants lose their significance, whereas plants of the class *Scheuchzerio-Caricetea fuscae* gain in importance; this indicates a further lowering of the water table. The increasing number of meadow species is the effect of human influence on the peat-bog communities.

The succession of local peat-bog vegetation as described here, starting with pioneer damp tundra communities, continuing with the moss-sedge communities typical of transition bogs, reed-swamp communities with *Cladium*, and ending with acid, low-sedge meadows, is found in other localities near ice-marginal valleys in the eastern part of the Polish coastal zone (Herbichowa 1975; Latałowa unpubl.).

History of the Lake Żarnowiec channel in the ligth of palaeobotanical investigations

Papers dealing with the origin and history of the Lake Żarnowiec channel are few. The earlier papers include those by Sonntag (1912) and Zaborski (1933); later ones include work by Rosa (1963) and Roszkówna (1964).

The palaeobotanical material presented in this dissertation is supplemented by data contained in "Dokumentacja wierceń geologicznych" (Geological drilling records, 1973, 1979), and provides new information about certain events in the history of this area. Obviously, they do not exhaust the whole of this complicated subject: this would require a large number od specialist analyses of many profiles from the lake itself and the peat-bogs surrounding it.

The formation of a body of water over what is now the northern part of the lake took place during the Younger Dryas at the latest. Very likely it was initiated by the melting of dead ice (Roszkówna 1964). This process was delayed in relation to other areas (see Kozarski 1963), probably because the ice-sheet remained longer here than elsewhere, and as a result of the preserving properties of the thick layer of outwash plain sands. At the same time, vegetation characteristic of shallow depressions began to take over the area south of the lake, which today is covered by peat-bog. Macrofossil analysis shows that land vegetation typical of river-valleys and lake shores had already taken over this area by the beginning of the Preboreal period. The material from the entire Holocene does not contain any aquatic sediments which could prove the existence of the Ancylus basin or Littorina bay (fjord) mentioned by Roszkówna (1964).

The profile from the northern part of the lake is more difficult to interpret. The shallowing of this part already began in the Preboreal period. There are no lake sediments from the start of the Boreal period in this profile; they are replaced by *Cladium* peat and *Cladium-Phragmites* peat which show that reed-swamp communities had encroached on to this area. Similar peat deposits are frequent over the whole northern part of the lake (Geological drilling records, 1973, 1979; Więckowski et. al 1973). These reedswamp communities prevailed at least until the early phases of the Atlantic period.

Samples from the early Subboreal period show that the effects of sea water were limited (see Fig. 24). This can probably be linked to the last phase of the Littorina transgression of the southern Baltic which, according to Rosa (1963) took the form of a short-lived ingression of sea water. It must be emphasized that the material in this dissertation is representative only of the northern part of the present Lake Żarnowiec, which during the Atlantic period was covered by a peat-bog. The deeper parts of the lake probably developed in quite a different way. Geological sampling did not reveal any peat interbedding of the sediments; the thickness of calcareous gyttja increases with depth of water and exceeds 20 m at the deepest point (Geological drilling records, 1973, 1979; Więckowski et al. 1973). A rapid sedimentation rate is confirmed by pollen analysis of several samples of gyttja which allowed the dating of sediments from a depth of 6 m below the lake bottom to the late Subboreal time (Latałowa 1977).

Very probably, the limited influx of sea water concerned only the northern peat-covered zone of the basin where limnic sedimentation followed the rise in the water table. There is no evidence for the influx of sea water into the whole of the channel, nor for the formation of a fjord. A transgression of the sea would have caused the rise of the water level in peat-bog at the south end of the lake (locality 1), even if it had not penetrated the whole channel. It is well known nowdays that sea water does in fact enter Lake Żarnowiec through the northern part of the river Piaśnica as a result of storm surges. There is the possibility that, during the Subboreal period, sea water penetrated the northern part of the Lake Żarnowiec in the similar way.

Peat-bog in Darżlubie Forest (Fig. 23)

Macrofossil assemblage zones:

Characeae MAZ — PD I (398-385 cm). *Characeae* oospores are dominant. Single fruits of *Sparganium minimum*, *Potamogeton filiformis*, *P. alpinus*, *P. natans* occur.

Carex lasiocarpa-C. pseudocyperus MAZ — PD II (385-335 cm). Remains of swamp vegetation such as *Carex rostrata* and *C. pseudocyperus* occur in this zone; also a large group of species typical of transition bogs: brown mosses (*Drepanocladus aduncus*, *Calliergon stramineum*, *C. giganteum*), peatmosses (*Sphagnum apiculatum*, *S. palustre*), sedges (*Carex lasiocarpa*, *C. diandra*), and *Comarum palustre*. Fruits of aquatic plants like *Potamogeton* and *Sparganium* are also present.

Cladium mariscus MAZ — PD III (335-315 cm). Characteristic of this zone are the nutlets and tissues of *Cladium mariscus*; also present are cf. *Dryopteris* tissues and nutlets of *Carex pseudocyperus* and *C. lasiocarpa*.

Oxycoccus quadripetalus-Sphagnum apiculatum MAZ — PD IV (315-265 cm). Remains of brown mosses (*Aulacomnium palustre*, *Meesea longiseta*), peatmosses (*Sphagnum apiculatum*, *S. palustre*), *Oxycoccus quadripetalus* leaves and roots, and *Carex lasiocarpa* nutlets appear in this zone.

Carex pseudocyperus-Potamogeton MAZ — PD V (265-120 cm). Numerous remains of swamp plants occur in this zone: *Carex pesudocyperus*, *Lycopus europaeus*, *Mentha* cf. *aquatica*, *Eleocharis palustris*, *Carex* t. *elata*. Also present are the remains of aquatic plants like *Potamogeton* and *Sparganium minimum*; they are accompanied by *Urtica dioica* fruits.

Carex elata-C. lasiocarpa MAZ — PD VI (120-30 cm). *Carex* t. *elata* nutlets are dominant; also present are *Phragmites* tissues and a few remains of transition bog plants such as *Carex lasiocarpa*, *Comarum palustre*, brown mosses and peatmosses.

Ranunculus flammula-Menyanthes trifoliata MAZ — PD VII (30-0 cm). This zone is dominated by species of the class *Scheuchzerio-Caricetea fuscae* such as *Ranunculus flammula*, *Menyanthes trifoliata*, *Hydrocotyle vulgaris* and *Comarum palustre*.

Especial care is required when interpreting the vegetational changes recorded in this macrofossil diagram. Its complexity is mainly due to the variable sedimentation rate which in some sections of the profile is up to 30 times as fast as in others (Fig. 7B). An illustration of this would be the particularly high concentration of seeds and fruits at depths from 170 to 200 cm. Another important problem is the small area and the mid-forest position of this peat-bog. Much of the macrofossil material is thus allochthonous and includes the seeds, wood and bark of *Pinus*, also *Betula* nutlets and wood, which are probably derived from the surrounding woodland. Also of allochthonous origin may be certain fruits and seeds dispersed by animals: *Empetrum nigrum*, *Fragaria vesca*, *Moehringia trinervia* and *Luzula* sp.

The vegetational succession in this locality began at the turn of the Younger Dryas and Holocene. The first communities were those of a shallow body of water (*Characeae* MAZ — PD I) dominated by *Characeae*. Also present were boreal species of *Potamogeton* (Hultén 1964) such as *Potamogeton filiformis*, *P. alpinus*, and *Sparganium minimum*. The high calcium carbonate content (80%) gives some indication of the fertility of the water.

Sedge-reed communities comprising *Carex rostrata*, *C. pseudocyperus* began the process of filling of the basin (*Carex rostrata-C. pseudocyperus* MAZ—PD II). Certain species of the class *Scheuchzerio-Caricetea fuscae* such as *Comarum palustre*, *Carex lasiocarpa*, *Sphagnum palustre*, *S. apiculatum*, *Drepanocladus aduncus*, *Calliergon stramineum*, *C. giganteum* also occurred. The relatively high water table is indicated by the presence of *Sparganium minimum* and *Potamogeton* stones. Fruits of *Urtica dioica* were numerous and this fact testifies to the eutrophic nature of the habitats.

The *Cladium mariscus* MAZ — PD III indicates the short-lived domination of *Cladium* — swamp during the first half of the Boreal period. The following species were also of some importance: *Carex pseudocyperus*, *C. lasiocarpa*, *C.* cf. *diandra*, *Lycopus europaeus* and cf. *Dryopteris* (mainly vessels and sporangia were found). After the fire which burned the surface vegetation of the peat-bog (charred remains of herbs), the type of vegetation altered (*Oxycoccus quadripetalus-Sphagnum apiculatum* MAZ — PD IV). Evidence for this is offered by the large numbers of laeves and roots of *Oxycoccus quadripetalus*, and the remains of brown mosses and peatmosses: *Sphagnum apiculatum*, *S. palustre*, *Aulacomnium palustre*, *Meesea longiseta*; *Carex lasiocarpa* also occurred. These plants show that a transition bog was developing (Minero-Sphagnioni genus of peat, Tołpa et al. 1967). These species indicate the existence of a community of the class *Scheuchzerio-Caricetea fuscae* which may have been similar to the oligotrophic variant *Caricetum lasiocarpae* (Jasnowski 1962). A rise in the water level favoured the re-entry of sedge-reed swamp communities of the allience *Magnocaricion* (*Carex pseudocyperus-Potamogeton* MAZ — PD V). Of the species identified, *Carex pseudocyperus*, *C.* t. *elata*, *C. rostrata*, *Phragmites communis*, *Lycopus europaeus* and *Mentha* cf. *aquatica* are of great importance. The nutlets of *Carex lasiocarpa* and *C.* cf. *diandra* make up but a small number of the macrofossils. A significant part of the macrofossil material contains the stones of *Potamogeton natans*, *P. compressus* and *P. gramineus*, and the fruits of *Sparganium minimum*. These indicate a high level of stagnant water on the peat-bog. Pollen grains of *Lythrum salicaria* and *Utricularia* sp. are found on the pollen diagram. The great concentration of fruits and seeds in this part of the profile is due to the low rate of sedimentation.

The presence of a large number of *Urtica dioica* fruits among remains of swamp plants is interesting. This highly eutrophic species is today found in the *Circeo-Alnetum* association and in communities of classes *Alnetea glutinosae* and *Salicetea purpureae*; it tolerates periodic submerging. It is also found in reed-swamp communities (*Scirpo-Phragmitetum* — land variant, Jasnowski

1962). The fact that *Urtica dioica* is so common in the Darżlubie Forest profile can probably be put down to the highly eutrophic environment of this small, mid-forest peat-bog. The frequent fires which burned the surface of the bog undoubtedly raised the fertility of the habitats in it (charred tissue remains are present throughout almost the whole profile).

From a depth of 170 cm upwards, a radical change in the macrofossil content is observed (*Carex elata-C. lasiocarpa* MAZ — PD VI). There is a rapid decline in the number of aquatic species (*Sparganium minimum*, *Potamogeton*) and swamp plants (*Carex pseudocyperus*, *C. rostrata*, *Lycopus europaeus*, *Mentha* cf. *aquatica* and the accompanying *Urtica dioica*). The diagram is dominated by *Carex* t. *elata* nutlets which on a number of levels are found together with remains of typical transition bog species such as *Sphagnum teres*, *S. apiculatum*, *Comarum palustre*, *Menyanthes trifoliata*, *Calla palustris*, *Carex lasiocarpa*, *C.* cf. *diandra* and *Eriophorum* sp. The species content of this section of the profile is similar to that of the *Caricetum elatae* association (Jasnowski 1962). In the topmost part of the profile (*Ranunculus flammula-Menyanthes trifoliata* MAZ — PD VII) the number of species from the class *Scheuchzerio-Caricetea fuscae* increases (*Comarum palustre*, *Menyanthes trifoliata*, *Hydrocotyle vulgaris*, *Ranunculus flammula*). These species also play an important part in the present-day vegetation of the peat-bog.

The complicated vegetational systems mentioned above, their variety as regards simultaneously occurring components, and the frequent changes taking place in the communities were largely the consequence of fluctuations in the water level. These fluctuations were undoubtedly favoured by the small area of the peat-bog, underlain as it is by permeable outwash plain sands.

SUMMARY

1. The material for this dissertation was taken from two localities in the Lake Żarnowiec channel (localities 1 and 2) and from one locality in the Lake Dobre channel (locality 3) — Fig. 5.

Pollen and macrofossil analyses were carried out and the basic physico-chemical properties of the sediment were analysed.

2. A palaeobotanical study of the profiles from the Lake Żarnoweic area enabled a reconstruction of the vegetational history from the Younger Dryas to the present day.

3. The material was interpreted on the basis of the following biostratigraphic units (pollen assemblage zones), which were distinguished on the pollen diagrams 1 — *Pinus-Juniperus-herbs*; 2 — *Juniperus-Pinus-Betula*; 3 — *Pinus-Betula*; 3 a — *Pinus-Betula-Filipendula*; 3 b — *Betula-Empetrum*; 3c — *Pinus*; 4 — *Corylus-Pinus*; 4a — *Corylus*; 4 b — *Corylus-Alnus*; 5 — *Tilia-Ulmus-Pinus*; 6 — *Quercus-Corylus*; 7 — *Quercus-Carpinus*; 8 — *Pinus-Fagus-Juniperus*.

4. 21 samples from the peat-bog profiles were radiocarbon-dated. The pollen

zones could then be correlated with the Blytt-Sernander system (adapted to Polish conditions), and the vegetation of different periods characterized.

a. During the Younger Dryas the vegetation of this area was of the park-tundra type, though more open than in other parts of lowland Poland. The diagrams are similar to those of north-western Europe: features in common include the presence of elements of Dryas flora, high percentage pollen values of *Juniperus* and large numbers of *Empetrum* seeds. The latter two features are signs of a climate more maritime than in other regions of Poland so far studied.

b. The transition zone between the Younger Dryas and the Preboreal period (DR-3/PB) is characterized by maximum *Juniperus* pollen values, which indicate the approaching polar range limit of the forest and an improvement in the climate.

c. In the Preboreal period, pollen subzones corresponding to the climatic oscillations of this period can be distinguished. These oscillations have already been described for north-west Europe (Behre 1967, 1978). Zone 2 — *Pinus-Betula-Juniperus* (DR-3/PB) and subzone 3 a — *Pinus-Betula-Filipendula* probably correspond to the Friesland Oscillation, subzone 3 b — *Betula-Empetrum*, to the Youngest Dryas, and subzone 3 c — *Pinus*, to the late Preboreal.

d. Open pine woods were dominant during the Boreal period, and hazel was abundant in their undergrowth. The first postglacial hazel pollen maximum is observed during the second half of this period. The *Ulmus* curve ascends distinctly at the start of the Boreal, to be followed by *Quercus*. Alder expands rapidly towards the end of this period.

e. Characteristic of the Atlantic period are mesophilous deciduous forests in which *Tilia cordata*, *T. platyphyllos*, elm and oak are very important. Pine woods and other forests with some pine still occupied a large area in the vicinity of Lake Żarnowiec.

f. Oakwoods and hazel expanded rapidly at the start of the Subboreal period. At the same time, species requiring a more fertile habitat (especially elm) declined, and the pollen value of pine was reduced to less than 20% of the total AP. In the second half of this period, the area of oakwoods decreased as a result of human activities, and hornbeam began to spread.

g. At the start of the Subatlantic period, the area of woodland of the oak-hornbeam type expanded in Darżlubie Forest; high percentage pollen values of oak and hornbeam are evidence for this. In the Lake Żarnowiec channel such communities were not very widespread. Then, from the Middle Ages onwards, the oak-hornbeam forests were rapidly destroyed, whereas beech and pine spread.

5. The diagrams were compared with one another and with other data from Western Pomerania, so that local and regional features could be elicited. The most important regional features include:

a. High *Juniperus* pollen values at the turn of the Younger Dryas and Holocene.

b. Climatic oscillations during the Preboreal period.

c. Low pollen values of pine during the Subboreal when broad-leaved forests were absolutely dominant.

d. High percentage pollen values of hornbeam during the second half of the Subboreal and at the start of the Subatlantic period.

e. The late spread of beech.

The local features of the diagrams are mostly the result of habitat differences in the neighbourhood of the localities surveyed.

6. On the basis of the pollen diagrams seven settlement phases were distinguished and characterized. The results were correlated with archaeological data;

a. The earliest traces of human activity come from the early Neolithic; the most intensive settlement in the Lake Żarnowiec area took place during the Hallstatt period and the early Middle Ages.

b. The importance of man in the transformation of forest vegetation was confirmed. The destruction of mixed deciduous forests occasioned by agricultural activities during the periods of the Lusatian and East Pomeranian cultures facilitated the expansion of hornbeam. The spread of beech was aided by massive deforestation during the early Middle Ages.

7. After analysing the macrofossils preserved in the sediments, the history of local plant communities and of the sedimentation basins could be reconstructed.

a. The body of water in the northern part of what is now Lake Żarnowiec arose no later than during the Younger Dryas. This part of the lake began to be filled in at the start of the Preboreal and coincides with the appearance of communities of calciphilous mosses and reed-swamp vegetation. Reed-swamps with dominant *Cladium mariscus* and *Phragmites communis* existed here during the Boreal and early Atlantic periods. The lake re-formed at the start of the Subboreal period because of a rise in the water level. In the bottom section of lake sediments of this period, diatom analysis has revealed the effect of slight salinity resulting from a short-lived ingression of sea-water.

b. The development of the vegetation in the southern part of the Lake Żarnowiec channel started from tundra communities in the Younger Dryas. Since that time, the vegetational changes have involved various types of peat-bog; for a long time, reed-swamps of *Cladium mariscus* and *Phragmites communis* dominated.

c. Communities characteristic of cool, pure waters formed the initial successional stages in the Darżlubie Forest peat-bog at the start of the Holocene. Later stages involved mainly marsh plants. Fires and frequent changes of water level resulted in a rich variety of peat-bog communities; transition bog vegetation occurred periodically.

8. The results of the palaeobotanical studies have enabled some corrections to be made to the theories of the past history of the Lake Żarnowiec channel

hitherto put forward. No traces of an Ancylus basin or a Littorina bay could be found in its southern part.

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STRESZCZENIE

Wstęp

Celem niniejszej pracy było poznanie polodowcowej historii szaty roślinnej na obszarze wschodniej części Pobrzeża Bałtyku oraz próba odtworzenia przemian roślinności lokalnej w obrębie wybranych zbiorników sedymentacyjnych. Teren wschodniej części Pobrzeża Bałtyku doczekał się do tej pory niewielkiej ilości danych paleobotanicznych, mimo że jest on szczególnie interesujący ze względu na fakt opóźnionej recesji lądolodu w tej części Pobrzeża (ryc. 1).

Przedstawione w tej pracy stanowiska zostały włączone do sieci punktów wzorcowych International Geological Correlation Programme IGCP nr 158 B poświęconego zmianom paleohydrologicznym w ciągu ostatnich 15 tysięcy lat w oparciu o badania osadów torfowych i limnicznych (Berglund & Digerfeldt 1976; Berglund 1979).

Metody badań

Podstawę opracowania stanowią materiały z dwóch stanowisk w rynnie Jeziora Żarnowieckiego (stanowiska 1 i 2) oraz z jednego stanowiska w Puszczy Darżlubskiej, w rynnie Jeziora Dobrego (stanowisko 3). Rozmieszczenie analizowanych profili wraz z ich symbolami zawiera objaśnienie do ryciny 4.

Materiały opracowano metodą analizy pyłkowej, wykonano badania zawartości szczątków makroskopowych oraz analizy podstawowych właściwości fizycznych i chemicznych osadów. W analizie pyłkowej oprócz obliczeń procentowych zastosowano metodę koncentracji sporomorf oraz obliczono wartości opadu pyłku/cm^2/rok.

Opis osadu wykonano wg systemu Troels-Smith'a (1955). W opisie oraz symbolach (ryc. 5) zastosowano uproszczenia.

Przedstawione w pracy profile posiadają 21 dat radiowęglowych. Datowania umożliwiły określenie czasu poszczególnych etapów przemian roślinności na badanym terenie, obliczenie tempa akumulacji złóż torfowych (ryc. 7) oraz wykreślenie diagramów opadu pyłku.

Diagramy pyłkowe zostały podzielone na jednostki biostratygraficzne (zespołowe poziomy pyłkowe — pollen assemblage zones — PAZ). Nazwy tych poziomów pochodzą od gatunków dominujących lub charakterystycznych dla danego odcinka diagramu. W diagramach poziomy pyłkowe zaznaczono numerami. W celu łatwiejszego nawiązania do dotychczasowych opracowanych diagramów z terenów Polski zastosowano również podział na piętra Blytta-Sernandera, które potraktowano, jako jednostki chronostratygraficzne (Środoń 1972).

Na jednostki biostratygraficzne podzielono również diagramy szczątków makroskopowych (zespołowe poziomy szczątków makroskopowych — macrofossil assemblage zones — MAZ) oraz diagram okrzemkowy (zespołowe poziomy okrzemek — diatom assemblage zones — DAZ).

Przemiany szaty roślinnej okolic Jeziora Żarnowieckiego

Pinus-Juniperus-herbs PAZ (1) > 10 200 lat BP. W okresie reprezentowanym przez ten poziom na badanym terenie panowała roślinność tundry parkowej, lecz o mniejszym zwarciu niż na innych terenach Polski niżowej. Wśród oznaczonych z tego poziomu gatunków znajduje się grupa roślin zaliczanych do tzw. flory dryasowej (sensu Iversen 1954, 1973). Stosunkowo wysokie wartości procentowe pyłku jałowca, któremu towarzyszą w osadzie pestki *Empetrum nigrum* s. l., świadczą o klimacie bardziej oceanicznym niż na innych dotychczas zbadanych terenach Polski.

Juniperus-Pinus-Betula PAZ (2) — około 10 200 lat BP. Poziom ten odznacza się maksymalnymi wartościami pyłku jałowca, które sygnalizują zbliżanie się polarnej granicy lasu związane z ocieplaniem się klimatu.

Pinus-Betula PAZ (3)—około 10000 - 9100 lat BP. W okresie reprezentowanym przez ten poziom na badanym terenie panowały lasy brzozowo-sosnowe i sosnowe. W diagramie Żar/76 wyróżniono w obrębie tego poziomu trzy podpoziomy pyłkowe. Podpoziomy te wraz z poziomem 2 nawiązują do oscylacji klimatycznych okresu preborealnego, opisanych z terenów Europy północno-zachodniej (Behre 1967, 1978): poziom (2) *Pinus-Betula-Juniperus* i podpoziom (3 a) *Pinus-Betula-Filipendula* odpowiadają prawdopodobnie Oscylacji Friesland, podpoziom (3 b) *Betula-Empetrum*—najmłodszemu dryasowi, podpoziom (3 c) *Pinus* odpowiada późnemu preborealowi.

Corylus-Pinus PAZ (4) — około 9100 - 8300 (7700) lat BP. Skład spektrów pyłkowych tego poziomu wskazuje, że w okolicach Jeziora Żarnowieckiego panowały świetliste bory sosnowe. W tym czasie nastąpiło rozprzestrzenienie się leszczyny, której krzywa osiąga w diagramach swoje pierwsze postglacjalne maksimum. Wzrastała również stopniowo rola wiązu, a następnie dębu. Pod koniec poziomu w diagramach szybko podnosi się krzywą olszy, która świadczy o ekspansji tego drzewa na wilgotne siedliska w sąsiedztwie jeziora.

Tilia-Ulmus-Pinus PAZ (5) — około 8300 (7700) - 5600 (4700) lat BP. W czasie, który ilustruje ten poziom na badanym terenie rozprzestrzeniły się mezofilne lasy liściaste, w których poważną rolę odgrywały *Tilia cordata* i *T. platyphyllos*, wiązy oraz dąb. Nadal jednak dużą powierzchnię pokrywały bory sosnowe i inne lasy z udziałem sosny. W poziomie tym zaznaczyła się pierwsza faza osadnicza związana z neolitem.

Quercus-Corylus PAZ (6) — około 5600 (4700) - 2800 lat BP. Poziom ten we wszystkich diagramach charakteryzuje się minimalnym udziałem pyłku sosny oraz maksymalnymi wartościami pyłku dębu. Towarzyszy im wzrost wartości procentowych leszczyny, której krzywa tworzy w tej części diagramów swoje drugie postglacjalne maksimum. Poziom ten interpretować można jako rozprzestrzenienie się lasów dębowych oraz leszczyny. Dąb wyparł sosnę nawet z uboższych gleb piaszczystych. Równocześnie w diagramach zaznaczył się spadek udziału gatunków o większych wymaganiach siedliskowych, a zwłaszcza wiązu. Z największą częstotliwością pojawia się też pyłek gatunków uznanych za wskaźnikowe dla optimum klimatycznego holocenu — *Hedera* i *Viscum*. W poziomie tym wyraźnie zaznacza się wpływ człowieka. Wyróżnione fazy osadnicze związane są z neolitem oraz wczesną epoką brązu.

Quercus-Carpinus PAZ (7) — około 2800 - 1200 lat BP. W okresie reprezentowanym przez ten poziom nastąpiła wyraźna zmiana w składzie lasów na badanym terenie. Zmniejszył się obszar zajmowany przez świetliste lasy dębowe, nastąpiło natomiast rozprzestrzenienie się lasów grabowych, nawiązujących do współczesnych grądów. Na podstawie diagramu pyłkowego z torfowiska koło Jeziora Żarnowieckiego (stanowisko 1) stwierdzono, że w samej rynnie jeziora występowanie grądów było jednak ograniczone. Wiązać to można z niewielką ilością siedlisk odpowiednich dla tego rodzaju zbiorowisk, a także z wczesnym i intensywnym osadnictwem w najbliższym sąsiedztwie jeziora. Z omawianym poziomem pyłkowym związane są dwie następne fazy osadnicze (5 — grupa kaszubska kultury łużyckiej, 6 — kultura wschodniopomorska).

Pinus-Fagus-Juniperus PAZ (8)-1200 lat BP. W poziomie tym ostatecznie obniżył się udział mezofilnych gatunków liściastych, w tym także graba. Zaznaczyła się natomiast ekspansja buka oraz sosny. Zmiany w szacie leśnej miały charakter gwałtowny i związane były z ostatnią z wyróżnionych faz osadniczych (7) — wczesnym średniowieczem.

Lokalne i regionale cechy diagramów z okolic Jeziora Żarnowieckiego

Na podstawie porównania opracowanych diagramów między sobą oraz niektórych danych z innych terenów Pomorza Zachodniego, wyróżniono podstawowe cechy regionalne i lokalne prezentowanych materiałów. Do najistotniejszych cech regionalnych zaliczono:

— wysokie wartości *Juniperus* na przełomie młodszego dryasu i holocenu,

— oscylacje klimatyczne w okresie preborealnym,

— niskie wartości sosny przy bezwzględnym panowaniu lasów liściastych w okresie subborealnym,

— wysokie wartości procentowe pyłku graba w drugiej części okresu subborealnego i na początku okresu subatlantyckiego,

— późne wkroczenie buka.

Cechy lokalne diagramów są związane głównie z różnicami siedliskowymi w sąsiedztwie badanych stanowisk.

Wpływ człowieka prahistorycznego na szatę roślinną badanego obszaru

Historia osadnictwa w okolicach Jeziora Żarnowieckiego jest stosunkowo dobrze poznana. Rozmieszczenie punktów osadniczych w różnych okresach prahistorii, od neolitu do wczesnego średniowiecza włącznie, przedstawiono na ryc. 10.

Zestawienie sumy wartości procentowych roślin uznanych za wskaźnikowe dla działalności człowieka, względem skali czasowej, pozwoliło na wyróżnienie siedmiu okresów wzmożonej intensywności gospodarczej (fazy osadnicze) na badanym terenie (ryc. 11). Pierwsze trzy fazy osadnicze są chronologicznie związane z neolitem. Towarzyszą im pojedyncze ziarna pyłku *Plantago lanceolata* oraz pierwszych zbóż. Zmiany w szacie leśnej badanego terenu były w tym czasie niewielkie, o czym świadczą nieznaczne depresje w krzywych drzew. Do poważniejszych zaburzeń przyczyniło się dopiero osadnictwo czwartej fazy(II-III okres epoki brązu). W diagramie z torfowiska koło Jeziora Żarnowieckiego spada w tym czasie udział drzew liściastych, a zwłaszcza wiązu, dębu i lipy., Wysokie wartości procentowe pyłku *Rumex acetosa* i *R. acetosella* wskazują na wzrastające zakwaszenie gleb. W fazie tej po raz pierwszy odnotowano pyłek *Secale*.

Ekspansja ludności grupy kaszubskiej kultury łużyckiej oraz kultury wschodniopomorskiej znalazła odzwierciedlenie w diagramach jako fazy osadnicze 5 i 6. Fazy te są związane z drastycznymi zmianami w dotychczas panujących zbiorowiskach dębowych. Zniszczenie lasów dębowych umożliwiło rozprzestrzenienie się graba, który nie odgrywał do tej pory poważnej roli. Bezpośrednim dowodem na trzebieże lasów za pomocą ognia są warstwy żarowe w osadach torfowiska z Puszczy Darżlubskiej.

Po omówionych fazach intensywnej działalności człowieka, wystąpił wyraźny regres gospodarczy na badanym terenie. W diagramie z Puszczy Darżlubskiej zanikają krzywe zbóż, opadają krzywe innych roślin wskaźnikowych. Znaczne podniesienie się krzywej *Carpinus* oraz innych drzew o wysokich wymaganiach siedliskowych (*Tilia*, *Ulmus*) świadczy o regeneracji lasu na terenach opuszczonych przez człowieka. Zjawisko to przypada w przybliżeniu na okres 375-570 n. e. (ryc. 11), który na terenie Europy północnej odbija się w diagramach jako okres recesji gospodarczej w czasie wędrówek ludów (Andersen 1978, Berglund 1969, Iversen 1973).

Ostatnia 7 faza osadnicza zaznaczona w stropowej części profilu, należy do okresu wczesnego średniowiecza. Wskazuje na to jej pozycja chronologiczna, a także cechy tej części diagramu: pyłek zbóż osiąga tu wysokie wartości procentowe (znaczną rolę odgrywa *Secale*). W stosunku do zbóż spada znacznie *Plantago lanceolata* (tab. 2). W okresie tym nastąpiła ekspansja sosny i buka, drzew znoszących postępujące zakwaszenie gleb.

Historia lokalnej roślinności w obrębie zbiorników sedymentacyjnych

Interpretacja historii badanych zbiorników oraz ich roślinności opiera się głównie na analizie makroskopowych szczątków roślinnych, wzbogaconej przez dane zawarte w diagramach pyłkowych. Podstawowe właściwości fizyczno-chemiczne osadów, a także analiza okrzemkowa fragmentu profilu J. Żar/78 uzupełniają uzyskane informacje.

Oznaczone szczątki makroskopowe oraz okrzemki stanowią podstawę do wyróżnienia poziomów makroszczątków (MAZ) oraz poziomów okrzemkowych (DAZ). Podobnie jak w przypadku poziomów pyłkowych są to jednostki biostratygraficzne, które charakteryzują się określoną kombinacją szczątków kopalnych. Ze względu na swój poligenetyczny charakter nie mogą być bezpośrednio identyfikowane z określonymi zbiorowiskami roślinnymi.

Rynna Jeziora Żarnowieckiego

Jezioro Żarnowieckie (stanowisko 2). Powstanie zbiornika wodnego w północnej części obecnego Jeziora Żarnowieckiego nastąpiło nie później niż w młodszym dryasie. W osadzie z tego okresu znajdują się nieliczne szczątki roślin wodnych oraz szczątki o wyraźnie allochtonicznym pochodzeniu. Od początku okresu preborealnego stwierdzono inicjalne stadia lądowacenia tej części jeziora, związane z występowaniem zbiorowisk mchów kalcifilnych oraz roślinności szuwarowej. W okresie borealnym i początkowej fazie okresu atlantyckiego panowały szuwary z kłocią i trzciną jako gatunkami dominującymi. Podniesienie się poziomu wody na początku okresu subborealnego doprowadziło do powtórnego powstania zbiornika wodnego. W dolnej części typowych osadów jeziornych tego odcinka profilu stwierdzono na podstawie analizy okrzemkowej (ryc. 24), wpływ niewielkiego zasolenia. Wyraża się ono przede wszystkim masowym pojawem mezohalobowego gatunku *Campylodiscus clypeus*.

Torfowisko koło Jeziora Żarnowieckiego (stanowisko 1). Rozwój roślinności na obszarze torfowiska w południowej części rynny Jeziora Żarnowieckiego rozpoczął się w młodszym dryasie zbiorowiskami wilgotnej tundry. W okresie preborealnym nastąpił rozwój torfowiska przejściowego, a od początku okresu borealnego rozprzestrzeniły się zbiorowiska szuwarowe z kłocią i trzciną. Tego rodzaju roślinność dominowała na tym stanowisku prawie do końca okresu subborealnego, kiedy to zastąpiły ją zbiorowiska bagienne z *Carex rostrata* i *Eleocharis palustris*, a następnie ugrupowania niskoturzycowych kwaśnych łąk.

Przeszłość rynny Jeziora Żarnowieckiego w świetle dotychczasowych badań paleobotanicznych

Wyniki badań palinologicznych oraz analizy makroszczątków ze stanowisk 1 i 2, uzupełnione analizą okrzemkową dostarczyły nowych danych dla kontrowersyjnej i do tej pory otwartej dyskusji nad przeszłością rynny Jeziora Żarnowieckiego, a zwłaszcza jej związku z morzem w holocenie. Uzyskane wyniki wskazują, że na terenie południowej części rynny Jeziora Żarnowieckiego od początku holocenu aż do czasów współczesnych panowały zbiorowiska lądowe typowo dla dolin rzecznych i obrzeży jezior; brak tam osadów, które by sugerowały obecność zbiornika ancylusowego oraz zatoki litorynowej, o których pisze Roszkówna w swojej pracy z 1964 r. Brak jest również osadów morskich w północnej części jeziora. Fakt pojawienia się na tym stanowisku flory okrzemkowej typowej dla tzw. „laguny clypeusowej" może jednak świadczyć o krótkotrwałej ingresji morza, co sugerował Rosa (1963). Być może w doprowadzeniu wody morskiej pewną rolę odegrał tutaj północny odcinek rzeki Piaśnicy.

Torfowisko w Puszczy Darżlubskiej (stanowisko 3)

Na tym stanowisku sukcesja roślinności rozpoczęła się na przełomie młodszego dryasu i holocenu zbiorowiskami płytkiego zbiornika wodnego. Proces lądowacenia zainicjowała roślinność szuwarowa. Dalsze etapy zarastania zbiornika związane były z roślinnością bagienną. Obecność licznych szczątków roślin wodnych, a zwłaszcza pestek kilku gatunków z rodzaju *Potamogeton*, świadczy o istnieniu lustra wody w różnych okresach rozwoju zbiornika. Pożary oraz częste wahania poziomu wody spowodowały dużą rożnorodność ugrupowań bagiennych, a także okresowe wchodzenie zbiorowisk typowych dla torfowisk przejściowych.

Podsumowanie

Przedstawione opracowanie opiera się na analizie materiałów paleobotanicznych pobranych na trzech stanowiskach w okolicach Jeziora Żarnowieckiego (ryc. 4). Analiza pyłkowa umożliwiła prześledzenie historii roślinności na tym terenie od młodszego dryasu do okresu subatlantyckiego na podstawie interpretacji wyróżnionych w diagramach 8 poziomów pyłkowych (pollen assemblage zones). Zwrócono uwagę na regionalny i lokalny charakter niektórych zjawisk uchwyconych w diagramach. Dane dotyczące historii roślinności regionalnej wskazują na wpływ wilgotnego klimatu morskiego na kształtowanie się szaty roślinnej w poszczególnych etapach jej postglacjalnej sukcesji. Istotną rolę w przemianach roślinności badanego terenu odegrał człowiek. Wśród siedmiu z wyróżnionych faz osadniczych najsilniejsze piętno wywarły 5 i 6 faza osadnicza (grupa kaszubska kultury łużyckiej i kultura wschodniopomorska) oraz osadnictwo wczesnego średniowiecza.

Analiza makroszczątków ze wszystkich trzech stanowisk umożliwiła prześledzenie historii lokalnej roślinności badanych zbiorników sedymentacyjnych. Wyniki uzyskane z materiałów pochodzących z rynny Jeziora Żarnowieckiego wskazują na brak osadów zbiornika ancylusowego oraz zatoki litorynowej na tym terenie.

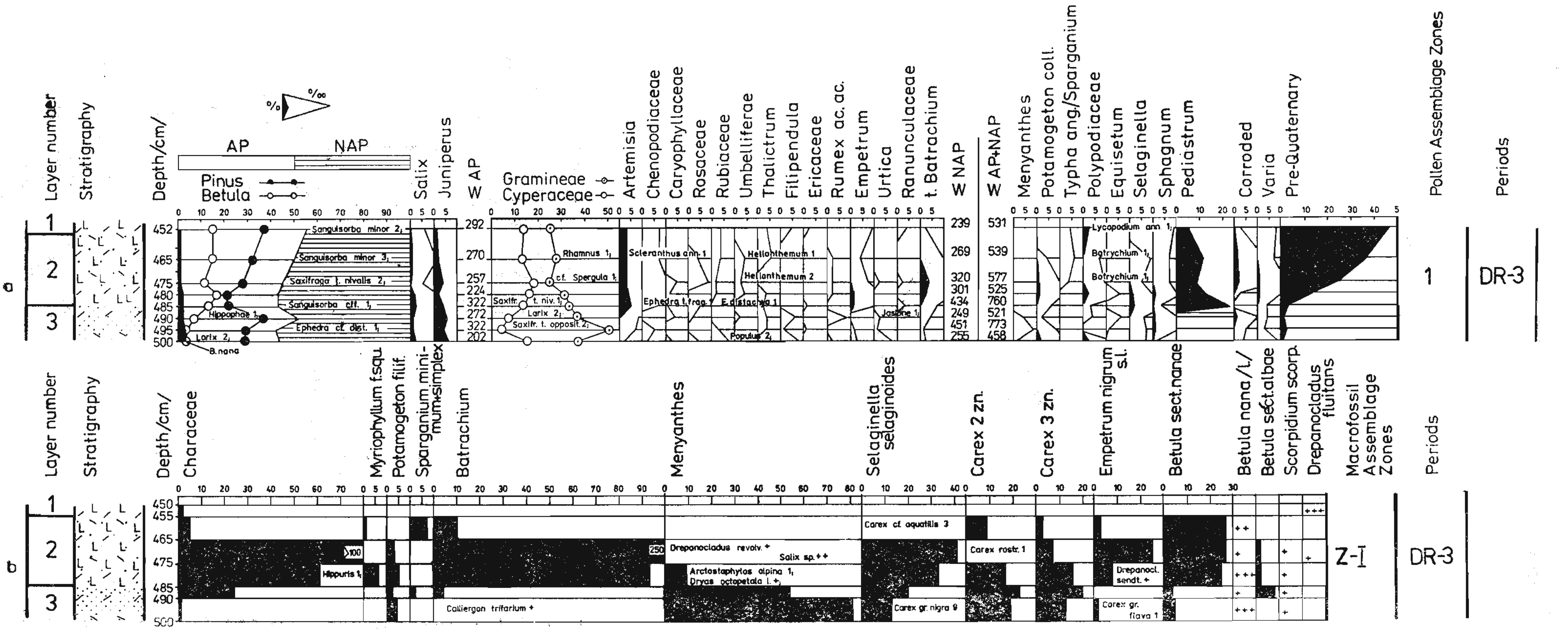

Fig. 12. Percentage diagram of pollen (a) and macrofossils (b) from the peat-bog near Lake Żarnowiec (profile Żar/75). For explanations, see text

M. Latałowa

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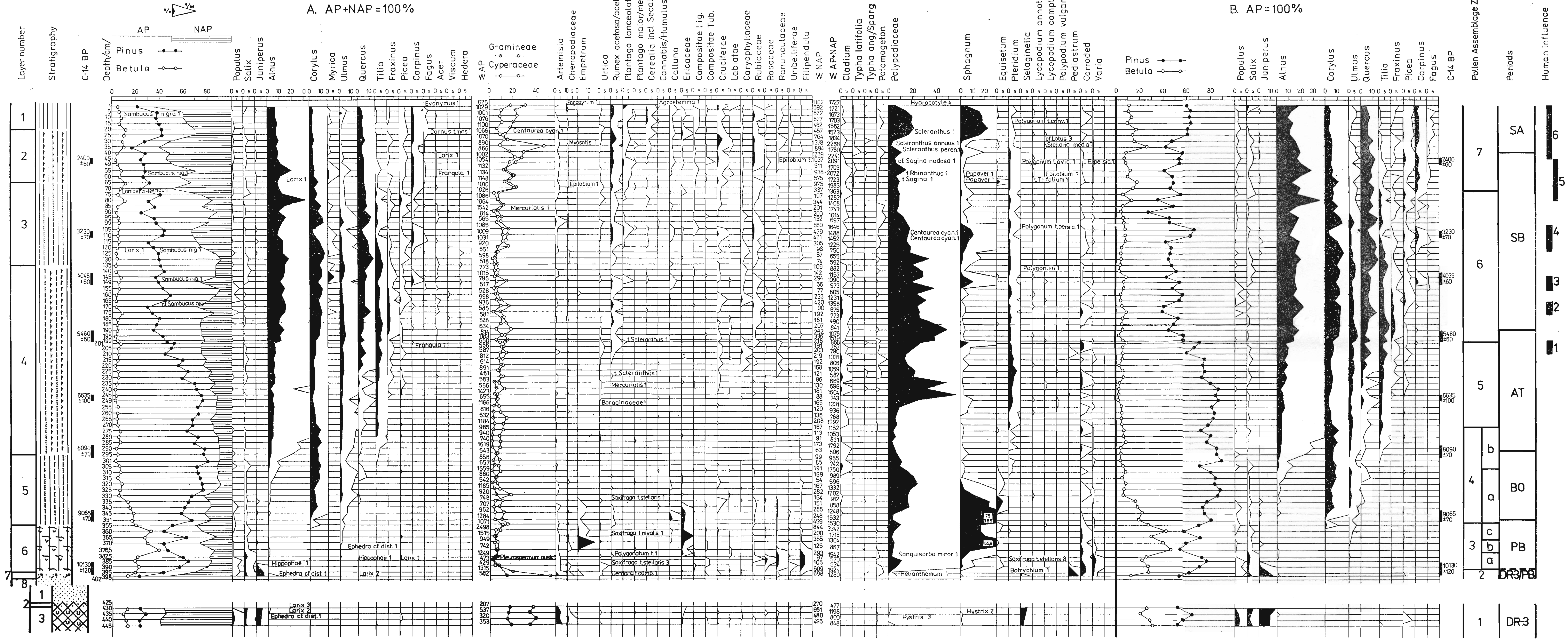

Fig. 13. Percentage pollen diagram for the peat-bog near Lake Żarnowiec (profile Żar/ 76). Percentage values of *Secale* pollen: 1-0,35%; 5-0,29%; 10-0,12%; 20-0,47%; 25-0,53%; 35-0,44%; 40-0,06%; 45-0,05%; 49-0,05%; 110-0,07%; 115-0,07%; 120-0,16%. For explanations, see text

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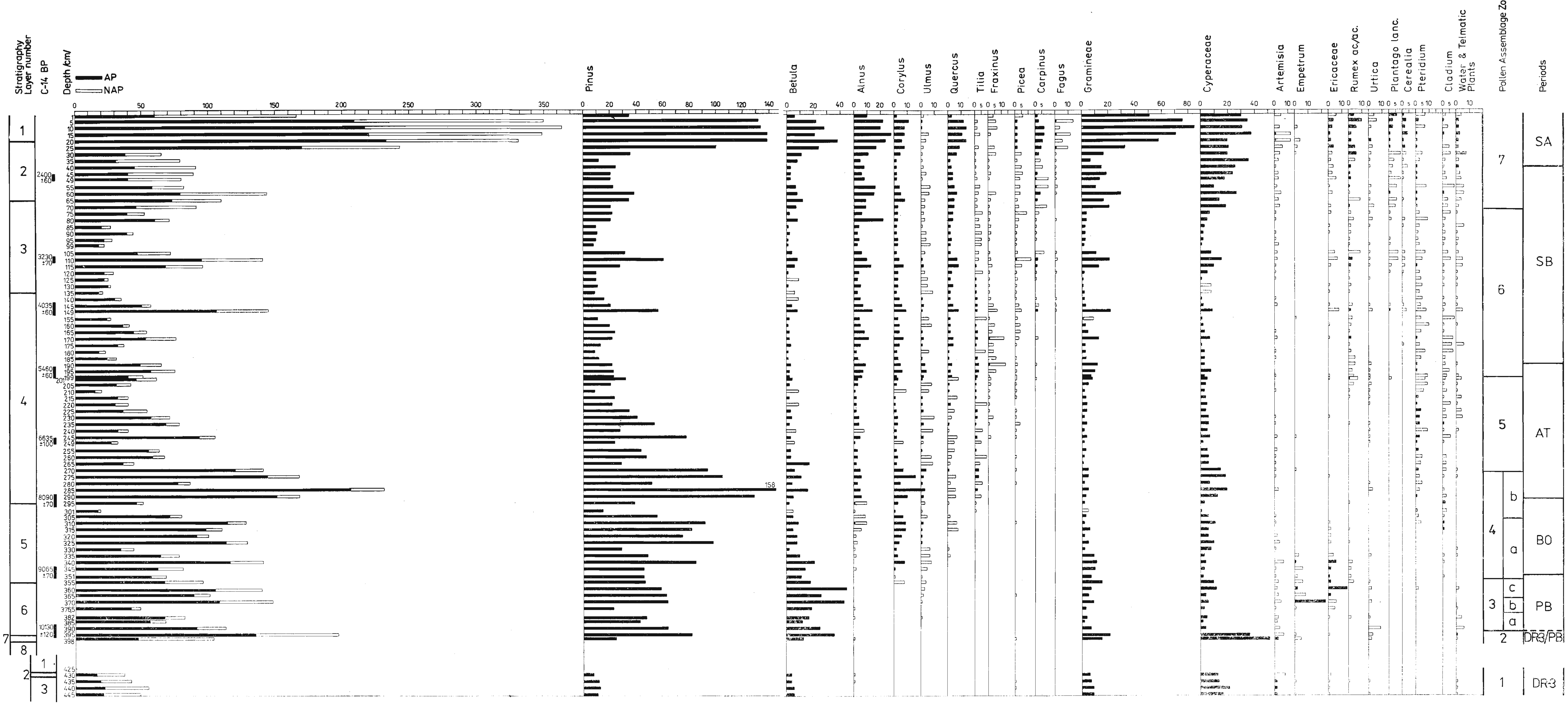

Fig. 14. Sporomorph concentration diagram for the peat-bog near Lake Żarnowiec (profile Żar/76). Values in thou/cm³ of sediment. Values in white columns have been multiplied by 10

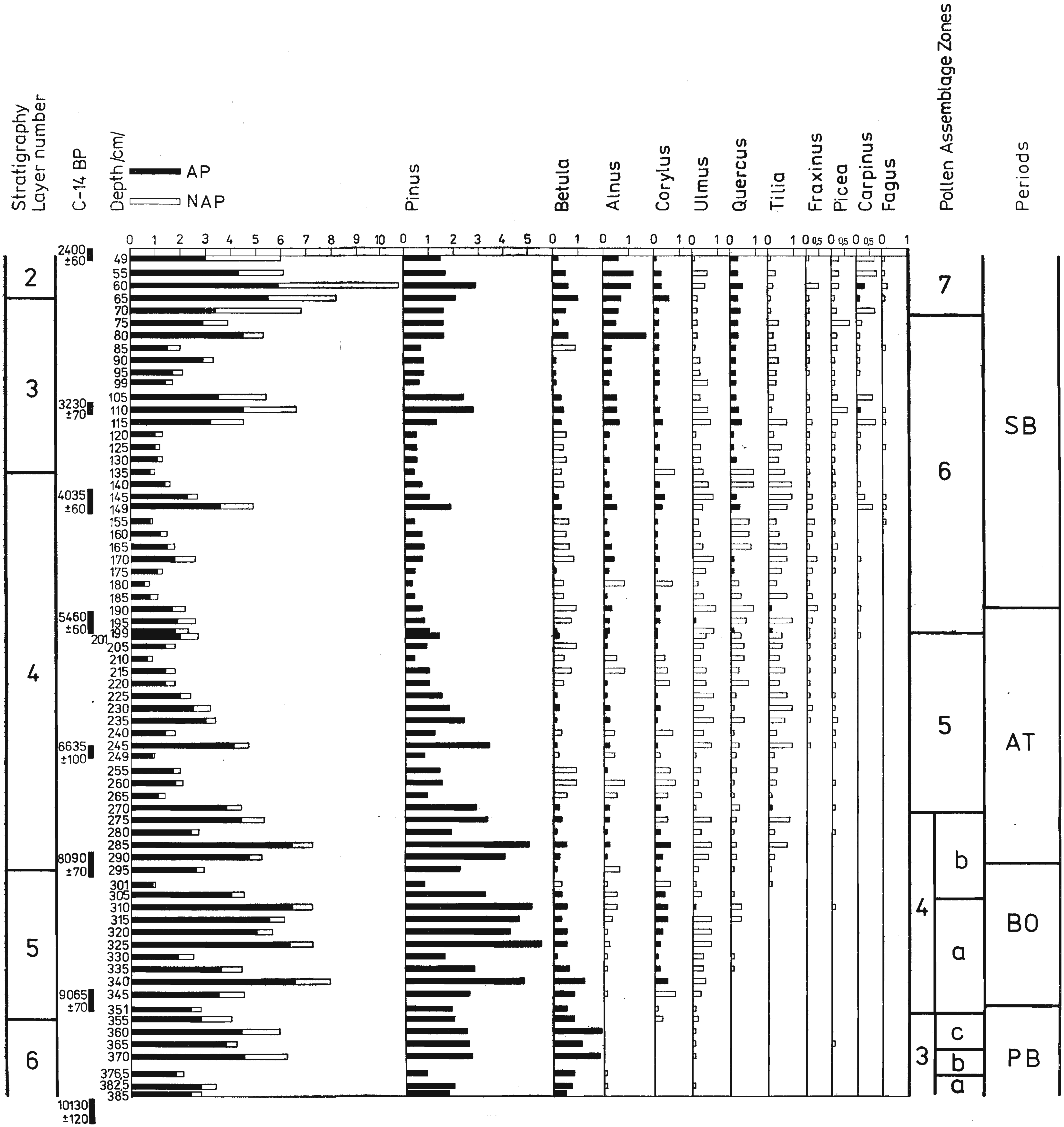

Fig. 15. Pollen influx diagram for the peat-bog near Lake Żarnowiec (profile Żar/76). Values in thou/cm²/year. Values in white columns have been multiplied by 10

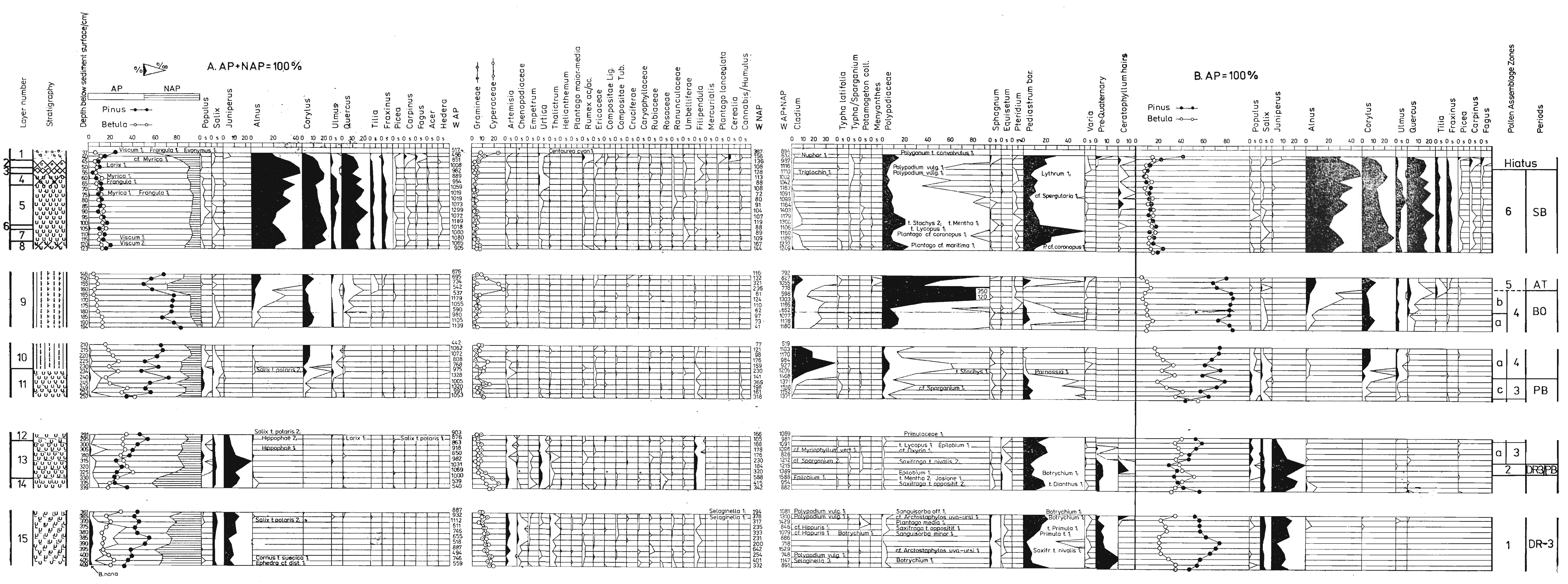

Fig. 16. Percentage pollen diagram for bottom sediments of Lake Żarnowiec (profile J. Żar/78). For explanations, see text

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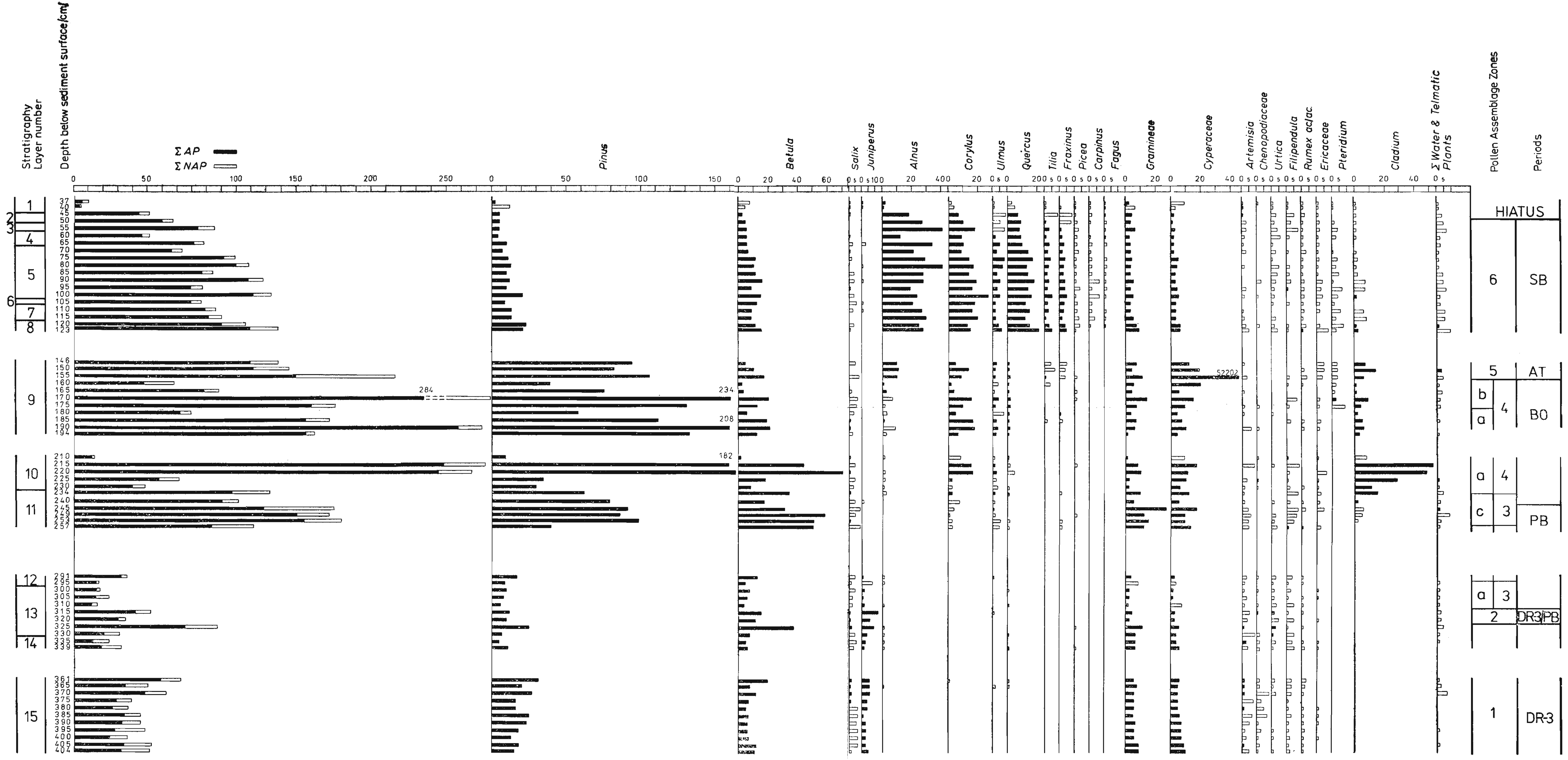

Fig. 17. Sporomorph concentration diagram for bottom sediments of Lake Żarnowiec (profile J. Żar/78). Values in thou/cm³ of sediment. Values in white columns have ben multiplied by 10

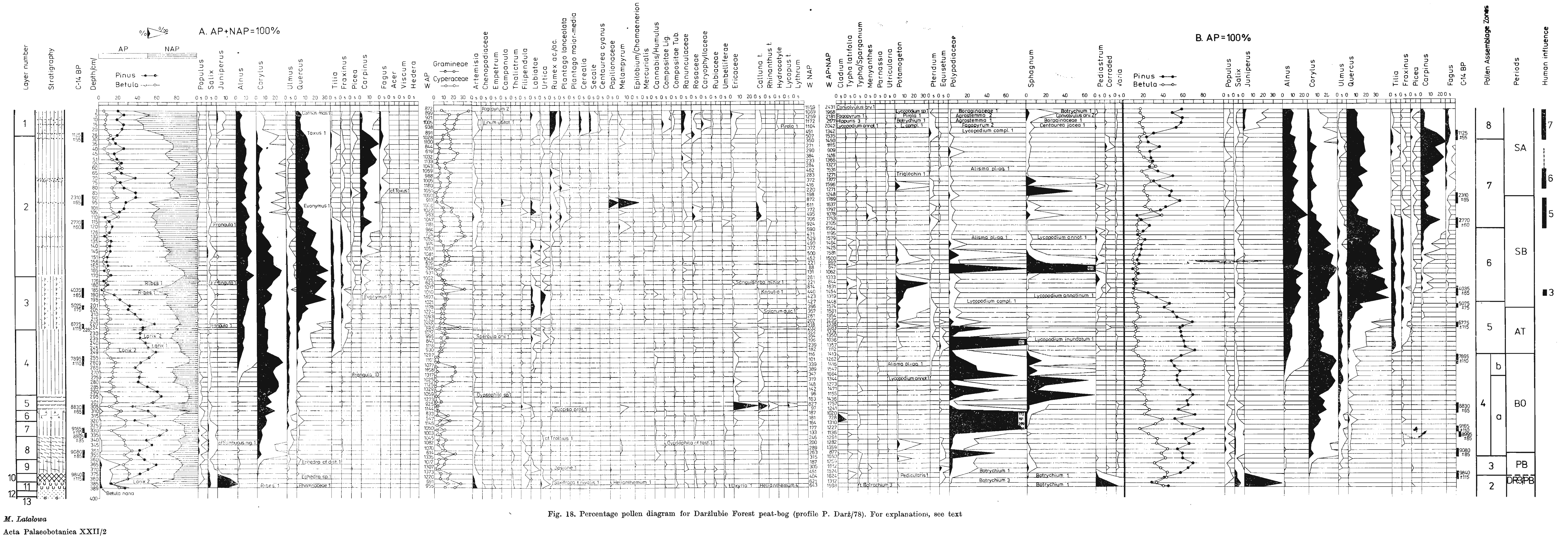

Fig. 18. Percentage pollen diagram for Darżlubie Forest peat-bog (profile P. Darż/78). For explanations, see text

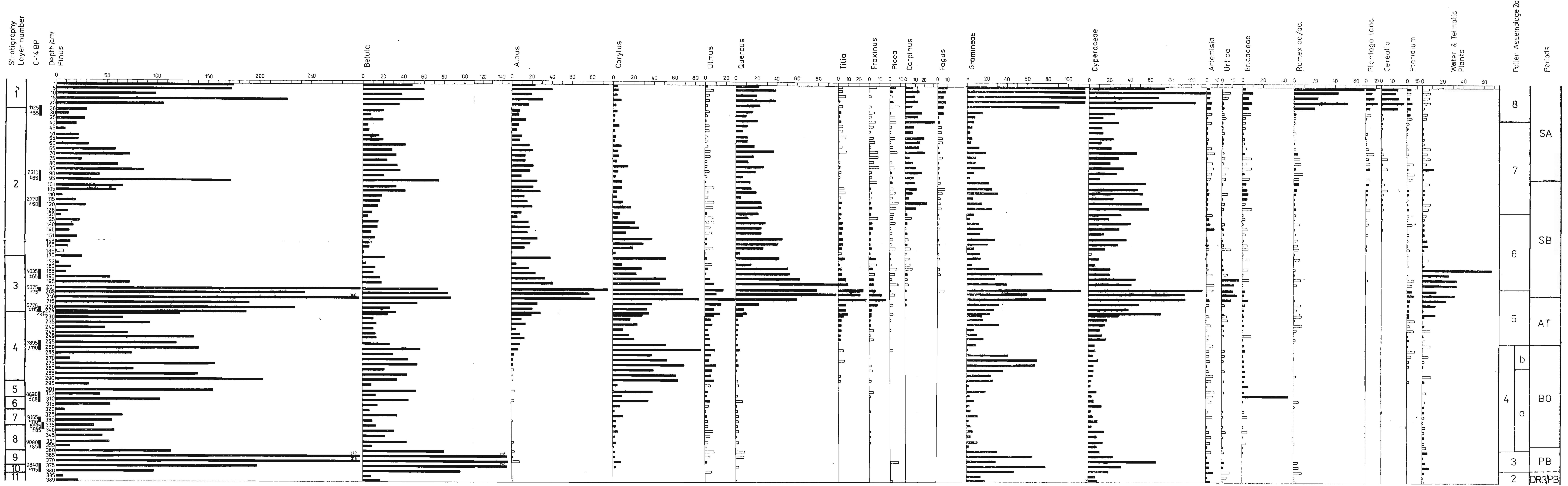

Fig. 19. Sporomorph concentration diagram for Darżlubie Forest peat-bog (profile P. Darż/78). Values in thou/cm³ of sediment. Values in white columns have been multiplied by 10

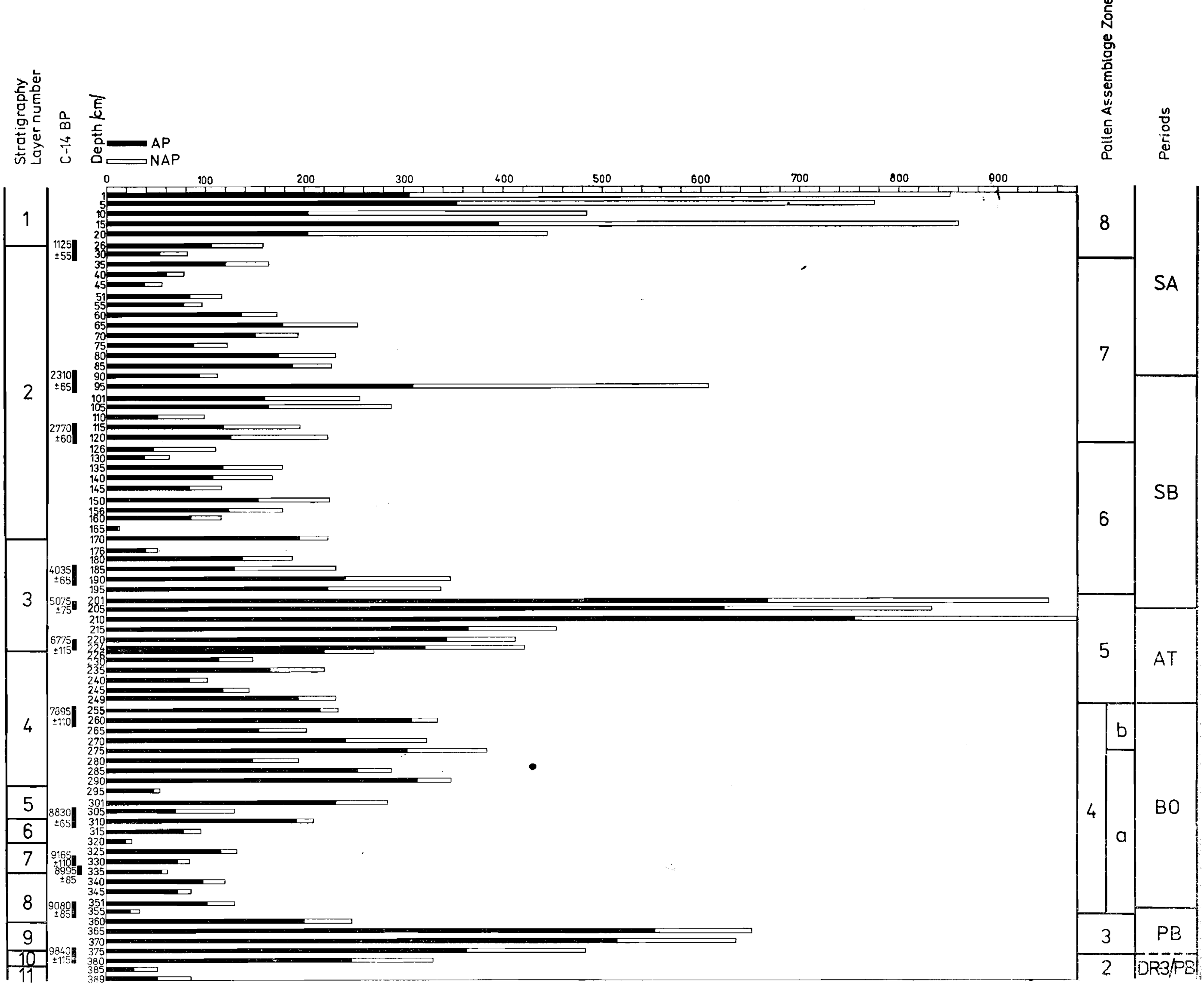

Fig. 19a. Sporomorph concentration diagram for Darżlubie Forest peat-bog (profile P. Darż/78). Values in thou/cm³ of sediment

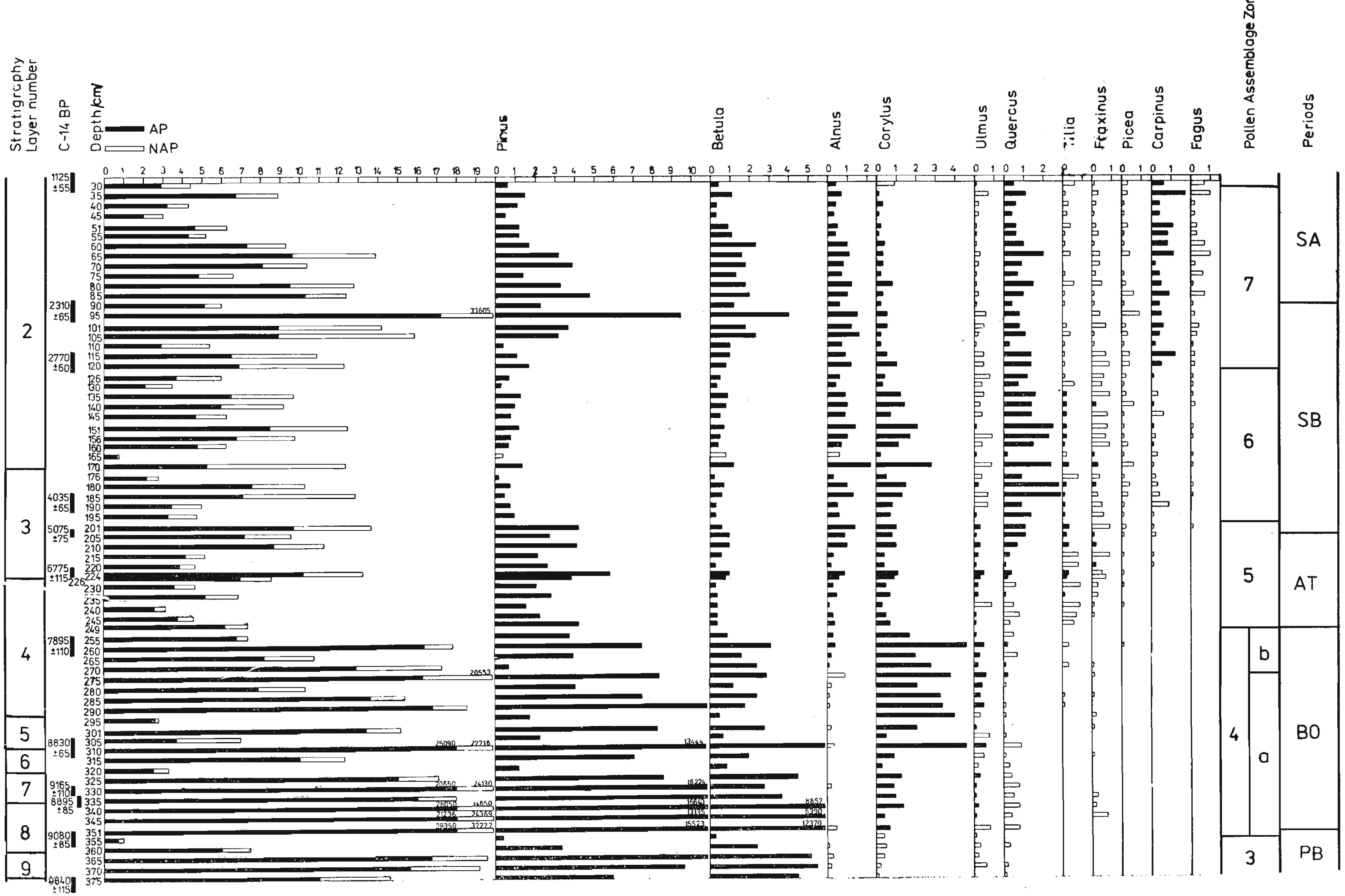

Fig. 20. Pollen influx for diagram Darżlubie Forest peat-bog (profile P. Darż/78). Values in thou/cm²/year. Values in white columns have been multiplied by 10

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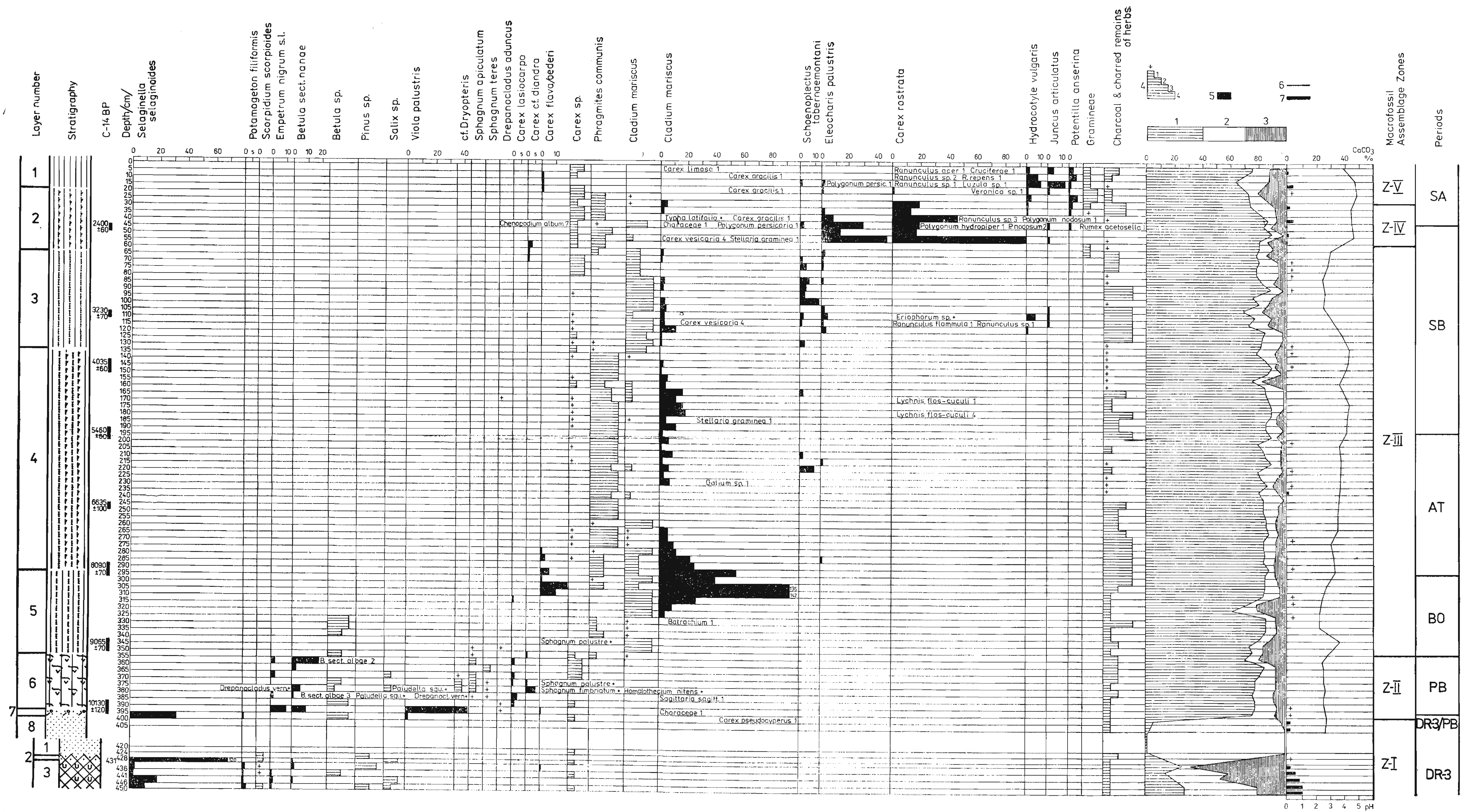

Fig. 21. Macrofossil diagram for the peat-bog near Lake Żarnowiec (profile Żar/78). 1 — Organic matter content; 2 — Silica content; 3 — Pure ash; 4 — Scale showing tissue content; 5 — Fruit and seed content; 6 — pH; 7 — $CaCO_3$ content. For other explanations, see text

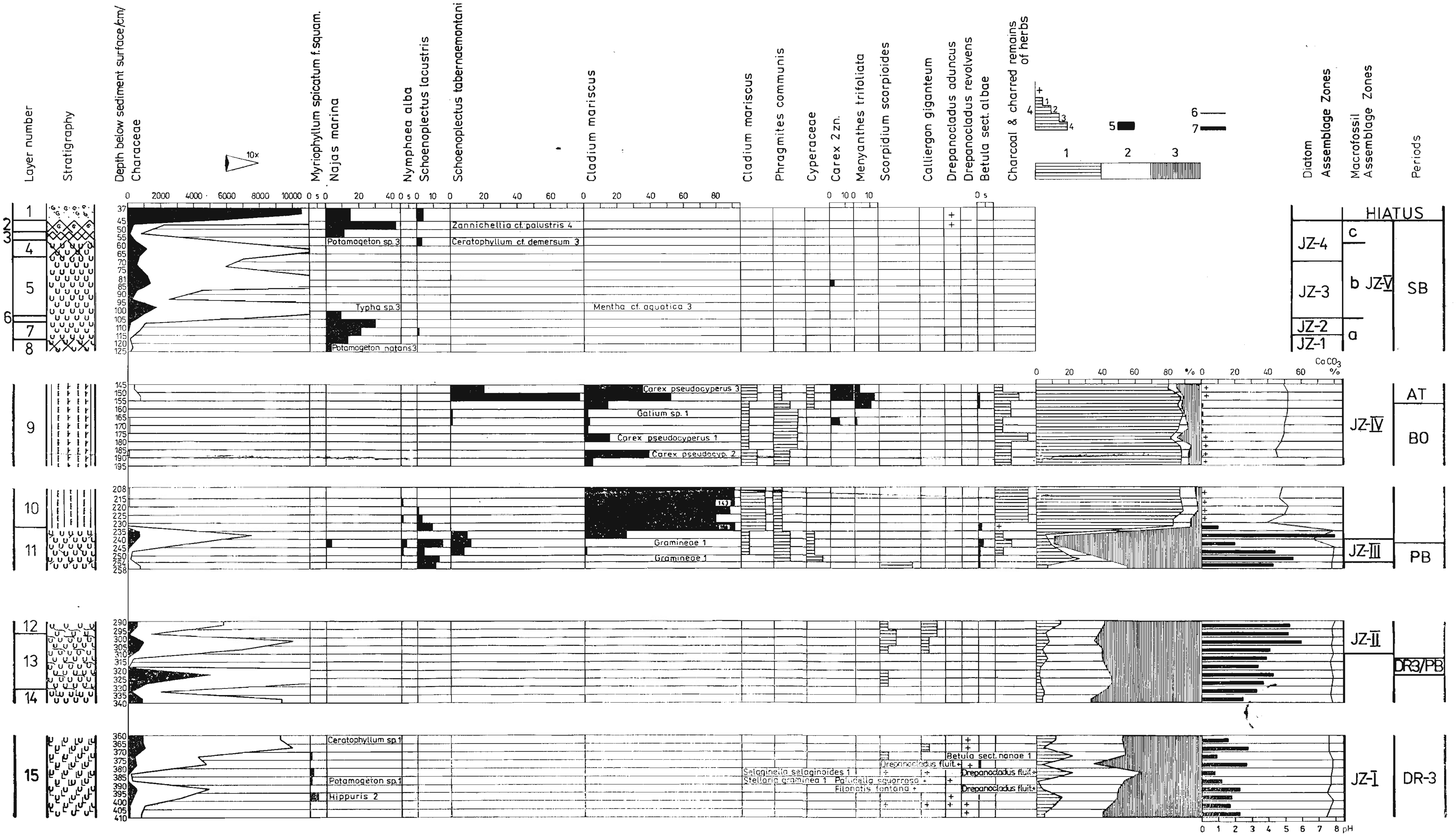

Fig. 22. Macrofossil diagram for bottom sediments of Lake Żarnowiec (profile J. Żar/78). 1 — Organic matter content; 2 — Silica content; 3 — Pure ash; 4 — Scale showing tissue content; 5 — Fruit and seed content; 6 — pH; 7 — CaCO$_3$ content. For other explanations, see text

Fig. 23. Macrofossil diagram for Darżlubie Forest peat-bog (profile P. Darż/78). 1 — Organic matter content; 2 — Silica content; 3 — Pure ash; 4 — Scale showing tissue content; 5 — Fruit and seed content; 6 — pH; 7 — CaCO₃ content. For other explanations, see text

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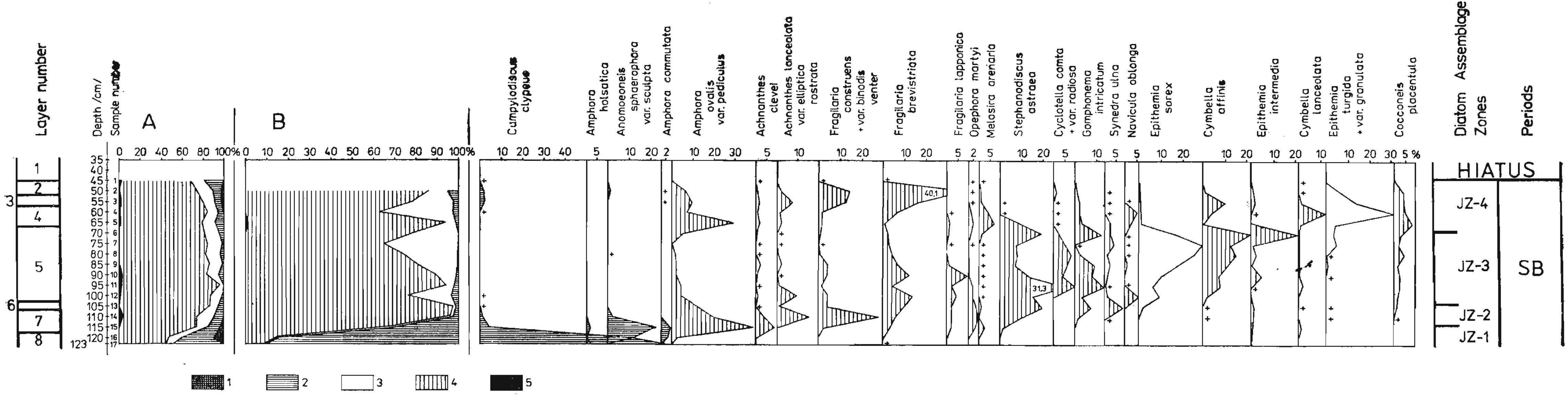

Fig. 24. Diatom diagram of the topmost section of the bottom sediment profile from Lake Żarnowiec (det. B. Adamczak). A — diatom species content in ecological groups; B — percentages of diatoms in ecological groups; 1 — euhalobes, 2 — mesohalobes, 3 — halophilous, 4 — oligohalobes, 5 — halophobes