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LATE MIDDLE POLISH GLACIATION, EEMIAN AND EARLY VISTULIAN VEGETATION AT IMBRAMOWICE NEAR WROCŁAW AND THE POLLEN STRATIGRAPHY OF THIS PART OF THE PLEISTOCENE IN POLAND

Roślinność schyłku zlodowacenia środkowopolskiego, interglacjału eemskiego i wczesnego Vistulianu w Imbramowicach koło Wrocławia oraz stratygrafia pyłkowa tej części plejstocenu w Polsce

ABSTRACT. The subject of this work is the development of vegetation in the Sudeten Foreland, as shown by a palaeobotanical study of the lacustrine deposits at Imbramowice (I) and the stratigraphic problems of the Eemian Interglacial and the adjacent glacial deposits in Poland (II).

The profile of Imbramowice has been studied by means of pollen and macrofossil analyses; some analyses of the deposit itself have also been carried out.

The pollen and macrofossil flora consists of 320 taxa of varying taxonomic ranks; 158 of them have been determined to specific level.

Fourteen local pollen assemblage zones (L PAZ) have been distinguished in the pollen diagram and 11 local macrofossil zones (L MAZ) in the macrofossil diagram.

The inferred history of vegetation in the area surrounding the Imbramowice Depression and that of the lake vegetation is described with reference to the division into regional pollen assemblage zones in Poland (described in the second part of the work). The history of vegetation covers a period from the Late Glacial of the Middle Polish Glaciation s. l. (= Saalian s. l.) to the first stadial of the Early Vistulian.

A scheme of pollen stratigraphy from the Late Glacial of the Middle Polish Glaciation s. l. to the end of the Early Vistulian is presented in the second part of this work. It includes only those glacial deposits which occur together with the Eemian in continuous profiles. The stratigraphy has been based on the regional pollen assemblage zones distinguished in Poland. Imbramowice is the type locality for many of them. The bases for establishing the boundaries between the Middle Polish Glaciation s. l. and the Eemian and between the Eemian and the Vistulian are given.

Three different types of succession have been found in the Late Glacial of the Middle Polish Glaciation. Two of them are of regional significance, Imbramowice and Szwajcaria being their type localities, the third one is represented by a tripartite sequence of pollen zones at Warszawa-Wawrzyszew, of a local nature at present but which will probably have a regional application in the future.

Seven regional pollen assemblage zones (E1—E7) with extensive geographic ranges have been distinguished in the Eemian. In the E4 — *Corylus-Quercus-Tilia* R PAZ subzone E4a is differentiated into three geographically significant variants on the basis of differences in the proportions of *Tilia* pollen.

The Early Vistulian pollen succession has been divided into five regional zones (EV1—EV5). Zones EV1, EV3 and EV5 correspond to three stadials. Zones EV2 and EV4 represent interstadial oscillations, which have been correlated with the Brørup (& Amersfoort) and Odderade Interstadials.

An attempt is made to carry out a reinterpretation of the phenomenon defined as the "second climatic optimum" in Polish literature. A dozen sites or so for which the pollen data do not justify this stratigraphic position have been withdrawn from the Eemian Interglacial.

CONTENTS

INTRODUCTION

This work consists of two parts: the results of studies on a profile at Imbramowice are given in the first part, while the second part is an attempt at synthesising the pollen stratigraphy of the Eemian and the glacial deposits that accompany it in continuous sequences in Poland.

The palynological study and identifications of most of the fruits and seeds from the Imbramowice profile have been carried out by the author of the present work (the genus *Carex* with the help of Dr. K. Rybniček). Several specialists also participated in this investigation: Dr. I. Kaczmarska studied diatoms (1976), Prof. K. Karczmarz mosses and stoneworts (this volume), Dr. M. Aalto identified fruits of *Potamogeton*, Z. Tomczyńska A.E. wood, Dr. I. Dmoch molluscs and Prof. J. Pawłowski *Coleoptera*. The fish remains were forwarded for study to Prof. A. Jerzmańska. Tests for organic matter and carbonate content were performed at the Laboratory of the Department of Soil Science, Agricultural University in Cracow, and granulometric analyses at the Geological Survey of Poland in Warsaw.

In 1904 the Imbramowice site was discovered by Gürich at a clay-pit, then in exploitation for bricks, and the first plant remains from it were identified by Lingelsheim (Gürich 1905). The macroscopic flora from the profile discovered by Gürich was studied by Hartmann (1907). Both Gürich and Hartmann referred the Imbramowice sediments to the Holstein Interglacial (= Mazovian Interglacial). Środoń (1960) was the first to suggest the Eemian age of this flora.

In 1925 the bed of plant fossiliferous silts and clays at the brickyard was considered to be completely worked out (Mühlen 1925, after Szczepankiewicz 1962). In 1960 Prof. S. Szczepankiewicz's geomorphological investigations resulted in the sinking of a boring in the Imbramowice Depression, which provided a 22-metre-deep profile.

A preliminary report on the results of pollen analysis of this profile covered a section from 2.40 to 11.15 m (Mamakowa 1976). The study was interrupted at 11.15 m, because of the high proportion of redeposited pollen, which at that level reached above 50% in relation to the total sum. Between 1976—1979 pollen analysis was also done for the lower part of the profile (11.15—21.65 m) and a macrofossil analysis was made for the whole of the profile. Those studies showed that late-glacial sediments extend downwards to 2.65 m below the layers discussed in the preliminary report.

The results of the pollen and macrofossil analyses of the part of the profile representing the Late Glacial of the Middle Polish Glaciation s. l., Eemian Interglacial and the Early Vistulian are given in the present paper. The results of studies on the older part of the profile will be published separately.

Part II of this work contains a survey and appraisal of all the available results of pollen analytical studies concerning the Eemian and the glacial stages accompanying it in continuous sequences from the territory of Poland made until 1985. An attempt is made to present the stratigraphy of this section of the Pleistocene in Poland on the basis of the recognizable regional pollen assemblage zones.

These problems were presented by the author at the scientific sessions in Wrocław (1980), Poznań and Warsaw (1984) and a report on the pollen stratigraphy of the Early Vistulian in Poland has been published (Mamakowa 1986).

STRATIGRAPHIC TERMINOLOGY

The term Middle Polish Glaciation (MPG) is used in a broad sense as a stage (age) of the Middle Polish Glaciation s. l. (= Saalian s. l.)

The term Late Glacial of the Middle Polish Glaciation (LG MPG) is used in the sense proposed by Menke (Menke & Ross 1967; Menke 1970), i.e. as the youngest substage (or age) of the Middle Polish Glaciation s. l. It is an informal unit, for the Middle Polish Glaciation s. l. has not, as yet, been divided biostratigraphically.

The term Eemian Interglacial (EI) is used in the sense of a chronostratigraphic unit with its stage rank acknowledged as the last interglacial (Andersen et al. 1960; Mangerud et al. 1974; Zagwijn & Staalduinen 1975).

The terms Vistulian (V) and Vistulian Glaciation (VG) are used in conformity with the resolutions made at the "Symposium on Vistulian stratigraphy, Poland 1979" as the equivalent of the youngest cold stage after the Eemian. In earlier Polish divisions they correspond with the terms: Varsovien 2 (Szafer 1928), Baltic Glaciation (Halicki 1946), North Polish Glaciation (Rühle 1957) and glaciation G IV (S. Z. Różycki 1972).

The term Early Vistulian (EV) is applied according to the proposed division of the "Weichselian Stage" (Mangerud et al. 1974) and the resolutions of the "Symposium on Vistulian Stratigraphy, Poland 1979".

The pollen assemblage zones (PAZ) are pollen-stratigraphic units of local and/or regional significance (L PAZ, R PAZ). The definition and bases for zone distinguishing are given in Part II, p. 98.

The macrofossil assemblage zones (MAZ) have been distinguished at Imbramowice and described as biostratigraphic units of local significance.

PART I. PALAEOBOTANICAL STUDIES AT IMBRAMOWICE

SITE DESCRIPTION

Imbramowice is situated between the rivers Bystrzyca and Strzegomka, about 40 km south-west of Wrocław, in the Sudeten Foreland (Fig. 1). The Imbramowice Depression, about 3 km in length and about 0.5 km across, is surrounded by a Pleistocene plateau with hills of Older Palaeozoic substrates rising above it in the south and in the north (Fig. 2). This area lies within the range of the South Polish Glaciation (= Elsterian Gl) and the Middle Polish Glaciation (= Saalian Gl) (Szczepankiewicz 1969). Only the maximum Odra range of the Middle Polish Glaciation (Odra Stadial = Radomka Glacistadial, acc. to S. Z. Różycki 1972)

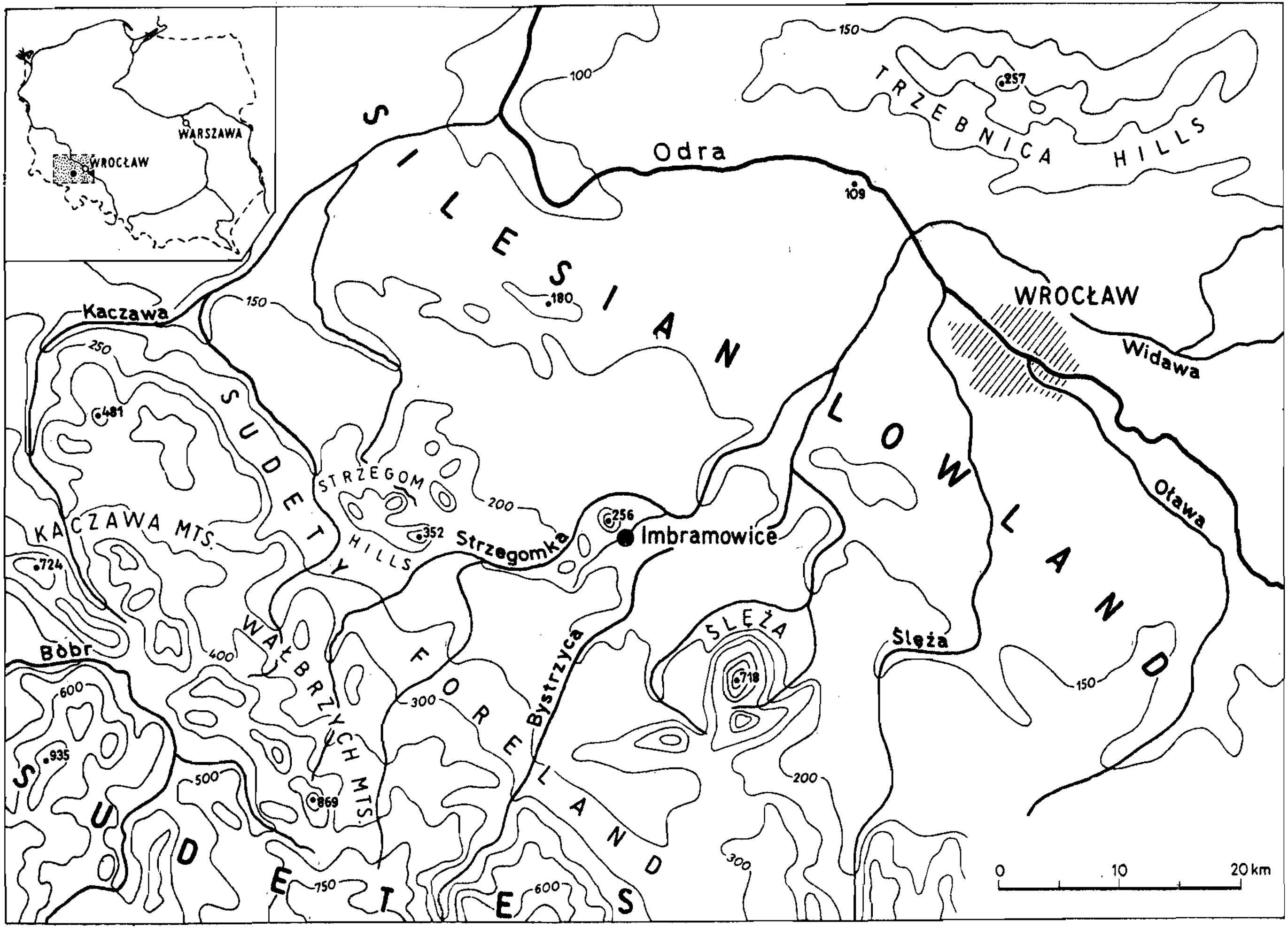

Fig. 1. Topographical map showing the area surrounding Imbramowice

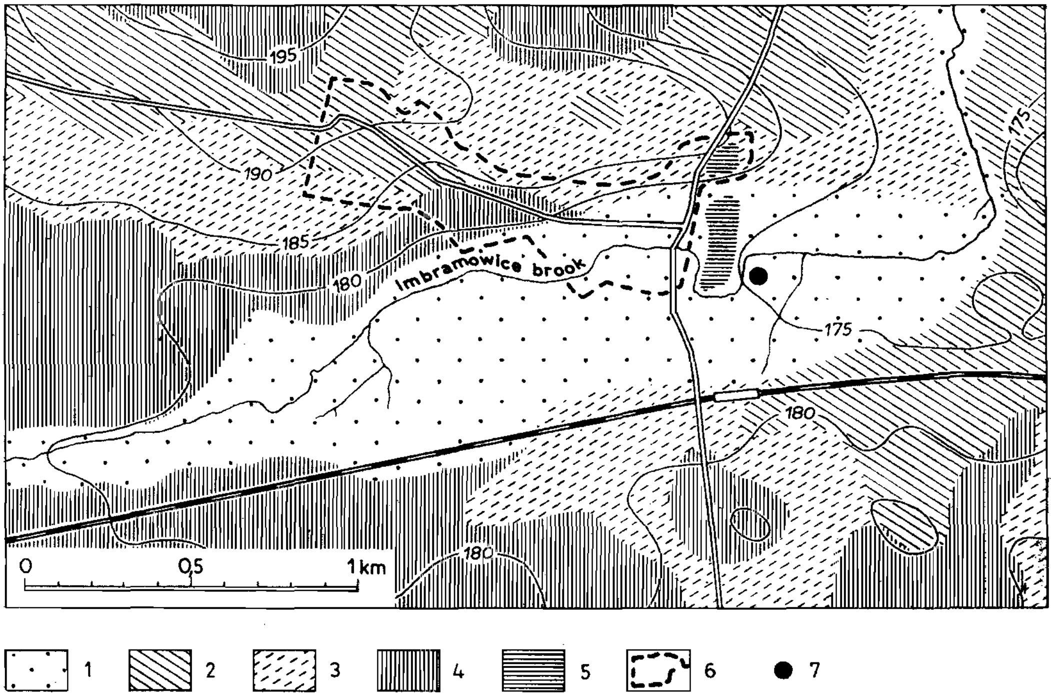

Fig. 2. Simplified geological sketch of the local vicinity of Imbramowice (after Szczepankiewicz 1962). 1 — mud and river gravels, 2 — loam and fine sands on boulder clay, 3 — loam and fine sands on glacifluvial deposits, 4 — loam and sands on Tertiary and older deposits, 5 — Tertiary clay in outcrop, 6 — boundary of the Imbramowice locality, 7 — location of boring

included this region. The terminal moraines, referred to the Warta Stadial, extend along the line of the Trzebnica Hills and Ostrzeszów Hills, that is, about 50 km to the north. In Szponar's (1965) opinion, in the forefield of the moraines of the Warta Stadial are the Rościsławice moraines, older than the former and associated with a retreating lobe of the Middle Polish Glaciation.

The Imbramowice Depression is of erosional origin prior to the advance of the Middle Polish ice. Varved clays deposited in front of the ice sheet constitute the oldest Pleistocene series here. The ground moraine clay and glaciofluvial sediments of the Maximum Stadial of the Middle Polish Glaciation were laid down on those clays in the period of the deglaciation of the Sudeten Foreland (Szczepankiewicz 1962, 1969, 1976a).

The profile studied in the present work is situated in the eastern, deepest part of the Imbramowice Depression. The boring performed here did not reach the boulder clay which, according to Szczepankiewicz (1962), sinks from the adjacent upland under the lacustrine sediments. The top of the moraine had, in his opinion, a concave shape in conformity to the relief of the older substratum. However, the moraine did not fill entirely the hollow and a series of lacustrine sediments was deposited in the remaining depression. It starts with sand and gravel washed from the top of the ground moraine (Szczepankiewicz 1962) and ends with silts, the upper part of which, in accordance with the interpretation presented in this paper, should be referred to the beginning of the Early Vistulian. Szczepankiewicz (1962) assigned only the slope deposits encroaching upon the lacustrine sediments at the margins of the depression to the periglacial of that glaciation. According to him, the youngest sedimentary series in the Imbramowice Depression consists of Holocene river gravels and muds, separated from the silts by a clear erosional boundary.

After the recession of the Middle Polish ice sheet the Imbramowice Depression found itself at the watershed of the Bystrzyca and Strzegomka rivers. It was not included in the system of Strzegomka tributaries before the transition period between the Pleistocene and the Holocene (Szczepankiewicz 1962).

BORING AND SEDIMENT DESCRIPTION

Sediment samples for analyses were derived from the core obtained by means of Kerst's apparatus over a space from 2.40 to 4.80 m and using a borer of the type used in the building industry to a depth of 21.65 m. Sand, flushed out by drilling fluid, was lost from a section between 6.05 and 6.20 m.

The location of the boring is shown in Fig. 2; its depth was measured from the surface of the meadow. A simplified system of Troels-Smith (1955) has been adopted in the sediment description. The symbols used for the constituents of the sediment are explained in Fig. 3. The upper layer boundary (lim. sup.) is differentiated as follows: lim. sup. 0 — boundary area > 1 cm; lim. sup. 1 (diffusus) — boundary area < 1 cm and > 2 mm; lim. sup. 2 (conspicuus) — boundary area < 2 mm and > 1 mm; lim. sup. 4 (acutus) — boundary area < 0.5 mm.

Layer No	Depth in m	Sediment description
22	0.00—0.40	Soil
21	0.40—1.20	Sandy-clayey mud.
20	1.20—2.40	Gravel with sand.
19	2.40—2.50	Sand with fine gravel; light grey; charcoal dust at 2.45 m depth. Ga 2, Gs 1, $Gg^{min+maj}$ 1 As +, [anth. (+)]; lim. sup. 4.
18	2.50—3.04	Silt with fine sand and a small admixture of gyttja; light grey to dark grey, with brown streaks; charcoal dust in several samples. Ag 2.5, Ga 1, Ld^1 0.5, As + +, Dg +, Gs +, Lso (+), $Gg^{min+maj}$(+), [anth. (+)]; lim. sup. 4.
17	3.04—3.20	Sand with silt and traces of fine gravel; light grey to dark grey; charcoal dust present. Ga 2, Ag 1.5, Gs 0.5, Ld^1 +, As +, Lso (+), $Gg^{min+maj}$ (+), [anth. (+)]; lim. sup. 4.
16	3.20—3.69	Sandy fine detritus silt with sporadic gravels; light grey; charcoal dust at 3.24—3.66 m depth. Ag 2, Ga 1.5, Dg 0,5, Ld^1 + + +, As +, Gs +, Lso (+), $Gg^{min+maj}$ (+), [anth. (+)]; lim. sup. 4.
15	3.69—4.40	Sandy silt with sporadic gravels and an admixture of fine detritus gyttja; variable coloration, from light beige to dark grey; small charcoal pieces at 3.72 and 4.35 m. Ag 3, Ga 0.5, Ld^2 0.5, Lso + +, Dg + +, As +, Gs +, Gg^{min} (+), [anth. (+)]; lim. sup. 1.
14	4.40—4.50	Fine detritus silt with gyttja and some sand, dark brown. Ag 3, Ld^2 1, Ga + + +, Dg + +, Dl +, Lc +, Lso +, As +; lim. sup. 0.
13	4.50—5.50	Coarse detritus sandy silt with gyttja; distinct band of sand with gravel at 4.65 m; variable colouration, dark and light brown; charcoal dust at

Layer No	Depth in m	Sediment description
		5.25 m. Ag 1.5, Ga 1.5, Ld^2 1, Dl + + +, Lso +, As +, Gs + Lc (+), [anth. +]; lim. sup. 0. Sand band: Ga 1.5, Gs 1, Ld^2 1, Ag 0.5, Dl + +, Dg +, As +, Gg$^{min+maj}$ (+).
12	5.50—5.70	Coarse detritus sandy silt with gyttja and with thin laminae of sand at 5.60—5.65 m; dark grey. Ag 1.5, Ga 1.5, Ld^2 1, Dg + +, Dl + +, Ga + +, Gg^{min} (+), (Lso ?); lim. sup. 2.
11	5.70—5.90	Sandy silt with a small admixture of gyttja and with sporadic fine gravels; grey-brown with rusty infiltrations. Ag 2.5, Ga 1, Ld^2 0.5, Gs + +, Dl +, As +, Lc (+), Lso (+), Gg$^{min+maj}$ (+); lim. sup. 1.
10	5.90—6.05	Silty sand with fine gravels; beige-rusty; charcoal dust at 6.00 m.Ga 2, Gs 1, Ag 1, Ld^2 + + +, Dg +, Dl +, As +, Lc (+), Lso (+), Gg$^{min+maj}$ (+), [anth. +]; lim. sup. 4.
9	6.05—6.20	Sand lost when boring.
8	6.20—6.40	Peaty coarse detritus gyttja with sandy silt, low CaCO$_3$ content and with snails at bottom (tyrphopel?); dark brown to almost black at top; charcoal dust at 6.25. Ld^2 2, Ag 1, Th^2 0.5, Ga 0.5, Gs + + +, Dh + +, Dl +, As +, Lc (+), Lso (+), [part. test, moll. + +], [anth. +]. No upper boundary owing to the loss of overlying sand.
7	6.40—6.95	Diatomaceous-calcareous gyttja, silty and with traces of sand, sporadic gravels and detritus; dark beige to light beige. Ld^2 1, Lc 1, Lso 1, Ag 1, Ga + + +, Dh + +, Dl +, As +, Gs (+), Gg$^{min+maj}$ (+), [part. test. moll. + + +]; lim. sup. 1.
6	6.95—8.00	Diatomaceous-calcareous gyttja with a small admixture of fine sand, with fine detritus and sporadic fine gravels; whitish-beige to 7.25 m depth, below beige with light grey bands. Lc 1.5, Ld^2 1, Lso 1, Ga 0.5, Ag + + +, Dg + +, Dh + +, Dl + +, As +, Gs (+), Gg^{min} (+), [part. test. moll. + +]; lim. sup. 0.
5	8.00—9.65	Diatomaceous-calcareous gyttja with silt, fine detritus and a small admixture of fine sand; dark beige to 9.15 m, below light beige; charcoal dust at 8.15 m. Lc 1.5, Ag 1, Ld^2 0.5, Lso 0.5, Ga 0.5, Dg + +, Dh +, Dl +, As +, Gs (+), [part. test. moll. + +], [anth. (+)]; lim. sup. 0.
4	9.65—10.20	Silt with diatomaceous-calcareous gyttja with traces of sand; light beige with grey bands; charcoal dust from 9.90—10.20 m. Ag 2, Lc 1, Ld^2 0.5, Lso 0.5, Ga + + +, Dg + +, Dh + +, Dl + +, As +, Gs (+), [part. test. moll. (+)], [anth. + +]; lim. sup. 1.
3	10.20—10.40	Sandy silt with a small admixture of calcareous gyttja; light beige; charcoal dust at layer bottom. Ag 2, Ga 1, Lc 0.5, Ld^2 0.5, Lso + + +, Dg +, As +, Gs (+), [anth. +]; lim. sup. 1.
2	10.40—12.40	Sandy silt with a small admixture of detritus gyttja and CaCO$_3$; changing shades of beige; charcoal dust in several samples and charred herbaceous remains at top. Ag 3, Ga 1, Lc + +, Ld^2 + +, Dg +, Dl +, As +, Lso (+), [part. test. moll. +], [anth. (+)]; lim. sup. 1.
1	12.40—13.90	Silt with traces of sand and some CaCO$_3$ and detritus gyttja content; variable colour — beige, brown, grey, rusty; indeterminable pieces of mollusc shells at 12.40—12.50 and 13.00—13.10 m, charcoal dust and small pieces of charred herbaceous remains in several samples. Ag 4, Dg + + +, Dl + +, Lc + +, Ld^2 + +, Ga + +, As +, Gs (+), [part. test. moll. (+)], [anth. + +]; lim. sup. 1.

METHODS

Sampling and sample preparation for pollen analysis

Samples for pollen analysis were taken from the central portion of the core Not all the samples taken were studied; the intervals between those examined were dependent on changes observed in the plant succession. Sample volume was about 10 cm^3, permitting the separation of material for diatom, loss on ignition and grain-size distribution analyses. Because of the small amount of material in some samples, a grain-size distribution analysis was carried out at several levels using material from neighbouring samples to those in which pollen analysis was done.

Samples containing carbonate were first treated with cold hydrochloric acid. All the samples were boiled with 10% KOH, decanted and screened to remove coarse sand and detritus. Next they were treated with hot hydrofluoric acid (about 10 min.), treated with hot hydrochloric acid and subjected to Erdtman's acetolysis. The residues were stained with basic fuchsin. The samples were stored and counted in pure glycerine.

Sediment analysis

The organic matter content in the sediment was determined as the loss on ignition for 3 hours at 450° C. It is expressed as percentages of the weight of dry sediment.

The $CaCO_3$ content was obtained by determining CO_2 by Scheibler's method in the residual material left after ignition. It is also expressed as percentages of the weight of dry sediment.

A grain-size distribution analysis was made by the pipette method. Whole snail shells including large fragments, and coarse animal and plant detritus were removed, but small fragments of shells may have remained in each fraction. In the results of this analysis, proportions of particular fractions were calculated as percentages by weight in the following grain-size groups (in mm): above 2,2—1, 1—0.5, 0.5—0.25, 0.25—0.1, 0.1—0.05, 0.05—0.01, 0.01—0.005, below 0.005. These intervals were reduced by interpolation to the scale used by Troels-Smith (1955); only one fraction of very fine-grained sand (0.1—0.06) was additionally distinguished.

The results of the foregoing analyses are presented on a diagram (Fig. 3). The amount and sort of detritus were estimated from the residue obtained by straining the material boiled in KOH and on the basis of observations made during macroscopic and microscopic studies. The colour of sediment was determined using damp material, but not immediately after its being collected.

Pollen and macrofossil analyses

Most of the samples were examined using an Amplival Zeiss microscope with apochromatic objectives: ×16—NA = 0.40, ×40—NA = 0.95, ×100HI—NA = 1.32 and a phase-contrast objective ×100HI—NA = 1.25. An OK 15KM PZO ocular micrometer was used for taking measurements.

Pollen spectra were counted on at least two slides. Depending on their frequency, pollen and spores were counted all over the area of the slide or in every second or third traverse but always right across the area, whereas the intermediate traverses were inspected.

The complete documentation has been deposited in the archives of the Department of Paleobotany, W. Szafer Institute of Botany, PAScs., in Cracow.

Material for macroscopic study was derived from the same core. On account of some difficulties in boring, samples were taken in sections of 10—30 cm each to a depth of 4.80 m and in 10- or 15-cm sections from 4.80 m to the bottom. The material was stored in a dry state.

About 250 cm^3 of sediment of each sample was used for study. It was boiled in water with an admixture of KOH and washed through double 0.5 and 0.2 mm mesh sieves. Both fractions of the material were searched under a binocular microscope for macrofossils, which were identified using an USSR MBS-2 microscope. Measurements, accurate within 0.05 mm, were taken with an ocular micrometer. The macrofossils are deposited in the museum of the W. Szafer Institute of Botany, PAScs, in Cracow.

Diagrams

The results of pollen analysis are presented in the form of a percentage pollen diagram (Fig. 3). The calculations are based on the basic pollen sum (ΣP), including trees, shrubs, dwarf shrubs and herbs but excluding aquatic and swamp plants, spores of *Pteridophyta* and *Sphagnum,* unknown, indeterminable because of deterioration, and redeposited Tertiary pollen and spores. Pollen of thermophilous trees and shrubs, common to the Quaternary and Tertiary were not excluded from the basic sum in the late-glacial and early-interglacial samples. However, as they are certainly, for the most part, redeposited, they have been marked with a different symbol on the diagram.

The bases for percentage calculations of sporomorphs and other microorganisms excluded from the basic sum are given on the diagram (Fig. 3).

The diagram shows all the results of the pollen analysis; in all the groups distinguished the taxa are arranged in stratigraphic order. The division applied for herbs is based on their habitat preferences with respect to moisture requirements; the taxa of higher rank (families, types, genera) and species with broad requirements or equivocal with regard to their moisture and habitat requirements are included in the group of plants of various habitats. The criteria for the division of herbs are based on the moisture numbers (Ellenberg 1974; Zarzycki 1984).

The results of the macrofossil analysis are given on a diagram in Fig. 4 as the numbers of specimens in the given sample (a single fragment is treated as one specimen). For remains that cannot be counted as whole specimens (e.g. fragments of leaves), only their presence is indicated by the symbol +. Moss remains are given on a three-point scale of abundance. Absolute numbers of specimens are given for animal remains or they are marked with the symbol + indicating the presence of remains which have not yet been studied.

The division of taxa into groups and their order within groups follow the same principles as in the pollen diagram.

A SHORT REVIEW OF EARLIER STUDIES AT IMBRAMOWICE

Gürich (1905) reported from Imbramowice 12 taxa identified by Lingelsheim, These were wood of *Picea excelsa*, *Pinus sylvestris* and *Salix* sp., fruits of *Tilia* sp.. *Quercus* sp., *Corylus avellana* and *Prunus spinosa,* numerous inflorescences of *Alnus glutinosa,* fruits of *Carex* sp., culms of *Gramineae* and remains of the moss *Dicranella* sp.

Hartmann (1907) continued floristic investigations of the Gürich profile and on the basis of the macrofossils distinguished 55 taxa (six taxa of *Charophyta*, six of *Bryophyta*, two of *Gymnospermae* and 41 of *Angiospermae*).

Hartmann's flora list has been supplemented by Kräusel (1920) and some corrections have been made by Mądalski (1961). Besides the species mentioned by Hartmann, Kräusel also identified sporangia of *Polypodiaceae*, numerous microsporangia, macrosporangia and macrospores of *Salvinia natans* and a rust from the family *Uredinaceae* on remains of *Phragmites communis*.

Mądalski (1961), on the basis of Hartmann's original material, called in question his identifications of *Potamogeton* species and found the presence of *P. compressus*, *P. pusillus*, *P. vaginatus* and *P. zosteraceus*. He left some species distinguished by Hartmann as *Potamogeton* sp.

Karczmarz (this volume) carried out a revision of the *Charophyta* species identified by Hartmann and also found that all the *Bryophyta* species identified now by him were new to the flora of Imbramowice.

At present it was impossible to verify Hartmann's complete material, because most of it is probably lost. The macrofossils made accessible to us by the Institute of Geological Sciences University of Wrocław, contain (according to Hartmann's identification) stones of *Potamogeton*, cone axes of *Alnus glutinosa* and fruits or seeds of *Acer campestre*, *Cornus sanguinea*, *Corylus avellana*, *Iris pseudoacorus* (?), *Najas marina*, *Nuphar luteum*, *Nymphaea alba*, *Quercus pedunculata* vel *sessiliflora* and *Trapa natans*. This material does not give grounds for the identification of *Alnus glutinosa* on the basis of cone axes only and the seeds identified as *Iris pseudoacorus* (?) do not belong to this genus but they have not been fully identified. The other remains agree with Hartmann's identifications.

Although the macrofossil flora of the profile under study is very rich, the following taxa have not been refound: *Acer tataricum*, *Alectorolophus* sp.?, *Carex pallescens*, *Ceratophyllum submersum*, *Eriophorum* sp., *Iris pseudoacorus* ?, *Ledum palustre* ?, *Luzula* sp., *Phragmites communis*, *Prunus spinosa*, *Quercus pedunculata* vel *sessiliflora*, *Sonchus oleraceus* ?, *Trifolium* sp. Neither have *Salix alba* and *S. fragilis* been distinguished on the basis of wood pieces. According to Z. Tomczyńska A. E., anatomical features mentioned by Hartmann are not an adequate basis for identifying these species.

Gürich's profile was not analysed in respect for pollen content, except for one spectrum obtained by W. Koperowa from the residual sediment gathered from the fruits and seeds preserved in Hartmann's collection (Środoń 1960). This spectrum, regarded by Środoń as Eemian, may be referred to the close of zone IP-10 in the present profile.

THE FLORA OF IMBRAMOWICE

The flora of Imbramowice comprises the taxa identified on the basis of pollen, spores, fruits, seeds and vegetative remains. Identification was done using various keys and publications as well as comparative material in the pollen-spore and seed-fruit collections of the Department of Paleobotany, W. Szafer Institute of Botany, PAScs, in Cracow. The names of vascular plants mainly follow the key "Rośliny Polskie" (Szafer et al. 1953). In some cases in which the names are taken after Ehrendorfer (1973) or "Flora Europaea", the name used in the "Rośliny Polskie" is given in brackets in the flora list.

H. J. B. Birks's (1973a) conventions have been adopted to indicate the level of taxonomic identifications and used for both sporomorphs and macrofossils.

FLORA LIST

Table 1

P - pollen
S - spores
M - macrospores, macrosporangia, microsporangia, sporangia
O - oospores, oogonia
\+ - Pediastrum occurrence
F - fruits, seeds, fruits scales etc.
V - hairs, leaves, needles, sclerotia etc.
W - wood

ʹ - single occurrence
— - maximum or abundant occurrence
← → - transition to the neighbouring zone
( ) - redeposited or considered as a contamination from above
(ʃ) - redeposited but mayby partly primary
/ / - presumably partly redeposited (if single - presumably redeposited)

* - see description in chapter "The flora of Imbramowice"

	LG MPG s.l.		EEMIAN INTERGLACIAL							EV
		Regional pollen assemblage zones								
			E1	E2	E3	E4	E5	E6	E7	EV1
	IP- 1	2-3	4-5	6	7	8-10	11	12	13	14
CHLOROPHYTA										
Hydrodictyaceae										
Pediastrum Meyen	+	+	+	+	+	±	+	+	+	±
CHAROPHYTA										
Characeae										
Chara hispida L.	.	$\underline{O}$	O	O	$\underline{O}$	O	.	.	.	.
Nitellaceae										
Nitella gracilis (Sm.) Ag.	.	.	.	.	.	.	.	.	$\underline{O}$	O
Nitella mucronata (A.Br.) Miquel	.	.	.	.	.	.	.	.	.	$\underline{O}$
Nitellopsidaceae										
Nitellopsis obtusa (Desv.) Grov.	O	O	O	O	$\underline{O}$	$\underline{O}$ →		.	O	O
MYCOTA										
Hyphomycetes										
Cenococcum graniformae (Sow.) Ferd. & Winge (= C. geophilum Fr.)	$\underline{V}$	$\underline{V}$	V	.	V	V →		V	V	V
BRYOPHYTA										
Anthocerotae										
Anthoceros Mich.	.	.	Sʹ	.	.	.	.	.	.	.
Musci										
Amblystegiaceae										
Amblystegium serpens (Hedw.) B.S.G.	V	V	.	.	.	.	.	.	.	.
Campylium chrysophyllum (Brid.) Bryhn.	V	V	.	.	.	.	.	.	.	.
Cratoneuron commutatum (Hedw.) Roth.	.	V	.	.	.	.	.	V	V	V
Cratoneuron decipiens (De Not) Loeske	.	.	.	.	.	.	.	V	.	.
Cratoneuron filicinum (Hedw.) Spruce	.	.	.	.	.	.	.	.	.	V
Drepanocladus aduncus var. aduncus (Hedw.) Mnkm.	.	.	.	.	.	.	.	.	.	V
Drepanocladus aduncus var. kneiffii (Brid. & Schimp.) Mnkm.	$\underline{V}$	V	V	V	V	V	.	V	V	V
Drepanocladus aduncus f. capillifolia (Warnst.) Mnkm.	.	.	.	.	.	.	.	.	.	$\underline{V}$
Leptodictyum riparium (Hedw.) Warnst.	.	.	.	.	.	.	.	.	.	V
Brachytheciaceae										
Brachythecium rutabulum (Hedw.) B.S.G.	.	.	.	.	.	V	V	V	.	.
Oxyrrhynchium swartzii (Turn.) Warnst.	.	.	.	.	.	V	.	V	.	.
Bryaceae										
Bryum caespiticium Hedw.	V	V	.	.	.	.	.	V	.	.
Bryum pseudotriquetrum (Hedw.) Schwägr.	.	Vʹ	.	.	.	.	.	.	.	.
Climaciaceae										
Climacium dendroides (Hedw.) Web. & Mohr.	.	.	.	.	.	V	.	.	.	.

Table 1 (cont.)

	LG MPG s.l.		EEMIAN INTERGLACIAL							EV
		Regional pollen assemblage zones								
			E1	E2	E3	E4	E5	E6	E7	EV1
	IP- 1	2-3	4-5	6	7	8-10	11	12	13	14
Ditrichaceae										
Ditrichum flexicaule (Schwägr.) Hampe	V	V	.	.	.	.	.	.	.	.
Ditrichum heteromallum (Hedw.) Britt	.	.	.	.	.	.	.	V	.	.
Encalyptaceae										
Encalypta streptocarpa Hedw.	.	V	.	.	.	.	.	.	.	.
Funariaceae										
Funaria hygrometrica Hedw.	.	.	.	.	.	.	V	.	.	.
Grimmiaceae										
Rhacomitrium canescens (Hedw.) Brid.	.	.	.	.	.	.	V	.	.	.
Hypnaceae										
Hypnum lindbergii Mitt.	.	V	V	V′	V	V	.	.	.	.
Leucodontaceae										
Leucodon sciuroides (Hedw.) Schwägr.	.	.	.	.	V	.	.	.	.	.
Mniaceae										
Plagomnium affine (Funck) Kop.	.	.	.	.	.	.	.	V′	.	.
Pottiaceae										
Pterygoneurum ovatum (Hedw.) Dix.	.	V	.	.	.	.	.	.	.	.
Tortula ruralis (Hedw.) Gaertn.	V′	.	.	.	.	.	.	.	.	.
Rhytidiaceae										
Rhytidiadelphus squarrosus (Hedw.) Mitt.	.	.	.	.	.	.	.	V	.	.
Sphagnaceae										
Sphagnum sect. Acutifolia	.	.	.	.	V′	.	.	.	.	.
Sphagnum Ehrh.	/S̲/	/S/	S	S′	S	S′	.	S	S̲	S̲
PTERIDOPHYTA										
Equisetaceae										
Equisetum L.	S	S̲	S	S	.	.	.	.	.	.
Lycopodiaceae										
Lycopodium annotinum L.	S′	S′	.	.	.	S′	.	S′	S′	S
Lycopodium clavatum	.	S	.	S′	.	.	.	S′	S′	S
Lycopodium complanatum L. emend. A.Brit./ /L. tristachyum Pursh. (= Diphasium complanatum (L.) Roth./D. tristachyum (Pursh.) Roth.	.	.	.	.	.	.	.	.	.	S′
Lycopodium selago L. (= Huperzia selago (L.) Bern. in Maur. & Schrank.)	.	.	.	.	.	.	.	S′	.	.
Ophioglossaceae										
Botrychium Sw.	.	S	S	S′	.	.	.	S	.	S
Ophioglossum L.	.	.	.	.	S	.	.	.	.	.
Osmundaceae										
Osmunda regalis L./O. claytoniana L.	.	.	.	.	.	.	.	S′	.	.
Polypodiaceae s.l.	.	.	M	M	M	M̲	M	M′	M′	.
Dryopteris filix-mas (L.) Schott s.str.	.	.	S	S̲	.	.	.	.	.	.
Dryopteris thelypteris (L.) A.Gray *	.	.	S	S	S	S	S̲	/S/	.	.
Phegopteris dryopteris (L.) Fée *	.	S′	.	.	S′	S′	.	S	S	S
Polypodium L.	.	.	S	.	.	.	.	S	S	S
Pteridium aquilinum (L.) Kuhn	.	.	.	.	S̲	S	S′	S	S	S
Polypodiaceae s.l. undiff.	/S/	/S/	S	S	S̲	S	S̲	/S/	S	S
Salviniaceae										
Salvinia natans (L.) All.	.	(M)	.	M	M	M̲	M̲	/M̲/	M̲	/M/

Table 1 (cont.)

	LG MPG s.l.		EEMIAN INTERGLACIAL							EV
		Regional pollen assemblage zones								
			E1	E2	E3	E4	E5	E6	E7	EV1
						IP-				
	1	2-3	4-5	6	7	8-10	11	12	13	14
Selaginellaceae										
Selaginella selaginoides (L.) Lk.	M	SM	SM´	•	S´	•	•	•	•	•
GYMNOSPERMAE										
Cupressaceae										
Juniperus L.	PW´	P	PW´	P	P	P	P	PW´	P	P
Ephedraceae										
Ephedra distachya L. type	•	P	P	•	P´	•	•	•	P	P
Ephedra fragilis Desf. type	•	P	•	•	•	•	•	•	P	P´
Ephedra cf. strobilacea Bunge	•	•	•	•	•	•	•	•	•	P´
Pinaceae										
Abies Mill.	(P)	(P)	•	•	•	P	P	PW→	P	/P/
Abies Mill. vel Juniperus L.	•	•	•	•	•	•	•	•	W →	
Larix Mill.	•	•	•	•	•	•	•	P	P	P
Picea abies (L.) Karsten (= P. excelsa (Lam.) Lk.)	(P)^	(P)^	P	P	P	P	P	P	P	P
Picea Dietr. vel Larix Mill.	•	•	•	•	•	W´	•	W	•	•
Pinus cembra L.	P	P	P	P´	•	•	•	•	P	P
Pinus sylvestris L.	W´	•	VW´	V´	•	•	•	W	•	•
Pinus sylvestris L. type	/P/	/P/	P	P	P	P	P	/P/	P	P
Pinus L.	•	•	•	•	•	•	•	W´	•	•
Taxaceae										
Taxus baccata L.	•	•	•	•	•	P	P	/P/	P	/P/
ANGIOSPERMAE										
Aceraceae										
Acer campestre L.	•	•	•	•	•	F	F	/F´/	•	•
Acer cf. platanoides L.	•	•	•	•	•	•	F´	•	•	•
Acer L.	(P´)	•	P´	•	PW´	P	P	/P/	P	/P/
Alismataceae										
Alisma cf. plantago-aquatica L.	•	•	•	P´	F	PF	F´	P´	P´	P´
Sagittaria L.	•	•	P´	•	•	•	•	•	•	P
Aquifoliaceae										
Ilex aquifolium L.	•	•	•	•	•		← F	F´	•	•
Ilex aquifolium L. type	•	(P)	•	•	•	P	P	P	P	(P´)
Araliaceae										
Hedera helix L.	•	•	•	P´	P	P	P	/P/	P	(P)
Betulaceae										
Alnus glutinosa (L.) Gaertn.	(F´)	•	•	•	•	F	F	/F/→		•
Alnus viridis (Chaix) DC	P	P	P	•	•	•	•	•	•	•
Alnus Mill. undiff.	(P)^	(PF)^	P(F´)	P	P	PF	PF	/PF/	PF´	/P/
Alnus Mill.	/W/	/W/	W	W	W	W	W	/W/	W	/W/
Betula sect. Albae	•	F	F	F	F	•	•	•	•	•
Betula pendula Roth. (= B. verrucosa Ehrh.)	•	•	•	•	•	F´	•	•	•	F
Betula cf. pendula Roth.	•	F	F	F	F	F	•	•	•	F
Betula cf. pubescens Ehrh.	F	F	F	F	F	F	•	F	F	F
Betula sect. Nanae	F´	F´	•	•	•	•	•	•	•	•
Betula nana L.	FV	FV	F	F	•	•	•	(F)	F	F
Betula cf. nana L.	PF´	PF	PF	F	•	•	•	•	F	PF
Betula L. undiff.	PF	PF	PF´	PF	PF	PF	P	/PF/	PF	PF
Betula L.	•	W	W´	•	•	W →		•	•	•
Carpinus betulus L.	•	•	•	•	•	F´	F	/F/	•	•
Carpinus L.	(P)	(P)	(P´)	•	P	P	P	/P/	P	/P/

Table 1 (cont.)

	LG MPG s.l.		EEMIAN INTERGLACIAL							EV
		Regional pollen assemblage zones								
			E1	E2	E3	E4	E5	E6	E7	EV1
IP-	1	2-3	4-5	6	7	8-10	11	12	13	14
Betulaceae (continued)										
Corylus L.	(P)	(P)	(P)	P′	PF	P̲	P̲	/P/	P	/P/
Butomaceae										
Butomus umbellatus L.	.	.	P	.	P	.	.	.	.	P
Callitrichaceae										
Callitriche hermaphroditica L. (= C. autumnalis L.)	.	.	.	.	.	.	.	F	.	.
Campanulaceae										
Campanula L.	.	.	.	.	.	P	P′	P	P	P
cf. Jasione montana L.	F′	.	.	.	.	.	.	.	.	.
Jasione L.	.	.	.	.	.	P′	.	P′	P′	P
Cannabaceae										
Humulus lupulus L.	.	.	.	P	P̲	P	P	P	P	P
Caprifoliaceae										
Sambucus nigra L.	(P′)	.	.	P	P	P	.	PF	P	P
Sambucus racemosa L.	.	.	.	.	.	.	.	F	.	.
Sambucus cf. racemosa L.	.	.	.	P	P	P	.	P	P	P
Sambucus L. undiff.	.	.	.	.	.	.	.	F	.	.
Viburnum L.	.	(P′)	.	P′	P′	P	P	P	P′	P′
Caryophyllaceae										
Cerastium L./Stellaria L. undiff.	.	.	.	.	.	P′	.	P	.	P
Dianthus L. type	.	P′	.	.	.	.	.	.	P′	P
Gypsophila cf. fastigiata L.	.	.	.	.	.	.	.	F	.	.
Gypsophila fastigiata L. type	.	P	P′	.	.	.	.	P	P	P
cf. Lychnis L.	.	.	.	.	.	.	.	P′	.	.
Melandrium Röhl. type	.	.	.	.	.	.	.	.	.	P
Scleranthus perennis L.	.	.	.	.	.	.	.	.	.	P′
Silene otites (L.) Wib.	.	.	.	.	.	.	.	.	.	F′
Silene L. type	P′	P	P	.	P	P′	.	P	P	P
Stellaria holostea L.	.	.	P′	.	.	P	.	P′	.	.
cf. Viscaria Röhl.	.	.	.	.	.	.	.	.	.	P′
Caryophyllaceae undiff.	F′	PF	P	.	P	P	P′	P	P	P̲F′
Ceratophyllaceae										
Ceratophyllum demersum L.	.	.	F	F	F′	F̲ →		F		← /F/
Ceratophyllum L.	.	V′	V̲	V	V	V̲	V	V	V	V′
Chenopodiaceae	P′	P̲	P	P	P	P	P′	P	P	P
Cistaceae										
Helianthemum canum (L.) Baumg./H. alpestre (Jacq.) DC.	P′	P	P′	.	.	.	.	.	P	P
Helianthemum nummularium (L.) Mill. type	.	P̲	P	.	P′	P	.	P	P	P
Helianthemum cf. oelandicum (L.) DC.	.	P′	.	.	.	.	.	.	.	P
Helianthemum Mill. undiff.	.	.	.	.	P′	.	.	.	.	P′
Compositae										
Compositae Liguliflorae	.	P	P	P	P	P	.	P	P	P
Taraxacum Wigg.	.	F	.	.	.	.	.	.	.	.
Compositae Tubuliflorae undiff.	.	P	P	P	P	P	.	P	P	P
Anthemis L. type	.	P	P	.	P	P′	.	P	P	P
Artemisia L.	P	P̲	P	P	P	P	P	/P/	P	P̲
Aster L. type	.	.	P′	P	P	P	P′	P	P	P
Carduus L.	.	.	.	.	.	F′	.	.	.	.
Centaurea jacea L. type	.	.	.	.	.	.	.	.	P′	P
Cirsium Mill./Carduus L.	.	.	.	.	.	.	.	P	P′	P

Table 1 (cont.)

	LG MPG s.l.		EEMIAN INTERGLACIAL							EV
		Regional pollen assemblage zones								
			E1	E2	E3	E4	E5	E6	E7	EV1
	IP-									
	1	2-3	4-5	6	7	8-10	11	12	13	14
Compositae (continued)										
Gnaphalium L. type	.	.	.	.	.	.	.	.	.	P
Saussurea DC. type	P′	.	.	.	.	.	.	.	.	.
cf. Xanthium L.	.	.	.	.	.	.	.	.	.	P
cf. Compositae	.	.	F′	.	.	.	.	.	.	.
Convolvulaceae										
Calystegia R.Br.	.	.	.	.	P′	P′	.	.	.	.
Cornaceae										
Cornus sanguinea L.	.	.	.	.	.	P′	P′F′	P′F	.	.
Cruciferae	.	P	P	P′	P′	P	P′	P	P	P
Rorippa palustris (L.) Bess. s.l. (= R. islandica auct.)	.	F′	F̲	F′	.	.	.	.	F′	.
Cyperaceae										
Bolboschoenus maritimus (L.) Palla	.	.	P	.	.	.	.	.	.	.
Carex sect. Acutae	F	F	F	F′	.	F	.	F̲	F	.
Carex aquatilis Wahlenb.	.	F	F̲	.	.	.	.	/F/	.	F
Carex cf. cespitosa L.	.	.	.	.	.	.	.	F →		.
Carex elata All. (= C. hudsonii Bennet)	.	.	.	.	.	.	.	F	.	.
Carex cf. elata All.	.	.	F′	.	.	.	.	F	.	.
Carex gracilis Curt.	.	F′	F	.	.	F′	.	F̲	F	F̲
Carex cf. gracilis Curt.	.	F	F	F′	.	.	.	.	.	F′
Carex nigra (L.) Reich. (= C. fusca All.)	.	F	.	.	.	.	.	F′	.	.
Carex cf. nigra (L.) Reich.	.	F′	F	.	.	.	.	F̲	.	F̲
Carex diandra Schrank	.	.	.	.	.	F′	.	.	.	.
Carex cf. diandra Schrank	.	.	.	.	F′	.	.	.	.	.
Carex disticha Huds.	.	.	F	.	.	.	.	.	.	.
Carex echinata Murr. (= C. stelullata Good.)	.	.	.	.	.	F′	.	.	.	.
Carex flava L.	.	.	F′	.	.	.	.	F′	.	.
Carex cf. flava L.	.	.	.	.	.	.	.	.	F′	F
Carex flava agg.	.	.	F′	.	.	.	.	.	F	.
Carex hirta L. type	.	P	P	.	.	.	.	.	.	P
Carex oederi Retz subsp. pulchella Lönnr. (= C. scandinavica Davies)	.	.	.	.	.	.	.	F′	.	.
Carex pseudocyperus L.	.	F′	F	F	F̲	F̲	F	F	F	F
Carex cf. pseudocyperus L.	.	F′	F′	.	F′	F′	.	F →		.
Carex riparia Curt.	.	.	.	.	.	F′	.	.	.	.
Carex rostrata Stokes	.	F	F̲	F	F	F̲	F	/F̲/	F	F̲
Carex vesicaria L.	.	.	.	.	.	F′	.	F	F	F
Carex L. undiff.	F	F	F′	.	.	F	.	F →		F′
Cladium mariscus (L.) Pohl	.	.	.	.	F′	F	.	F′	P′F′	/P′/
cf. Cladium mariscus (L.) Pohl	.	.	.	.	.	F′	.	.	.	.
Cyperus fuscus L.	.	.	.	.	F	F	.	.	.	.
cf. Cyperus fuscus L.	.	.	.	.	F	F	.	.	.	.
Eleocharis palustris (L.) R. & Sch./E. mamillata Lindb. f.	.	F′	F	.	F′	F	.	F	F	F̲
Schoenoplectus lacustris (L.) Palla	.	F′	F	F	F	F	F	F	.	F′
cf. Schoenoplectus lacustris (L.) Palla	.	.	F′→		.	.	.	.	.	.
Schoenoplectus tabernaemontani (Gmel.) Palla	.	.	F′	.	.	.	.	.	.	F
cf. Schoenoplectus tabernaemontani (Gmel.) Palla	.	.	.	.	.	.	.	F	.	.
Scirpus sylvaticus L.	.	.	.	.	.	F′	.	.	.	.
Cyperaceae undiff.	P	P̲F	P	PF′	P	P	P	/PF′/	P	P̲
Dipsacaceae										
Knautia arvensis (L.) Coult.	.	.	.	.	.	.	.	.	.	F′
Scabiosa canescens W. & K. type	.	.	.	.	.	.	.	P′	.	.

Table 1 (cont.)

	LG MPG s.l.		EEMIAN INTERGLACIAL							EV
		Regional pollen assemblage zones								
			E1	E2	E3	E4	E5	E6	E7	EV1
IP-	1	2-3	4-5	6	7	8-10	11	12	13	14
Droseraceae										
Aldrovanda vesiculosa L.	.	.	.	.	.	F′	.	.	.	.
Eleagnaceae										
Hippophae rhamnoides L.	.	P	P	.	.	.	.	.	.	P′
Empetraceae										
Empetrum L.	.	P′	.	.	.	.	.	.	.	P′
Ericaceae										
Calluna vulgaris (L.) Hull.	P′	P	P′	P′	P	P	P	P	P	P
Ledum palustre L.	.	.	P′	.	.	.	.	.	.	.
Vaccinium L. type	P′	.	.	.	.	.	.	P	P′	P′
Ericaceae undiff.	P	P	P	.	.	P′	.	P	P	P
Euphorbiaceae										
cf. Euphorbia L.	.	.	.	.	.	P′	P′	.	.	.
Mercurialis cf. perennis L.	.	.	.	.	.	.	.	P	.	P′
Fagaceae										
Fagus L.	(P)	(P)	(P′)	.	.	P	.	P′	P	(P)
Quercus L.	(P)	(P)	PW	P	PW	PW	P	/P/	P	/P/
Gentianaceae										
Gentiana pneumonanthe L. type	.	P	.	.	.	.	.	.	P′	.
Geraniaceae										
Geranium L.	.	.	.	.	.	.	.	.	.	P
Gramineae	.	F	F	F	F	F	.	F′	.	.
Elymus L. type	.	P	P′	.	.	.	.	.	.	P
Phragmites Adans. type	.	.	P	P	P	P	P	/P/	P	P
Gramineae undiff.	P	P	P	P	P	P	P	/P/	P	P
Guttiferae										
Hypericum L.	.	.	.	.	P′	.	.	.	.	P′
Halorrhagidaceae										
Myriophyllum spicatum L.	.	PF	PF′	P	PF′	PF	P	PF′	PF	PF
Myriophyllum verticillatum L.	.	.	P	PF	PF	PF →	P	PF →	P	P
Myriophyllum L. undiff.	.	F′	F →		F	F	F′	F	F	F
Hippuridaceae										
Hippuris vulgaris L.	.	P′F′	P′F	.	F′	P′	.	/F/	F′	F
Hydrocharitaceae										
Hydrocharis morsus-ranae L.	.	.	.	.	P′	.	.	.	.	.
Stratiotes aloides L.	.	.	.	.	.	V	.	.	.	P
Juncaceae										
Juncus L.	F′	F	.	.	.	F	.	F′	.	.
Labiatae										
Ajuga reptans L.	.	.	.	.	.	F	.	F	.	.
Lycopus europaeus L.	.	.	F′	F	F	F	F′	F′	.	.
Lycopus L. undiff.	.	(F′)	F′	F	F	F	.	.	.	F
Mentha cf. aquatica L.	/F′/	/F′/	.	F	F	F →		F	F	.
Mentha L. type	P	P	P	P	P	P	P	P	P	P
Prunella L. type	.	P′	P	P′	.	P	.	P	P	P
Labiatae undiff.	.	F′	.	.	.	.	.	.	.	.
Lemnaceae										
Lemna cf. trisulca L.	.	.	.	.	.	F →		.	.	.

Table 1 (cont.)

	LG MPG s.l.		EEMIAN INTERGLACIAL							EV
		Regional pollen assemblage zones								
			E1	E2	E3	E4	E5	E6	E7	EV1
	1	2-3	4-5	6	7	IP- 8-10	11	12	13	14
Lemnaceae (continued)										
Lemna L.	•	•	P′	•	•	P′	•	P	P′	P
Lentibulariaceae										
cf. Pinguicula L.	•	•	•	•	•	•	P′	•	•	•
Liliaceae										
Allium vineale L. type	•	•	•	•	P′	P′	•	P	•	P′
Ornithogalum umbellatum L.	•	•	•	•	•	•	•	•	•	P′
Linaceae										
Linum austriacum L. type	•	•	•	•	•	•	•	P′	•	•
Loranthaceae										
Viscum L.	•	•	•	•	•	PW′	P	P	P	/P/
Lythraceae										
Lythrum salicaria L./L. virgatum L.	•	•	•	•	F	F	•	•	•	F
Lythrum L.	•	•	•	P′	P	P	P′	P	•	P
cf. Peplis L.	•	•	•	•	•	•	•	P′	•	•
Menyanthaceae										
Menyanthes trifoliata L.	•	•	•	•	P	P	P	P	P	P′
Najadaceae										
Najas marina L. *	(F)	(F)	F	F	F	F̲	F̲	F	F′	/F′/
Nymphaeaceae										
Brasenia schreberi Gmel.	•	•	•	•	•	P′F′→	P′	•	•	•
Nuphar lutea (L.) Sm.	•	•	F′	F′	F′	F	F	F	•	•
Nuphar cf. lutea (L.) Sm.	•	•	P	P	P	P	P	P	P	P
Nuphar Sm. undiff.	•	(F′)	F	F	F	F	F	F	•	•
Nymphaea alba L.	•	•	P′	F	PF	PF →	P	P	•	/P′/
Nymphaea cf. candida Presl.	•	•	P′	P	P	P′	•	•	•	•
Oenotheraceae										
cf. Chamaenerion auct. (= Chamaerion (Rafin.) Rafin.)	•	•	•	•	•	•	•	P′	•	P′
cf. Epilobium L.	•	•	•	•	•	•	•	•	•	P
Trapa cf. conocarpa (Areschoug) Fleroff	•	•	•	•	•	F̲	F̲	/F/	•	•
Trapa natans L.	•	•	•	•	•	F	•	•	•	•
Trapa cf. natans L.	•	•	•	•	•	F →		•	•	•
Trapa L.	•	•	•	•	•	•	P	F	P′	•
Oleaceae										
Fraxinus L.	(P)	(P′)	•	P	P̲	P̲W →	P	/P/	P	/P/
Ligustrum vulgare L.	•	•	•	•	P	P	•	P′	•	•
Papaveraceae										
Corydalis Med.	•	•	•	•	•	•	•	P	•	•
Papaver rhoeas L. type	•	F′	•	•	•	•	•	•	•	F
Papaver L.	•	P	•	•	•	•	•	•	•	P
Papilionaceae										
Lotus L.	•	P	•	•	P	•	•	•	•	P
Papilionaceae undiff.	•	•	P′	•	•	•	•	P′	P	P
Plantaginaceae										
Plantago lanceolata L.	P′	•	•	•	•	•	•	•	•	P
Plantago major L.	•	•	•	•	•	•	•	P′	•	P
Plantago maritima s.str. (most probably P. maritima L. s.str.)	•	P	P′	•	P′	•	•	P′	P	P̲

Table 1 (cont.)

	LG MPG s.l.		EEMIAN INTERGLACIAL							EV
		Regional pollen assemblage zones								
			E1	E2	E3	E4	E5	E6	E7	EV1
	IP- 1	2-3	4-5	6	7	8-10	11	12	13	14
Plantaginaceae (continued)										
Plantago maritima s.l. (most probably P. maritima var. salsa (Pallas) Pilger or P. carinata Schrad. ex Mert. & Koch) *	.	.	P´	.	.	.	.	.	P	P
Plantago media L.	.	.	.	.	.	.	.	P´	P	P
Plumbaginaceae										
Armeria Willd. *	.	.	P´	.	.	.	.	P	P	P
Polemoniaceae										
Polemonium L.	.	.	.	.	.	.	.	.	.	P´
Polygonaceae										
cf. Koenigia islandica L.	.	.	.	.	.	.	.	.	.	P´
Polygonum aviculare L.	.	.	.	.	.	.	.	F´	.	.
Polygonum aviculare L. type	P´	P	P	.	.	P	.	P̲	P	P
Polygonum bistorta L./P. viviparum L.	.	P´	.	.	.	P´	.	P	P	P
Polygonum persicaria L. type	.	.	.	.	.	.	.	.	.	P
Rumex acetosa L. type	.	P´	P	.	P	P	.	P	P	P
Rumex acetosella L.	.	.	.	.	.	.	.	.	.	F´
Rumex acetosella L. type	.	P	P	P	P	P	P	P	P	P̲
Rumex aquaticus L./R. hydrolapathum Huds.	.	.	.	P´	.	P´	P´	.	.	P´
Rumex crispus L. type	.	P´	P	.	.	P´	.	.	P	P
Rumex maritimus L.	.	.	F̲	.	.	.	.	.	.	.
Rumex cf. maritimus L.	.	.	F´	.	.	.	.	.	.	.
Rumex L. undiff.	.	P´	.	.	.	P´	.	P	P´	P
Potamogetonaceae										
Potamogeton sect. Coleogeton	P	P̲F	P	.	PF´	PF´	.	F	P	P
Potamogeton filiformis Pers.	.	F̲	.	.	.	F´	.	F̲	F	F
Potamogeton pectinatus L.	.	.	.	F´	.	F	.	F´	.	.
Potamogeton cf. pectinatus L.	.	.	.	.	.	F´	.	F	.	.
Potamogeton vaginatus Turcz.	.	F	.	.	.	.	.		← F	F̲
Potamogeton cf. vaginatus Turcz.	.	F´	F´	.	.	.	.	.	.	.
Potamogeton sect. Eupotamogeton	P´	P̲	P	P	P	P̲	P	P	P	P
Potamogeton alpinus Balb.	.	.	.	.	.	.	.	F	.	.
Potamogeton berchtoldii Fieb. (= P. pusillus L. sensu auct. scand.)	.	.	.	.	.	.	.	F	.	.
Potamogeton crispus L.	.	.	.	.	.	F´	F´	F´	F	F
Potamogeton friesii Rupr. (= P. mucronatus Schrad.)	.	.	F´	.	.	.	.	.	.	.
Potamogeton gramineus L.	.	.	.	.	.	.	.	.	F´	F̲
Potamogeton cf. gramineus L.	.	F´	.	.	.	.	.	F	.	.
Potamogeton lucens L.	.	.	.	F´	.	.	.	.	.	F
Potamogeton natans L.	.	F´	F´	.	.	.	.	F	F	.
Potamogeton obtusifolius Mert. & Koch.	.	.	.	.	.	.	.	F	.	.
Potamogeton cf. obtusifolius Mert. & Koch.	.	.	.	.	.	.	.	.	F´→	
Potamogeton panormitanus Biv. (= P. pusillus L. sensu Dandy & Taylor)	.	.	.	.	.	.	.	.	.	F
Potamogeton perfoliatus L.	.	F	F	.	.	F →		F	.	F
Potamogeton cf. perfoliatus L.	.	F´	.	.	.	.	.	F´→		F
Potamogeton praelongus Wulf.	.	.	F´	.	.	.	.	.	F →	
Potamogeton L. undiff.	.	F	F	F´	.	.	.	F	F	F̲
Zannichellia palustris L.	.	.	.	.	.	F´	.	F´	.	.
Primulaceae										
Lysimachia nemorum L.	.	.	.	.	.	P´	.	.	.	.
Lysimachia thyrsiflora L.	.	.	.	.	.	.	.	P	.	PF´
Lysimachia vulgaris L. type	.	.	.	.	.	.	.	.	.	P´

Table 1 (cont.)

	LG MPG s.l.		EEMIAN INTERGLACIAL							EV
		Regional pollen assemblage zones								
			E1	E2	E3	E4	E5	E6	E7	EV1
						IP-				
	1	2-3	4-5	6	7	8-10	11	12	13	14
Ranunculaceae										
Anemone L. type	•	•	P′	•	•	P′	•	P	P	P′
Batrachium (DC.) S.F.Gray	•	F̲	F̲	F′	F	F →		/F̲/	F	F̲
Caltha L. type	•	P′	•	•	•	P′	P	P	P	P
Ranunculus cf. acris L. (= R. cf. acer L.)	•	•	•	•	•	•	•	•	•	F′
Ranunculus acris L. type *	•	P̲	P	P	P	P	P	P	P	P
Ranunculus flammula L.	•	•	•	•	•	•	•	F	F′	F′
Ranunculus cf. flammula L.	•	•	•	•	•	•	•	F	•	F′
Ranunculus repens L.	•	•	•	•	•	•	•	F′	•	•
Ranunculus sceleratus L.	/F′/	F	F̲	F	F	F →		/F/	F	F̲
Ranunculus trichophyllus Chaix type	•	P	P	•	P′	P	•	/P/	P	P
Ranunculus L. undiff.	•	•	•	•	•	•	•	F	F	F
Thalictrum L.	P′	P	P̲	P	P	P′	P′	/P/	P	P
Trollius L.	•	•	P′	•	•	•	•	•	•	•
Rhamnaceae										
Rhamnus L.	•	•	•	•	•	•	•	•	•	P′
Frangula Mill.	(P′)	•	•	P′	P′	P′	P	P	P	P
Rosaceae										
Alchemilla L.	•	•	•	•	•	•	F′	•	•	•
Aruncus sylvestris Kostel	•	•	•	•	•	•	•	P′	•	•
cf. Comarum palustre L. (= cf. Potentilla palustris (L.) Scop.)	•	P′	P′	P′	P′	•	•	P	P	P
Filipendula Mill.	•	P′	P	P	P′	P	P′	P′	P	P̲
Geum L.	•	•	•	•	•	•	•	•	•	P
Potentilla anserina L.	•	•	•	•	•	•	F′	F̲ →		•
Potentilla supina L.	•	•	F	•	•	•	•	•	•	•
Potentilla L. type	•	P	P′	P′	•	•	•	P	•	P
Potentilla L. undiff.	/F′/	/F/	•	F′	F	F	•	F̲	F	F̲
Prunus L.	•	•	P′	P′	•	•	•	•	•	•
cf. Rosa L.	•	•	•	•	•	•	•	•	•	P′
Rubus chamaemorus L.	•	•	•	•	•	•	•	P′	•	•
Rubus saxatilis L.	•	•	•	•	•	•	•	P	•	P′
Rubus L. sp.div. *	•	•	•	•	•	•	•	F	•	•
Rubus L. undiff.	•	•	•	•	•	•	•	•	•	P
Sanguisorba officinalis L. 2n=28	•	P	•	•	•	P′	•	•	P	P
Sanguisorba officinalis L. 2n=56	•	•	•	•	•	P′	•	P′	•	•
Sorbus L.	•	P′	P	P′	•	•	•	•	•	P
Rosaceae undiff.	P	P̲	P	P′	P	P	P′	P	P	P
Rubiaceae	•	P̲	P	P	P	P	P′	P	P	P
Salicaceae										
Populus L.	P′	P	P̲	P	P	P	P	P	P	P
Populus L. vel Salix L.	•	•	•	•	•	•	•	•	•	W
Salix glauca auct. type	P	P̲	P	P	P	P	P	P	P	P
Salix pentandra L. type	•	P̲	P	P	P	P	•	P	P	P
Salix L.	W	W	V′W	W	W	V′W	V′	VW	VW	V̲W̲
Saxifragaceae										
Parnassia palustris L.	•	•	•	•	P	P	•	P′	P′	•
cf. Parnassia palustris L.	•	F	•	•	•	•	•	•	•	•
cf. Saxifraga nivalis L.	•	P	•	•	•	•	•	•	•	P′
Saxifraga oppositifolia L. type	•	P′	P′	•	•	•	•	P′	•	•
cf. Saxifraga stellaris L.	•	P′	•	•	•	•	•	•	•	P′
Scrophulariaceae										
Melampyrum L.	•	•	•	•	•	•	•	P	•	•
Rhinanthus L. type	•	P	P	•	•	•	•	P	P	P

Table 1 (cont.)

	LG MPG s.l.		EEMIAN INTERGLACIAL							EV
		Regional pollen assemblage zones								
			E1	E2	E3	E4	E5	E6	E7	EV1
					IP-					
	1	2-3	4-5	6	7	8-10	11	12	13	14
Scrophulariaceae (continued)										
Veronica L.	•	P	•	•	P′	•	•	P	P	P
Solanaceae										
Solanum dulcamara L.	•	•	•	•	•	•	•	F′→		P
Sparganiaceae										
Sparganium minimum Fr.	•	•	F′	•	•	•	F′	F′	•	F′
Sparganium ramosum Huds. s.l. (= S. erectum L.)	•	•	F′	F	F	F	F	F	•	•
Sparganium L. type	P	P	P	P	P	P	P	/P/	P	P
Tiliaceae										
Tilia cordata Mill. type (incl. T. tomentosa Moench.)*	(P′)	(P)	•	•	•	P	P	/P/	P	/P/
Tilia platyphyllos Scop.	•	•	•	•	F′		← F	/F′/	•	•
Tilia platyphyllos Scop. type	•	•	•	•	P′	P	P	P′	P	/P′/
Typhaceae										
Typha latifolia L.	/P′/	•	P	P	P	P	P	P	P	P
Typha L.	•	/F/	F	F	F	F →		F	•	F
Ulmaceae										
Ulmus L. (mostly U. scabra Mill. + U. campestris L. em. Huds.) *	(P)	(P)	P	P	P	PW	P	/P/	P	/P/
Umbelliferae										
Bupleurum L.	•	•	•	•	•	•	•	•	P	P
Pimpinella L.	•	•	•	•	•	•	•	•	•	P
Pleurospermum austriacum (L.) Hoffm.	•	•	•	•	•	•	•	•	•	P′
cf. Umbelliferae	•	•	F′	•	•	•	•	•	•	•
Umbelliferae undiff.	P′	P	P	P	P	P	P	P	P	P
Urticaceae										
Urtica dioica L.	•	P	F	F	F	P′F	P′F	F	P′F	PF
Valerianaceae										
Valeriana L.	•	•	•	•	•	•	•	P	P	P
Violaceae										
Viola palustris L. type	•	•	•	•	•	•	•	•	•	P

The abbreviation "undiff." = "undifferentiated" indicates that some taxa of lower rank, belonging to the same family/genus have also been determined. The term "type" is used when more than two species or genera have sporomorphs or diaspores of the same morphological type. The specific designation is given not only when a species has been identified on the basis of the morphological characters of the remains, but also when a genus is monospecific, in general or in the flora of Europe or, finally, in the flora of Central and North Europe.

The flora list (Table 1) includes all the taxa identified and recognized as autochthonous in the flora of Imbramowice. If some of them are regarded as redeposited or partly redeposited in certain zones, or are derived from younger layers in the profile, this is indicated when appropriate.

A total of 320 taxa of various taxonomic ranks have been determined in the flora of Imbramowice, 158 of them being identified to specific level and 43 to the level of a group of species. The pollen flora has been confirmed to a large extent by macrofossils, which allows a more exact interpretation of the pollen diagram; the family *Cyperaceae*, represented among the macrofossils by 22 species in seven genera, serves as an example. In the group of plants represented exclusively by macrofossils there are some taxa whose pollen is never or only exceptionally noted; nevertheless, they are of great importance to the Imbramowice flora (*Najas marina, Ceratophyllum demersum, Callitriche hermaphroditica*).

Out of the taxa identified, more than ten species are absent from the present flora of Poland and two taxa may represent a foreign species in addition to the species growing in Poland. These are *Osmunda regalis/O. claytoniana* and *Helianthemum canum/H. alpestre*. The species absent from the present-day flora of Poland are listed in Table 2, in which they are divided into two groups: indicator plants of the climatic optimum, their occurrence being restricted to the middle and late parts of the interglacial, and the plants present only in the glacial sections of the profile and in the Eemian sections adjacent to them.

Table 2

Stratigraphic distribution of plants identified from Imbramowice but not present in the modern flora of Poland and the nearest regions of their present occurrence

Plants identified from Imbramowice	LG MPG	EEMIAN			EV	Nearest regions of present occurrence
		EE	ME	LE		
Brasenia schreberi Gmel.			+			North America, tropical Africa, India (d)
Ilex aquifolium L.			+	+		NE Germany, Austria (i)
Ilex aquifolium L. type	[+]		+	+	[+]	
Tilia tomentosa Moench. (incl. to T. cordata type)			+	+	[+]	North Hungary, West Ukraine (a)
cf. Koenigia islandica L.					+	Scandinavian Mountains (f)
Ephedra cf. strobilacea Bunge					+	Turan Lowland (j)
Plantago maritima s.l.		+		+	+	
most probably:						
P. maritima var. salsa (Pallas) Pilger						East Podolia - USSR (h)
P. carinata Schrad. ex Mert. & Koch						South Tirol, Julian Alps, Yugoslavia (b)
Potamogeton vaginatus Turcz.	+	+		+	+	Gulf of Bothnia coast (f)
Ephedra distachya L. type	+	+		+	+	Podolia - USSR, North Hungary (e,g)
Carex aquatilis Wahlenb.	+	+		+		South Sweden, N. Estonia (f), Germany (c)
Ephedra fragilis Desf. type	+			+	+	Mediterranean region (j)
cf. Saxifraga stellaris L.	+				+	Alps, SE Carpathians, Scandinavian Mts. (g)
Helianthemum cf. oelandicum (L.)DC	+				+	Öland (f)

EE - Early Eemian (IP-4 - IP-6), ME - Middle Eemian (IP-7 - IP-11), LE - Late Eemian (IP-12 - IP-13)

[+] - probably redeposited or transported from long distance

References: a. Browicz 1968; b. Casper 1974; c. Ehrendorfer 1973; d. Engler 1964; e. Gajewski 1931; f. Hultén 1950; g. Meusel et al. 1965; h. Tacik 1967; i. Webb 1968; j. Welten 1957.

Notes on identifications

Out of the Imbramowice flora only the taxa which — in the author's opinion — call for a more detailed discussion or need taxonomic remarks or a description of the bases for their determinations, are described below.

Pollen and spores

Pteridophyta

Lycopodiaceae

Identifications based on Erdtman et al. (1961) and K. Faegri (unpublished key).

Osmundaceae

Osmunda regalis L./*O. claytoniana* L. One trilete spore with sculpture elements varying in shape, fused into a kind of reticulum. This spore differs from the *O. cinnamomea* L. spores, which have baculoid sculpture elements separated.

Polypodiaceae s. l.

Dryopteris filix-mas (L.) Schott s. str. Monolete spores with folded perine. Fold height: 5—7 μm. Perine surface smooth or slightly granulate. Spores different from those of *D. borreri* Newm. (cf. Sorsa 1964). Altogether 37 spores.

Dryopteris thelypteris (L.) A. Gray (= *Thelypteris palustris* Schott, *Lastrea thelypteris* (L.) Bory) (Pl. I). Monolete spores with perine bearing numerous spines and papillae and with characteristic radiate reticulum in between or with perine without spines and papillae but with visible reticulum (cf. the description of *L. thelypteris* in Sorsa 1964). Spores frequent, up to 33.1%.

Phegopteris dryopteris (L.) Fée (= *Gymnocarpium dryopteris* (L.) Newm., *Thelypteris dryopteris* (L.) Slosson, *Lastrea dryopteris* (L.) Bory). Monolete spores with delicate low verrucae, perine not preserved (Andersen 1961; Sorsa 1964; H. J. B. Birks 1973a). Altogether 28 spores.

Salviniaceae

Salvinia natans (L.) All. (Pl. I). Numerous microsporangia and their fragments of characteristic vacuolate structure, often with microspores visible inside them. These microsporangia are assigned to *S. natans*, for numerous macrosporangia and macrospores of this species were obtained in macroscopic analysis.

Gymnospermae

Pinaceae

Pinus cembra L. Pollen grains referred to this species had the saccus attachments with the body broader than in *P. sylvestris* L. type but narrower than in *P. haploxylon* Rudolph type. The body sculpture on the distal side was of the verruca type, sparsely distributed (cf. Ueno 1958). According to Zwanden (1977), this type of sculpture on the distal side (qualified by him as maculata) suffices to identify this species. Pollen grains present only at the bottom and at the top of the profile.

Angiospermae

Alismataceae

Alisma cf. *plantago-aquatica* L. Pollen grains from Imbramowice agree with morphological descriptions of this species (Andersen 1961; H. J. B. Birks 1973a). Its identification is confirmed by numerous fruits and seeds. 12 pollen grains.

Aquifoliaceae

Ilex aquifolium L. type. This taxon includes pollen grains with characters given for this species by Erdtman et al. (1961). 17 grains from several zones were identified. In zones IP-2 and IP-3 pollen grains of *I. aquifolium* type belong to the redeposited Tertiary pollen, which contains also *I. verticillatum* type pollen with much smaller grains than in *I. aquifolium* type and with much smaller clavae (Menke 1976a). The sites of *Ilex* pollen in the Eemian in Poland are shown in Fig. 22.

Betulaceae

Alnus viridis (Chaix) DC. 11 pollen grains from the bottom zones were referred to this species. They were 5-pore, thin-walled grains, 16—17 μm in diameter, with pores weakly protruding and arci worse developed than in the grains included in *Alnus* undiff.

Alnus Mill. undiff. Pollen represents mainly *A. glutinosa*, which is confirmed by numerous nuts of this species. However, the presence of *A. incana* pollen cannot be excluded.

Betula cf. *nana* L. Morphological criteria were applied in identification (Erdtman et al. 1961; Praglowski 1962), and the grain size was checked whenever possible. All the pollen grains were below 21 μm. The percentage values of the pollen determined are probably underestimated, which seems to be indicated by large numbers of macrofossils (cf. Figs. 3 and 4).

Cannabaceae

Humulus lupulus L. Exclusively small pollen grains, 17—20 μm in diameter.

Caryophyllaceae

Cerastium L./*Stellaria* L. undiff. sensu Andersen (1961). *S. holostea* L. not included. Altogether 44 pollen grains.

Dianthus L. type. It includes *Dianthus*, *Saponaria*, *Tunica* and *Vaccaria*. On the basis of the morphological differences between these genera, given by Andersen (1961), the presence of *Dianthus* seems most probable.

Silene L. type = *Silene*/*Arenaria* sensu Andersen (1961). Pollen grains numerous in top zones, sporadic in the remaining ones.

Cistaceae

Helianthemum canum (L.) Baumg./*H. alpestre* (Jacq.) DC. Both these species belong to *H. oelandicum*-group sensu Erdtman et al. (1961). They have been insolated from that group on the basis of the morphological characters described by Wasylikowa (1964). 35 pollen grains.

Helianthemum cf. *oelandicum* (L.) DC. Five very narrow pollen grains with fine bacula and very distinct striae (Erdtman et al. 1961) are numbered in here.

Compositae Tubuliflorae

Gnaphalium L. type sensu Stix (1960). It corresponds with *Antennaria* type (H. J. B. Birks 1973a; Ralska-Jasiewiczowa 1980). Two pollen grains.

cf. *Xanthium* L. The only genus in the flora of Poland with pollen belonging to *Ambrosia* type sensu H. J. B. Birks (1973a). Two identified pollen grains had spines shorter than 1 μm and columellae more distinct than in *Ambrosia* (cf. McAndrews et al. 1973).

Cyperaceae

Bolboschoenus maritimus (L.) Palla. It corresponds to *Scirpus maritimus* L. sensu Faegri & Iversen (1978).

Dipsacaceae

Scabiosa canescens W. et K. type. One pollen grain, morphologically of the *Succisa pratensis* Moench. type (Erdtman et al. 1961). The differences concern mostly the columellae. In *Scabiosa canescens* type the columellae are thin, narrowly and delicately branching at the top. They stand close to each other but do not coalesced. According to my observations such a pollen type occurs, out of the Polish species, in *S. canescens*, *S. columbaria* L. and *S. ochroleuca* L.

Euphorbiaceae

Mercurialis cf. *perennis* L. Species distinguished on the basis of description given by H. J. B. Birks (1973a). One pollen grain.

Lemnaceae

Lemna L. 25 pollen grains, 20.5—26.5 μm in diameter, with spines rather densely distributed and with a readily seen pore. Pore diameter and spine length within limits given by Beug (1961). The identification of two fruits of *Lemna* cf. *trisulca* L. suggests that the pollen belongs to this species.

Liliaceae

Ornithogalum umbellatum L. Identification following Beug (1961). One pollen grain. This is the first find in the Eemian.

Nymphaeaceae

Nuphar cf. *lutea* (L.) Sm. Numerous pollen grains with relatively thick and densely distributed spines. In *N. pumila* (Timm.) DC. the spines are sparser and generally thinner (Watts 1959). Identification confirmed by numerous seeds of *N. lutea.*

Papaveraceae

Corydalis Med. Two syncolpate, verrucate-scabrate pollen grains. Furrows rather broad, scabrate. 13 native and foreign species were reviewed.

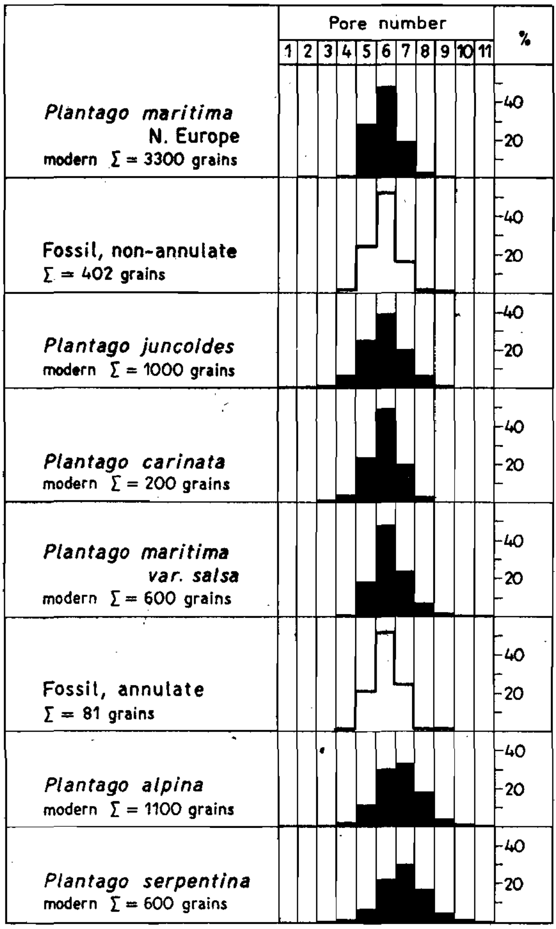

Fig. 5. Pore number-frequency distribution in modern pollen from species within the *Plantago maritima* complex (acc. to Andersen 1961 — black silhouettes) and fossil pollen of *P. maritima* with non-annulate and annulate pores (white silhouettes)

Plantaginaceae

Plantago maritima s. l. Identification included 402 pollen grains with non-annulate pores and 81 grains with pores with annulus. Pores were counted in all the grains to compare their numbers with the pore number-frequency distribution in the present-day taxa within the complex *Plantago maritima*. The data for comparison come from Andersen (1961). They permit the statement that the pollen with non-annulate pores dominates in the North-European taxon *P. maritima* L., whereas the pollen with pores with annulus prevails in the alpine species *P. alpina* L., *P. serpentina* All. and *P. carinata* Schrad. ex Mert. & Koch, as well as in *P. juncoides* Lam. (NE America and Greenland) and *P. maritima* var. *salsa* (Pallas) Pilger (Southern Russia and Asia).

A comparison of the material with respect to pore number-frequency distribution (Fig. 5) indicates that all the fossil pollen grains with non-annulate pores belong to *Plantago maritima* s. str. and the grains with annulate pores to *P. maritima* var. *salsa* or *P. carinata*.

Plumbaginaceae

Armeria Willd. 14 pollen grains of the morphological type "A" and 7 of the type "B" of *Armeria maritima* (Erdtman et al. 1961). They may represent *A. maritima* agg., and the type "A" also *A. sibirica* s. l. (cf. Szafer 1945; Praglowski & Erdtman 1969).

Polygonaceae

Rumex crispus L. type sensu H. J. B. Birks (1973a) (= *R. domesticus* Hartm. type sensu Andersen 1961). 13 pollen grains.

Primulaceae

Lysimachia spp. On the basis of Jørgensen's unpublished key *L. nemorum* L., *L. thyrsiflora* L. and *L. vulgaris* L. type were distinguished.

Ranunculaceae

Ranunculus acris L. type (= *R. acer* type sensu Andersen 1961).

Ranunculus trichophyllus Chaix type sensu Andersen (1961). Probably it represents mainly *Batrachium* (DC.) Gray and *Ranunculus sceleratus* L., the fruits of which occur throughout the profile. Pollen values are very low in relation to the numbers of fruits of these taxa.

Rosaceae

Aruncus sylvestris Kostel. Separated from the *Geum* type sensu Faegri & Iversen (1978) because of its smaller size (grain length — 15 μm).

Saxifragaceae

cf. *Saxifraga stellaris* L. Pollen grains of this species described by Faegri & Iversen (1978) and H. J. B. Birks (1973a) as tricolpate and by Erdtman et al. (1961) as tricolporoidate. Two grains from Imbramowice were tricolporoidate.

Scrophulariaceae

Rhinanthus L. type. It includes *Rhinanthus* (= *Alectorolophus* All.) and *Euphrasia* L. (Andersen 1961). According to my observations, it may also contain less typical pollen grains of *Veronica* L. 26 pollen grains were identified.

Veronica L. Pollen grains much resembling the *Rhinanthus* type but with coarser columellae (Andersen 1961; H. J. B. Birks 1973a). 16 pollen grains.

Tiliaceae

Tilia cordata Mill. type (Pl. I). It comprises pollen of *T. cordata* Mill., *T. tomentosa* Moench and perhaps also not very typical grains of *T. platyphyllos* Scop.

In addition to the pollen that agrees with the morphological characteristics of *Tilia cordata* (Praglowski 1962; Andrew 1971; Stockmarr 1974), grains with smaller funnel-shaped concavities and narrower thickenings of endexine round the aperture grading to almost no thickening at all, were found. Beug's data concerning the number of funnels in the polar surface of the present-day pollen of *T. cordata, T. tomentosa, T. platyphyllos* and *T. vulgaris* (Jung et al. 1972, Abb. 10) and my own observation of comparative materials of *T. tomentosa* suggest that pollen grains with characteristics given above belonged to *T. tomentosa* (Pl. I). The proportion of this pollen in the total number of pollen grains referred to *T. cordata* type is as follows:

Local pollen zones	*Tilia cordata* type	Including *Tilia tomentosa*
IP-14	68	1
IP-13	171	6
IP-12	399	9
IP-11	205	7
IP-10	491	11
IP-9	208	3
IP-8	17	—
Sum	1559	37

Tilia platyphyllos Scop. type (Pl. I). This morphological pollen type (Praglowski 1962; Andrew 1971; Stockmarr 1974) most probably corresponds with *T. platyphyllos*, whose fruits occur at Imbramowice. As there are no observations of both polar areas, it is not unlikely that some grains with the "platyphyllos" sculpture may come from *T. cordata* or from hybrids (Andrew 1971). The pollen of *T. platyphyllos* was described for the first time by Trela (1928).

Ulmaceae

Ulmus L. An attempt was made to differentiate the pollen grains of *Ulmus* from zones IP-5—IP-13 by comparing the number of pores of the fossil pollen

Table 3

Percentage distribution of pore numbers in modern pollen grains of four Ulmus species, acc. to Stockmarr 1970, and in fossil Ulmus pollen grains from Imbramowice

		Pore number			
		4	5	6	7
		Percentage distribution of pores in modern pollen			
Ulmus glabra Huds. (= U. scabra Mill.)		10 - 30	65 - 80	5 - 15	-
Ulmus laevis Pall.		great variation		-	-
Ulmus minor Mill. (= U. campestris L. em. Huds.)		(rest)	more than 80	(rest)	-
Ulmus procera Salisb.		-	rest	50 - 85	up to 10
Local pollen zones at Imbramowice	No of grains	Percentage distribution of pores in fossil pollen			
IP-13	45	24.4	71.1	4.5	-
IP-11 - IP-12	163	6.1	85.9	8.0	-
IP- 8 - IP-10	292	15.1	80.5	4.4	-
IP-7	216	12.0	82.9	5.1	-
IP-5 - IP-6	216	15.3	77.3	7.4	-
IP-5 - IP-13 (total)	932	13.3	80.8	5.9	-

with Stockmarr's (1970) data for four modern species (Table 3). An interpretation of the data allows the statement that in the whole fossil elm population (zones IP-5—IP-13) the proportion of 5-pored pollen is at the upper limit for *U. scabra* Mill. (= *U. glabra* Huds.) and at the lower limit for *U. campestris* L. em. Huds. (= *U. minor* Mill.). Out of the remaining two species, the occurrence of *U. procera* Salisb. is excluded and that of *U. laevis* Pall. is hardly probable because of the constant predomination of 5-pored grains in the fossil material and the presence of 6-pored grains. The dominance of *Ulmus scabra* pollen is fairly distinct in the period of the first interglacial maximum of elm (IP-5—IP-6). In the climatic optimum (IP-7—IP-10) a change in percentages (see Table 3) indicates an increase of *U. campestris* pollen, up to its complete dominance in IP-11 and IP-12. At the decline of the interglacial (IP-13) the percentages of 4- and 5-pored grains again imply a remarkable dominance of *U. scabra* pollen and perhaps even rule out an admixture of *U. campestris* pollen.

Macrofossils

Charophyta*, *Bryophyta

Prof. K. Karczmarz identified and described four charophytic species and 26 species of mosses (Karczmarz this volume). They are all included in the flora list (Table 1) and in the diagram (Fig. 4).

Mycota

Hyphomycetes

Cenococcum graniformae (Sow.) Ferd et Winge (= *C. geophilum* Fr.) (cf. Ławrynowicz 1983). 1232 sclerotia, black in colour; diameter of 50 specimens: 0.61 (0.15—1.40) mm. Diameter of present-day sclerotia ranges from 0.1 to 10.0 mm (Ławrynowicz 1983). Sclerotia of *C. graniformae* are known from many Pleistocene deposits as *C. geophilum*.

Pteridophyta

Polypodiaceae s. l. 83 sporangia and 20 empty annuli. Sporangia round or elliptic. Diameter of former — 0.22 (0.15—0.25) mm, dimensions of latter — 0.25 × 0.20 mm. The occurrence of the first sporangia coincides with the appearance of *Dryopteris thelypteris* spores in zone IP-5, which allows their being assigned to this species.

Salviniaceae

Salvinia natans (L.) All. 32 macrosporangia, 185 whole macrospores, 84 damaged ones and 342 microsporangia. Macrosporangia with a dark thin wall with polygonal cells, usually without sporangiophore or only with its fragment. Macrospores ellipsoidal, mostly rounded at distal area, divided into three valves in the proximal area, distinctly separated by a narrowing from the distal part. Surface, from strongly tuberculate to almost smooth, white to grey-blue. Size, calculated from 10 macrospores: 0.55(0.5—0.6) × 0.43(0.35—0.50) mm. Microsporangia round, pitted; diameter, from 15 specimens: 0.19(0.15—0.25) mm.

Gemnospermae

Pinaceae

Abies Mill. Two small pieces of wood at IP-13/IP-14 boundary, where the maximum of *Abies* pollen (2.6%) occurs.

Abies Mill. vel *Juniperus* L. Three wood pieces in sample 7, corresponding with the beginning of the continuous *Juniperus* pollen curve and the declining part of the continuous *Abies* curve. Both alternative identifications are thus equally probable.

Picea Dietr. vel *Larix* Mill. Four wood pieces. Wood from sample 28 (within the limits of the continuous *Picea abies* curve) belongs in all probability to *Picea*. The number of cells bordering the resin canal, as in *Picea* does not exceed 10, whereas in *Larix* it is 10—15 or more. The remaining wood pieces may belong to either of these genera.

Pinus sylvestris L. Five apical fragments of needles, below 2 mm in length (fragment from sample 55 is charred), and six pieces of wood with marginal ray tracheids diagnostic for *P. sylvestris*. In the zones containing macrofossils the pollen values of *Pinus sylvestris* type range from 8.3 to 65.0%, the highest values coinciding with the presence of needles.

Angiospermae

Aquifoliaceae

Ilex aquifolium L. (Pl. III). Three whole fruit-stones, measuring 7.65 × 4.45 and 7.50 × 4.35 mm, and 2 halves. Ribbed dorsally in an almost parallel manner; on the ventral side, which is flattened or slightly convex, the ribbing is less distinct and less parallel. Imbramowice is the second Eemian site with stones of *I. aquifolium* in Poland. They were first reported by Heck (1929) from Rusinów.

Betulaceae

Alnus glutinosa (L.) Gaertn. Fruits, 882 in number. It is important to emphasize that the fruits in sample 39 correspond with only 3.4% *Alnus* undiff. pollen.

Alnus Mill. undiff. 135 fruits, unripe or in a poor state of preservation, 37 cone axes and several of their fragments, and 232 small wood pieces, including many thin twigs. The remains from the zones of occurrence of *A. glutinosa* belong probably to this species, but the wood pieces from the bottom sections may come from other species.

Betula nana L. 606 nutlets (mostly without wings), 24 fruit scales and 13 fragmentary leaves were identified. 38 less typical or damaged fruits, two whole and several fragmentary fruit scales were identified as *B.* cf. *nana*. The morphological characters given by Białobrzeska & Truchanowiczówna (1960) were used for determining fruits and scales but the shape-line method was applied only for about a dozen nutlets from zones IM-9—IM-11 (tables and graphs are deposited in the archives).

Betula sect. *Nanae*. Two fruit scales, which may well belong to *B. humilis* Schrank.

Betula pendula Roth. (= *B. verrucosa* Ehrh.). Two nutlets with well-preserved broad wings, protruding far above the top of the nutlet, obovate in shape, and a fruit scale with long lateral lobes, bent strongly downwards.

Betula cf. *pendula* Roth. (Pl. II). 205 narrow and obovate nutlets, void of wings, appear much later than do the nutlets of *B.* cf. *pubescens*.

Betula cf. *pubescens* Ehrh. (Pl. II). 195 nutlets, elongate, symmetrically elliptical and void of wings, were identified. The maximum of their occurrence in zone IM-4 coincides with the highest pollen values of *Betula* undiff.

Betula sect. *Albae*. 94 nutlets, mostly malformed or damaged, two whole fruit scales and 18 fragments, part of a well-preserved staminate catkin with anthers (Pl. II) containing pollen, permitting its reference to the section *Albae*.

Carpinus betulus L. 28 whole and 26 fragmentary fruits. In the zone in which the first fruit was found, the pollen value was 0.34%.

Corylus L. Two anthers with small numbers of pollen grains in zone IM-6.

Caprifoliaceae

Sambucus L. 21 whole, 9 damaged and numerous fragments of fruit-stones.

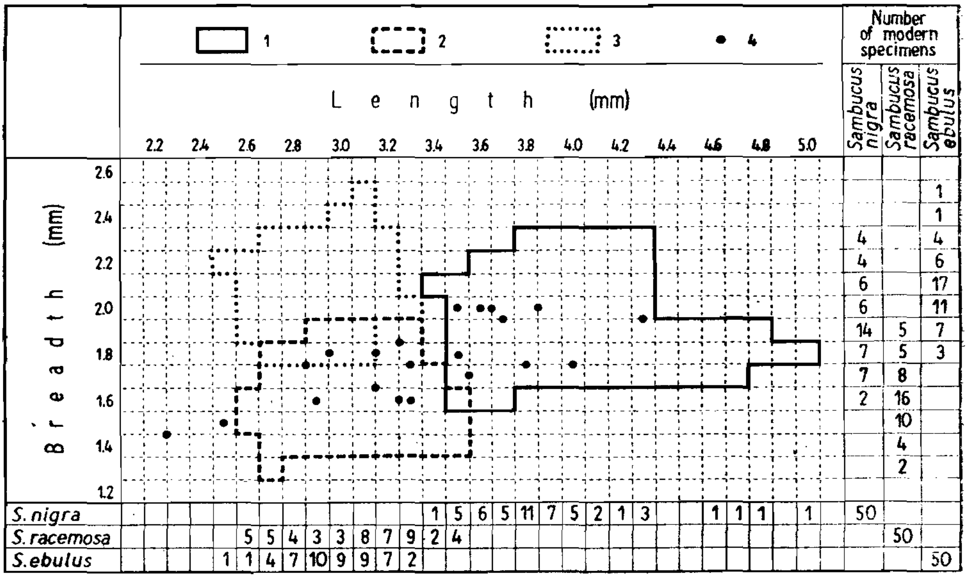

Fig. 6. Fossil stones of *Sambucus* from Imbramowice (4) within the ranges of dimensions of moder stones of *S. nigra* (1), *S. racemosa* (2) and *S. ebulus* (3). Dimensions of modern stones acc. to Wieser 1982

An attempt to identify the species was made on the basis of the results of a biometrical study carried out by Wieser (1982) on the modern material of *S. ebulus* L., *S. nigra* L. and *S. racemosa* L. from different Polish and Swedish sites. Basing himself on length and breadth measurements, he found that these species form groups, which only slightly overlap in the extreme values (cf. Fig. 6). A comparison of the measurements of undamaged specimens from Imbramowice with the modern material shows that 10 of them lie within the size range of *S. nigra* and 10 within the range of *S. racemosa* (Fig. 6). One specimen of sample 14, shorter than today's specimens of *S. racemosa*, is included in *S.* cf. *racemosa* (Note: three stones regarded as *S. racemosa* on the basis of their measurements have coarse wrinkles and dark colouration, given by Kac et al. (1965) as characteristic of *S. nigra*).

Caryophyllaceae

Gypsophila cf. *fastigiata* L. (Pl. II). One complete and 2 damaged seeds. The shape and arrangement of tubercles in all the seeds resemble those in *G. fastigiata*. The damaged seeds also correspond in size with the present-day seeds of this species, ranging within limits 1.0—1.35 × 1.15—1.25 mm. The seed in a good state of preservation is somewhat larger (1.4 × 1.25 mm). The occurrence of these seeds is correlated with the presence of *Gypsophila fastigiata* type pollen, which appears also in other zones.

Silene otites (L.) Wib. (Pl. II). One seed measuring 0.8 × 0.65 mm with a characteristic sculpture of the surface. The dorsal side, with four rows of transversely elongate tubercles, is bent towards the middle. On the lateral sides of the seed the tubercles are flat and narrow, arranged in more or less concentric rows. Close to the hilum the boundaries between the tubercles are blurred and they form radial wrinkles. This species has not hitherto been recorded from the Eemian of Poland.

Ceratophyllaceae

Ceratophyllum demersum L. 102 fruits with smooth surface and seven (in zone

IM-7) with fine tubercles (Pl. III). Fruits with tubercles are described as *C. demersum* var. *strypense* Zapał. (Pawłowski 1927). The maximum frequency of *C. demersum* occurs much later than that of *Ceratophyllum* hairs identified in the course of pollen analysis.

Cyperaceae

Carex aquatilis Wahlenb. (Pl. II). One fruit in a nerveless utricle with only sparse purple cells and 14 without utricles, of which six are identified as *C.* cf. *aquatilis*. Size of fruits: 1.34(1.05—1.45)×0.89(0.75—1.00) mm; they taper from the very middle narrowly towards the base. *C. aquatilis* was reported from several sites referred to the last glaciation (Wasylikowa 1964) and from the Eemian at Rusinów (Heck 1929).

Carex elata All. (= *C. hudsonii* Bennet) (Pl. II). Five fruits, without utricles, resembling *C. gracilis* Curt. in shape, but larger; size of two fruits: 2.0×1.3 and 2.25×1.25 mm. Remaining three fruits identified as *C.* cf. *elata*.

Carex gracilis Curt. (Pl. II). 84 fruits without utricles, 53 of them typical, elongate, with a slightly obtuse or almost right angle between the beak and the fruit body; the ring at its base is thick. Size of 12 fruits: 1.52(1.3—2.0)×1.17(1.0—1.4) mm. 31 less typical fruits identified as *C.* cf. *gracilis*.

Carex nigra (L.) Reich. (= *C. fusca* All.) (Pl. II). Three whole fruits and a half, of typical shape, broadly convex in the middle part and with an obtuse angle between the beak and the fruit body; thick ring at the base. Size: 1.0×0.85, 1.15×0.85, 1.4×1.25 and 1.65×1.4 mm. 15 fruits, a little less typical in shape but more resembling *C. nigra* than *C. gracilis*, identified as *C.* cf. *nigra*.

Carex cf. *oederi* Retz. ssp. *pulchella* Lönnr. (=*C. scandinavica* Davies) (Pl. II). One fruit in sample 18, triangular, without stipe; beak very short, walls slightly concave, somewhat obovate in shape. Size: 1.15×0.95 mm. This is an extremely small form of *C. flava* agg.

Carex pseudocyperus L. (Pl. II). 97 fruits and their numerous fragments, without utricles, seven fruits in utricles and several fragments of empty utricles. Size of 7 fruits: 1.59(1.35—1.95)×0.89(0.75—1.05) mm. Size of utricles: 3.25—4.20××1.15—1.50 mm. 11 less typical fruits identified as *C.* cf. *pseudocyperus*.

Carex rostrata Stokes (Pl. II). 693 whole fruits, and 54 damaged, without utricles, 9 with utricles and several empty utricles. Fruits differentiated very much in respect of size and their slenderness. Size: 25 elongate fruits — 1.84(1.50—2.35)××1.12(0.95—1.30) mm and 15 broad specimens — 1.62(1.20—2.00)×1.25(0.85—1.50) mm. Surface of epidermis identical in both forms, with verrucae lying very close to each other. Both forms with fairly long, thin and curved beak often preserved.

Eleocharis palustris (L.) R. et Sch./*E. mamillata* Lindb. f. 34 fruits, without beak, obovate, with rounded edges and crumpled epidermis; no distinct sculpture. Length of 15 fruits: 1.3(1.0—1.5) mm. The distinction between fruits of *E. palustris* and *E. mamillata*, with no beaks preserved, is not reliable. The shape of the fruits suggests *E. palustris* (cf. Żukowski 1965).

Dipsacaceae

Knautia arvensis (L.) Coult (Pl. III). One fruit, void of hairs. Size: 4.25×2.15 mm. The fruits of *K. arvensis* are broader and shorter than those of *K. sylvatica* (L.) Duby, while *K. kitaibelii* (Schult.) Borb. has shorter apical denticles and more distinct and longer ribs.

Fagaceae

Quercus L. Six pieces of wood, 0.1—2.5 cm long. Two of them, in sample 55, coincide with the beginning of the continuous *Quercus* pollen curve, with values below 1%.

Hydrocharitaceae

Stratiotes aloides L. (Pl. III). Seven spines, 0.6—1.2 mm long, their apical part bearing no sculpture, cells below sculptureless part visibly elongated. *Najas* has similar spines as regards shape and size, but their apical part is grooved and the cells underneath are subsquare.

Labiatae

Mentha cf. *aquatica* L. 124 nutlets, oval in outline; ventral side bi-angular and rounded, dorsal side rounded and flattened. Pyramid-shaped hilum, with 3 unequal areas. Some nutlets are covered by a thin spongy layer with a very distinct reticulum, others with traces of the spongy layer and still others, smooth, without this layer. The nutlets preserved with the spongy reticulate layer most resemble *M. aquatica*. The mean size of 6 specimens is 0.85 × 0.6 mm, the diameter of reticulum meshes being 14—42 μm. The nutlets with the surface deteriorated probably belong to this same species. Körber-Grohne (1967) draws attention to the great variability of the surface in the present-day nutlets of *M. aquatica;* the nutlets examined by her from North Germany and from the western coast of the Netherlands (var. *salina*) were pitted and those from England relatively smooth.

Lemnaceae

Lemna cf. *trisulca* L. (Pl. IV). Two fruits in sample 25, one oval and other more or less quadrangular, slightly flattened. Size: 0.9 × 0.6 and 0.9 × 0.65 mm. Ribs distinct, rather broad and rounded at top. The fruits of *Lemna* sp. are known from two Eemian sites, from Nakło (Noryśkiewicz 1978) and Jaworzyna Śląska (Kuszell 1980).

Loranthaceae

Viscum L. (Pl. III). A piece of wood within the range of the continuous curve of *Viscum* pollen.

Lythraceae

Lythrum salicaria L./L. *virgatum* L. (Pl. III). Six seeds with surface covered by linearly arranged elongate cells. Size: 0.69(0.55—0.80) × 0.34(0.25—0.40) mm. *L. hyssopifolia* L. seeds are considerably shorter and roundish in outline. Imbramowice is the first Eemian site of *Lythrum* seeds; pollen was reported from Bedlno (Środoń & Gołąbowa 1956), Józefów (Sobolewska 1966), Główczyn (Niklewski 1968) and Żyrardów (Krupiński 1978).

Najadaceae

Najas marina L. 245 whole fruits, 1726 halves and 111 damaged. Fruits characterized by great variability of size and shape (Pl. IV). The past studies of *N. marina* fossil fruits (Gawłowska 1935; Backman 1941; Środoń 1954a; Kräusel 1955; Jung, in Jung et al. 1972) were resumed and attempts made to differentiate the Imbramowice material from the systematic stand-point, including 1140 specimens suitable for measuring from zones IM-5—IM-10 (58.2%). The length and breadth of fruits were measured and the length:breadth ratio was calculated for particular specimens. At the same time, attention was given to the shape of fruits. The table with the results of measurements and descriptions of the shape are deposited in the archives.

The mean length from all the fruits is 4.6(2.5—6.3) mm and the mean breadth 2.2(1.1—3.3) mm. The fruits with the length:breadth ratio < 3 and therefore, according to Backman (1941), corresponding to the form ovata, are decidedly more prevalent in all zones (95—99%). The broadest fruits with the length:breadth ratio < 2 dominated in samples 54—45 (62.9—53.5%), in younger zones their proportion approximated 36%. The size of these fruits was strongly differentiated but short specimens, rounded at both ends, similar to those described by Środoń (1954a) as the form ovata, occurred only sporadically. Scarcely 24 (2.1%) decidedly

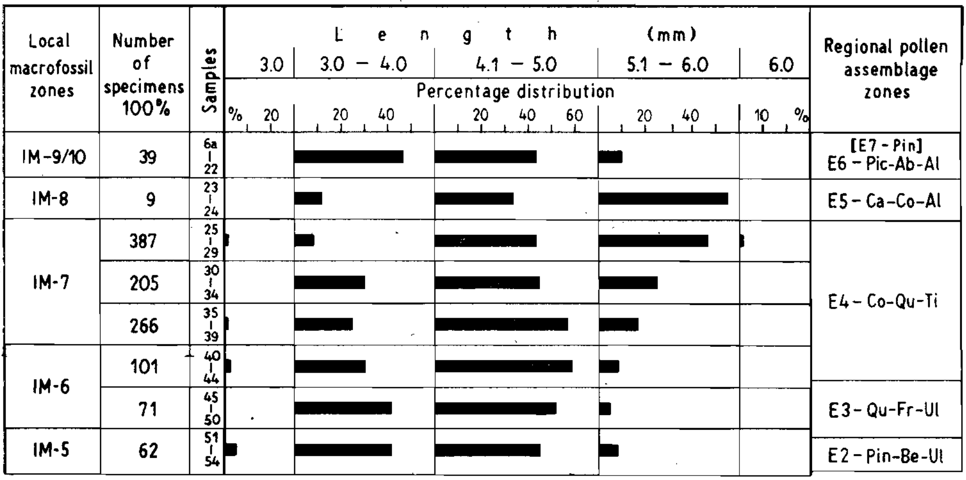

Fig. 7. Variation in length of fossil fruits of *Najas marina* through local macrofossil zones IM-5—IM-9/10 (for description see below)

narrow fruits, with the length:breadth ratio $\geqslant 3$ (forma typica sensu Backman) were found in the whole material. On the basis of the foregoing shape analysis no results have been obtained to differrentiate the fruits with respect either to taxonomy or to stratigraphy.

An analysis of the length of fruits showed that the specimens 3.0—4.0 mm long formed 23% of the whole population, the specimens 4.1—5.0 mm long — 49.0% and those 5.1—6.0 mm long — 26.6%. Twelve fruits (ca. 1%) were shorter than 3 mm or longer than 6 mm. Fruits of all the three length groups mentioned were present in all the zones of the profile in which fruits of *N. marina* were found, but the proportion of fruits exceeding 4 mm in length distinctly increases from the older to the younger part of the interglacial (Fig. 7). This tendency reached a maximum in the climatic optimum, in particular in the upper part of zone IM-7 with the longest fruits in the whole profile, and persisted in zone IM-8; in the terminal period of occurrence of *Najas marina*, falling in zone IM-9, the percentage of long fruits decreased rapidly. The variability of fruit length in *N. marina* from Imbramowice is very distinct and is correlated with climatic changes (cf. Fig. 7). A similar correlation was observed by Środoń (1954a), Kräusel (1955) and Jung (Jung et al. 1972).

This differentiation of the fruit length permits also the distinction of at least two forms of this species in the Imbramowice material: a small-fruit form, resembling modern *N. marina* var. *intermedia* Wolfg., distinguished, among other features, on the basis of 3—4-mm-long fruits (Rendle 1901; Lilienfeldówna 1919; Markgraf 1981), and a big-fruit form (above 4 mm in length), which perhaps agrees with modern *N. marina* var. *communis* Rendle or embraces also other varieties.

Oenotheraceae

Trapa L. The distinctly differentiated shape and size of the horns suggested the occurrence of two species. The material was thus examined by Prof. J. Staszkiewicz and Dr. J. Wójcicki. They found that in addition to *T. natans* L. it also represented *T.* cf. *conocarpa* (Areschoug) Fleroff in Tacik's (1963) systematic approach.

Trapa natans L. (Pl. IV). Five fragmentary necks, narrowed beneath well-developed broad apical corona, radially folded; 9 horns, varying in size, probably both upper and lower ones, dilated and concave at base; a fragmentary fruit body with a basal ring and one lower horn.

Trapa cf. *conocarpa* (Areschoug) Fleroff (Pl. IV). 45 horns, of varied size, some with fragments of nuts. Most horns thin, uniformly broadening toward base, without concavities and with longitudinal ribs of various thickness, or smooth. Together with the horns bearing features of *T. conocarpa*, there were also tubercles, detached or with fragments of nuts, in several samples. They were noted both in the samples which contained only horns with characters of *T. conocarpa* and in sample 30, in which there were only remains of *T. natans*. They varied in size from 2.7×2.0 to 7.0×4.2 mm. According to Tacik (1963), nuts which have big interhorn tubercles, about 4 mm long and approximately equally thick, or somewhat shorter, belong to a separate species, *T. muzzanensis* (Jägg.) Szafer, Kulcz. et Pawł. According to Staszkiewicz and Wójcicki (1979) nuts with tubercles form "a small proportion in many populations of *T. natans* and even appear in populations resembling *T. conocarpa*". It seems that this is just the situation observed in the material from Imbramowice.

Determination of *T. natans* and *T.* cf. *conocarpa* at Imbramowice makes it possible to call in question the hypothesis of Staszkiewicz and Wójcicki (1979) that they are young species, at the most, of Holocene age.

Papaveraceae

Papaver rhoeas L. type (Pl. III). Three seeds, measuring 1.25×0.95, 1.30×0.9 and 1.2×0.85 mm. The type includes *P. rhoeas* L., *P. dubium* L. and *P. strigosum* (Boenn.) Schur. (Wasylikowa 1978).

Polygonaceae

Rumex maritimus L. (Pl. III). Thirteen inner perianth sepals sufficiently well preserved, with long setae and elongate-ovate tubercles (cf. Marek 1954). One fruit in sample 56 with sharp edges, 1.30×0.85 mm in size, was identified as *R.* cf. *maritimus* on the basis of the presence of inner perianth sepals of this species. Fruits of *R. maritimus* are morphologically very similar to those of *R. ucrainicus* Fisch. (Marek 1954).

Potamogetonaceae

Dr. M. Aalto identified 14 species of *Potamogeton* L., among them *P. vaginatus* Turcz., absent from the modern flora of Poland.

Primulaceae

Lysimachia thyrsiflora L. (Pl. IV). One seed, 1.2×0.9 mm. Its dorsal side oval and slightly convex; ventral side bi-angular, with straight scar on rib. Surface covered densely with fine cells. *L. thyrsiflora* pollen was found in a sample correlated with the location of the seed and, in addition, in three other samples.

Rosaceae

Alchemilla L. (Pl. III). One fruit, asymmetrically ovate. Cells, arranged in rows, form a striate sculpture. Size: 0.95×0.6 mm. The size of present-day fruits shows great variability. The measurements of 50 fruits of various species, picked out at random, are 1.37(0.75—2.10)×0.94(0.50—1.20) mm.

This is the first record of *Alchemilla* in the Eemian in Poland.

Rubus sp. div. One complete fruit-stone and two halves. The whole stone belongs most likely to the *R. plicatus* W. et N. type, which comprises different species of the section *Rubus* except *R. caesius* L. (Wasylikowa 1978); two halves are probably *R. idaeus* L.

Saxifragaceae

cf. *Parnassia palustris* L. Seven seeds. Their identification was based on the characteristic spumy structure of the tissue surrounding the seed and very typical cells on its surface. As the seeds are heavily disfigured and only one of them has the characteristic shape of a slightly bent cylinder preserved, the identification is not quite certain. *P. palustris* pollen was not recorded before the younger zones.

Ulmaceae

Ulmus L. Six small pieces of wood in sample 38, corresponding to zone IP-8b, in which the values of *Ulmus* pollen range from 0.77 to 1.30%.

OTHER FOSSILS

Redeposited pollen and spores

Sporomorphs of pre-Quaternary, mainly Tertiary age abound in zones IP-1—IP-4a, which correspond with silt deposits. They were also observed sporadically in zones IP-4b and IP-6 and again at the top of the profile, in zones IP-12b, IP-13 and IP-14 (silts and sands). The highest values, reaching 41.1%, were found in zone IP-1 (Fig. 3).

Table 4

List of redeposited Tertiary pollen and spores

Araliaceae
cf. Arecaceae
cf. Barleria^{+}
cf. Callitris^{+}
Carya
Castanea/Castanopsis *
Cedrus *
Celtis
cf. Concavisporites sp.$^{+}$
Coniferae saccatae indeterminatae
Corylopsis^{+}
Corylus americana type
cf. Corypha^{+}
Cryptomeria
Cryptomeria/Sequoia
Cunninghamia
Cyathea cf. vestita^{+}
Cyatheaceae/Schizeaceae
Cyrillaceae/Clethraceae
cf. Dacrydium
Diervillea^{+}
Eleagnaceae^{+}
Eleagnus^{+}
Engelhardtia *
Gleicheniaceae
Glyptostrobus
cf. Hamamelis^{+}
Ilex verticillatum type
Juglans^{+}
Liliodendron^{+}
Liquidambar
Lycopodium cernuum type^{+}
Lygodium sp. 1^{+}
Lygodium sp. 2
Mohria^{+}
cf. Myrica
Nyssa (f. minor*, f. media * f. magna *)
Oenotheraceae
Oleaceae^{+}
Osmunda cf. bromeliifolia^{+}
Osmunda cinnamomea type
cf. Ostrya
cf. Parrotia^{+}
Pinus haploxylon type (f. minor, f. media *, f.major*)
Podocarpus
Podocarpus cf. dacrydioides^{+}
Pollenites laesus
Proteaceae^{+}
cf. Ptelea^{+}
Pterocarya *
Rhus^{+}
Sapindus^{+}
Sciadopitys *
Sequoia *
Sporae trilete indeterminatae
Symplocos
Taxodium
Taxodiaceae/Cupressaceae *
Trudopolis pertrudens
Tsuga canadensis type *
Tsuga diversifolia type
Tsuga sp.
Zelkova
Indeterminatae (Tertiary)

+ - sporadic (in no more than three samples) * - most abundant

A large number of indeterminable sporomorphs was also found in zones IP-1—IP-4a. All the four classes of deterioration distinguished by Cushing (1967a) were observed. Crumpled pollen (reaching 11.4% in IP-2) and broken (8.1% in IP-1) was most abundant. The concurrent occurrence of Tertiary and indeterminable deteriorated sporomorphs suggests that the latter also result from redeposition and presumably are mainly of Tertiary age, as well.

The sporomorphs acknowledged as older than Quaternary were not determined very closely. Most of them were identified to family or genus (Table 4). The indeterminate trilete spores belonged to different families, mainly of the class *Filicinae*. The group of Tertiary indeterminatae as a rule comprises tricolpate, tricolporoidate and tricolporate pollen grains. Presumably, they mostly include *Quercoidites henrici* R. Pot., uncertain grains of *Rhus*, *Araliaceae*, *Cornaceae*, *Oleaceae* and less typical *Cyrillaceae*/*Clethraceae*.

There were also numerous and various *Hystrichosphaeridae* present in the samples with pre-Quaternary sporomorphs. Some round organisms with a reticulum or various types of processes on the surface, most likely representing marine plankton, accompanied them (cf. Stuchlik 1964, Pl. XXV; Oszast & Stuchlik 1977, Pl. XIV). Several forms of *Ovoidites ligneolus* R. Pot. were noted in zones IP-1 and IP-2. The occurrence of all these microorganisms is shown in the pollen diagram (Fig. 3).

A macrospore of *Azolla filiculoides* Lam., measuring 0.4×0.3 mm, was also found in macroscopic zone IM-2.

Remains of animals

Spongiae

Gemmules of sponges, not determined more closely.

Mollusca

The state of preservation of these remains was poor. Probably, they were heavily damaged while being boiled and rinsed. They were identified by Dr. I. Dmoch and all the data included here come from her expert analysis.

Bithynia tentaculata (Linné). 344 complete or nearly complete opercula and their numerous fragments were identified. They varied much in size, from 4.2×2.9 to 1.0×1.07 mm. It lives in shallow fresh, preferably stagnant waters, on muddy bottoms with luxuriant vegetation.

Valvata cf. *cristata* Müller. Two damaged specimens.

Valvata cf. *piscinalis* Müller. Five damaged specimens.

Valvata sp. Eighteen fragments, mostly of one or two first whorls each.

The genus *Valvata* is characteristic of stagnant fresh waters.

Euconulus fulvus (Müller). One crumbled specimen. This species occurs in areas adjacent to swamps and in wet meadows.

Succinea pfeifferi Rossmäsler. A shell fragment of first two whorls. Occurrence as in *Euconulus fulvus*.

Pisidium sp. A juvenile mussel shell and a fragment of mature one. It occurs in quiet freshwater basins.

Bryozoa

Cristatella mucedo Cuvier. Round statoblasts, some of them surrounded with fine hooks. Diameter (without hooks): 0.71(0.55—0.95) mm.

Cladocera

Daphnidae. Ephippia with one or two egg locules.

Coleoptera

Not many specimens found at Imbramowice were identified by Prof. J. Pawłowski (Institute of Systematic and Experimental Zoology, PAScs, in Cracow). All the data included here come from his expert analysis.

Carabidae

Epaphius rivularis (Gyll.). One elytron. It is a Euro-Siberian species now, characteristic of wet forest communities. In Poland known from the Vistulian Late Glacial and Holocene, also from the decline of the Eemian.

Curculionidae

Notaris aethiops (Fabr.). Head with snout. Curculionid, associated stenotopically with peatbogs, but showing a relatively great tolerance. At present it is a Holarctic species. It is common at Pleistocene sites, particularly frequent in the Vistulian, and reported also from the Early Holocene.

Sitona flavescens (Marsh.). Nearly whole specimen. As it is only slightly damaged, a suspicion arises that it got to the material accidentally at the time of boring.

POLLEN STRATIGRAPHY

The pollen percentage diagram (Fig. 3) has been divided into 14 local pollen assemblage zones (L PAZ), which are numbered from the bottom upwards, the numbers being preceded with the symbol IP- (Imbramowice Pollen). Further in the course of descriptions, when it is already known that we are concerned with a pollen assemblage zone, the term pollen zone or simply zone is used. Most of the local pollen assemblage zones distinguished are also of regional use (Table 5).

Zone IP-1: 13.80—12.50 m. Represented by four random samples only. The lower boundary is placed consistently with the lower boundary of the first macrofossil assemblage zone (IM-1), with numerous remains of *Betula nana* and mosses, and above a zone almost completely void of macrofossils. The pollen frequency * is very low, 23—45 AP grains/cm² and 5—12 NAP grains/cm². Tree pollen values exceed 70%. *Pinus sylvestris* type is dominant (35 to over 45%). *Betula* cf. *nana* pollen with its values reaching 3.6% is characteristic of the zone. Herbs are represented by a very small number of taxa, *Cyperaceae* undiff. pollen being dominant. Pollen of thermophilous deciduous trees and *Corylus*, *Picea* and *Abies* is present (probably mainly redeposited). Tertiary sporomorphs, *Hystrichosphaeridae* and other microfossils of unknown affinities are very abundant. The upper boundary is placed below the sample with the increased herb values.

Zone IP-2: 12.50—11.10 m. Pollen frequency low, 23—46 AP grains/cm² and 12—41 NAP grains/cm². Herb pollen values exceed 30%, but the variety of herb taxa is still small. In addition to *Cyperaceae* undiff. (over 20%) and *Artemisia* (up to 4%), pollen of *Gramineae* undiff., *Ericaceae* undiff., *Rosaceae* undiff. and spores of *Polypodiaceae* s. l. undiff. have relatively high values. *Pinus sylvestris* type dominates among trees. Pollen of *Salix glauca* type, *Juniperus* and *Betula* cf. *nana* are constantly present. Redeposited pollen of thermophilous deciduous trees and *Corylus*, *Picea* and *Abies* as well as pollen and spores of pre-Quaternary age remain present, as do *Hystrichosphaeridae*. The upper boundary is placed where *Artemisia* increases from 3.3 to 5.7%. Total values of Tertiary sporomorphs decrease from 33.8 to 14.2%.

Zone IP-3: 11.10—10.45 m. Increase in pollen frequencies: 38—102 AP grains/cm² and 35—70 NAP grains/cm². Herb pollen reaches high values (max. 52.4%). *Cyperaceae* undiff. pollen still dominant. A rise occurs in the pollen values of

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* The pollen frequency is expressed as a number of pollen grains per 1 cm² of microscope slide.

Table 5

Correlation of the various local biostratigraphical units distinguished in the Imbramowice profile with the regional pollen assemblage zones (R PAZ)

	Regional pollen assemblage zones					Local zones pollen	Local zones macrofossil	Diatom periods (Kaczmarska 1976)	Depth m
EARLY VISTULIAN	EV1		Gramineae-Artemisia-Betula nana			IP-14	IM-11	VI	3
EEMIAN	E7		Pinus			IP-13	IM-10	V C	4
	E6		Picea-Abies-Alnus		b	IP-12	IM-9	B	
					a			A	5 6
	E5		Carpinus-Corylus-Alnus			IP-11	IM-8		
	E4	b	Corylus-Quercus-Tilia	Tilia-Carpinus subzone		IP-10	IM-7	IV	
						IP-9			7
		a		Corylus-Quercus subzone	b	IP-8			
					a		IM-6		8
	E3	b	Quercus-Fraxinus-Ulmus	Corylus subzone	b	IP-7			
		a		Pinus subzone	a				9
	E2		Pinus-Betula-Ulmus			IP-6	IM-5	III B	
	E1	b	Pinus-Betula	Betula subzone		IP-5	IM-4		
		a			b	IP-4		A	10
					a				
MIDDLE-POLISH GLACIATION s.l. (= SAALIAN s.l.) Late Glacial			Cyperaceae-Artemisia--Betula nana	Juniperus subzone		IP-3	IM-3	II I B	11
						IP-2	IM-2	A	12
						IP-1	IM-1		13

Artemisia (to 9.3%), *Chenopodiaceae* and *Ranunculus acris* type. There is a great variety of herb taxa. More significant in these are *Helianthemum*, *Gypsophila fastigiata* type, *Gentiana pneumonanthe* type, cf. *Saxifraga nivalis*, *S. oppositifolia* type and *Selaginella selaginoides*. The values of *Juniperus* pollen increase, *Populus* is present, and *Hippophaë rhamnoides* and *Ephedra fragilis* type appear. In the upper part of the zone the values of Tertiary pollen and redeposited pollen of thermophilous deciduous trees decrease rapidly. The upper boundary is placed where the NAP values fall transitorily below 25% and those of *Pinus sylvestris* type increase to more than 40%.

Zone IP-4: 10.45—9.67 m. Pollen frequency increases: 71—374 AP grains/cm² and 26—128 NAP grains/cm². *Pinus sylvestris* type is dominant (51.6%), the values of *Betula* undiff. being somewhat lower. *Gramineae* undiff. and *Cyperaceae* undiff. have the highest pollen values among the herbs (20—30%), those of *Artemisia*, *Chenopodiaceae*, *Ranunculus acris* type and *Thalictrum* are lower, and the other taxa do not exceed 1% or occur sporadically. New taxa of aquatic and swamp plants appear. Tertiary pollen declines in the top part of the zone. The upper boundary is based at the rapid fall of pollen values of *Pinus sylvestris* type and herbs and the disappearance of *Betula* cf. *nana* pollen.

Zone IP-4 is divided into two subzones at a depth of 10.15 m.

Subzone IP-4a is characterized by more abundantly occurring *Juniperus*.

Subzone IP-4b has the highest values of *Populus* in the whole profile. As regards reedswamp plants, *Sparganium* type and *Phragmites* type reach their highest pollen values.

Zone IP-5: 9.67—9.57 m. AP frequency increases rapidly to 454 grains/cm² and NAP comes to 48 grains/cm². The zone is represented only by one sample and characterized by the increase of *Betula* undiff. pollen values to 57.7%. The upper boundary is marked by another fall in the pollen values of *Betula* undiff. and the increase of *Ulmus* and *Pinus sylvestris* type.

Zone IP-6: 9.57—9.15 m. AP frequency high, variable, ranging from 176 to 1210 grains/cm²; NAP frequency moderately low, 17—40 grains/cm², with an isolated maximum of 143 grains/cm². *Pinus sylvestris* type pollen attains the highest values (max. 65.1%). Values of *Betula* undiff. and *Populus* are decreasing. The highest values of *Ulmus* pollen in the whole interglacial, with a maximum of 4.0%, are a characteristic feature of this zone. *Quercus* pollen rises to about 6%, *Fraxinus* and *Picea* are continuously present but with low values. *Hedera helix* occurs for the first time. NAP values are low, 8—11%, with dominant *Gramineae* undiff. The continuous curve of *Humulus lupulus* starts. Aquatic and marsh plants are represented by numerous taxa. The upper boundary is placed at the beginning of the decline of *Pinus sylvestris* type pollen and the rise of *Quercus*.

Zone IP-7: 9.15—8.45 m. AP frequency high, variable, 168—523 grains/cm², NAP 22—83 grains/cm². Pollen of *Quercus* and *Pinus sylvestris* type dominate but the values of *Pinus* fall consistently. *Quercus* and *Fraxinus* are characteristic of the zone. The values of *Fraxinus* pollen are relatively low, with an absolute maximum 3.2%. NAP values are somewhat higher than in IP-6, *Gramineae* undiff. being dominant. Pollen of aquatic and marsh plants is fairly frequent, *Sparganium* type and *Phragmites* type being most abundant. The upper boundary is placed where the pollen values of *Quercus* fall below 30% and *Pinus sylvestris* type below 20%, whereas those of *Corylus* exceed 40%.

Zone IP-7 is divided into two subzones at a depth of 8.62 m.

Subzone IP-7a is characterized by the continuous increase of *Quercus* pollen values (max. 41.3%) and the continuous curve of *Corylus* (10.1% close to the upper boundary of the subzone). *Ligustrum vulgare* pollen appears sporadically in the upper part of the subzone and *Hedera helix* is more frequent.

Subzone IP-7b is distinguished by a small decrease in the values of *Quercus* pollen and the further rise of *Corylus*, to over 30%.

Zone IP-8: 8.45—7.45 m. AP frequency high, variable, 184—646 grains/cm², NAP low, 12—38 grains/cm². *Corylus* is the dominant pollen type, with a maximum of 71.1% (244.4% in relation to AP sum without *Corylus*; 64.4% of AP sum including *Corylus* but after applying Andersen's correction factors (1970, 1973a)). *Quercus* values decrease, values of *Pinus sylvestris* type fluctuate around 10% and the continuous *Carpinus* curve begins. Herb pollen does not exceed 7%. *Humulus* *lupulus* is relatively significant (up to 0.4%). Aquatic and swamp plants are represented by less abundant pollen than in zones IP-4—IP-7. The upper boundary is marked below the rise of pollen values of *Taxus baccata*.

Zone IP-8 is divided into two subzones at a depth of 7.85 m.

Subzone IP-8a shows an absolute maximum of *Corylus*, relatively high values of *Fraxinus* (to 3.0%) and rising pollen values of *Alnus* undiff.

Subzone IP-8b is characterized by the increase of *Alnus* undiff. values to 11.3% and the beginning of the continuous low-percentage curves of *Taxus baccata* and *Tilia cordata* type.

Zone IP-9: 7.45—6.98 m. AP frequency 307—650 grains/cm², NAP — 10—30 grains/cm². Values of *Corylus* pollen are lower than in zone IP-8 but are still high (45—50%). The high frequencies of *Taxus baccata* pollen, with a maximum of 11.8%, are a characteristic feature. Pollen values of *Tilia cordata* type rise to 4.4%, whereas those of *Quercus* and *Alnus* remain at about 10%. *Hedera* occurs continuously; *Viscum* and *Viburnum* have their continuous curves starting here, while pollen grains of *Ilex aquifolium* type and *Cornus sanguinea* occur singly. Pollen of aquatic and swamp plants is poorly represented. The upper boundary is placed at the distinct fall of *Taxus baccata* pollen values and the small rise of *Tilia cordata* type, *T. platyphyllos* type and *Alnus* undiff.

Zone IP-10: 6.98—6.42 m. AP frequency 170—383 grains/cm², NAP — 8—17 grains/cm² (lowest in the whole interglacial). *Corylus* still dominant (35—45%). The highest values of *Tilia cordata* type in the interglacial and somewhat more frequent occurrence of *T. platyphyllos* type are characteristic of this zone. Values of *Taxus baccata* fluctuate about 5%, with a peak of 8.3%. Frequencies of *Alnus* undiff. and *Carpinus* increase, and so do, once again, values of *Fraxinus* (2.6%). *Hedera helix* and *Viscum* pollen are constantly present and *Ligustrum vulgare* is noted in the top part of the zone. The upper boundary lies below the rise of *Carpinus* pollen values to over 10% and the fall of *Corylus* below 40%.

Zone IP-11: 6.42—6.07 m. AP frequency 83—209 grains/cm², with a peak of 604 grains/cm², NAP — 5—38 grains/cm², with a peak of 71 grains/cm². *Carpinus*, with a maximum of 23.6%, is the distinctive taxon of the zone. Values of *Corylus*, *Quercus*, *Tilia*, *Taxus* and *Alnus* are somewhat lower than in zone IP-10. *Ilex aquifolium* type occurs nearly continuously. *Picea* pollen values increase and the continuous occurrence of *Abies* begins at the top of the zone. In the top part of the zone NAP values, chiefly *Cyperaceae* undiff. and *Gramineae* undiff., increase slightly; values of *Polypodiaceae* s. l. undiff. and *Dryopteris thelypteris* rise rapidly. *Trapa* pollen appears and microsporangia of *Salvinia natana* are more frequent. The upper boundary is at the steep fall of values of *Carpinus* as well as *Corylus*, *Taxus*, *Tilia cordata* type, *Quercus*, *Fraxinus*, *Ulmus* and *Acer* and the rise of *Picea abies* values to about 7%.

Zone IP-12: 6.07—4.40 m. AP frequency variable, 107—375 grains/cm², NAP — 28—115 grains/cm². *Picea abies* and *Abies* are characteristic of the zone and *Alnus* undiff. and *Pinus sylvestris* type dominant in it. The percentages of *Carpinus* and *Corylus* remain relatively high. Pollen of other thermophilous trees has low values. Single grains of *Larix* pollen appear. NAP values rise rapidly and the variety of taxa distinguished among them increases; *Cyperaceae* undiff. and *Gramineae* undiff. are dominant. The continuous curve of *Sphagnum* begins above the lower boundary. The upper boundary is at the level of the increase in pollen values of *Pinus sylvestris* type and herbs.

Zone IP-12 is divided into two subzones at a depth of 5.37 m.

Subzone IP-12a is characterized by consistently increasing pollen values of *Picea* (to 9.0%) and *Abies* (to 2.8%); values of *Pinus sylvestris* type and NAP are high.

Subzone IP-12b is marked by maximum values of *Picea* and *Abies* and the dominance of *Alnus* undiff. Percentages of *Pinus sylvestris* type and NAP decrease and those of *Carpinus*, *Corylus*, *Taxus*, *Tilia cordata* type, *Ulmus* and *Acer* rise slightly.

Zone IP-13: 4.40—3.83 m. Pollen frequency: 157—653 AP grains/cm^2 and 61—243 NAP grains/cm^2. High pollen values of *Pinus sylvestris* type and herbs are characteristic. In the top part of the zone *Betula* undiff. has somewhat increased values. Curves of *Alnus*, *Corylus*, *Picea* and *Abies* decrease consistently. The continuous curves of *Salix glauca* type and *Juniperus* re-appear. There are sporadic pollen grains of *Ephedra* distachya type and *E. fragilis* type. The upper boundary is placed below the sample in which NAP values rise to 43% and *Artemisia* reaches 3.7%.

Zone IP-14: 3.83—2.45 m. AP and NAP frequencies, variable in a parallel manner, are, respectively, 91—804 and 91—621 grains/cm^2. The rise in pollen values of herbs to 59.4% and the great variety of taxa distinguished are a characteristic feature of the zone. Pollen of *Cyperaceae* undiff., *Gramineae* undiff. and *Artemisia* are most abundant. The last two taxa are distinctive in the zone. Percentages of *Plantago maritima* s. str. and *Filipendula* are also relatively high and numerous herb taxa occur continuously, though in small quantities. *Pinus sylvestris* type dominates among the trees (max. 40.9%). Pollen values of *Betula* undiff. increase to about 10% and those of *Larix* to 0.7%. The continuous curve of *Betula* cf. *nana* and the nearly continuous curve of *Pinus cembra* begin. Aquatic and swamp plants are represented by fairly numerous taxa. The zone has no upper boundary.

MACROFOSSIL STRATIGRAPHY

The diagram of macrofossils (Fig. 4) has been divided into 11 local macrofossil assemblage zones (L MAZ) designated with numbers from the bottom upwards, preceded with the symbol IM (Imbramowice Macrofossil). They have been determined on the basis of one or more macrofossil taxa, diagnostic for the zone or which are particularly abundant. The correlation of the macrofossil zones with other stratigraphic units distinguished is presented in Table 5.

Zone IM-1: 13.80—12.50 m. Only remains of *Betula nana* and mosses, mainly *Ditrichum flexicaule*, *Campyllium chrysophyllum* and *Drepanocladus aduncus* var. *kneiffii*, are relatively numerous. *Cenococcum graniformae* is abundant. Other remains are rare and some of them have probably been derived from the upper part of the profile. The upper boundary is below the abundant occurrence of *Betula nana*.

Zone IM-2: 12.50—11.10 m. This is the zone with the most abundant occurrence of *Betula nana*. The nutlets of tree birches are fairly numerous only in the top sample of the zone. *Selaginella selaginoides* macrospores are present. The mosses are abundant, with a number of new species. *Cenococcum graniformae* reaches its maximum occurrence here. *Nitellopsis obtusa*, *Chara hispida* and *Potamogeton filiformis* are very numerous in the last sample of the zone. The upper boundary is above the decrease of *Betula nana* and below the abundant occurrence of *Potamogeton filiformis*.

Zone IM-3: 11.10—10.60 m. The nutlets of tree birches occur continuously and the proportion of *Betula nana* is low. The variety of aquatic taxa increases. *Potamogeton filiformis*, characteristic of this zone, attains its absolute maximum;

P. vaginatus and *P. perfoliatus* appear. The upper boundary is marked above the fall of *Potamogeton filiformis* and below the increase of tree birches.

Zone IM-4: 10.60—9.65 m. The tree birches occur in abundance, *Betula* cf. *pendula* and *Pinus sylvestris* appear for the first time. The remains of *Betula nana* decline in the upper part of the zone. *Ranunculus sceleratus, Batrachium, Carex rostrata, Nitellopsis obtusa* and *Rorippa palustris* are the most abundantly represented taxa. *Carex aquatilis* and the shrinking proportion of *Cenococcum graniformae* are noteworthy. The upper boundary is placed below the beginning of the continuous occurrence of *Najas marina.*

Zone IM-5: 9.65—9.10 m. This is a zone of the maximum occurrence of tree birches, mainly *Betula* cf. *pendula.* As regards aquatic plants, *Najas marina* and *Nitellopsis obtusa* are fairly abundant and *Myriophyllum verticillatum* has its absolute maximum. *Nymphaea alba* appears and *Salvinia natans* begins to occur continuously. *Carex pseudocyperus* and *Urtica dioica* are numerous. The upper boundary is marked above the maximum of tree birches and below the abundant appearance of *Typha.*

Zone IM-6: 9.10—7.90 m. The fruits of tree birches are still rather numerous but disappear at the top of the zone. The zone is characterized by the absolute maximum of *Nitellopsis obtusa, Chara hispida* and *Typha* and the first culmination of *Salvinia natans.* There are very many *Urtica dioica* fruits. The upper boundary is placed at the beginning of the continuous occurrence of *Alnus glutinosa* fruits and the increase of *Najas marina.*

Zone IM-7: 7.90—6.35 m. *Alnus glutinosa* prevails among the tree remains. *Ilex aquifolium* and *Viscum* appear singly. The aquatic taxa are dominated by *Najas marina* and, in the top part of the zone, again by *Nitellopsis obtusa* and *Salvinia natans. Ceratophyllum demersum* fruits attain a maximum in the lower part of the zone and those of *Carex rostrata* are again abundant. In the mosses, *Brachythecium rutabulum, Oxyrrhynchium swartzii* and *Climacium dendroides* appear for the first time. The upper boundary is marked above the fall in the numbers of *Najas marina, Ceratophyllum demersum* and *Nitellopsis obtusa.*

Zone IM-8: 6.35—6.17 m. The fruits of *Alnus glutinosa* are still numerous but fewer than in IM-7. The remains of *Carpinus betulus* and *Tilia platyphyllos* increase in number and there are some further stones of *Ilex aquifolium. Salvinia natans* prevails among the aquatic taxa and of the mosses only *Brachythecium rutabulum, Funaria hygrometrica* and *Rhacomitrium canescens* are noted. The upper boundary is placed above the absolute culmination of *Salvinia natans.*

Zone IM-9: 6.17—4.50 m. *Alnus glutinosa* fruits, first not numerous, become abundant in the upper part of the zone. This is the only zone in which stones of *Sambucus nigra* and *S. racemosa* are present. In the middle of the zone fruits of *Betula nana* and tree birches re-appear. As for the aquatic taxa, *Salvinia natans* is still abundant and *Batrachium* and *Potamogeton filiformis* re-appear. There are also maximum quantities of *Carex rostrata, Potentilla anserina, Potentilla* undiff. and *Urtica dioica. Cratoneuron decipiens, Ditrichum heteromallum, Plagiomnium affine* and *Rhitidiadelphus squarrosus* appear. The upper boundary is marked above the rapid fall in the number of *Alnus glutinosa* fruits and below the almost continuous occurrence of *Betula nana* fruits and the appearance of *Potamogeton vaginatus* stones.

Zone IM-10: 4.50—3.50 m. The nutlets of tree birches and *Betula nana* are not numerous. *Alnus glutinosa* is present only in one sample. *Potamogeton vaginatus, Nitella gracilis* and *N. mucronata* are abundant and *Salvinia natans* is still frequent. The wide variety of taxa remains high. The upper boundary is placed above the fall in the number of *Potamogeton vaginatus, Salvinia natans* and *Urtica dioica* remains and below the rise of *Potamogeton gramineus*, *Myriophyllum spicatum* and *Carex rostrata*.

Zone IM-11: 3.50—2.40 m. The remains of tree birches, *Betula nana*, *Alnus* and *Salix* are present in small numbers. Various species of *Potamogeton* are abundant among the aquatic taxa, but *P. gramineus* prevails, as do, *Batrachium* and *Myriophyllum spicatum*. *Carex rostrata* occurs in abundance. In the mosses, *Cratoneuron filicinum*, *Drepanocladus aduncus* var. *aduncus* and *Leptodictyum riparium* appear for the first time. The zone has no upper boundary.

CHRONOSTRATIGRAPHY

The geological situation of the basin at Imbramowice gives no explicit grounds to refer its sediments to any definite section of the Pleistocene, because the boring did not reach boulder clay at the bottom of the lacustrine sediments and there is no moraine cover at the top (Szczepankiewicz 1962). The deposits from Imbramowice have not been dated radiometrically. Thus the assignment of these deposits, from which a sequence of 14 pollen assemblage zones has been described, to a definite part of the Pleistocene must be based mainly on the characteristic features of the vegetational development.

The local pollen assemblage zones (L PAZ) represent: IP-1—IP-3 a forestless period, IP-4—IP-13 an interglacial vegetational succession, and IP-14 again a forestless period. The characteristic features of the interglacial vegetational succession at Imbramowice include (1) the expansion of trees and hazel in the following order: *Betula-Pinus*, *Ulmus*, *Quercus-Fraxinus*, *Corylus*, *Alnus*, *Taxus*, *Tilia*, *Carpinus*, *Picea-Abies* and *Pinus*, and (2) the high *Corylus* values, with a maximum of 71.1%. These features permit an unquestionable correlation of this interglacial with the Eemian, with its type locality on the Eem River near Amersfoort in the Netherlands (Zagwijn 1961).

The lower boundary of the Eemian Interglacial from Imbramowice coincides with the upper boundary of L PAZ IP-3 (see p. 47). The changes observed in the pollen assemblage zones indicate a transition from a subarctic, park-tundra type landscape to a landscape with boreal forests. This defined boundary fulfils the criteria proposed by Zagwijn (1961).

No hiatus is observed in the sediments below the Eemian sequence of local pollen zones and so zones IP-1—IP-3 represent the Late Glacial of the Middle Polish Glaciation s. l. At Imbramowice its lower boundary is placed at the appearance of *Betula nana* macrofossils above the series of sediments that are nearly completely lacking in macroscopic plant remains.

The upper boundary of the Eemian Interglacial at Imbramowice is marked by the upper boundary of L PAZ IP-13. The pollen changes found here (see p. 51) indicate the replacement of forest by open vegetation. This boundary conforms to the criteria assumed in pollen stratigraphy for the Eemian/Vistulian boundary at the stratotype locality (Zagwijn 1961).

The acceptance of the opinion that the Vistulian followed directly the Eemian Interglacial leads, at the same time, to the statement that the type locality of the Eemian Interglacial is the boundary stratotype for the Eemian/Vistulian Stage boundary (cf. Mangerud et al. 1979a). The upper boundary of the Eemian in the Imbramowice profile, fixed on the basis of pollen stratigraphy, is therefore the lower boundary of the Vistulian, because there is no hiatus in the sediments of this section of the profile. Local pollen assemblage zone IP-14 represents the first cooling of the Early Vistulian.

VEGETATIONAL HISTORY

The local pollen zones distinguished in the Imbramowice profile have a number of features that resemble those in other Eemian diagrams from the territory of Poland. These similarities provide the basis for defining and designating the regional pollen assemblage zones — R PAZ — for the Eemian Interglacial, the Late Glacial of the Middle Polish Glaciation s. l. and the Early Vistulian in Poland (see p. 98). Imbramowice is the type locality for most of the regional zones distinguished.

The vegetational history of the surroundings of the Imbramowice Depression and of the aquatic vegetation is presented with reference to R PAZ-s. The correlation of the local pollen and macrofossil assemblage zones and the diatomaceous zones distinguished by Kaczmarska (1976) with the regional pollen assemblage zones is given in Table 5.

The large number of taxa identified to species (158) makes it possible, in some cases, to attempt to compare the fossil assemblages with modern communities on the assumption that under similar ecological conditions some phytocenoses similar to the present may have developed in the past. The use of these similarities seems admissible despite reservations which may be presented when communities of the remote past are compared with present-day associations. This seems, however, possible owing to many common characteristics of the vegetational succession of the Eemian and the Holocene. Szafer (1925) was the first in Poland who paid attention to these common features and Jessen (Jessen & Milthers 1928) shared that opinion.

Comparisons of the combinations of fossil species with the present-day associations were chiefly based on the characteristic species of particular syntaxonomic units according to the Braun-Blanquet system. Phytosociological classification and nomenclature follow Medwecka-Kornaś et al. (1972), with supplements based on W. Matuszkiewicz (1981) and Tomaszewicz (1979).

LATE GLACIAL OF THE MIDDLE POLISH GLACIATION S. L.

Local zones IP-1, IM-1

The very high proportion of Tertiary sporomorphs and indeterminable pollen, the presence of *Hystrichosphaeridae* and marine plankton and numerous sclerotia of *Cenococcum graniformae* indicate intense erosion of soil, still poorly protected by vegetation.

Such great quantities of redeposited Tertiary pollen prove indirectly that redeposition is also responsible for the presence of pollen of plants common to both the Tertiary and the Quaternary, especially trees and shrubs with high climatic demands as well as *Picea, Abies* and presumably part of the *Pinus sylvestris* type pollen and *Polypodiaceae* and *Sphagnum* spores. The curves of these parallel to the curve of Tertiary sporomorphs. Thus the relatively high values of *Pinus sylvestris* type pollen do not point at an abundance of pine in the vicinity of the lake, the more so, since part of the pollen certainly comes from long-distance transport under conditions of an open landscape.

In conjunction with the low pollen frequency and the small number of autochthonous taxa, these features indicate extremely poor terrestrial vegetation and an almost complete absence of vegetation from the lake. There were presumably pioneer sedge and grass communities colonizing fresh, deglaciated areas and patches of communities resembling shrub-tundra with dominant *Betula nana*, with willow shrubs, *Juniperus*, *Calluna vulgaris* and other *Ericaceae*. *Silene* type, *Thalictrum*, *Lycopodium annotinum* may be referred to those communities, while *Saussurea* type (?*S. alpina*), *Plantago lanceolata*, *Polygonum aviculare* type, *Artemisia* (?*A. absinthium* or *A. vulgaris*), *Equisetum*, *Juncus* and *Selaginella selaginoides* may be connected with more fertile habitats. Open grass communities with *Artemisia*, *Chenopodiaceae*, *Helianthemum canum*/*H. alpestre* and *Juniperus* expanded in drier habitats. In such habitats, rich in calcium carbonate, the mosses *Ditrichum flexicaule*, *Campylium chrysophyllum*, *Bryum caespiticium*, *Tortula ruralis* and *Amblystegium serpens* found favourable conditions. The seed of cf. *Jasione montana* may indicate the colonization of oligotrophic sandy areas.

The fruits of *Betula* cf. *pubescens*, a piece of *Pinus sylvestris* wood and clumps of *Populus* pollen suggest the occurrence of these trees in the close vicinity of the lake, probably as scattered trees only; this may be inferred from the above-described conditions of sedimentation and the low pollen frequency. The low pollen values of *Pinus cembra* (maximum 1.8%) may, but not necessarily, prove its presence in the neighbourhood. Kral (1971) assumes on the basis of his studies in the Dachstein Massif in the Alps that in the dwarf pine zone and in open forests no less than 6% of *Pinus cembra* pollen indicates its occurrence *in situ* but similar or even higher pollen values may also occur if the regional conditions allowed long-distance transport.

The occurrence of alder is a particularly difficult question. The curve of *Alnus* undiff. pollen behaves in this and the next zone similarly to the curves of other thermophilous trees, the presence of which is attributed to redeposition. This suggests that most *Alnus* undiff. pollen may also have been derived from redeposition. However, the presence of *Alnus* wood in zones IM-1 and IM-2 and also in the nearly whole glacial part of the profile (Mamakowa unpubl.) encourages the supposition that part of the *Alnus* undiff. pollen in IP-1 may be referred to *A. incana*, whose occurrence at that time was possible ecologically. It may well be also that some wood pieces belonged to *Alnus viridis*, two pollen grains of which were found in zone IP-1 and nine in IP-3 and IP-4a. In the Late Glacial of the profile Tarnawa II (Bieszczady Mts.) fossil wood of this shrub occurred with similarly low pollen values of *Alnus* cf. *viridis* and in the Late Vistulian interstadial at Smerek nutlets of *A. viridis* were found while its pollen was completely missing (Ralska-Jasiewiczowa 1980). Macrofossils of *Alnus viridis* are known from the glacial floras of the Middle Polish Glaciation at Góra Kalwaria near Warsaw (Środoń 1974) and at Krystynopol near Sokal (Szafer 1912).

Aquatic and lake-shore vegetation

With a sediment organic-matter content up to 6.5% and $CaCO_3$ content ranging from 3.8—4.6%, the lake had presumably an extremely poor flora. Algae were represented by *Pediastrum* (no diatom analysis has been performed for that zone) and macrophytes by small quantities of *Potagometon* (pollen of *P.* sect. *Coleogeton* and *P.* sect. *Eupotamogeton*) and perhaps also *Nitellopsis obtusa*. The species of the genus *Potamogeton* may have been *P. filiformis*, *P. vaginatus*, *P. perfoliatus* and *P. gramineus*, the fruits of which appear as soon as zones IM-2 and IM-3.

The presence of *Sparganium* type pollen in this section of the Late Glacial might be associated with the occurrence of *S. angustifolium* (= *S. affine*), a species characteristic of waters poor in organic compounds and mineral salts. *Drepanocladus aduncus* var. *kneiffii* occurred in the inshore zone of the lake. *Typha latifolia*, *Ra*-

nunculus sceleratus and *Mentha* cf. *aquatica* perhaps occurred sporadically in the inshore zone, but they may well have been carried down by the borer from overlying zones, because their continuous occurrence did not start before the beginning of the interglacial. The fragmentary fruits of *Najas marina* undoubtedly come from higher strata.

No animal remains were found in this zone.

Cyperaceae-Artemisia-Betula nana R PAZ

(IP-2, IP-3; IM-2, IM-3, samples 63, 62 from IM-4)

The high proportion of silt with an admixture of fine sand and the low organic matter content in the sediment (4.5—11.1%) indicate an open plant cover still in the catchment area of the lake and a low biomass production in the lake. The initially numerous sclerotia of *Cenococcum graniformae* and relatively high values of redeposited pollen give evidence of soil erosion. The progressive process of closing-up and enrichment of the vegetation is suggested by the increasing pollen values of herbs and, towards the end of IP-3, also trees, correlated with the decrease of the percentages of redeposited taxa (cf. p. 48).

The increase in pollen frequency includes chiefly *Cyperaceae* and *Pinus sylvestris* type and, in zone IP-3, also *Gramineae*, *Artemisia*, *Ranunculus acris* type, *Chenopodiaceae*, *Betula* undiff. and *Juniperus*.

In the older part of the zone (IP-2, IM-2) the vegetation still formed a kind of mosaic of various communities with the dominance of shrub-tundra. The abundant macrofossils of dwarf birch evidence its significance in the close neighbourhood of the lake despite the relatively low values of its pollen (to 2.2%). A fairly marked rise in the proportion of willow-shrubs (in more fertile habitats) is indicated by the frequent pieces of *Salix* wood and the pollen values of *Salix glauca* type, reaching 4.6%. These values are not low if we take into account the fact that in present-day spectra from arctic regions willow is a poorly represented taxon in comparison with its actual proportion in the vegetational composition (Firbas 1934; Iversen 1945; Welten 1950; H. J. B. Birks 1973a, 1973b). Similarly, *Ericaceae* may have played a marked role in dwarf-shrub communities despite its low pollen values, in view of the under-representation of its pollen in the modern spectra from arctic regions.

Juniperus, present in the surroundings of the lake in the previous zone, increases somewhat in importance (rising to 2.6%).

The increasing pollen values of *Cyperaceae* and *Gramineae* evidence that the patches of shrub-tundra left many open habitats unoccupied, in which sedge-grass communities still prevailed. *Selaginella selaginoides*, the megaspores of which are most numerous in this zone, must have abounded. Such new taxa as *Caltha* type, *Filipendula* (?*F. ulmaria*), *Sanguisorba officinalis* ($2n = 28$), *Bryum pseudotriquetrum*, *Hypnum lindbergii* and supposedly two arctic-alpine species of *Saxifraga* — cf. *S. nivalis* and cf. *S. stellaris* — enriched the vegetation of moist habitats. At present *S. nivalis* grows, as regards Central Europe, only in the Western Sudetes and *S. stellaris* in the Alps, Scandinavian Mts. and south-eastern Carpathians.

The rise in the *Artemisia* and *Gramineae* values towards the end of the *Cyperaceae-Artemisia-Betula nana* R PAZ and the somewhat more consistent occurrence of *Chenopodiaceae* pollen probably signal an expansion of grass communities in drier places. Besides the mosses mentioned earlier, *Encalypta streptocarpa* and *Pterygoneurum ovatum* may be referred to such habitats on calcareous bedrock.

In the *Juniperus* subzone (IP-3) the curves of the Tertiary and indeterminable pollen decrease rapidly and the number of *Cenococcum graniformae* sclerotia decline parallel to them, which suggests the close of erosive processes. The stabilization of the substratum was probably the essential factor favouring the expansion of the already existing open communities in new habitats.

The rise in the *Juniperus* pollen values (max. 6.5%), characteristic of this subzone, is presumably due to the expansion of juniper in new habitats and maybe to more luxuriant flowering in connection with improved climatic conditions. It could spread, above all, into open steppe-like grass communities, which only then attained the most favourable conditions of development. This is indicated by the highest values of *Artemisia* (up to 9.2%) and *Chenopodiaceae* (to 3.1%), the great proportion of *Gramineae* and the fairly often noted pollen of *Ephedra* distachya type, *E. fragilis* type, *Hippophaë rhamnoides* and *Helianthemum nummularium* type. The communities of the grassland type on sandy soils and grassland communities on the neighbouring hills may have been the source of pollen of *Helianthemum canum/H. alpestre, H.* cf. *oelandicum, Gypsophila fastigiata* type, *Rumex acetosella* type and *Elymus* type. Grass communities of different types were probably the source of many taxa of higher rank, notably of *Saxifraga oppositifolia* type, *Papaver, Veronica, Dianthus* type, *Silene* type, *Anthemis* type, *Cruciferae* and *Umbelliferae*.

The rapid decrease in *Betula nana* macrofossils and pollen reflects a reduction of shrub-tundra communities. The parallel rise in the pollen values of *Betula* undiff. and the continuous occurrence of fruits of *B. pubescens* and *B.* sec. *Albae* suggests the appearance of birch forest stands, chiefly in the habitats previously occupied by communities with *Betula nana.*

Aquatic and lake-shore vegetation

In spite of the still low organic matter content in the sediments, the aquatic vegetation was already somewhat more abundant and changes occurred in it.

In the older part of the *Cyperaceae-Artemisia-Betula nana* R PAZ (IP-2, IM-2) *Nitellopsis obtusa* and *Chara hispida* were represented by large numbers of oospores but only in one sample. The contingent displacement of these oospores from some upper parts of the profile must be ruled out, because sample 68 is lacking in the other taxa which are numerous in higher zones abounding in these stoneworts. And so it may be assumed that towards the end of the older part of the zone, the development of ephemeral pioneer communities with *Nitellopsis obtusa* and *Chara hispida* occurred which may have been monospecific counterparts of the present-day associations *Charetum hispidae* Corillion 1957 and *Nitellopsidetum obtusae* (Sauer 1937) Dąmb. 1961. There were perhaps rare individuals of *Potamogeton filiformis* and *P. vaginatus* in them. Ephemeral appearances are a significant character of the contemporary communities of the class *Charetea* (W. Matuszkiewicz 1981).

Patches with *Chara hispida* probably overgrew shallower parts of the lake, to a depth of 2 m. *Nitellopsis obtusa* supposedly colonized its deeper parts just as it does in large lakes at present that are not heavily silted (Dąmbska 1964).

The abundant occurrence of stoneworts indicates the high alkalinity of water, probably connected with the high base-status of late-glacial waters and the drainage of water rich in calcium carbonate into the lake. According to Stroede (1938, after Dąmbska 1964), the Ca content required by *Nitellopsis obtusa* cannot be lower than 15 mg. The alkalinity of water is also confirmed by the large proportion of alkaliphilous and alkalibiontic diatomaceous species (Kaczmarska 1976), among which *Cymbella affinis* dominated in the older part of the zone and *Gyrosigma attenuatum* at the beginning of the younger part. This last species is considered to be characteristic of the Late Glacial of the last glaciation (Round 1964, after Kaczmarska 1976).

Stones of *Potamogeton filiformis*, appearing in large numbers at the close of the older part of the *Cyperaceae-Artemisia-Betula nana* R PAZ and occurring in abundance in its younger part (IM-3), suggest that the then prevailing conditions suited the development of a more stable community resembling the present association *Potamogetonetum filiformis* Koch 1926. This community probably overgrew the littoral part of the lake on the mineral substratum. The presence of other pondweeds, like *Potamogeton vaginatus* (absent from the modern flora of Poland), *P. perfoliatus* and *P.* cf. *gramineus* can be referred to this community as well, as can that of *Myriophyllum spicatum, Ceratophyllum* (?*C. demersum*), *Batrachium* and *Nitellopsis obtusa.* The present conditions of the occurrence of *Potamogetonetum filiformis* association (Tomaszewicz 1979), suggest that at the decline of the Late Glacial the lake may have been meso- or even eutrophic with a pH between 7.5 and 8.6.

Sedgeswamp communities began to develop during the *Cyperaceae-Artemisia-Betula nana* R PAZ, as indicated by the presence of macrofossils of *Carex aquatilis, C. rostrata, C. gracilis, C. pseudocyperus, Schoenoplectus lacustris, Eleocharis palustris/E. mamillata* and *Hippuris vulgaris* (the fruits of *Typha* were probably a contamination from higher zones). Special attention should be given to the presence of *Carex aquatilis*, a species unknown to the modern flora of Poland but a common component of the glacial and late-glacial floras of Poland and Central Europe at the time of the last glaciation (cf. Wasylikowa 1964).

The first animal remains — the bryozoan *Cristatella mucedo*, sponges, ostracods, molluscs (*Bithynia tentaculata* and *Valvata* sp.) and fishes (first scales) — appear in the older part of the zone, whereas in the younger part (IM-3 and beginning of IM-4) fish remains are already noted in all samples and statoblasts of *Cristatella mucedo* are very numerous. These last indicate clean and calm waters in the lake (Dehm in Jung et al. 1972).

EEMIAN INTERGLACIAL

Pinus-Betula R PAZ

(IP-4, IP-5; samples 61—55 from IM-4, sample 54 from IM-5)

The *Pinus-Betula* zone corresponds to the initial phase of the interglacial. The proportion of organic matter in the sediment is increasing gradually to 22.7% and $CaCO_3$ to about 20% (at the top to 38.4%). The tree pollen frequencies, mainly of *Pinus sylvestris* type and *Betula* undiff., and those of *Gramineae* undiff. rise considerably. At the same time the frequencies of Tertiary and deteriorated pollen and sclerotia of *Cenococcum decrease* until they disappear completely at the top of the zone. All these features indicate the decline of erosional processes, the stabilization of soils and the progressive closing of the plant cover.

The rise of the *Pinus sylvestris* type pollen values from 26.8 to 46.8% and the significant decrease in pollen values of herbs and *Juniperus* at the beginning of the zone show that the spread of pine-birch forests and the simultaneous shrinkage of open area communities started as early as the oldest part of this zone.

However, the picture of vegetation, especially in the older part of the zone

(IP-4a), has a transitional character. The continuous occurrence of *Juniperus* and *Salix glauca* type pollen, the frequent macrofossils of *Betula nana* despite the low values of its pollen and the sporadic presence of *Hippophaë rhamnoides* in IP-4a and *Ephedra distachya* type in IP-4b indicate the still important role of shrub communities in both dry and moist habitats. The same is true of the herb communities in which a relatively great variety of taxa still occurred beside the quantitatively dominant *Cyperaceae* and *Gramineae*.

The xerothermic grass communities continue to be fairly numerously represented by *Artemisia* and *Chenopodiaceae* and pollen of *Helianthemum nummularium* type still occurs. The indicator taxa of other types of grass communities, that is *Gypsophila fastigiata* type, *Helianthemum canum/H. alpestre*, *Saxifraga oppositifolia* type, *Selaginella selaginoides*, *Plantago maritima* s. l. and *Rumex acetosella* type, are also present. The sporadic grains of *Filipendula* (?*F. ulmaria*) and *Trollius* pollen may be referred to wet meadow communities, with which the occurrence of *Rhinanthus* type, *Thalictrum*, *Anthemis* type and *Hypnum lindbergii* is perhaps connected as well.

The variety of herbs decreased towards the end of the older part of the *Pinus-Betula* zone but the consistently high values of *Cyperaceae* and the rise of *Gramineae* suggest that the grass communities impoverished in species may have survived in many habitats. Grass and sedge pollen may also come from swamp communities and the increase in grasses may also be partly connected with the then dominant pine forests.

The predominance of *Pinus sylvestris* type pollen over *Betula* undiff. in spite of the presence of tree birches in the vicinity of the lake (nutlets, fruit scales) seems to indicate widespread open coniferous forests with dominant common pine. In the fresh postglacial landscape they occupied habitats on mineral soils, postglacial sands and on morainic hills. *Betula pendula* perhaps formed an admixture in drier habitats in these forests.

The presence of *Betula* cf. *pubescens* nutlets suggests that the pine-birch community with *B. pubescens*, possibly similar to the present-day community of *Molinio-Pinetum* prov. (= community *Pinus-Molinia* J. Mat. 1973), may have been developing in wet sandy habitats in the flat Imbramowice Depression. The increase in the proportion of *Gramineae* (?*Molinia coerulea*) pollen in the younger part of the *Pinus-Betula* zone supports this suggestion. The presence of pine in the vicinity of the lake in IP-4b is confirmed by the finds of needles and wood. The sporadic sporomorphs of *Polypodium*, *Calluna vulgaris* and *Ledum palustre* are probably connected with the pine-birch communities.

The relatively high pollen values of *Populus* (?*P. tremula*) in the younger part of the *Pinus-Betula* zone (IP-4b, IP-5), the more frequent occurrence of *Salix pentandra* type pollen, a bud and a piece of *Salix* wood and the continuous presence of *Alnus* wood may indicate the development of communities resembling the present-day *Salici-Populetum* (R. Tx. 1931) Meijer Drees 1936 in the valleys of the Bystrzyca River and its tributaries. *Populus* pollen, sporadic *Sorbus* pollen grains and, at the decline of IP-4b, the presence of *Quercus* wood and the continuous curve of its pollen (reaching 0.37%) and the beginning of the continuous *Ulmus* curve signal the changes in pine forest, leading to the development of mixed forests at the close of the zone.

The sporadic pollen grains of *Prunus* and *Stellaria holostea* in IP-5 may suggest the enrichment of shrub communities and thickets on the warm slopes of the surrounding hills.

The youngest part of the *Pinus-Betula* zone, local zone IP-5, is characterized by the highest percentage of *Betula* undiff. pollen in the whole profile (57.7%), which seems to express the optimal conditions for the flowering of tree birches. Although this is a short-lived phenomenon, it is a regional character of wide range (cf. p. 107 and Fig. 17) as the *Betula* subzone.

Aquatic and lake-shore vegetation

A series of changes are observed in the lake and its marginal part, but the major ones did not occur until the younger part of the zone. The older part is intermediate in nature: *Potamogeton filiformis*, abundant in the Late Glacial, declines, *Batrachium* and *Nitellopsis obtusa* are less abundant, and new species appear in inconsiderable quantities.

In the younger part of the zone (IP-4b, IP-5) the variety of species, now characteristic of various phytosociological units of the *Potamogetonetea*, *Phragmitetea*, *Isoëto-Nanojuncetea* and *Bidentetalia tripartitae*, increases and many of these species have their maxima. From among the aquatic taxa *Nitellopsis obtusa* is again fairly prominent and *Batrachium* reaches its maximum in the whole interglacial (many fruits).

The role of various *Batrachium* species in the present aquatic communities in Poland, listed by Tomaszewicz (1979), permits the statement that only *Batrachium circinatum*, with a small admixture of other species, forms autonomous dense phytocenoses, distinguished as the association *Ranunculetum circinati* (Bennema et Westh. 1943) Segal 1965. It occurs most frequently in shallow waters, to 2 m in depth, at pH 7.0—8.5. The large number of *Batrachium* fruits in the *Pinus-Betula* zone suggests that a similar type of community may have developed in the Imbramowice lake at that time and prevailed in it together with a community resembling the *Nitellopsidetum obtusae*.

Myriophyllum spicatum, *M. verticillatum*, *Nuphar lutea*, *Nymphaea alba*, *N.* cf. *candida*, *Potamogeton perfoliatus* and other pondweeds, less numerously represented, were probably associated chiefly with the community of the *Ranunculetum circinati* type. The numerous hairs of *Ceratophyllum* may indicate a higher proportion of *Ceratophyllum demersum* than would be implied by only one fruit.

The somewhat more abundant occurrence of *Pediastrum* in this zone signals the eutrophication of the lake (cf. Mangerud 1970) and at the same time evidences the decline of the water inflow to the lake (cf. Tołpa 1961). The considerable numbers of alkaliphilous diatom species, especially *Stephanodiscus astraea* var. *minutulus* indicate the great fertility of the water and high pH (Kaczmarska 1976).

The expansion of swamp vegetation took place in the younger part of the *Pinus-Betula* zone. The reedswamp vegetation is represented by macrofossils or/and pollen of several species now characteristic of various syntaxa of the *Phragmitetea* (*Hippuris vulgaris*, *Schoenoplectus lacustris*, *Sch. tabernaemontani*, *Typha latifolia*, *Eleocharis palustris*/*E. mamillata* and *Bolboschoenus maritimus*) and by such taxa of higher rank as *Typha*, *Sagittaria*, *Sparganium* type (?*Typha angustifolia*, ?*Sparganium ramosum*) and *Phragmites* type. Pollen of *Phragmites* type and *Sparganium* type and, as regards macrofossils, stones of *Hippuris vulgaris* occur most abundantly. *Typha latifolia* pollen and *Schoenoplectus lacustris* fruits are less abundant. This may be so because of the development of some variants of a community resembling the present-day *Scirpo-Phragmitetum* Koch 1926, varying with water depth. The patches with *Schoenoplectus lacustris* may have been contiguous with the aquatic communities and those with *Hippuris vulgaris* with the communities of *Magnocaricion*. The patches with *Phragmites communis* and frequent *Typha latifolia* among them were probably abundant. Towards the end of the *Pinus-Betula* zone some patches similar to the modern *Thelypteridi-Phrygmitetum* Kuiper 1957 may have begun to develop close to the edge of the lake. It is suggested by the appearance of *Dryopteris thelypteris* spores in IP-5 with the simultaneous rise of *Polypodiaceae* spores and the presence of a single sporangium of *Polypodiaceae* s. l. (caryopses of *Gramineae* may belong to *Phragmites*).

The sedgeswamp is represented by fruits of *Carex rostrata, C. aquatilis, C. disticha, C. elata, C. gracilis* and *C. pseudocyperus* and by relatively high pollen values of *Cyperaceae*. The abundant occurrence of *C. rostrata* may suggest the development of a community resembling the present-day association *Caricetum rostratae* Rübel 1912. It presumably represents an early developmental stage which usually occurs on a mineral substratum (see Tomaszewicz 1979).

The peat species *Carex nigra, C. flava, Drepanocladus aduncus,* cf. *Comarum palustre* and — appearing in various communities of wet habitats — *Lycopus europaeus,* and *Urtica dioica* probably originate from the margins of the swamp communities.

At that time a rich community of therophytes developed in partly drying-up eutrophic lake-shore habitats. It is represented by numerous macrofossils of species now characteristic of various *Bidentetalia tripartitae* units, namely *Ranunculus sceleratus, Rorippa palustris* and *Rumex maritimus.* Most probably associated with this community is the presence of *Potentilla supina, Anthoceros* (?*A. laevis,* ?*A. punctatus*), *Polygonum aviculare* type and *Compositae Tubuliflorae* undiff. (? species of *Bidens*).

Plantago maritima s. str. may point to the salinity of some wet habitats in the surroundings of the lake.

The fauna shows no significant changes in relation to the final section of the Late Glacial. *Cristatella mucedo* and fish remains abound; *Daphnidae, Ostracoda* and *Mollusca* are sporadic. Within the *Mollusca*, a single specimen of *Succinea pfeifferi* represents the wet lake-shore habitats. The number of *Cristatella mucedo* statoblasts — regarded as an indicator of clean and calm water in the lake (cf. p. 58) — is variable, which is probably due to changes in water depth.

Pinus-Betula-Ulmus R PAZ

(IP-6; IM-5)

The low percentages of herb pollen (8—11%) and the small variety of taxa indicate that the forest cover was already closed and forest communities approached the lake. The only important taxon of herbs are grasses (pollen and caryopses), which, to be sure, represent chiefly the reedswamp communities and those of moist lake-shore habitats, signalled by the somewhat more frequently encountered *Filipendula* pollen (?*F. ulmaria*).

The absolute dominance of *Pinus sylvestris* type pollen allows the assumption that pine encroached upon all habitats accessible to it at that time. The moist pine forests, in which *Pinus sylvestris* was to a great extent accompanied by *Betula pubescens,* continued to grow in the Imbramowice Depression. The presence of these trees in proximity of the lake is evidenced by the continuously occurring nutlets of *B.* cf. *pubescens* and pollen clumps and unripe tetrads of *Pinus sylvestris* type, as well as stomata and associated guard cells and a fragment of a pine needle.

The increase in the pollen values of *Quercus* reflects some changes already taking place in the pine communities on richer soils. *Betula pendula,* the nutlets of which are most numerous now, may have occurred more abundantly in this type of forests; *Populus tremula* may also have occurred, and *Viburnum opulus, Frangula alnus* and *Sorbus aucuparia* were probably present in the understorey (pollen of *Populus, Frangula, Viburnum* and *Sorbus*).

The absolute, though low, percentage maximum of elm (4.0%) is a characteristic feature of the *Pinus-Betula-Ulmus* zone. An examination of pore number frequency (see p. 37) permits the statement that this maximum reflects the expansion of both *Ulmus scabra* and *U. campestris*, the former being probably predominant.

Pollen of *U. scabra*, a species with a wider ecological amplitude than *U. campestris*, may have originated from various forest communities. It was able to occur on fertile moist habitats in the lower montane positions and in Sudeten Foreland (until then occupied by *Pinus sylvestris* and *Betula pendula*), and to enter riverside floodplain communities. The presence of *Ulmus campestris* pollen and the already continuous curve of *Fraxinus* pollen indicate the development of the community of the elm-ash riverine forest type, perhaps resembling the present association *Fraxino-Ulmetum campestris* (R. Tx. ap. Lohm. 1952) Oberd 1955, in which the tree layer may have been composed of both *Ulmus* species and *Fraxinus excelsior*. *Alnus glutinosa* may already have accompanied them sporadically (continuous low-percentage curve of pollen and wood of *Alnus* undiff.).

The willow-dominated communities, presumably, still persisted in wetter habitats, closer to the lake and in river valleys, as indicated by the continuous occurrence of *Salix glauca* type pollen and rather numerous pieces of *Salix* wood. The pollen of *Humulus lupulus*, *Sambucus nigra* and *S.* cf. *racemosa* as well as the fruits of *Lycopus europaeus* and *Urtica dioica* may, in all probability, be referred to these very communities and to elm-ash riverine forests.

Despite the great density of forests and marked improvement of climatic conditions evidenced (in addition to the data mentioned above) by the first pollen grain of *Hedera helix*, the close surroundings of the lake still supported some relict sites of *Betula nana* (5 nutlets).

The communities of dry habitats completely lost their past significance, which is shown by the very low pollen values of *Artemisia* and *Rumex acetosella* type and the only sporadic occurrence of *Chenopodiaceae* pollen.

Aquatic and lake-shore vegetation

A distinct rise in the organic matter content and carbonate content in the sediment was observed in the upper part of the previous zone. The high level of carbonates (to 38.8%) remains high whereas the organic matter content falls temporarily to about 11%.

The changes in the aquatic vegetation are more significant than those in the terrestrial vegetation and a series of features which concern this zone alone can be distinguished. The macrophytic flora gets enriched and the aquatic communities differentiate. *Myriophyllum verticillatum*, *Nitellopsis obtusa* and *Najas marina* were represented most abundantly. The schizocarps of *M. verticillatum*, present in large numbers only in this zone, show that a community that may have been similar to the facies of the present-day association *Myriophyllo-Nupharetum* Koch 1926 (distinguished also as the separate association *Myriophylletum verticillati* Soó 1927) developed in this part of the lake. At that time the stands of this community may have constituted an initial stage in the deepest part of the lake and were soon ousted by other communities. This agrees with the role ascribed also to the stands of *Myriophylletum verticillati* in contemporary lakes (Tomaszewicz 1979).

In the *Pinus-Betula-Ulmus* zone a community with *Najas marina*, occurring here in at least two varieties also began to develop (see p. 43). The small-fruit form, similar to the present-day *N. marina* var. *intermedia*, was as frequent then as the big-fruit form, with fruits exceeding 4 mm in length. The expansion of *N. marina* indicates the presence of such places, well exposed to the sun and sheltered from the wind, in the lake, as are demanded by its present communities (Dąmbska 1961; Tomaszewicz 1979; W. Matuszkiewicz 1981).

The stands of communities dominated by *Myriophyllum verticillatum*, *Nitellopsis obtusa* or *Najas marina* were accompanied by an admixture of *Nymphaea alba*, *N.* cf. *candida*, *Nuphar lutea*, *Ceratophyllum demersum*, *Potamogeton lucens*, *P. perfoliatus*, *Chara hispida* and — starting from the younger part of the zone — *Salvinia natans*.

The dominant macrophytes of the lake, the appearance of *Salvinia natans* and the high proportions of alkaliphilous and alkalibiontic diatom species indicate that it was a eutrophic water body, most likely with a pH value at 7.0—8.5. The disappearance of *Cenococcum graniformae* marks the complete cessation of soil erosion into the lake. The very high Foged C:P index is, according to Kaczmarska (1976), indicative of the greatest depth of the lake at that time. A rise of water level is also suggested by the rapid fall of the *Pediastrum* and *Cristatella mucedo* curves (cf. Zachowicz et al. 1982; Dehm in Jung et al. 1972).

At that time the warm eutrophic lake supported fishes, sponges and, out of the molluscs, mainly *Bithynia tentaculata*. There were also small numbers of *Cristatella mucedo*.

In the reedswamp belt, the proportions of *Phragmites communis* and *Schoenoplectus lacustris* supposedly decreased then, whereas the pollen values of *Sparganium* type suggest an increase in the proportion either of *Sparganium* (perhaps *S. ramosum* s. l., two stones of which were found in this zone) or of *Typha angustifolia. T. latifolia*, *Alisma* cf. *plantago-aquatica* and *Rumex aquaticus*/*R. hydrolapathum* (probably *R. hydrolapathum*) are present as well.

In the belt of tall-sedgeswamp *Carex rostrata* nearly completely disappeared, which may have been due to the rise of the water level and the inundation of the stands nearest the lake. On the other hand, *Carex pseudocyperus* grew in importance, most probably because of better climatic conditions and a higher trophic status of the lake. The presence of *Dryopteris thelypteris*, represented not only by spores but also presumably by sporangia of *Polypodiaceae* s. l., indicates the probable persistance of stands resembling the contemporary association *Thelypteridi-Phragmitetum*, overgrowing shallow, inshore places. The remains of *Lycopus europaeus*, *Lythrum* (?*L. salicaria*), cf. *Comarum palustre*, *Mentha* cf. *aquatica*, *Alisma* cf. *plantago-aquatica* and *Carex gracilis* can also be referred to lake-shore communities. Periodically wet habitats were very poorly represented by *Ranunculus sceleratus* and *Rorippa palustris*.

Quercus-Fraxinus-Ulmus R PAZ

(IP-7; samples 50—45 from IM-6)

A small rise in the NAP curve in this zone (to 15.4%), caused by the increase in *Cyperaceae* and *Gramineae*, is presumably connected mainly with swamp development. Plants of wet and moist habitats prevail among the remaining herb taxa and are represented by sporadic pollen grains of *Menyanthes trifoliata*, *Parnassia palustris*, cf. *Comarum palustre*, *Lythrum*, *Filipendula* (?*F. ulmaria*), *Plantago maritima* s. str. as well as *Rumex acetosa* type, *Thalictrum*, *Ranunculus acris* type, *Rubiaceae* and single spores of *Selaginella selaginoides* and *Ophioglossum*.

The picture presented by the tree pollen diagram shows an initially still fairly great proportion of tree-birches and pine; the latter was, however, consistently ousted by *Quercus*, which was the most prominent taxon in the plant composition of this zone. *Fraxinus* was also of great importance, with its pollen value reaching

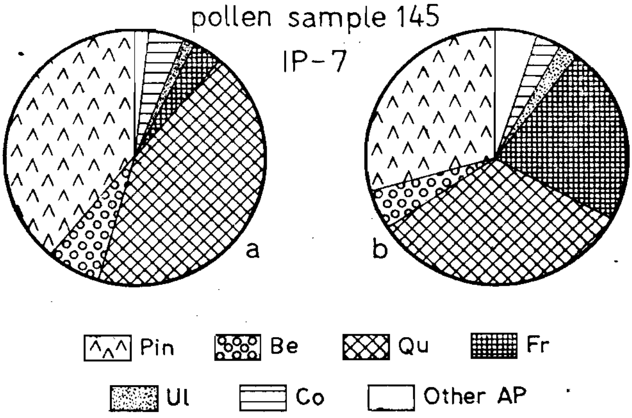

Fig. 8. Percentages of trees in the sample with the maximum frequency of *Fraxinus* in the *Quercus-Fraxinus-Ulmus* R PAZ, calculated from the AP sum: a — based on the basic AP sum, b — after the application of Andersen's (1970, 1973a) correction factors. Abbreviations: Pin — *Pinus*, Be — *Betula*, Qu — *Quercus*, Fr — *Fraxinus*, Ul — *Ulmus*, Co — *Corylus*

an interglacial maximum (3.2%). In view of the under-representation of its pollen in pollen spectra, an attempt was made to reconstruct the likely role of ash, applying Andersen's (1970, 1973a) correction factors. In the corrected tree pollen spectrum (Fig. 8) the proportion of *Fraxinus* was 22.2%, which seems to confirm its important role in the vegetation of this zone. Small changes in the other significant taxa occur in the corrected spectrum.

The changes observed, supported partly by the macrofossils, permit the conclusion that no later than the *Pinus* subzone (IP-7a), mixed forests formed on more fertile soils, perhaps similar to the now broadly conceived association *Pino-Quercetum* Kozł. 1925 em. Mat. et Polak 1955. The presence of wood and pollen tetrads of *Quercus* and stomata of *Pinus* may indicate the occurrence of such a community in the close neighbourhood. *Betula pendula*, *B. pubescens*, *Populus* (?*P. tremula*) and *Tilia platyphyllos* may also have been present in it. In the understorey there were probably *Juniperus*, *Frangula*, *Viburnum* (?*V. opulus*) and, at the decline of the *Pinus* subzone, also *Corylus*. The appearance of *Pteridium aquilinum* spores is perhaps connected with the herb layer of these forests. This community may have occurred widely, both on the hills of the Sudeten Foreland and in the Sudeten Foothills zone.

At the decline of the *Pinus* subzone the pine-oak communities underwent a transformation into oak-dominated stands with an admixture of pine (max. values of *Quercus* — 41.2 and 40.4%). On dry fertile soils rich in calcium carbonate, oak forest resembling the present-day association *Potentillo albae-Quercetum* Libb. 1933 may have developed by that time. Presumably, thermophilous xerothermic communities, signalled by the relatively frequent records of *Ligustrum vulgare* pollen were developing at their margins. The range of modern communities with *L. vulgare* (*Ligustro-Prunetum* R. Tx. 1928, 1952) is restricted to southern Poland and, among other areas, includes the Silesian Lowlands and Sudeten Foreland. These exceedingly thermophilous communities may have had much more favourable conditions for development in south-western Poland at the climatic optimum of the Eemian than they have at present, owing to the presence of fertile postglacial clays rich in calcium in those times. Such habitats may also have constituted a refuge for late-glacial steppe-like communities and these were perhaps the source of the sporadic pollen grains of *Helianthemum nummularium* type, *Allium vineale* type (*A. vineale*, *A. sphaerocephallum* and *A. scorodoprasum*) and *Ephedra distachya* type, as well as the already low *Artemisia* and *Chenopodiaceae* pollen values.

The moist eutrophic habitats were probably still supporting riverine elm-ash communities, either similar to the present-day *Fraxino-Ulmetum campestris* (which would be indicated by the increase in the frequencies of *Ulmus campestris* pollen, cf. p. 38), or somewhat different, with dominant ash, as suggested by the increased values of its pollen. They may have been communities resembling the present-day association *Astrantio-Fraxinetum* Oberd. 1953, which in Poland only occurs now on the border between the Silesian Lowland and the Sudeten Foreland or the association *Carici remotae-Fraxinetum* Koch 1926, now occurring in the Sudeten Foreland and the Sudeten Mts. (W. Matuszkiewicz 1981).

Acer (wood and pollen), *Alnus* (wood, beginning of its continuous low-percentage pollen curve), *Hedera*, *Sambucus nigra* and *Salix pentandra* type (?*S. alba*) may have occurred in the ash and elm riverine forests. *Humulus lupulus* (max. 1%) and perhaps *Calystegia*, as well as *Dryopteris thelypteris* and *Polypodiaceae* s. l. may come, at least in part, from these forests.

A similar set of communities, but with pine successively declining in significance, survived in the younger part of the *Quercus-Fraxinus-Ulmus* zone, i.e. the *Corylus* subzone (IP-7b). The late but rapid expansion of hazel brings an important change in. It must have invaded the understorey of the then existing forests and perhaps spread into the thermophilous xerothermic communities on sites occupied by *Ligustrum vulgare* (see p. 64). Its presence in the close vicinity of the lake at the end of the zone is evidenced by two anthers with well-preserved pollen found during a macroscopic analysis.

Aquatic and lake-shore vegetation

In this zone the deposition of carbonates in the lake decreases temporarily, their content in the sediment falling from 34.5 to 13.8%. At the same time the percentage of organic matter rises from about 15 to 22%. The aquatic vegetation indicates the continuing eutrophic nature of the lake, at pH 7—8.5. This is evidenced both by the main communities of macrophytes and by diatoms.

The increasing numbers of *Nitellopsis obtusa* with its first maximum and the reappearance of *Chara hispida* suggest another period of the dominance of stands resembling the *Nitellopsidetum obtusae* and *Charetum hispidae*, which was probably connected with a rise in the organic-matter content of the sediment and the shallowing of some parts of the lake. Such a relationship is indicated by the present-day development of phytocenoses of *Nitellopsidetum obtusae*, which thrive particularly well in shallow, silted parts of lakes (Dąmbska 1961, 1964; Tomaszewicz 1979). The numerous hairs of *Ceratophyllum* may evidence the presence of weakly fruiting *C. demersum* (only one fruit spine), which is now dominant in some of the deepest stands of *Nitellopsidetum obtusae* (cf. Dąmbska 1961). Indirect evidence of the dominance of a *Nitellopsidetum obtusae*-like community is provided by the presence of only a few seeds and some pollen of floating-leaved plants (*Nymphaea alba*, *N.* cf. *candida*, *Nuphar lutea* and *Nuphar* undiff.), which is characteristic of this association (Tomaszewicz 1979).

The proportion of *Najas marina* among the submerged plants is similar to that in the previous zone, but with the increasing prevalence of the variety with fruits longer than 4 mm, corresponding perhaps to *N. marina* var. *communis* (see p. 43).

A pleuston community dominated by *Salvinia natans* began to increasingly cover the water surface. However, this coverage cannot have been considerable, as is shown by the maximum development of the *Nitellopsidetum obtusae*-type community. Its compact phytocenoses are, to a great extent, conditioned by the transparency of water.

The vigorous development of macrophytes and the shallowing of at least some parts of the lake are reflected by the nearly complete lack of euplanctonic diatoms and the large number of littoral-plankton, benthonic and epiphytic species. The alkaliphilous species, chiefly of the genera *Navicula* and *Fragillaria*, are dominant, the values of alkalibiontic diatoms being lower (cf. Kaczmarska 1976). The shallowing of the lake is also evidenced by the re-appearance of somewhat larger quantities of *Pediastrum*.

As regards animal remains, the bryozoan *Cristatello mucedo*, more numerous again, indicates clear quiet water in the lake, while the fairly frequent occurrence of *Bithynia tentaculata* points to the existence of extensive shallow areas. Rather frequent fish remains confirm conditions favourable for the fauna.

Some essential changes took place in the reedswamp belt. The abundance of *Typha* seeds and the fairly frequent pollen of *T. latifolia* suggest the development of a community dominated by this species (?*Typhetum latifoliae* Soó 1927) during this zone. Its extensive development was undoubtedly influenced by the then prevailing good climatic conditions, the lowering of the water level in the lake and the rise in the organic matter content. The relatively high values of *Sparganium* type may here represent *S. ramosum* s. l., the fruits of which are present in this zone, and partly also *Typha angustifolia*. *Alisma* cf. *plantago-aquatica*, *Hippuris vulgaris*, *Eleocharis palustris*/*E. mamillata*, *Schoenoplectus lacustris*, *Cladium mariscus* and *Butomus umbellatus* and perhaps *Lythrum salicaria*/*L. virgatum*, *Mentha* cf. *aquatica* and partly *Phragmites* type, occurring in small quantities, may also be referred to this community. However, the correlation of the rise in the pollen values of *Phragmites* type with the reappearance of *Dryopteris thelypteris* spores and the presence of *Polypodiaceae* sporangia (belonging in all probability to that species) and with the simultaneous increase in the *Polypodiaceae* spore values may also indicate the expansion of a community similar to the modern *Thelypteridi-Phragmitetum*.

The significance of sedgeswamps was rather slight. Nevertheless, *Carex pseudocyperus*, whose fruits occur in this zone in the highest numbers in the whole interglacial, seems to have formed rather less extensive stands in the shallowest, eutrophic habitats.

In periodically wet nitrogen-rich places the communities of therophytes with *Ranunculus sceleratus* and *Cyperus fuscus* (the latter appears here for the first time), begin to play a somewhat greater role again. Some nitrophilous communities, abundantly represented by fruits of *Urtica dioica*, presumably developed in dried-out areas, rich in organic remains, adjoining the swamp forests that come near the lake.

Corylus-Quercus-Tilia R PAZ

(IP-8, IP-9, IP-10; samples 44—40 from IM-6, IM-7)

The lowest pollen values of herbs in the whole interglacial (3.1—6.3%) indicate the maximum extent of forest communities in all types of habitats. The role of pine and tree-birches in these stands was insignificant, nevertheless the still local presence of tree-birches in the surroundings of the lake is evidenced by the occasional macrofossils.

The very high pollen values of *Corylus*, diagnostic of the climatic optimum of the Eemian Interglacial, form the most characteristic and significant feature of the zone.

The rapid deposition of sediments in the lake in this part of the interglacial permits a close investigation of the order of succession and expansion of particular trees. Four phases determined by the maximum or considerable proportions of the main components of forests prevailing in this area are represented by local zones IP-8a, IP-8b, IP-9 and IP-10, corresponding to two subzones of regional extent: *Corylus-Quercus* and *Tilia-Carpinus*.

Andersen's correction factors (1970, 1973a) were used in several cases to characterize conditions prevailing in the forest communities of that period. This seemed expedient because of the under-representation of taxa, important to this section of the profile, such as *Fraxinus* and *Tilia*, beside the simultaneous over-representation of *Corylus* in the pollen spectra.

The absolute culmination of hazel as early as the older part of the *Corylus-Quercus* subzone (IP-8a) proves that it spread into this area before *Alnus*, *Taxus* and *Tilia* did, although these may have been present since the very beginning of the zone. Some of the *Corylus* pollen in this zone undoubtedly originates from the hazel understorey of the still dominating oak forest and various riverine forests. However, the very high pollen values of hazel, characteristic of the climatic optimum of the Eemian, must have had also some other sources. Presumably, these were communities of thermophilous thickets or even hazel woods (cf. Jonassen 1950; Neustadt 1953; Müller 1953), perhaps approximating to the present-day association *Peucedano cervariae-Coryletum* Kozł. 1925 em. Medw.-Korn. 1952. At that time a community of this type had probably excellent conditions to develop on warm slopes rich in calcium carbonate in the Sudeten Foreland and Foothills, where thickets with *Ligustrum vulgare* were still present. The wide ecological amplitude of hazel certainly allowed it to ascend high in the Sudeten Mts., higher than it does now and perhaps higher than in the period of its maximum expansion in the Holocene (cf. Firbas 1949; Neustadt 1953).

The course of the *Corylus* curve in the diagram from Imbramowice shows that after a rapid expansion in the older part of *Corylus-Quercus* subzone (IP-8a) hazel prevailed in communities throughout the *Corylus-Quercus-Tilia* zone, barely decreasing in importance.

The relatively high *Quercus* values and the continuous presence of *Fraxinus* and *Ulmus* pollen in the whole *Corylus-Quercus* subzone highlight the still considerable role played by mixed oak forests and riverine forest communities. In these last communities *Fraxinus* was probably of greater importance than elm was and, in the older part of the subzone, than *Alnus* (cf. Fig. 9). Starting from the beginning of the subzone, these forests were enriched with new components, which is evidenced by the almost continuous presence of *Acer* pollen, relatively frequent *Tilia cordata* type, *Taxus baccata* and *Carpinus*, as well as sporadic *Tilia platyphyllos* type. In the understorey, there grew — besides *Corylus* — also *Sambucus nigra*, *S.* cf. *racemosa*, *Viburnum* (?*V. opulus*) and *Ilex aquifolium; Hedera helix* must have been a particularly frequent component, whose pollen had been present continuously since the previous zone. Mistletoe also appeared in the forests towards the end of the older part of the *Corylus-Quercus* subzone (IP-8a).

Oak forests, most probably open ones may have been the source of *Pteridium aquilinum* spores and of *Anemone* type, *Euphorbia* and *Campanula* pollen. *Ajuga reptans* (fruit) could probably be referred to a mixed oak forest.

In the younger part of the *Corylus-Quercus* subzone (IP-8b) a distinct change in forest communities was caused by the expansion of *Alnus glutinosa*. The ap-

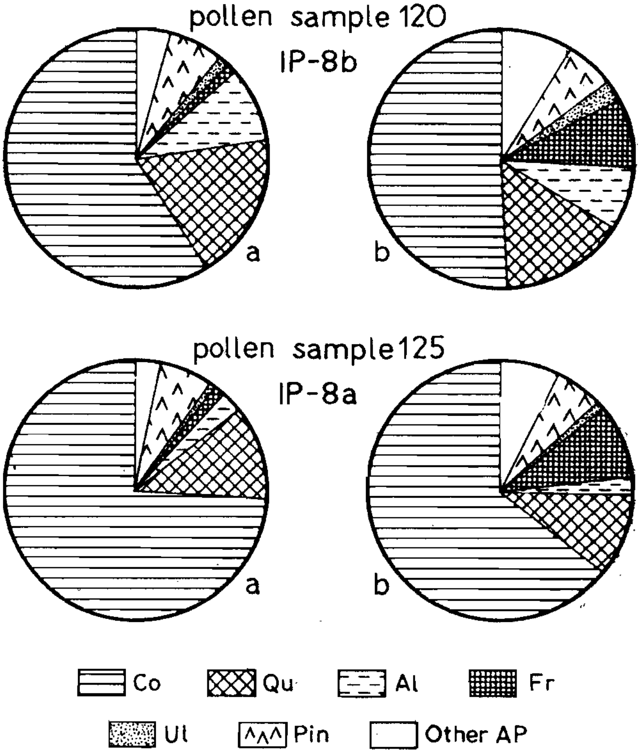

Fig. 9. Percentages of trees in the samples with the maximum frequencies of *Fraxinus* and *Ulmus* in the *Corylus-Quercus-Tilia* R PAZ, calculated from the AP sum: a — based on the basic AP sum, b — after the application of Andersen's (1970, 1973a) correction factors. Abbreviations: Co — *Corylus*, Qu — *Quercus*, Al — *Alnus*, Fr — *Fraxinus*, Ul — *Ulmus*, Pin — *Pinus*

pearance of considerable numbers of fruits of *A. glutinosa* parallel to the rise of the *Alnus* undiff. pollen values indicates the development of communities with a contribution of that species in the direct neighbourhood of the lake. The fall in the *Fraxinus* pollen values correlated with this phenomenon, seems to indicate the encroachment of *Alnus glutinosa*, above all, into all the habitats occupied by ash-elm forests until then and their transformation into ash-alder forests (?*Circaeo-Alnetum* Oberd. 1953). The communities of this type may have developed also in the already overgrown and drying up marginal parts of the lake. In more swampy places *Alnus glutinosa* may have given rise to communities resembling present-day wet alderwoods.

The relatively frequent occurrence of *Humulus lupulus* pollen, the presence of fruits of *Lycopus europaeus*, *Urtica dioica*, *Lythrum salicaria/L. virgatum*, pollen of *Calystegia*, spores of *Dryopteris thelypteris* and — perhaps — partly spores and sporangia of *Polypodiaceae* s. l. are connected with riverine forest communities and wet alderwoods and, no doubt, in part also with nitrophilous open riparian habitats.

In the older part of the following *Tilia-Carpinus* subzone (IP-9) the changes in forest communities were caused by the vigorous expansion of *Taxus baccata* and, somewhat later, of *Tilia*. The high values of *Taxus* pollen, occurring as early as this section of the Eemian, are characteristic of the profile at Imbramowice and link it together with such western localities as Zeifen and Eurach (Jung et al. 1972; Beug 1973, 1979), Samerberg (Grüger 1979) and Gondiswil (Wegmüller 1986) in the foreland of the Alps, Wallensen in the Mittelgebirge (Grüger 1968), Kittlitz in Lower Lusatia (Erd 1973) and many other sites in the north-western part of Western Germany (Behre 1962, 1970; Menke 1967; Menke & Ross 1967; Averdieck 1967a, 1967b; Müller 1974).

The changes observed in the Imbramowice diagram suggest that *Taxus* spread

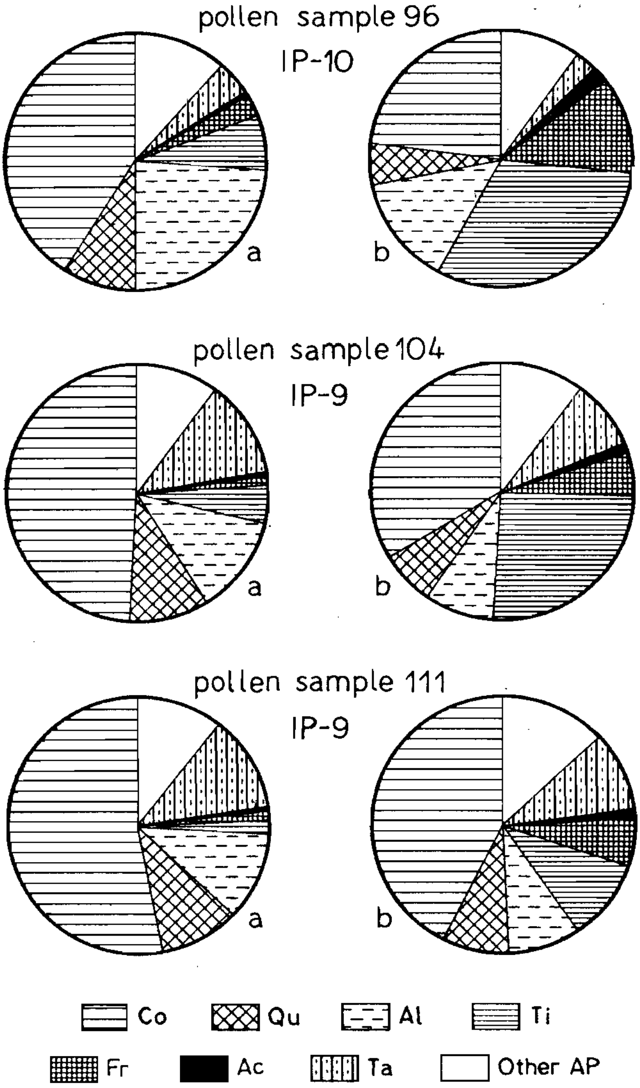

Fig. 10. Percentages of trees in the samples with the maximum frequencies of *Taxus* and *Tilia* in the *Corylus-Quercus-Tilia* R PAZ, calculated from the AP sum: a — based on the basic AP sum, b — after the application of Andersen's (1970, 1973a) correction factors. Abbreviations: Co — *Corylus*, Qu — *Quercus*, Al — *Alnus*, Ti — *Tilia*, Fr — *Fraxinus*, Ac — *Acer*, Ta — *Taxus*

here at the cost of *Corylus*, presumably chiefly invading the understorey of open oak forests, in which, as a shade-tolerant tree, it was able to compete successfully with the heliophilous hazel. Owing to its great adaptability, it could also enter the understorey or form a second tree layer in other communities predominating at that time. The present distribution of *Taxus baccata* stands within its range in Poland allows the assumption that it may have encroached on alder-ash riverine forests, on neutral or somewhat basic fertile soils in alderwoods, on potential habitats of forests of the *Querco-Carpinetum* s. l. type and also on the habitats occupied by more acidophilous oak communities (cf. Król 1975). The exceptionally high pollen values of *Taxus* at Imbramowice suggest that in the oceanic climate of this zone it may in addition have formed communities unshaded by an upper canopy of other trees, just as they do in southern England at present (Dallimore & Jackson 1954 after Król 1975).

Lime began to spread in forests in the close neighbourhood of Imbramowice simultaneously with yew. The corrected spectrum from sample 111 (Fig. 10) suggests that its proportion in the communities of mixed deciduous forests in zone IP-9 may have been somewhat greater than that shown in the total diagram. Three species of lime may have already occurred at that time: *Tilia cordata*, *T. platyphyllos* and *T. tomentosa* (see p. 37).

The expansion of lime in forest communities, in which the proportion of yew was still great, began towards the end of the older part of the *Tilia-Carpinus* subzone (IP-9). However, it did not reach its maximum until the younger part of this subzone. The role of yew was distinctly reduced then, which may have been due to the expansion of lime (cf. Fig. 10, samples 104 and 96). Behre (1970) drew attention to the great role of lime in competition with yew, a problem also discussed by Beug (Jung et al. 1972).

In addition to the then existing communities, the formation of a species-rich deciduous and mixed forests began at that time (IP-10), presumably with a high proportion of lime, mainly *Tilia cordata*, but also *T. platyphyllos* and probably *T. tomentosa*, with frequent *Acer campestre* (fruits) and an already invading *Carpinus*, the presence of which in the close vicinity of the lake is confirmed by its fruits.

The presence of *Ilex aquifolium* (a fruit-stone and pollen), no doubt *in situ*, indicates the formation of a community resembling the present-day West-European oak-hornbeam forest. Oberdorfer (1957) regards *Ilex aquifolium* as geographically distinctive of various groups in the associations *Stellario-Carpinetum*, *Galio-Carpinetum* and *Poa-Carpinetum*. In the south of Poland the present range of the association *Galio-Carpinetum* Oberd. 1957 (without *Ilex aquifolium*) includes the Sudeten Foreland and Foothills (Traczyk 1962; Medwecka-Kornaś in Medwecka-Kornaś et al. 1972; W. Matuszkiewicz 1981). The presence of *Stellaria holostea* is also associated with the herb layer of oak-hornbeam forests.

Alnus glutinosa was undoubtedly the tree that played the most important role locally throughout the *Tilia-Carpinus* subzone, especially in its younger part (IP-10). This is evidenced, besides the high pollen values of *Alnus* undiff., by the numerous fruits of *A. glutinosa*, cone axes and wood (mostly small twigs) of *Alnus*, probably belonging also to this species. The distinct increase in the pollen values of *Fraxinus* coinciding with that of *Alnus* (cf. Figs. 3 and 10, sample 96) and the presence of its wood seem to indicate the increase of the significance of the ash-alder community (?*Circaeo-Alnetum*) in the Imbramowice Depression and, in peaty places on the lake shore, perhaps as a community similar to the contemporary association *Carici elongatae-Alnetum* (Koch 1926) R. Tx. et Bodeaux 1955.

The presence of spruce *in situ* as early as this zone could probably be referred to these very alderwoods. This is suggested, in spite of the low pollen value of *Picea* (below 3%), by a piece of wood of *Picea* vel *Larix;* here its assignment to *Larix* can probably be excluded.

Hedera helix and *Viburnum* were frequent in the understorey of the deciduous forest communities of different types, especially in the younger part of the *Tilia-Carpinus* subzone; they were accompanied by *Sambucus nigra*, *S.* cf. *racemosa*, *Frangula* and *Cornus sanguinea*. Of the plants connected certainly with the herb layer of deciduous forests, *Ajuga reptans*, *Lysimachia nemorum* and *Climacium dendroides* occur in the subzone. The last two species are most probably associated with the riparian alderwoods.

Special attention should be given to the exceptionally abundant occurrence of pollen and the presence of a piece of *Viscum* wood (IP-10), belonging presumably to *V. album*, which parazitizes many hosts in deciduous forests.

Aquatic and lake-shore vegetation

During the *Corylus-Quercus-Tilia* zone the aquatic vegetation was exceedingly luxuriant. *Najas marina* and *Nitellopsis obtusa* predominated, while the proportions of *Ceratophyllum demersum* and *Salvinia natans* were periodically great.

The community with *Najas marina*, approximating perhaps to the modern subassociation *Parvopotamo-Zannichellietum najadetosum* distinguished by Oberdorfer (1957), reached a peak in its development at that time. *Zannichellia palustris* played rather an insignificant role in it, as evidenced by the presence of its only one fruit. This community supposedly occupied deeper sites (cf. its present occurrence — Dąmbska 1961), pushing the community similar to the *Nitellopsidetum obtusae* into shallow habitats. *Nitellopsis obtusa* may have lost some of its importance temporarily as a result of the expansion of *Najas marina* in the older part of the zone.

At the beginning of the *Corylus-Quercus-Tilia* zone the community with *Salvinia natans* was still of some significance, but later, in the middle section of the zone (IP-8b, IP-9 = lower part of IM-7) it disappeared almost completely for some time (cf. Fig. 4).

During the younger part of the *Corylus-Quercus* subzone, fairly significant stands with *Ceratophyllum demersum* presumably developed, as shown by its rather numerous fruits, which did not appear until then. As a shade-tolerating species, *C. demersum* can be seen in different habitats now, but it finds optimum conditions on an organic substratum in the belt of floating-leaved communities (Dąmbska 1961; Tomaszewicz 1979; W. Matuszkiewicz 1981). Such conditions probably arose in the eutrophic and progressively shallowing Imbramowice lake, in which the layer of highly organic gyttja exceeded 2 m in thickness in this zone.

Brasenia schreberi (pollen) appeared in the lake in the same younger part of the *Corylus-Quercus* subzone and *Aldrovanda vesiculosa* (1 seed) somewhat later, in the *Tilia-Carpinus* subzone. Although it resembles *Najas marina* in climatic demands, *Aldrovanda* was not a common plant in the Imbramowice lake, no doubt because of alkaline reaction of the water; today it grows in waters at pH 4.5—5.5 (Zarzycki 1984).

In the younger part of the *Tilia-Carpinus* subzone, macrofossils of nearly all components of the extant communities occurred in large numbers. The abundance of oospores of *Nitellopsis obtusa* indicates another expansion of the community resembling the *Nitellopsidetum obtusae* and the community with *Najas marina* supposedly reached a climax in its development. The proportion of the big-fruit variety, which may have corresponded to the modern *N. marina* var. *communis*, was increasing consistently from the beginning of the zone to reach 91% of the whole population here (cf. Fig. 7). A similarly increasing prevalence of big-fruit populations of *N. marina*, as the climate became milder in the interglacial, was observed by Kräusel (1955) and Jung (Jung et al. 1972) and in the interstadial of Tarzymiechy by Środoń (1954a).

The pleustonic community with *Salvinia natans*, now enriched with *Lemna* cf *trisulca*, again began to expand. The prominence of the floating-leaved plants also increased. *Nuphar lutea* and *Nymphaea alba* supposedly grew in greater numbers than in the older part of the subzone (pollen and seeds). *N.* cf. *candida* and *Brasenia schreberi* were present and *Trapa natans*, *T.* cf. *conocarpa* and *Stratiotes aloides*, this last represented by spines, appeared for the first time.

The continuous occurrence of *Nuphar lutea* and *Nymphaea alba* seems to suggest the formation of a phytocenosis dominated by these species (?*Nuphareto-Nymphaeetum albae* Tomasz. 1977). The progressing eutrophication and shallowing of the lake with organic sediments, indicated by the increase in the amount of organic matter in them, created optimum conditions for this community (Fig. 3).

The intensification of these phenomena towards the end of the zone is confirmed by the presence of *Trapa* and especially *Stratiotes aloides*, which plays an important role in the processes of shallowing and overgrowing of present-day water bodies (see Podbielkowski & Tomaszewicz 1982). It is also corroborated by the almost total lack of euplanktonic diatoms of the *Centricae* subdivision, parallel to the abundant occurrence of littoral-planktonic, benthonic and epiphytic diatoms (Kaczmarska 1976). According to Kaczmarska, the shallowing of the lake even led to a slight rise in salinity, which is evidenced by an increase in the proportion of the oligohalobous and halophilous diatoms (*Navicula cincta*, *Anomoeoneis sphaerophora*).

The warm and gradually shallowing lake made a perfect habitat for a fauna represented by fishes, abundant bryozoan *Cristatella mucedo*, *Daphnidae* and *Mollusca*, among which *Bithynia tentaculata* was particularly numerous. Its maximum occurrence towards the end of the zone also proves the shallowing of the lake. The disappearance of *Cristatella mucedo* statoblasts in the last part of the zone may have been due to the worsening transparency of water caused by the development of floating-leaved vegetation and a pleustonic community with abundant *Salvinia natans*.

In the *Corylus-Quercus-Tilia* zone the change in the reedswamp belt consists chiefly in the restriction of the community with *Typha* as early as the younger part of the *Corylus-Quercus* subzone. The decrease in the number of *Typha* seeds and in *Phragmites* type pollen values is correlated with the somewhat more frequent and numerous occurrences of *Alisma* cf. *plantago-aquatica* fruits and the more frequent fruits of *Schoenoplectus lacustris* and *Sparganium ramosum* s. l. At the same time the number of *Carex rostrata* and *C. pseudocyperus* fruits rises gradually again. These changes seem to suggest the decline of the reedswamp dominated by *Typha* (?*T. latifolia*) and the origin of a poorer variant (of the *Sparganietum erecti* Roll. 1938 type?) with dominant *Alisma plantago-aquatica* and higher values of *Sparganium ramosum*. This community probably bordered upon stands of the *Caricetum rostratae* type with a fairly high percentage of *Carex pseudocyperus* (cf. Tomaszewicz 1979; Podbielkowski & Tomaszewicz 1982). However, the fairly frequent *C. pseudocyperus* nutlets do not rule out the formation of separate patches with its local dominance, especially at the outer edge of the sedgeswamps.

In addition to the above-mentioned dominant taxa, swamps may have included taxa noted in small numbers or sporadically, like *C. vesicaria*, *C. gracilis*, *C. riparia*, *Eleocharis palustris*/*E. mamillata*, *Cladium mariscus* and perhaps also *Mentha* cf. *aquatica, Lythrum salicaria/L. virgatum, Dryopteris thelypteris, Lycopus europaeus* and, in the older part of the zone, *Drepanocladus aduncus* var. *kneiffii.*

At the decline of the zone the sedgeswamps presumably underwent an impoverishment, which is reflected by the absence of *Carex rostrata* and *C. pseudocyperus* fruits. This probably proves the progressive drying-up of parts of the littoral area of the lake.

Numerous taxa of herbs from various types of communities in wet habitats, though only recorded sporadically, point to a great floristic diversity in the lake edge zone and riparian bog forest communities. The following taxa can be mentioned here: *Ranunculus sceleratus, Cyperus fuscus, Juncus, Scirpus sylvaticus, Carex diandra, C. echinata, Filipendula* (?*F. ulmaria*), *Sanguisorba officinalis* (2n = 28 and 2n = 56), *Lythrum, Menyanthes trifoliata, Parnassia palustris, Caltha* type, *Polygonum bistorta/P. viviparum, P. aviculare* type, *Rumex crispus* type, *Climacium dendroides, Oxyrrhynchium swartzii* and *Hypnum lindbergii.* The pollen of most taxa of higher rank, also sporadically recorded, are no doubt connected with the above-mentioned habitats.

Carpinus-Corylus-Alnus R PAZ

(IP-11; IM-8)

The percentages of tree pollen within limits of 85—95% indicate the dominance of still dense forests in the surroundings of Imbramowice. The low tree pollen frequency in some samples of this zone is associated with great amounts of plant detritus and a huge over-representation of *Polypodiaceae* undiff. and *Dryopteris thelypteris* spores. It does not necessarily indicate any impoverishment of forest communities.

The slight rise in herb pollen values in the younger part of the zone is caused by *Gramineae* and *Cyperaceae* (?reedswamp). The low percentage values and small variety of the remaining herbaceous taxa indicate that the vegetation of open habitats still played an insignificant role in this zone. It was limited mainly to wet habitats: *Caltha* type, *Filipendula* (? *F. ulmaria*), *Lythrum, Menyanthes trifoliata,* cf. *Pinguicula, Humulus lupulus, Urtica dioica, Mentha* type, *Thalictrum, Rubiaceae* and *Potentilla anserina* (1 fruit).

Carpinus was the dominant tree. Its maximum expansion must have brought about a regrouping in the communities of the deciduous oak-hornbeam forests, in which it had gained predominance, presumably forming a second tree layer and also partly eliminating hazel from the understorey (a fall in pollen values). Since the edaphic demands of these species are similar, hornbeam secured its dominance, particularly on fertile soils, because it is more shade-tolerant (cf. Gostyńska-Jakuszewska & Zieliński 1976; Zarzycki 1984). It may also have spread in oak-hornbeam forests replacing lime and oak, as indicated by the fall in their pollen values, especially in the younger part of the zone. The better tolerance of hornbeam for soil acidity may have made it easier for it to displace lime (cf. Andersen 1975 and, quoted by him, Ellenberg 1963).

The oak-hornbeam forests in the vicinity of Imbramowice were supposedly still in the nature of present-day West-European oak-hornbeam forests, which is evidenced by stones and pollen of *Ilex aquifolium.* Fairly numerous fruits of *Carpinus betulus* show that these forests came close to the lake. *C. betulus, Tilia cordata* and *Quercus* may have been accompanied by *Tilia platyphyllos* (pollen and fruits), *T. tomentosa* (pollen), *Acer campestre* and *A. platanoides* (fruits and frequent pollen) and *Ulmus* (?*U. scabra*). It may well be that *Picea abies, Abies alba* and *Alnus glutinosa* also penetrated into these stands (cf. Oberdorfer 1957; Medwecka-

Kornaś in Medwecka-Kornaś et al. 1972). The still frequent occurrence of *Hedera helix* is most probably connected with these forests.

Hazel continued to play a conspicuous role in the prevailing communities. The continuous abundance of its pollen suggests that warm thickets or woods with dominant *Corylus avellana* persisted, losing little in significance, until the end of the *Carpinus-Corylus-Alnus* zone.

The rise of pollen values of *Picea* to 7.3%, the first leap of the *Pinus sylvestris* type values and the beginning of the continuous *Abies* curve towards the end of the zone, signal the outset of major changes in the forest communities.

The expansion of hornbeam and the increasing significance of spruce exerted only a small influence on the alder communities, which still played a major role on swamp soils in the vicinity of the lake. This is evidenced by the abundance of *Alnus glutinosa* fruits and other remains of *Alnus*. The relatively high values of *Fraxinus* suggest the survival of the ash-alder community near the lake. Spruce may have been present in both these communities.

Viburnum (?*V. opulus*), *Frangula*, *Cornus sanguinea*, *Humulus lupulus*, *Urtica dioica* and *Lycopus europaeus* can be referred mostly to these forests.

The proportion of *Taxus baccata* in the prevailing forest communities may have been somewhat lower in this zone than at the decline of the previous one. This is mainly true of the middle part of the zone, in which its pollen values fall temporarily to about 2%. It cannot, however, be excluded that owing to a large amount of detritus in these samples some grains of *Taxus* pollen were overlooked.

Aquatic and lake-shore vegetation

During the zone under discussion the process of lake shallowing was rapid and the water chemistry was undergoing changes. This is indicated by a very great increase in organic matter correlated with the almost complete decline of the $CaCO_3$ content (Fig. 3). The change from diatom-calcareous gyttja into coarse-detritus peaty gyttja with sandy silt (of tyrphopel type) proves deficiency of oxygen in the deeper part of the lake and a large supply of allochthonous organic matter (cf. Mikulski 1982).

This process was most likely dependent on the mass development of a pleustonic community dominated by *Salvinia natans* and probably resembled the present-day *Salvinietum natantis* Slavnič 1956, which limited the air circulation in the water and darkened its depths, impeding the photosynthesis of aquatic plants. In extreme cases *S. natans* can even cover the whole surface of a water body (cf. Podbielkowski & Tomaszewicz 1982) and it is just such conditions that are indicated by the abundance of *S. natans* remains together with the simultaneous poverty of remains of other aquatics in the *Carpinus-Corylus-Alnus* zone.

The *Dryopteris thelypteris* — dominated community may have played a similar role in the littoral region. Its development and wide distribution and abundance are reflected by exceptionally large numbers of spores of *D. thelypteris* and spores and sporangia of *Polypodiaceae*, which, probably, in this zone belonged mainly to that species. The low or sporadic occurrence of other components of swamp vegetation points to its poor floristic composition. Nowadays a community with very high proportion of *Dryopteris thelypteris* distinguished as the association *Thelypteridi-Phragmitetum* plays an important role in the final stages of the overgrowing of some markedly shallowed lakes (Tomaszewicz 1977; 1979; Podbielkowski & Tomaszewicz 1982; W. Matuszkiewicz 1981). It usually forms thick floating mats shading the deeper parts of the lake waters and hindering their aeration.

The intensity of these phenomena, depending upon the two above-mentioned communities, must have been rather conspicuous in the Imbramowice lake, as suggested by the drastic disappearance of macrofossil remains of *Nitellopsis* obtusa and *Najas marina*. The low pollen values of *Myriophyllum verticillatum* and the sporadic presence of macrofossils or pollen of other aquatics also indicate the general degradation of the aquatic vegetation or very unfavourable conditions for flowering and fruit production.

The progressive lake-shallowing process is confirmed by the appearance of a number of new species of euterrestrial diatoms, or such as were only sporadically recorded before (*Hantzschia amphioxys*, *Navicula mutica*, *N. neoventricosa* and *Pinnularia borealis*), and benthonic diatoms like *Pinnularia viridis*, *Anomoeoneis sphaerophora* and *Gyrosigma acuminatum* (Kaczmarska 1976).

The shallow, shaded and poorly aerated lake probably ceased supporting any fauna, as evidenced by the total lack of animal remains.

At the decline of the zone the coarse-grained sand content in the peaty gyttja increased (cf. the grain-size distribution column in Fig. 3, sample 85). This undoubtedly indicates the outset of pronounced rainfall and slope wash, which disturbed the dense vegetational cover in the forest period and deposited a sand layer in the lake; part of the sand layer (15 cm) was lost in the course of boring (cf. p. 17). This rainfall most probably brought about a rise in the water level.

Picea-Abies-Alnus R PAZ
(IP-12; IM-9)

Representing all the characteristics of this section of the interglacial, the *Picea-Abies-Alnus* zone at Imbramowice at the same time shows a division into two parts unobserved in the other Eemian diagrams from the territory of Poland. In a preliminary report (Mamakowa 1976) written before the sediment analyses had been made and the macrofossils studied, two subzones, h_1 and h_2 (= IP-12a and IP-12b), were distinguished and a suggestion of a temporary improvement in climatic conditions in h_2 after relatively cool subzone h_1 was put forward. This suggestion was prompted by the fairly great rise in pollen values of *Carpinus*, *Corylus* and other thermophilous trees in subzone h_2 as well as the reappearance and almost continuous occurrence of *Hedera helix* with a simultaneous fall in the values of *Pinus sylvestris* type, *Betula* undiff. and NAP, relatively high in the subzone h_1.

This original interpretation of the division into h_1 and h_2 was undermined by some of the results of macrofossil and diatom analyses. For instance, having appeared for the first time in IP-12a (= h_1), *Potamogeton alpinus* fruits occurred pretty regularly throughout the zone IP-12, and cold-loving diatom species as *Pinnularia lagerstedtii*, *P. nodosa*, *P. borealis*, *Navicula pseudosilicula*, *N. semen*, *N. amphibola* and some others were recorded also in IP-12b (= h_2) (cf. Kaczmarska 1976, Fig. 2). These contradict the hypothesis about a milder climate in the younger part of the zone.

The grain-size distribution, which showed very significant changes in the sedimentation regime throughout zone IP-12, threw some more light on the possible causes of the division. The input of coarse-grained sand with traces of gravel implies very intense rainfall and floods (cf. Fig. 3). Observed for the first time at the decline of the *Carpinus-Corylus-Alnus* zone (see above), they recurred with variable intensity throughout the *Picea-Abies-Alnus* zone. By redepositing organic matter together with mineral material, they may have been a factor that disturbed the pollen picture and undoubtedly reflected increased humidity of climate, soil changes, swamping and the rise of the water level in the lake.

The appearance of somewhat more abundant *Cenococcum*, only sporadically recorded from the beginning of the interglacial, is another sign of soil erosion. However, in comparison with the Late Glacial its numbers are small and indicate that the erosion of organic deposits was not very intense.

It was difficult to evaluate the importance of redeposition, because no other borings were made to provide more information about the shape of the lake basin. On the basis of the changes in aquatic vegetation investigated from the Late Glacial and in water level in the lake, it was acknowledged that erosion might have affected both the youngest sediments at the period of maximum lake shallowing and the older sediments formed in the upper parts of the lake basin during the period of high water level (cf. Fig. 4.3 in West 1969). An attempt was made to establish the range of pollen redeposition in zone IP-12 by comparing the pollen frequencies of basic taxa per 1 cm^2 in particular spectra of this zone with the mean frequencies for these taxa in the late-glacial zone (IP-1—IP-3), in the early interglacial zone (IP-4) and in zone IP-11 (all the materials are deposited in the archives).

The results of those analyses show, above all, the considerable complexity of the causes of variation in the zone under discussion. Summing up the conclusions, it can be stated that the influence of the redeposition of older sediments on the increase in pollen values of pine and herbs in zone IP-12 is not large. The redeposition of late-glacial sediments is scarcely probable, seeing that the Tertiary pollen, abundant in those sediments, is completely absent from IP-12. The redeposition of sediments of zone IP-4, very probable throughout zone IP-12, may have been responsible for the presence of single macrofossils, e.g. sporadic nutlets of *Betula nana*, but presumably was not able to change the pollen picture significantly. The fall in the percentages of *Pinus sylvestris* type, *Betula* undiff. and NAP and the simultaneous increases in pollen values of *Carpinus*, *Corylus* and other thermophilous trees in the younger part of the *Picea-Abies-Alnus* zone (IP-12b) were probably brought about by the redeposition of sediments from zone IP-11. This hardly concerns *Alnus*, whose high pollen values in IP-12b should rather be referred to the humidity of climate and the origin of new swamps, which favoured the expansion of this tree and to the local over-representation of its pollen.

High values of *Alnus* undiff. pollen and its frequent clumps, macrofossils, more abundant than hitherto, and especially numerous nutlets of *A. glutinosa* reflect the abundant occurrence of this tree *in situ*. The rise of the water level in the Imbramowice lake and the silting of its littoral part by floods increased the habitats suitable for development of wet alderwoods (?*Carici elongatae-Alnetum*). Similar processes certainly took place in the valley of the Odra and its tributaries, where oak-hornbeam forest communities may have turned successively into alder or ash-alder riverine forests. The occurrence of *Frangula*, *Viburnum* (?*V. opulus*) *Humulus lupulus*, *Lycopus europaeus*, *Urtica dioica*, *Dryopteris thelypteris*, *Osmunda regalis*/*O. claytoniana*, *Plagiomnium affine*, *Brachythecium rutabulum* and perhaps also pollen of *Anemone* type (?*A. nemorosa*), *Caltha* type, *Mentha* type and others are connected mainly with alder communities.

In the younger part of the zone the find of an elytron of the beetle *Epaphius rivularis*, which is a species characteristic of wet forest communities, deserves notice (cf. p. 47).

The expansion and the maximum percentage of spruce and fir in the forest communities of this zone constitute an unquestionable regional feature of wide range. Their presence *in situ* is confirmed by the finds of wood fragments of *Abies*, stomata and guard cells of *Picea* and wood of *Picea* vel *Larix*, yet most probably of spruce.

On the other hand, the low pollen values of *Abies* indicate that its role in the communities of the Imbramowice Depression was small. This is implied by the local significance of the *Abies* component in pollen spectra, which is consistent with data about the transport of its pollen over short distances (Faegri & Iversen 1978; Suszka 1983). Anyhow, it must not be forgotten that the low proportion of *Abies* and *Picea* pollen in the diagram from Imbramowice was also due to the local over-representation of *Alnus* pollen and, to some degree, also the redeposition of thermophilous tree pollen from zone IP-11.

The participation of fir in the forest communities of this region in the *Picea-Abies-Alnus* zone was much higher than that shown by the diagram from Imbramowice. This is evidenced by data from the nearest sites, i.e. those at Jaworzyna Śląska, Wołów and Szklary Dolne (Kuszell 1980; Borówko-Dłużakowa & Janczyk-Kopikowa 1963). The values of *Abies*, reaching, respectively, 38, 23 and 12% in those sites, indicate the occurrence of coniferous forests in the territory of south-western Poland, dominated by fir and with lower percentages of spruce and pine.

In the Imbramowice Depression and all over the Silesian Lowland spruce may have encroached upon riverine forests and wet alderwoods as well as the still existing oak-hornbeam communities. It may have spread also on mineral habitats deposited by water. Spruce-fir communities, resembling the present-day forests of the lower montane zone, certainly developed in higher situations in the Sudeten Foreland. Pollen influx from these forests may also have had an influence on the *Picea abies* values in the Imbramowice profile.

A re-expansion of pine in the Imbramowice Depression started as early as the beginning of the *Picea-Abies-Alnus* zone. It was facilitated by local conditions, chiefly new habitats formed by floods and swamping. The presence of pine in the neighbourhood of the lake is indicated by wood fragments and sporadically recorded pollen lumps and stomata (IP-12a).

The occurrence of sporomorphs of *Vaccinium* type, *Lycopodium annotinum*, *L. clavatum*, *L. selago*, *Pteridium aquilinum*, *Rubus saxatilis*, *Calluna vulgaris*, perhaps also *Rumex acetosella* type, *Melampyrum* and, probably, part of the pollen of *Gramineae* undiff. and other taxa of higher rank may be referred to coniferous forest communities.

The changes in soils connected with leaching, increasing acidity and podsolization, proceeding faster in the wet climate, were particularly important to the changes taking place in the vegetation in the *Picea-Abies-Alnus* zone. At Imbramowice the intensification of these processes is signalled, in addition to the expansion of *Picea*, by the appearance of *Rubus chamaemorus*, the beginning of continuous *Sphagnum* values, the almost continuous occurrence of *Calluna vulgaris* and the greater pollen frequency of *Ericaceae* and *Rumex acetosella* type and, in the lake, acidophilous diatoms.

The beginning of soil podsolization gave rise to the recession of dense forest communities in conjunction with the favouring of open woods and bog and heath vegetation. This is evidenced by a rise in pollen values of the herbs and, particularly, their greater variety. However, thanks to its great lithological and geomorphological differentiation (Kondracki 1978, Fig. 111), the whole Sudeten foreland was still capable of providing favourable conditions for the survival of deciduous forests, mainly oak-hornbeam ones, dominated by hornbeam, with lime and other thermophilous trees occurring rather singly. The continuous presence of *Taxus* pollen may also be connected with these forests. It seems that even considering the effect of redeposition and over-representation of *Alnus*, the proportion of deciduous forests in this zone could not be lower than that during the following zone. The deciduous forest communities were the source of *Stellaria holostea* pollen, and the so-far unrecorded *Corydalis*, *Mercurialis* cf. *perennis* and *Aruncus sylvestris* pollen, and fruits of *Ajuga reptans*. The frequent occurrence of *Hedera* and *Viscum* pollen and the presence of *Ilex aquifolium* (macrofossils and sporadic pollen grains) may be referred chiefly to these forests.

Numerous macrofossills signal the appearance of nitrophilous communities in the surroundings of the lake, probably in habitats damaged by heavy rain, periodically flooded and subsequent drying up and perhaps also in habitats developing after fires (charcoal dust at a depth of 6 m). The presence of fruit-stones of *Sambucus nigra*, *S. racemosa* and *Rubus* sp. div. and wood and buds of *Salix* may indicate the development of shrub communities, leading to the regeneration of forest in various habitats (perhaps resembling the present-day *Sambuco-Salicion* R. Tx. et Neum. 1950). The exceptionally abundant occurrence of fruits of *Potentilla anserina*, *Potentilla* undiff. and *Urtica dioica* may evidence the simultaneous development of nitrophilous perennial communities on the shore of the lake. *Potentilla anserina* may signal the slight salinity of these nitrophilous habitats (Kornaś in Medwecka-Kornaś et al. (1972).

The presence of *Ranunculus sceleratus*, *R. repens*, *Chamaenerion*, *Plantago maritima* s. str., cf. *Peplis*, *Polygonum aviculare* (1 fruit and pollen of *P. aviculare* type), *Juncus* (1 fruit), *Cirsium/Carduus*, *Veronica* and the somewhat more abundant occurrence of *Artemisia* (?*A. vulgaris*, *A. absinthium*) may be associated with the nitrophilous communities.

The increasing variety of taxa which may have represented communities similar to modern associations of the *Molinietalia* and *Scheuchzerio-Caricetea fuscae* indicated another increase in the significance of wet and boggy meadows and fens in the lake surroundings. They were chiefly the source of pollen or macrofossils of *Filipendula* (?*F. ulmaria*), *Caltha* type, *Lythrum* (?*L. salicaria*), *Sanguisorba officinalis* (2n = 56), cf. *Lychnis*, *Polygonum bistorta/P. viviparum*, *Rumex acetosa* type, *Valeriana*, cf. *Comarum palustre*, *Menyanthes trifoliata*, *Parnassia palustris*, *Carex nigra*, *C. flava*, *C. oederi* ssp. *pulchella*, *Ranunculus flammula*, *Brachythecium rutabulum*, *Cratoneuron decipiens*, *Rhytidiadelphus squarrosus* and *Drepanocladus aduncus* var. *kneiffii*. Probably the pollen of *Campanula*, *Cerastium/Stellaria* undiff., *Potentilla* type, *Prunella* type, *Ranunculus acris* type, *Rhinanthus* type, *Silene* type and *Thalictrum* are also connected with these communities. Some of these taxa appeared in this zone for the first time.

The primary occurrence of *Saxifraga oppositifolia* type pollen and, from among the representatives of dry habitats, *Helianthemum nummularium* type and *Gypsophila fastigiata* type in the communities of that period may be disputable. However, their redeposition from zone IP-4 is hardly probable because of their only sporadic occurrence in the sediments of this last zone. Seeds of *Gypsophila* cf. *fastigiata*, found for the first time in zone IP-12, seem to indicate its presence in close vicinity.

At the same time, the appearance of such taxa, unrecorded from the Late Glacial and the beginning of the interglacial, as *Allium vineale* type (*A. vineale*, *A. sphaerocephalum*, *A. scorodoprasum*), *Armeria* B-type, *Linum austriacum* type, *Plantago media*, *Scabiosa canescens* type (*S. canescens*, *S. columbaria*, *S. ochroleuca*) and *Jasione*, seems to suggest that the changes in the forest communities towards a more open nature created fairly good conditions for pollen transport from various kinds of open dry habitats.

Aquatic and lake-shore vegetation

A higher and more intense rainfall raised the water level in the lake, which was already being overgrown. This led to the restoration of the aquatic vegetation and to changes in its composition, as evidenced mainly by the diversity of taxa recorded. Many species appear here for the first time (*Potamogeton alpinus*, *P. obtusifolius*, *P. berchtoldii* and *Callitriche hermaphroditica*), whereas some, whose redeposition from another zone is hardly probable, e.g. *Potamogeton crispus*, *P. perfoliatus*, *P. natans*, *Myriophyllum spicatum* and *Sparganium minimum*, are also present. The few remains of *Najas marina*, *Ceratophyllum demersum*, *Myriophyllum verticillatum*, *Nuphar lutea* and *Trapa* cf. *conocarpa*, whose redeposition from zone IP-11 was possible, may, however, with great probability be assigned to the vegetation occurring at that time (cf. p. 76).

Salvinia natans, *Potamogeton filiformis* and *Batrachium* belong to the most abundantly represented macrophytes. Some of the fruit of *Batrachium* may come from the redeposited sediments of zone IM-4 (= ±IP-4), in which they were most numerous. However, the fact that the *Picea-Abies-Alnus* zone lacks other taxa abundant in IM-4, e.g. *Rorippa palustris* and *Nitellopsis obtusa*, suggests a minor amount of redeposition. The redeposition of fruits of *Potamogeton filiformis* can, in principle, be ruled out, because they were absent from IM-4 and IM-8. It is very hard to estimate the extent of the redeposition of *Salvinia natans* remains. Dominant in the lake throughout the *Carpinus-Corylus-Alnus* zone, it stood a good chance of survival in abundance despite the changing climatic and edaphic conditions of the *Picea-Abies-Alnus* zone. It should, however, be taken into consideration that its particularly abundant remains in the younger part of the zone may be, to some extent, due to redeposition of sediments from zone IM-8 (= IP-11).

The foregoing analysis permits the assumption that besides the community with *Salvinia natans*, in which *Lemna* was also present, the community resembling the present-day *Potamogetonetum filiformis* again developed in the lake. In addition to *Potamogeton filiformis*, *P. alpinus*, the species now characteristic also of this association (cf. Tomaszewicz 1979), was rather commonly represented in it. Nearly all the species of aquatic plants recorded from this zone can be associated with this very community.

The appearance of most pond-weeds and *Callitriche hermaphroditica* indicates a worsening of the trophic conditions and a change in the reaction of water into neutral or slightly acid. This is also supported by changes in the diatom flora (Kaczmarska 1976).

The run-off water is presumably responsible for the nearly complete disappearance of *Pediastrum*. Noryśkiewicz (1978) drew also attention to a similar situation in the same Eemian zone in the lake at Nakło.

Animal life had probably not yet responded to the changes in conditions of the lake. Only two sponge gemmules and one specimen of *Cristatella mucedo* were found.

The rise of the water level in the lake again brought about the development of sedge swamps. *Carex rostrata* spread most abundantly. Even allowing for the possibility of redeposition of some fruits from IM-4, its abundance must have been considerable. There undoubtedly appeared some groupings of *C. gracilis*, the fruits of which are, for the first time, somewhat more numerous in this zone. Other swamp species, like *C. pseudocyperus*, *C. elata*, *C. vesicaria*, *Cladium mariscus*, *Alisma* cf. *plantago-aquatica*, *Eleocharis palustris*/*E. mamillata*, *Schoenoplectus tabernaemontani*, *Sch. lacustris* and *Sparganium ramosum* s. l., certainly occurred as an admixture in the communities dominated by *Carex rostrata* and *C. gracilis*.

It is, however, difficult to determine whether the presence of *C. aquatilis* fruits should be referred to its re-appearance in the lake or to redeposition, for this species has hitherto been recorded only from the decline of the Late Glacial and from zone IM-4. Similar qualifications can be extended to the fossils of *Hippuris vulgaris*, which were fairly numerous only in zone IM-4, and also to the increased pollen proportions of *Phragmites* type, *Sparganium* type and even *Typha latifolia*. This phenomenon is hard to evaluate, since the increase in rainfall favouring the development of swamp communities may have been responsible also for the partial redeposition of those taxa.

Pinus R PAZ

(IP-13; samples 9—7 from IM-10)

The decline in the extent of the fluvial processes during this zone, as evidenced by the nearly complete disappearance of coarser sand fractions and coarse plant detritus in the sediment (cf. Fig. 3), permits the assumption that at the decline of the interglacial, redeposition was already no longer important in comparison with the *Picea-Abies-Alnus* zone. Nevertheless, in this zone the rise of pollen values of all thermophilous trees and *Corylus* in sample 43 suggests some disturbance connected with redeposition of older sediments.

Changes in the vegetation are expressed by a further expansion of pine forests, probably with an admixture of tree-birches, increasing somewhat towards the end of the zone, and with a simultaneous regression of other forest communities. The regression of alder communities is indicated by the rapid disappearance of *Alnus* macrofossils, especially fruits of *A. glutinosa*. The fall in the values of *Polypodiaceae* s. l. undiff. and, to a certain extent, also the decrease in the number of *Urtica dioica* fruits no doubt may be associated with this regression.

In spite of their downward trend the pollen values of *Picea*, ranging between 7 and 5% of the total sum (9—7% of the AP sum), suggest that it was still fairly abundant in the Imbramowice Depression or that it still played a significant role in the communities of the Sudeten Foreland and Sudeten Mts. (cf. Faegri 1950; Moe 1970; Tallantire 1977). The still great importance of spruce in the Sudeten Mts. at that time is confirmed by the profile from Jaworzyna Śląska (Kuszell 1980), where the rise of *Pinus* values to about 45% is accompanied by 20% *Picea* pollen. In the Imbramowice Depression spruce may have survived both in the already degrading wet alderwoods and in riverine forests. Its role in the expanding pine forests may have been prominent, especially in bog pinewoods (cf. Medwecka-Kornaś in Medwecka-Kornaś et al. 1972; W. Matuszkiewicz & J. Matuszkiewicz 1973; W. Matuszkiewicz 1981), which perhaps included the habitats occupied by wet alderwoods until then. The rise of *Sphagnum* values may indicate the development of bog-type pine forests in this zone.

The decreasing but continuous values of *Abies* pollen show that fir occurred locally in the close surroundings of the lake until the end of the zone. Its local presence at the start of the zone is supported also by well-preserved wood fragments.

In view of the changes taking place in the plant composition at the decline of the interglacial, the still continuous occurrence of *Hedera helix* pollen and the presence of *Viscum* and *Ilex aquifolium* type pollen paralleling the occurrence of *Betula nana* macrofossils and pollen of *Ephedra fragilis* type and *E. distachya* type is a problem that is hard to interpret. Pollen of *Ilex aquifolium* type is most probably connected with the redeposition observed in sample 43, in which it occurs. However, *Hedera* and *Viscum* may have persisted in ecologically favourable habitats, even to the end of the interglacial. It may well be also that the nutlets of *Betula nana*, present in all the samples of the zone, mark the beginning of its migration. The presence of its relict site in this part of Poland seems to suggest that this shrub may have also survived throughout the Eemian Interglacial and started a fresh expansion towards its end.

While pine forests were expanding and other forest communities receding, different types of communities appeared in open habitats. Under conditions of deteriorating climate and degrading soils, shrub communities began to develop (a rise in the values of *Salix glauca* type and *Juniperus*) as did, above all, herb communities. Their increasing significance is reflected, not only by the percentage values of NAP, but also by the increasing diversity and continuous occurrence of herb taxa.

The rise in values of *Cyperaceae* and *Gramineae* seems to be connected with sedge-swamps to a small degree only, which is evidenced by a fall in the number of macrofossils of plants characteristic of the alliance *Magnocaricion*. Owing to their drying-out, sedge-swamps with *Carex gracilis* and *C. rostrata* may have turned into fens and transitional bogs (presence of diaspores of *Carex flava*, *Ranunculus flammula* and pollen of cf. *Comarum palustre*, *Menyanthes trifoliata* and *Parnassia palustris*) or meadow variants. The increase in values of *Gramineae*, the increased occurrences of *Filipendula* (?*F. ulmaria*), *Caltha* type and *Valeriana* pollen, the appearance of *Sanguisorba officinalis* (2n = 28), and the fruits of *Carex* cf. *caespitosa*, occurring for the first time, suggest meadow communities, developing probably on fresh fertile mineral soils. Wet meadows could also be a source for the fairly often recorded pollen of *Thalictrum*, *Rhinanthus* type, *Rumex acetosa* type (?*R. acetosa*), *Ranunculus acris* type (?*R. acris*), *Polygonum bistorta*/*P. viviparum* (?*P. bistorta*) and many other taxa of higher rank. The rise of the *Sphagnum* curve may be associated both with bog pinewoods and with the onset of the development of bogs surrounding the lake.

At that time the nitrophilous communities underwent essential changes. The rapid disappearance of *Potentilla anserina* fruits and the fall in the number of *Urtica dioica* fruits, with the simultaneous rise of *Polygonum aviculare* type pollen values may indicate the drying-out of some habitats. Becoming unsuitable for *Potentilla anserina* or *Urtica dioica*, they were invaded by moderately nitrophilous and drier grassland communities. The fruits of *Potentilla* undiff., again abundant in this zone, are perhaps associated with these communities.

The increase in pollen of *Chenopodiaceae*, *Compositae Tubuliflorae* undiff. and *Cruciferae*, which have many species characteristic of modern associations from the order *Bidentetalia* can, at least, be in part referred to those nitrophilous communities.

The consistently appearing pollen grains of *Plantago maritima* s. str. and the beginning of its continuous curve at the decline of the zone point to the salinity of some habitats. At that time this taxon could spread into drying-out muddy places, giving rise to halophilous meadow communities.

The rise in pollen values of *Chenopodiaceae*, *Artemisia* and *Rumex acetosella* type, accompanied by the presence of pollen of *Helianthemum nummularium* type, *H. canum*/*H. alpestre*, *Gypsophila fastigiata* type, *Ephedra distachya* type, *E. fragilis* type, *Jasione*, *Bupleurum* (?*B. falcatum*) and *Plantago media*, indicates the expansion of steppe-like and grassland communities. These are undoubtedly responsible for part of the *Gramineae* and *Cyperaceae* pollen.

Aquatic and lake-shore vegetation

The temporary decline in fluvial processes led eventually to the re-appearance of large numbers of *Cristatella mucedo* statoblasts and colonies of *Pediastrum*.

The decrease in percentages of acidophilous and indifferent diatoms and the rise again of percentages of alkalibiontic and alkaliphilous ones and, in particular, of some *Fragillaria* species point to a change in the lake-water chemistry caused probably by small influxes of acid water (Kaczmarska 1976).

The community with *Salvinia natans* probably still persisted in the older part of this zone. Nevertheless, it may well be that some of the remains of *Salvinia* come from redeposition, as suggested by the disturbed pollen spectrum of sample 43 (see p. 80) within macrofossil sample 8. In this light, the presence of *Nitellopsis obtusa*, which occurs only in sample 8, may also be questionable. It is difficult to interpret this phenomenon, because the ephemeral appearance of *N. obtusa* at that time cannot be excluded (cf. p. 57). As in the Late Glacial, *N. obtusa* may have colonized more minerogenic sediments brought into the lake during the preceding zone.

The frequent nuts and the new increase in *Myriophyllum spicatum* pollen values suggest that the phytocenoses in which it was present were perhaps similar to the present-day *Myriophylletum spicati* Soó 1927 and played a major role in the lake, perhaps even greater than at the outset of the interglacial. It was favoured by a rise in the water level and, above all, by the re-appearance of mineral habitats.

Particularly noteworthy is the abundance of *Potamogeton vaginatus* stones, recorded only in small numbers from the Late Glacial, and of oospores of *Nitella gracilis*. The abundance of their remains shows that at the decline of the interglacial the communities dominated by these two species prevailed in the lake.

Potamogeton vaginatus, which now occurs in Europe along the coast of the Gulf of Bothnia, had a considerably wider range in the Pleistocene. It was reported from the interglacial and glacial floras of the middle and younger Pleistocene of Poland (Paszewski 1950; Tołpa 1952, 1961; Środoń 1954a, 1974; Bitner 1956a, 1957; Stachurska 1957, 1961; Mądalski 1961; Janczyk-Kopikowa 1966a, 1975a). In the interglacials it was mainly found in the early and final parts. In the Eemian sporadic stones were recorded also from its climatic optimum (Tołpa 1952; Janczyk-Kopikowa 1966a).

The presence of *Nitella gracilis* oospores in only one sample indicates its ephemeral appearance, which would agree with the instability of its present-day stands (Dąmbska 1964).

Numerous species of *Potamogeton* (*P. crispus*, *P. filiformis*, *P. gramineus*, *P. natans*, *P. obtusifolius*, *P. perfoliatus* and *P. praelongus*), *Myriophyllum verticillatum* and probably also *Ceratophyllum demersum*, *Nuphar lutea* and *Trapa* very probably formed a small admixture in the communities dominated either by *Potamogeton vaginatus* or by *Myriophyllum spicatum*. The *Nitella gracilis*-dominated communities were rather floristically poor, just as they are nowadays (Tomaszewicz 1979; W. Matuszkiewicz 1981).

The spread of *Myriophyllum spicatum* and *Nitella gracilis* indicates the mesotrophic or even eutrophic nature of neutral or slightly alkaline water of the lake (cf. Tomaszewicz 1979; Zarzycki 1984).

Against the background of this rather rich vegetation the complete lack of fish remains is surprising. Only *Cristatella mucedo* occurs in abundance and sponges are present.

The reedswamps were rather poor at the decline of the interglacial. They were represented by low pollen values of *Sparganium* type, *Phragmites* type and *Typha latifolia*. *Alisma* cf. *plantago-aquatica*, *Hippuris vulgaris* and *Eleocharis palustris*/*E. mamillata* may have occurred within them sporadically.

The high values of *Cyperaceae* pollen probably, in part, represent sedgeswamps, in which *Carex rostrata* and *C. gracilis* were important and *C. pseudocyperus*, *C. vesicaria* and *Cladium mariscus* were present. However, the smaller numbers of their remains reflect a gradual decline of sedgeswamps in connection with the drying-out of some habitats.

FIRST STADIAL OF THE EARLY VISTULIAN

Gramineae-Artemisia-Betula nana R PAZ

(IP-14; samples 6a and 6 from IM-10, IM-11)

Drastic changes in the horizon considered to be the boundary between the interglacial and the glacial plant succession are expressed by the rise in herb pollen values to 43%, the start of the continuous occurrence of *Larix* and *Betula* cf. *nana* pollen and the rapid fall of pollen values of nearly all trees and *Corylus.*

These changes are accompanied by a successive increase in the proportion of coarser sand fractions in the sediment, symptomatic of the re-intensification of erosional processes. There occurred small amounts of Tertiary pollen and sporadic *Hystrichosphaeridae* and an increase of deteriorated, indeterminable pollen and *Cenococcum graniformae.* The rise in pollen values of *Alnus* undiff., *Corylus, Tilia cordata* type, *Quercus* and *Abies* and the re-appearance of sporadic pollen grains of *Ulmus, Fraxinus, Tilia platyphyllos* type, *Taxus baccata* and *Hedera helix* indicate the redeposition of interglacial sediments in the layer in which the proportion of coarser sand fractions of the sediment reaches a maximum (3.04—3.30 m).

The rising values of *Pinus sylvestris* type at the beginning of the zone, immediately after the rise of the NAP curve cannot be recognized as a sign of expansion of pinewoods. Under the circumstances of the progressive opening of the landscape they, above all, express the increasing possibilities of long-distance transport of pine pollen. In this situation the values of *Pinus sylvestris* type pollen, within limits of 30—40%, may imply very open pinewoods or pine stands with sporadic tree-birches and some larches, in a mosaic arrangement of various open communities. However, the presence of pine in the close vicinity of the lake is confirmed by a pollen tetrad in sample 20 and a group of badly developed pollen in sample 24 and the presence of tree-birches by nutlets of *Betula* cf. *pubescens, B. pendula* and *B.* cf. *pendula.*

Of the other tress, *Picea* and *Alnus glutinosa* may have persisted in small numbers, especially at the beginning of the Early Vistulian. Despite low pollen values and the possibility that part of it was redeposited, their presence *in situ* is proved by the clump of badly developed pollen of *Alnus* undiff. in sample 35, a tetrad of *Picea* in sample 27 and wood fragments of *Alnus* particularly numerous in macroscopic sample 3. The presence of *Populus* in the surroundings of the lake is shown by a large group of pollen in sample 20, a rise in its values in the upper part of the zone and, which is less reliable, two wood fragments of *Populus* vel *Salix.* At the beginning of the zone *Frangula* was presumably still present in the habitats formerly occupied by alderwoods. Under conditions of an open landscape the sporadic and low-percentage curve of *Pinus cembra* most probably results from long-distance transport from the Sudeten Mts.

The developing shrub communities resembled in character those at the close of the Late Glacial, but the percentages of their main components (*Juniperus, Salix* and *Betula nana*) were relatively low at the onset of the first stadial. The presence of *Betula nana* is now shown, in addition to its nutlets, by the continuous occurrence of well-preserved pollen. The presence of willow in the lake surroundings is confirmed by numerous wood fragments and well-preserved buds of *Salix*. Pollen of *Rubus* undiff., cf. *Rosa, Rhamnus cathartica, Hippophaë rhamnoides, Ephedra distachya* type, *E. fragilis* type and *E.* cf. *strobilacea* also indicates the occurrence of these shrubs in open communities.

The consistently increasing values of NAP express the progressive expansion of herb communities in open habitats. The number of taxa, considerably larger than in the Late Glacial (17 of them appear here for the first time) and the great variety of indicator plants of various communities shows a greater differentiation of habitats than at the decline of the previous glaciation. The more abundant and more continuous occurrence of many taxa than in the Late Glacial is also noticeable.

The high values of *Cyperaceae* pollen, the not high but continuous values of *Sphagnum*, the frequent remains of *Drepanocladus aduncus* (notably *D. aduncus* for. *capillifolia*), the occasional fruits of *Carex* cf. *nigra*, *C.* cf. *flava*, *Ranunculus flammula* and pollen of cf. *Comarum palustre* and *Menyanthes trifoliata* all indicate an increase in the importance of swamp meadows or fens(?*Scheuchzerio-Caricetea*). *Betula nana* no doubt encroached upon acidophilous habitats and pollen of *Polemonium*, noted here for the first time, may be also referred to them.

These communities may have been developing into wet meadows. The evidence of the role of these communities is given by the continuous pollen curve of *Filipendula* (?*F. ulmaria*), *Rumex acetosa* type and *Caltha* type, frequent occurrences of *Valeriana*, *Polygonum bistorta/P. viviparum* (?*P. bistorta*) and, in particular, *Sanguisorba officinalis* (2n = 28), and clumps of its pollen in several samples. These communities were certainly the source of pollen of *Lysimachia vulgaris* type, *Plantago lanceolata* and *Lythrum*, seeds of *Lythrum salicaria/L. virgatum* and a fruit of *Ranunculus* cf. *acris*.

Pleurospermum austriacum, recorded only from this zone, is perhaps indicative of the presence of tall-herb communities (?*Adenostyletalia*). The sporadically noted pollen grains of *Humulus lupulus*, *Anemone* type, *Mercurialis* cf. *perennis*, *Rubus saxatilis*, *Solanum dulcamara* and fairly frequent spores of *Phegopteris dryopteris*, representing remnants of the herb layer of degraded forests, can also be referred to these communities. They may also be represented by taxa of higher rank, embracing species characteristic of these communities, e.g. *Gnaphalium* type (?*G. norvegicum*), *Bupleurum* (?*B. longifolium*), *Geranium*, cf. *Rosa* and *Sorbus*.

In the older part of the zone *Ranunculus sceleratus* was still rather numerous in the communities of therophytes, which are perhaps responsible also for pollen of *Polygonum persicaria* type, including species characteristic of different units of the *Bidentetalia tripartitae* (*Polygonum mite*, *P. nodosum*, *P. hydropiper*, *P. minus* and *P. brittingeri*).

The continuous occurrence of *P. aviculare* type pollen and, nearly continuous, of *Plantago major* evidence the fairly marked role played by the nitrophilous communities of low perennials (modern *Potentillo-Polygonetalia* R. Tx. 1947). Drier nitrophilous habitats may have been responsible for the single pollen grains of cf. *Xanthium*, cf. *Chamaenerion*, cf. *Epilobium* and *Papaver*, a seed of *Papaver rhoeas* type, and the rise in pollen values of many taxa of higher rank, including numerous species characteristic of nitrophilous communities (*Chenopodiaceae*, *Cruciferae*, *Compositae Tubuliflorae* undiff., *Umbelliferae* undiff., *Prunella* type, *Artemisia*, *Potentilla* type). The presence of fruits of *Potentilla* undiff. should presumably be ascribed to them as well.

The continuous and abundant occurrence of pollen of *Plantago maritima* s. str. and *P. maritima* s. l., most probably belonging to *P. maritima* var. *salsa*, in this zone (cf. p. 36 and Fig. 5) is particularly significant. They are indicators of the spread of halophilous meadows both in damp habitats (?*Armerion maritimae* Br.-Bl.

et De Leeuw 1956) and in drier ones. This latter case would be indicated by the probable presence of *P. maritima* var. *salsa* (cf. Pilger 1937), which now extends only to the eastern part of Podolia (Tacik 1967). Pollen of *Lotus* (?*L. tenuifolius*) and *Armeria* (?*A. maritima*) comes presumably from these communities.

The formation of different communities in drier habitats is revealed by a long list of species now characteristic of various syntaxonomic units representative of such habitats. Frequent pollen of *Plantago media* and *Helianthemum nummularium* type, with the recurrence of *Ephedra distachya* type, *E. fragilis* type and *E.* cf. *strobilacea* suggests the important role of steppe-like grasslands. They may also be the source of pollen of *Rubus* undiff., cf. *Rosa* and *Rhamnus*, and sporadic pollen grains of *Pimpinella*, *Allium vineale* type and *Anemone* type (?*A. sylvestris*).

Grasslands spread on sands deposited by water and exposed by further erosion and also into acidophilous deforested areas. This is shown — by analogy with the modern communities of the class *Sedo-Scleranthetea* — by the continuous occurrence of *Rumex acetosella* type pollen, frequent *Gypsophila fastigiata* type pollen and macrofossils of *Silene otites*, *Knautia arvensis* and *Rumex acetosella* as well as sporadic pollen grains of *Scleranthus perennis*, *Jasione*, *Centaurea jacea* type (?*C. rhenana*), *Armeria* (?*A. elongata*, *Hippophaë rhamnoides* and *Elymus* type. *Silene* type pollen, belonging perhaps to *S. otites*, may probably be referred mainly to sandy grasslands.

The continuous occurrence of *Calluna vulgaris* and rather frequent spores of *Lycopodium clavatum* and *Botrychium* suggest the formation of stands of heath on poor acid sand soils or in open pine communities. *Lycopodium complanatum*/*L. tristachyum* and *Empetrum* (?*E. nigrum*) may also be linked up with them.

Taxa suggesting the formation of subalpine meadow-type communities in the Sudeten Foreland on the threshold of the Early Vistulian appeared at the very beginning of the zone. They are *Helianthemum canum*/*H. alpestre*, *H.* cf. *oelandicum*, cf. *Koenigia islandica*, cf. *Saxifraga nivalis*, cf. *S. stellaris* and *Betula nana*.

Aquatic and lake-shore vegetation

The movement of water in the lake and its increased turbidity caused by inwashed allochthonous sediments are responsible for another fall in the values of *Pediastrum* and the rapid disappearance of *Cristatella mucedo* statoblasts.

Water level again rose in the lake, which may have induced the ephemeral development of a community with *Nitella mucronata*, represented by abundant oogonia and oospores in one sample. It may have dominated the deeper parts of the lake for a short time as a pioneer community, just as it does nowadays (Tomaszewicz 1979). The *Potamogeton vaginatus*-dominated community still occurred parallel to it.

An abundance of *P. gramineus* stones and somewhat less numerous nuts of *Myriophyllum spicatum* appeared in the younger part of the zone. This presumably indicates the formation of two communities on mineral deposits: at the edge of the lake a community related to the modern association *Potamogetonetum graminei* (W. Koch 1926) Pass. 1964, occurring usually at a depth of 0.5 m at pH 6.3—8.0 (Tomaszewicz 1979; W. Matuszkiewicz 1981), and, somewhat deeper, a community similar to the modern *Myriophylletum spicati*. The presence of *Potamogeton filiformis*, *P. perfoliatus*, *P. lucens*, *Ceratophyllum demersum* and *Batrachium* may be associated with these two communities.

The regression of the community with *Potamogeton gramineus* observed at the top of the zone may have been brought about by the intense inwashing of mineral material (sand layer at a depth of 3.04—3.20 m), which caused the shallowing of the littoral parts of the lake, whereas some stands with *Myriophyllum spicatum* may have persisted in its deeper parts.

Stratiotes aloides pollen, noted from the beginning of the zone, perhaps points to the development of a community resembling the modern *Hydrochari-Stratiotetum* in shallow places but on a more organic substratum. Exceptionally frequent *Lemna* pollen may be an indicator of the prominence of pleustonic communities with duckweeds.

The rise in pollen values of *Sparganium* type, *Phragmites* type and *Typha latifolia*, and, at the same time, the fairly frequently recorded macrofossils of *Eleocharis palustris/E. mamillata* and *Hippuris vulgaris* show another expansion of reedswamps as early as the beginning of the zone. A comparison with the changes taking place in aquatic communities suggests that the communities dominated by *Eleocharis palustris*, with relatively frequent *Hippuris vulgaris*, could find favourable conditions for development on newly-deposited mineral sediments. *Butomus umbellatus*, *Alisma* cf. *plantago-aquatica*, *Sagittaria*, *Schoenoplectus lacustris* and *Sch. tabernaemontani* probably entered these communities. The increase in pollen values of *Phragmites* type and *Typha latifolia* indicates the expansion of *T. latifolia* and *Phragmites communis* patches in a deeper part of the lake. Towards the land, communities with *Eleocharis* (?*E. palustris*) surely passed into *Carex rostrata*-dominated sedgeswamps, in which *C. gracilis* may have played an important role initially. *Lysimachia thyrsiflora*, *Carex pseudocyperus*, *C. vesicaria* and *C. aquatilis* occurred sporadically in these sedgeswamps.

In view of the deforestation caused by climatic cooling and worsening, it is difficult to interpret the presence of pollen or macrofossils of several aquatic and swamp plants which now occur in moderately warm regions. Their occurrence may be due to redeposition but it may also well be that some of them persisted in south-western Poland until the beginning of the Early Vistulian. The survival of *Salvinia natans*, *Najas marina*, *Ceratophyllum demersum*, *Nymphaea alba* and *Cladium mariscus* is most questionable.

The nature of the aquatic and swamp flora shows that the Imbramowice lake in spite of signs of shallowing, still had a good chance of survival, at least throughout a part of the early glacial. An analysis of the diatom flora leads to a similar conclusion (cf. Kaczmarska 1976). The absence of younger sediments is therefore the result of their erosion during a later period (cf. Szczepankiewicz 1962).

CLIMATIC INFERENCES

Late Glacial of the Middle Polish Glaciation s. l.

The share of organic matter in the sediments of the whole Late Glacial in the Imbramowice profile does not exceed 10% except for the top sample. This share is as low as in Norwegian lakes in the zone of the ice-front oscillations in the cold parts of the Vistulian Late Glacial (Mangerud 1970; Mangerud et al. 1979c). In the Allerød the proportion of organic matter at those sites increased, reaching about 12 and above 20%.

The low percentage of organic matter in the Imbramowice profile, with the simultaneous erosion and redeposition of allochthonous sediments, indicates not only the poverty of vegetation in the lake but also a low supply of organic material from the catchment area compared with that of minerogenic matter. This implies the openness of the plant cover. However, the results of palaeobotanical studies do not permit us to say definitively whether this was due to the severe climate or to the activities of periglacial conditions and water erosion.

The presence of the fruiting dwarf birch from the very beginning of zone IP-1 evidences moderately cold climatic conditions and weakly marked continentality. The occurrence of *Betula pubescens* fruitlets and *Pinus sylvestris* wood in the younger part of zone IP-1 suggests an improvement in the climatic conditions at that time. Presumably, the mean temperature of the warmest month towards the end of zone IP-1 was not lower than about 10°C (Hustich 1948; Iversen 1954; Wasylikowa 1964) and the presence of pine may even suggest a temperature up to 12°C.

In the light of these data the poverty of aquatic vegetation at the beginning of the Late Glacial is surprising. The intense inflow of cold periglacial water and the movement and turbidity of the water were probably restricting factors.

Starting from the older part of the *Cyperaceae-Artemisia-Betula nana* zone (IP-2), the symptoms of climatic continentality increase, which is mainly reflected by the rise in significance of the steppe-like communities. Their maximum expansion in the younger part of this zone (IP-3) indicates the driest climate at the close of the Late Glacial. And so the final section of the Late Glacial of the Middle Polish Glaciation becomes similar to the Younger Dryas. The palaeobotanical data from Imbramowice do not provide any evidence that the driest section was at the same time very cold. The proof of the dry but increasingly warm climate is the enriched composition of herb communities and the rise in the frequency of their pollen, the continuous presence of *Betula* cf. *pubescens* fruitlets and, during the transition to the interglacial, also of *B.* cf. *pendula*, as well as the cessation of erosion and of sediment redeposition. The relatively abundant occurrence of two species of tree-birches towards the end of the Late Glacial shows that the temperature of the warmest month was not lower than 12°C.

However, the luxuriant development of aquatic vegetation, the formation of reedswamp communities and the appearance of species with large thermal demands, e.g. *Ceratophyllum* (?*C. demersum*), *Potamogeton perfoliatus*, *Schoenoplectus lacustris* and, in meadow communities, *Sanguisorba officinalis*, may indicate the mean temperature of the warmest month approximated 13°C.

Kaczmarska (1976) drew attention to the fact that at the close of the Late Glacial at Imbramowice many diatom taxa were more abundant than in its older parts and that some species characteristic of the climatic optimum appeared. This may suggest that the diatoms responded to the milder climate earlier than did the aquatic macrophytes and terrestrial plants.

The palaeobotanical data from Imbramowice give no grounds for the distinction of climatic oscillations in the Late Glacial of the Middle Polish Glaciation s. l. similar to those found in the Vistulian Late Glacial.

Eemian Interglacial

The expansion of forest communities with a high proportion of pine, the increase of the tree pollen frequencies, and the rise of organic matter in the sediments to 20% at the top of the *Pinus-Betula* zone give evidence of climatic improvement — its warming up — at the very beginning of the interglacial. The survival of steppe-like communities with a fairly diverse composition until the end of this zone suggests that it was still a continental climate. Traces of fires, present in the form of a charred fragmentary pine needle and charcoal dust, indicate its dryness.

The mean temperature of the warmest month in the younger part of the *Pinus-Betula* zone can be estimated on the basis of the continuous occurrence of *Typha latifolia* and macrofossils of *Rumex maritimus* and *Lycopus europaeus* to be at least at 14—15°C. The first fruits of *Najas marina*, which admittedly already occur *in situ*, imply even a somewhat higher temperature.

In Kaczmarska's (1976) opinion, the predominance of littoral-planktonic and benthonic diatoms over the euplanktonic ones in the older part of the *Pinus-Betula* zone indicates still rather severe climatic conditions. The abundant appearance of the planktonic species *Stephanodiscus astraea* var. *minutulus* in the younger part of the zone is indicative of a milder climate.

The increasing abundance and diversity of aquatic plants now confined to moderately warm regions (*Najas marina*, *Salvinia natans*, *Myriophyllum verticillatum*), indicate a further improvement of the climate in the *Pinus-Betula-Ulmus* zone. Particularly significant is the appearance of large numbers of *Navicula seminuloides* among the diatoms, a species, so far not recorded from Europe, that has great climatic demands (Kaczmarska 1976). A favourable climate is also indicated, according to Kaczmarska, by the diatoms from the *Centricae* subdivision, numerous in this zone, with a high proportion of species of the genus *Cyclotella* and a consistent decrease in the number of *Chrysophyceae* cysts.

The increasing oceanicity of the climate at the decline of the *Pinus-Betula-Ulmus* zone is revealed by the appearance of *Hedera helix*. It can be inferred on this basis (cf. Iversen 1944) that as early as this part of the interglacial the summer temperatures were moderately high, whereas the temperature of the coldest month did not fall below −1.5°C.

In the *Quercus-Fraxinus-Ulmus* zone the climate underwent a further improvement. The fairly frequent occurrence of *Ligustrum vulgare*, which at present grows in particularly warm and dry habitats, indicates high summer temperatures, whereas the already continuous occurrence of *Hedera* implies mild winters. The abundance of *Salvinia natans* and *Najas marina* and, as regards the diatoms, the rise in the proportion of *Navicula seminuloides* lead to similar conclusions.

The rapid expansion of hazel in the younger part of the *Quercus-Fraxinus-Ulmus* zone suggests further increases in the oceanicity of the climate. The migration of *Corylus* in north-western Europe, later in the Eemian than in the Holocene (in relation to *Ulmus* and *Quercus*), was attributed by Jessen to its sensitiveness to the Atlantic climate; he considered its development to have been dependent upon the transgression of the Eemian sea (Jessen & Milthers 1928). A similarly late migration of *Corylus* is observed in sediments of all the Eemian sites in Poland. Investigations carried out for many years in the valley of the Lower Vistula (Halicki 1951; Halicki & Brodniewicz 1961; Makowska 1979b) allow the statement that the transgression of the Eemian Tychnowy sea preceded the expansion of *Corylus*. A pollen analysis made by Janczyk-Kopikowa (Makowska 1979b) for marine sediments from the site lying farthest to the south (Kwidzyn region) showed that the Tychnowy sea had reached this area at the decline of the *Quercus-Fraxinus-Ulmus* zone. In Makowska's (1979b) opinion, it was the greatest sea transgression in the Quaternary of Poland. According to her, the marine fauna indicates a Mediterranean climate in this region.

In the Holocene a similarly delayed migration of *Corylus* in relation to *Ulmus* took place only in the continental south-eastern part of Poland (Szafer & Jaroń 1935; Mamakowa 1962; Mamakowa & Starkel 1974, 1977; Ralska-Jasiewiczowa 1980, 1983). In its north-eastern part the expansion of *Corylus* and *Ulmus* in the Holocene was more or less simultaneous (Ralska-Jasiewiczowa 1983).

The *Corylus-Quercus-Tilia* and *Carpinus-Corylus-Alnus* zones provide a number of further data informing about a very warm and oceanic climate in this part of Poland. In the zone of the maximum spread of *Corylus* (IP-8a), *Ilex aquifolium* and *Taxus baccata* appeared, indicating milder winters than it could be judged only from the presence of *Hedera* (Iversen 1944). *Ilex aquifolium*, bearing fruits in this region towards the end of the *Corylus-Quercus-Tilia* zone, proves that the mean temperature of the coldest month was only slightly lower than 0° C then (cf. Iversen 1944).

Tilia tomentosa, a sub-Mediterranean Balkan species (Walter & Straka 1970), presumably appeared in south-western Poland in the younger part of the *Corylus-Quercus-Tilia* zone. It might be assumed on this basis after Frenzel (1967) that the mean July temperature of this region was about 3° C higher than the present mean temperature which according to Kondracki (1978) is 17° C for the Sudeten Foreland and 18.8° C for the Silesian Lowland. The high temperature of the climatic optimum is also evidenced by the abundance of aquatic vegetation dominated by the thermophilous *Najas marina*, by *Salvinia natans* abundant in its younger part, and fruiting *Brasenia schreberi* and *Aldrovanda vesiculosa*. An analysis of the diatoms, among which *Navicula seminuloides* reached a maximum and *N. confervacea*, regarded as a tropical species (Hustedt 1966 after Kaczmarska 1976) made an appearance, leads to similar conclusions.

The maximum proportion of *Salvinia natans*, high values of *Hedera*, presence of *Tilia tomentosa* and *Viscum* as well as the constantly significant percentage of *Taxus* and fruit-bearing *Ilex aquifolium* suggest still similar climatic conditions also in the older part of the *Carpinus-Corylus-Alnus* zone. Some changes signalling a deterioration of the climate occurred as early as its younger part. In addition to such frequently discussed phenomena as encroachments made by *Picea abies*, *Pinus sylvestris* and *Abies* upon forest communities, the Imbramowice profile provides other data implying a climatic change. This is recorded by an increase in the proportion of coarser sand fractions in the sediments, indicating intense rains and floods, which fell in the period of the maximum shallowing of the lake. The cooling of the climate is evidenced by the diatoms *Navicula semen*, *Pinnularia lagerstedtii* and *P. borealis* (Kaczmarska 1976). The moist and slightly cooler climate may have caused a shift in balance between precipitation and that of evaporation in favour of the former, resulting in the rise of the water level in the lake.

Niklewski (1968) emphasized the presence of hydrological changes throughout the hornbeam zone in the profile at Główczyn and Krupiński (1978) in those at Żyrardów. In both cases peatbogs were inundated and mineral sediments washed in. The hydrological changes in this zone can also be observed at other Eemian sites (see p. 122).

The increase in humidity and the traces of cooling in the younger part of the *Carpinus-Corylus-Alnus* zone in the Eemian may correspond with the sort of changes observed in the Holocene in the Subboreal period.

It is difficult to evaluate the climatic changes taking place in the *Picea-Abies-Alnus* zone on the basis of the Imbramowice profile in connection with disturbances caused by the redeposition of pollen. The differences in the delivery of rather coarse mineral fractions may reflect heavy rains and floods at the beginning and towards the end of the zone. The fact that *Potamogeton filiformis*, a Boreal species, was again fairly abundant and the appearance of *P. alpinus*, *Callitriche hermaphroditica* and many cool-loving diatoms, which had not occurred before or had been sporadic, indicate a deterioration in thermal conditions of the water. However, the expansion of spruce and fir suggests, at the most, moderately cool climatic conditions, similar to those in the lower montane zone of today.

Pollen of *Hedera* still frequent, the somewhat less regular presence of *Viscum* and above all the presence of an *Ilex aquifolium* fruit-stone are indicative of the mean temperatures of the coldest and the warmest month. In view of the data presented by Iversen (1944) the presence of the fruit-bearing *Ilex* allows us to state that the mean temperature in the coldest month was not lower than −0.5°C and so it was higher than the present one, −1.7°C, in this region of Poland (cf. Kondracki 1978). The presence of *Viscum*, with reference to Iversen's thermal data, indicates that the mean temperature of the warmest month was not lower than 17°C during the *Picea-Abies-Alnus* zone. If we allow for the presence of *Tilia tomentosa* pollen, it may have been much higher.

In the last interglacial zone there were some features indicating an increase in continentality of climate: the decrease in heavy rain, salinity of some habitats and re-formation of steppe-like communities. However, the survival of *Hedera* until the end of the interglacial evidences that the mean temperature of the coldest month could not be below −4°C to −5°C (cf. Iversen 1944, Fig. 4).

Early Vistulian

The changes which mark the boundary between the interglacial and the early-glacial vegetational successions indicate great changes in the climatic conditions. Further continentality is shown by the development of steppe-like communities and, above all, halophilous ones with abundant *Plantago maritima* and probably also with *P. maritima* var. *salsa*. In Godwin's (1975) opinion, the occurrence of saline habitats and halophytic plants in the Early and Middle Vistulian in Britain was probably associated with "the combination of permafrost in the ground and the big evaporation of a very continental climate, conditions that produce strongly saline habitats and communities today in the Lena Valley of Siberia and in north-eastern Greenland".

A change in the thermal conditions is manifested by the already undoubtful presence of *Betula nana* in this zone, the re-appearance of Arctic-Alpine species — cf. *Saxifraga nivalis* and cf. *S. stellaris* — in the flora of the Sudeten Foreland and, in the lake, by the dominance of the Boreal species *Potamogeton gramineus* and the more abundant occurrence of Boreal and even Arctic species of diatoms than in the Late Glacial of the Middle Polish Glaciation s. l.

PART II. PROBLEMS OF THE POLLEN STRATIGRAPHY OF THE EEMIAN AND GLACIAL DEPOSITS ADJACENT TO IT IN POLAND

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HISTORY OF PALYNOLOGICAL STUDIES

It is difficult to fix the time of the beginning of palynological studies on the last interglacial in Poland; the more so, because many sites, now considered to be unquestionably Eemian, were initially connected with an older interglacial. The earliest mention of an attempt to find pollen in sediment was at Imbramowice (Hartmann 1907). The first pollen analysis was performed by Lilpop (1925) for the profile from Koszary, a site now situated beyond the eastern boundary of Poland. The first percentage pollen diagram of Eemian sediments was that presented by Paszewski (1927) from Szeląg two years later. However, the first more detailed elaborations by means of pollen analysis were published — almost at the same time — by Szafer & Trela (1928) from Szeląg and Heck (1929) from Rusinów.

In 1928 Szafer presented the first stratigraphy of the Pleistocene of Poland. Then, he referred to the older interglacial (= Masovien I) not only Szeląg, but also a number of other sites recognized later as Eemian, such as Imbramowice (Hartmann 1907), Szczerców (Premik 1925) and, of the sites now lying beyond the eastern frontier of Poland, Koszary (Lilpop 1925), Poniemuń and Samostrzelniki (Szafer 1925). Only the Żoliborz site in Warsaw was correlated by him to the Eemian (= Masovien II) on the basis of scanty macroscopic material (Szafer 1928).

In the thirties a few new Eemian sites, analysed palynologically, were included in the studies of the Pleistocene. These are as follows: Żoliborz (Raniecka 1930), Szczerców and Dzbanki Kościuszkowskie (Piech 1930a, b, 1932), Bedlno (Szafer et al. 1931), Rusinów (Stark et al. 1932) and Winiary (Gołąb & Urbański 1938). Although the work by Jessen and Milthers (1928) was already known at that time, only the sites of Żoliborz and Rusinów were referred correctly to the Eemian Interglacial.

Woldstedt's (1947) paper was of great importance to the interpretation of the palynological studies from Poland. Basing himself on Jessen's stratigraphic division (Jessen & Milthers 1928), he rectified the stratigraphic position of the localities Dzbanki Kościuszkowskie, Szczerców and Szeląg, assigning them to the Eemian Interglacial. Nevertheless, at the beginning of the fifties only 7 Eemian sites, elaborated palynologically, were known from the territory of Poland.

An increase in palaeobotanic studies of the Pleistocene and of the Eemian did not take place before the next decades. Then it was, to a great extent, due to a resolution passed at the conference devoted to the questions of the Pleistocene, held in Cracow in 1946. This resolution aimed at tightening collaboration between geologists and botanists. Since then palaeobotanists in Cracow, Warsaw and Wrocław have been working out material delivered by the State Institute of Geology (see Środoń 1981). At the same time a study of Pleistocene floras was taken up in the Museum of Earth in Warsaw.

Six years later Szafer (1953) presented the "Pleistocene stratigraphy of Poland from the floristical point of view", based on the profiles worked out up to 1952. In that work he expresses his opinion that there were four glacials and three interglacials in Poland, at the same time assuming the existence of two interglacials for the Polish Lowlands — Masovien I and Masovien II. This scheme was concurrent with the stratigraphic approaches of Woldstedt (1947) and Grichuk (1950) but differed from the scheme presented by Halicki (1950), who assumed the occurrence of six glacials and five interglacials for the European Lowland. On the basis of palaeobotanical data, Szafer (1953) correlated the Masovien II Interglacial with the fourth interglacial in Halicki's scheme, the Eemian Interglacial in north-western Europe, the Valday-Dnieper Interglacial in the USSR and the Riss/Würm Interglacial in Germany. Considering the sequence of changes in the vegetation, he divided the interglacials into four parts (I—IV), which he named "Stages". Their definition was based on the occurrence of pollen of the "indicator tree taxa". This division is the prototype of fourfold divisions proposed later by various authors for the Holocene and interglacials (Neustadt 1959; Turner & West 1968; Hafsten 1969).

Somewhat earlier Środoń (1950) divided the Eemian diagrams from the Grodno region into 8 phases (I—VIII) and claimed that they can be correlated with zones b—i of Jessen's scheme (Jessen & Milthers 1928). In Poland Jessen's scheme was first applied in the division of the pollen diagram from Bedlno (Środoń & Gołąbowa 1956).

In the following years the above-mentioned stratigraphic divisions (Jessen

& Milthers 1928; Środoń 1950; Szafer 1953) as well as other individual divisions (e.g. Tołpa 1952; Raniecka-Bobrowska 1954) were applied in Poland. However, Jessen's scheme or its version modified by Środoń (1967a) has been chiefly used from the end of the fifties until recently.

The years preceding the INQUA Congress in 1961 were in Poland a period of particularly intense palynological studies in the Pleistocene. However, the greatest number of Eemian sites have been identified by means of pollen analyses in the last 15 years. To the 46 localities listed at the beginning of the seventies by Środoń (1972), more than 50 new ones were added up to the end of 1985. Unluckily, many of them were worked out in a discontinuous manner (at random) using widely spaced samples (cf. Fig. 12), thereby supplying comparatively little information about the vegetational history, as well as being very disadvantageous when the increasingly complicated stratigraphy of the Pleistocene that is emerging at present augments the liability of misclassification of individual pollen spectra (cf. pp. 141, 142).

LIST OF SITES

The number of sites given in Polish literature as representing the Eemian Interglacial is dependent upon the criteria adopted for the distinction of this stratigraphic unit. On the basis of the modern morphology of the terrain Halicki (1953) estimated their number at hundreds. Kalniet (1955), assuming Halicki's guiding principles, distinguished 600 such sites only in the southern part of the Polish Lowlands. The Eemian age of these fossil lakes was confirmed by means of pollen analysis only in a few cases; the remaining ones had not been analysed yet.

At the start of the seventies S. Z. Różycki (1972) maintained that there were about 100 sites known with organogenic sediments of the last interglacial in Poland. At the same time, basing himself on palaeobotanical data, Środoń (1972) referred 46 localities to the Eemian. Recently, Straszewska and Stupnicka (1980) assigned 111 localities to the Eemian Interglacial, but only 75 of them having pollen data worked out.

Ninety-nine sites referred to the Eemian Interglacial on the basis of palynological results are listed in the present work. Several of the sites listed both by Środoń (1972) and by Straszewska and Stupnicka (1980) are missing from this survey, because they have been excluded by the present author from the Eemian Interglacial (see p. 141). On the other hand, it is supplemented by the sites published in 1978—1985 and some dozen extra sites, unpublished so far. The latter ones came from the Archives of the Geological Survey of Poland in Warsaw or were obtained directly from the authors who gave their consent for their inclusion in the stratigraphic table on the basis of the criteria adopted by the author of the present work.

The numbering of the sites listed corresponds with that on the map (Fig. 11), in the stratigraphic table (Fig. 12) and is placed in square brackets [ ] in the text. It fulfils the role of an identifier and reference symbol (to the list of sites). An attempt was made to give all significant palaeobotanical studies for each site and, for some of them, also geological ones. If the site name is provided with more reference items, the asterisk (*) indicates those from which pollen data and the lithological descriptions of the profiles included in the stratigraphic table are derived. If a locality has more than one profile worked out by means of pollen analysis, only those that comprise longer stratigraphic series, are supplementary to the basic profile or come

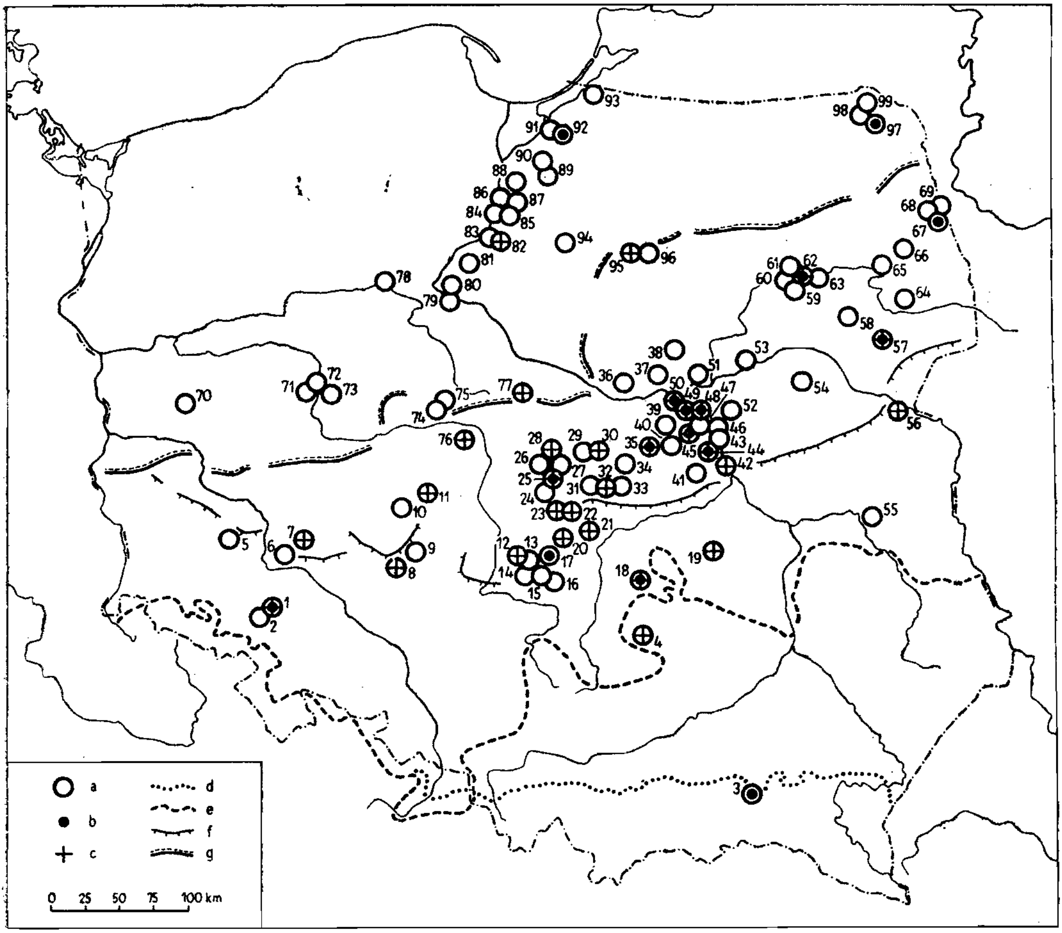


Fig. 11. Sites of Eemian floras (a) in Poland in relation to the extent of the glaciations. Separate symbols are used for the Late Glacial of the Middle Polish Glaciation s. l. (b) and the Early Vistulian (c), distinguished in the continuous pollen sequences with the Eemian Interglacial. Site numbers on the map are the same as in the list (below). Ranges of glaciations, acc. to Galon & Roszkówna 1967: d — South Polish Glaciation (= Cracovien Glaciation), e — Middle Polish Glaciation — Maximum Stadial, f — Middle Polish Glaciation — Warta Stadial (= Warta Phase), g — Vistulian Glaciation (= Baltic Glaciation)

from later studies and give a fuller picture than do the previous ones are presented in the stratigraphic table.

1. Imbramowice (Gürich 1905; Hartmann 1907; Kräusel 1920; Środoń 1960; Mądalski 1961; Szczepankiewicz 1962; Mamakowa 1976; This paper, Part I*).
2. Jaworzyna Śląska (Dyjor & Kuszell 1977; Kuszell 1980*).
3. Dąbrówka near Jasło (Mamakowa & Wójcik 1987).
4. Zakrucze (Lindner & Ziembińska-Tworzydło 1974).
5. Szklary Dolne (Borówko-Dłużakowa & Janczyk-Kopikowa 1963*; Borówko-Dłużakowa 1973a).
6. Wołów (Kuszell 1980).

7. Raki (Kuszell 1980).
8. Domasłów (Rotnicki & Tobolski 1965*; K. Tobolski unpubl., A. Mickiewicz Univ., Quater. Res. Inst., Poznań).
9. Mechnice (K. Tobolski unpubl., l. c.).
10. Zębców (Borówko-Dłużakowa 1978).
11. Kalisz (Tołpa 1952).
12. Dzbanki Kościuszkowskie (Piech 1930a, b, 1932*; Woldstedt 1947).
13. Szczerców (Piech 1930a, b, 1932*; Woldstedt 1947).
14. Leśna Niwa (Janczyk-Kopikowa 1966b*, 1971*).
15. Faustynów (Janczyk-Kopikowa 1966b*, 1971*).
16. Aleksandrów (Janczyk-Kopikowa 1966b*, 1971*).
17. Bełchatów (Goździk & Jastrzębska-Mamełka 1982).
18. Bedlno (Szafer et al. 1931; Środoń & Gołąbowa 1956*).
19. Sławno (Rühle 1961; Tołpa 1961*; Środoń 1967a).
20. Krzepczów (Klatkowa 1972*, pollen analysis by J. Jersak; J. Jersak unpubl. tables, Silesian Univ., Sosnowiec*).
21. Świątniki (Jastrzębska-Mamełka 1984).
22. Pałczew (Wieczorkowska 1975*, pollen analysis by J. Oszast; Oszast 1972*).
23. Kalinko (Z. Balwierz unpubl., Dep. of Geomorph. Inst. of Geogr., Łódź Univ., Łódź).
24. Łódź-Polesie (Borówko-Dłużakowa 1956*, 1973a; F. Różycki 1979*).
25. Zgierz-Rudunki (Jastrzębska-Mamełka 1979, 1985*).
26. Ozorków (M. Jastrzębska-Mamełka unpubl., Dep. of Geomorph. Inst. of Geogr., Łódź Univ., Łódź).
27. Besiekierz (Klatkowa 1972, pollen analysis by M. Sobolewska).
28. Piaski Stare (Jewtuchowicz 1970*, pollen analysis by M. Sobolewska; M. Sobolewska unpubl. tables, Paleobot. Archives of the W. Szafer Institute of Botany PAScs*).
29. Skaratki (Chmielewski 1961, pollen analysis J. De Ploey).
30. Bobrówka Valley — Lake Okręt (Klajnert & Piechocki 1972, pollen analysis O. K. Hulshof).
31. Rogów (Janczyk-Kopikowa 1985).
32. Józefów (Sobolewska 1966).
    Józefów B (Dylik 1967, 1968* pollen analysis J. De Ploey).
33. Białynin (Borówko-Dłużakowa 1973a, 1973b*).
34. Skierniewice (Borówko-Dłużakowa 1973a, 1973b*).
35. Żyrardów (Krupiński 1978).
36. Główczyn (Niklewski 1968).
37. Falbogi (Baraniecka 1974, pollen analysis Z. Janczyk-Kopikowa).
38. Bylice (Borówko-Dłużakowa 1959*, 1973a).
39. Błonie (Janczyk-Kopikowa 1975b*; Karaszewski 1975).
40. Grodzisk Mazowiecki (Janczyk-Kopikowa 1973).
41. Pawłowice (Baraniecka 1980, pollen analysis K. Szczepanek).
42. Góra Kalwaria (Sobolewska 1961).
43. Gawroniec (Borówko-Dłużakowa 1973c).
44. Gołków (Gadomska 1966; Janczyk-Kopikowa 1966a*).
45. Komorów (K. M. Krupiński unpubl., Inst. of Geol., Warsaw Univ., Warsaw).
46. Warszawa-Siekierki (Borówko-Dłużakowa 1985).
47. Warszawa-Włochy (Borówko-Dłużakowa 1977a).
48. Warszawa-Wola (Raniecka-Bobrowska 1954; Rühle 1954a; Borówko-Dłużakowa 1960*).

49. Warszawa-Wawrzyszew (Morawski 1976, 1978; K. M. Krupiński unpubl., l. c.*).
50. Warszawa-Żoliborz (Raniecka 1930; Raniecka-Bobrowska 1954*; Rühle 1954a).
51. Moczydło (Borówko-Dłużakowa 1962*, 1973a; Mojski 1962*).
52. Ossów (Borówko-Dłużakowa 1977b).
53. Wyszków (Borówko-Dłużakowa 1973a, 1973b*).
54. Błoniewo (Borówko-Dłużakowa & Halicki 1957).
55. Karczunek (Krupiński et al. 1982).
56. Horoszki (Bitner 1954).
57. Otapy (Bitner 1956a).
58. Mystki (Borówko-Dłużakowa 1971b*, 1973a; Bałuk 1973*).
59. Konopki Leśne (Borówko-Dłużakowa & Halicki 1957*; Borówko-Dłużakowa 1971a).
60. Kupiski Nowe (Borówko-Dłużakowa 1975a*; Bałuk 1978).
61. Jednaczewo (Bałuk 1975; Borówko-Dłużakowa 1975a*).
62. Łomża-Łomżyca (Niklewski & Dąbrowski 1974; Straszewska & Goździk 1978; K. M. Krupiński unpubl., l. c.).
63. Niewodowo (Musiał et al. 1982).
64. Klewinowo (Borówko-Dłużakowa 1973a, 1974*; Mojski 1974).
65. Bagno-Kalinówka (Borówko-Dłużakowa & Halicki 1957).
66. Czarna Wieś (Bitner 1956b).
67. Ludomirowo (Bitner 1957).
68. Zacisze (Bitner 1957).
69. Miklewszczyzna (Bitner 1957).
70. Rusinów (Heck 1929; Stark et al. 1932*).
71. Szeląg (Paszewski 1927; Szafer & Trela 1928; Woldstedt 1947; Środoń 1956*).
72. Winiary (Gołąb & Urbański 1938, pollen analysis J. Bąkowski).
73. Swarzędz (Kunkel & Tobolski 1977).
74. Kazimierz near Konin (Stankowski & Tobolski 1981).
75. Jóźwin (Borówko-Dłużakowa 1979).
76. Władysławów (Tobolski 1986).
77. Kaliska (Janczyk-Kopikowa 1964, 1965a*).
78. Nakło (Borówko-Dłużakowa 1973a; Noryśkiewicz 1978*).
79. Przyłubie (Janczyk-Kopikowa 1970*; Makowska 1979b*).
80. Zła Wieś Wielka (Janczyk-Kopikowa 1970*; Makowska 1979b*).
81. Bajerze (Janczyk-Kopikowa 1965b*; Makowska 1979b).
82. Grudziądz-Mniszek (Drozdowski & Tobolski 1972*; Makowska 1979b, pollen analysis Z. Borówko-Dłużakowa & Z. Janczyk-Kopikowa).
83. Rządz (Drozdowski & Tobolski 1972).
84. Kaniczki (Janczyk-Kopikowa 1970*; Makowska 1979b*).
85. Białki (Janczyk-Kopikowa 1968*; Makowska 1979b*).
86. Grabówka (Janczyk-Kopikowa 1970*; Makowska 1979b*).
87. Kwidzyn-Nicponie (Janczyk-Kopikowa 1970*; Makowska 1979b*).
88. Tychnowy (Halicki 1951, pollen analysis M. Bremówna).
89. Dzierzgoń (Woldstedt 1950*, pollen analysis H. Gross; Halicki 1951).
90. Nowiny (Janczyk-Kopikowa 1976a*; Makowska 1979a*, 1986).
91. Elbląg (Woldstedt 1947*, pollen analysis H. Gross; Halicki 1951).
92. Elbląg-Bażantarnia (Halicki & Brodniewicz 1961, pollen analysis W. Ołtuszewski).
93. Podleśne near Braniewo (Wiśniewski & Pietkiewicz 1985, pollen analysis B. Noryśkiewicz).

94. Nowe Miasto (Bitner 1956b).
95. Nidzica-Sewerynów (Szczepanek 1962).
96. Nidzica (Borówko-Dłużakowa 1976*; Marciniak & Kowalski 1978, pollen analysis J. Niklewski).
97. Szwajcaria (Borówko-Dłużakowa & Halicki 1957*; Borówko-Dłużakowa 1975b).
98. Błaskowizna (Borówko-Dłużakowa 1966*, 1973a*; Ber 1974).
99. Smolniki (Borówko-Dłużakowa 1971c*, 1973a).

EVALUATION OF MATERIAL

The material listed above was evaluated with respect to the palynological-stratigraphic classification on the basis of uniform criteria. On account of the varying presentations of results by particular authors, the pollen data obtained from all the sites have been brought into a comparable state as far as it was possible. As regards the sites from which herbaceous pollen had already been distinguished, the percentages of particular taxa were calculated on the basis of the total tree, shrub and terrestrial herb pollen (excluding *Bryophyta*, *Pteridophyta* and pre-Quaternary taxa). Considering the sites of Kalisz [11], Dzbanki Kościuszkowskie [12], Szczerców [13], Rusinów [70], Dzierzgoń [89] and Elbląg [91], for which herbaceous pollen was not distinguished, and that of Krzepczów [20], for which the NAP sum, the only one given by the author, contains, in all probability, very high quantities of *Polypodiaceae* spores, the recalculation was based on the tree and shrub pollen sum.

The recalculation of all the diagrams permitted a comparison of the local pollen assemblage zones distinguished in them, which in turn made it possible to define regional pollen assemblage zones (see p. 98), and these latter zones are the basis for the pollen stratigraphy proposed for this part of the Pleistocene in Poland. In this scheme, it appeared necessary to revise partly the past divisions given by the authors of the earliest papers. The results are presented in a stratigraphic table (Fig. 12) and the details concerning the changes introduced are given in a table deposited in the archives of the Department of Paleobotany, W. Szafer Institute of Botany, PAScs, Cracow.

Naturally, we were confronted with some difficulties. The lack of herb pollen makes it impossible to mark the boundary between the Late Glacial and the Eemian at Kalisz I [11], and because of insufficient information about the NAP composition this boundary is not quite reliable at Elbląg-Bażantarnia [92] and Warszawa-Żoliborz [50]. For the same reason the presumed boundary could not be marked between the Eemian and the Early Vistulian at Kalisz I [11], Rusinów [70] and Elbląg [91]. On the basis of macrofossils of *Betula nana* alone the boundary was delimited — despite the lack of NAP — at Dzbanki Kościuszkowskie [12] and — despite low values of NAP — at Otapy I [57]. The marking of this boundary and the division of the Early Vistulian in the diagrams from Krzepczów [20] are unreliable because in these diagrams the NAP is not differentiated.

Another problem is connected with samples taken too wide apart in profiles treated seemingly in a continuous manner. This prevents the reconstruction of the succession of trees, especially in the initial period of the interglacial, when the changes in the vegetational development are quick. This is exemplified by the following sites: Gołków [44] — zone E1 missing (interval 20 cm), Faustynów 50/18a [15] — E2 missing (interval 20 cm), Aleksandrów 57/19 [16] — E2 and E3 missing (interval 20 cm), Horoszki [56] — E2 and E3 missing (interval 70 cm), Krzepczów A [20] — E3 and E4 missing (interval 70 cm). As a result of at least 30-centimetre intervals of sampling at Elbląg-Bażantarnia [92] zones E3 and E5 are missing and a similar situation occurs at the Eem/Early Vistulian boundary at Kalisz II [11], where the interval of 42 cm probably hides a part of zone E7 and zone EV1. Because the very thick top sections of the profiles from Faustynów 50/18a [15], Białynin [33] and Moczydło [51] were studied only at random, they are excluded from the stratigraphic evaluation, as are the highest samples from the profiles of Bobrówka Valley [30] and Piaski Stare [28] (see pp. 135, 136, 137).

The foregoing remarks indicate that although the number of sites recognized as Eemian on the basis of palynological data is rather large, only some of them fulfil the conditions required for determining the regional pollen stratigraphy.

Still another problem is connected with difficulties in determining the geographical extent of the pollen assemblage zones and the directions of tree migrations in the Eemian Interglacial in Poland on account of the lack of sites of this age in southern, south-eastern and north-western part of the country. There are also some large blank areas in the western part of middle Poland and in north-eastern Poland (cf. Fig. 11). The consequences of such a situation are exemplified by the occurrence of yew in the Eemian in the territory of Poland. It was thought until recently that *Taxus* was rare in the Eemian in Poland (Phillips 1974). The increase in the number of sites in the last decade (Mamakowa 1976; Noryśkiewicz 1978; Krupiński 1978; Jastrzębska-Mamełka 1979, 1985; Kuszell 1980; Goździk & Jastrzębska-Mamełka 1982; Krupiński et al. 1982; Musiał et al. 1982; Janczyk-Kopikowa 1985) and the improvement of the methods used has resulted in a change in this opinion (cf. Fig. 20).

In the future, it will be necessary to try to implement similar principles for interglacials to those of the Holocene Programme IGCP 158B. And so it is indispensable to carry out a comprehensive study of at least one type profile from a relatively large fossil lake or peatbog in each fairly extensive physiographic unit. This will permit more reliable correlations of the results obtained from small waterbodies, which usually show local vegetational changes and at the same time provide much valuable information about the differentiation of communities in an area (Andersen 1975). This will also permit easier correlations of the results obtained from the profiles analysed at random.

INTRODUCTORY REMARKS TO THE POLLEN STRATIGRAPHY

Different schemes were applied in dividing the Eemian pollen diagrams in Poland (cf. p. 91). The introduction of Jessen's scheme (Jessen & Milthers 1928) in the fifties brought about their relative unification. The scheme itself or its version modified by Środoń (1967a) has been used until now. However, this relative uniformity did not provide any generally applied univocal criteria for the division of diagrams, which is so because various pollen assemblages were referred to zones marked with the same letter. This is particularly well exemplified by the various criteria for distinguishing Jessen's zone *e*.

Using Jessen's scheme in its "classic" version, some palaeobotanists referred the pine-birch spectra with elm to zone *e*. This division was applied in diagrams from Bedlno (Środoń & Gołąbowa 1956), Warszawa-Wola (Borówko-Dłużakowa 1960), Główczyn (Niklewski 1968), Nidzica (Marciniak & Kowalski 1978), Niewodowo (Musiał et al. 1982) and Karczunek (Krupiński et al. 1982). In this interpretation pollen spectra with maximum values of both *Quercus* and *Corylus* were included in zone *f*. Other palaeobotanists, using Jessen's scheme, placed the spectra with maximum values of *Quercus* in zone *e*. These sites are: Józefów (Sobolewska 1966), Gołków (Janczyk-Kopikowa 1966a), Imbramowice (Mamakowa 1976), Nakło (Noryśkiewicz 1978), Żyrardów (Krupiński 1978) and Kazimierz near Konin (Stankowski & Tobolski 1981).

And so, zone *f* was identified in the diagrams from these sites only on the basis of maximum values of *Corylus*. Środoń (1967a), too, adopted this mode of division in his scheme and at the same time proposed to change the symbols used to designate the zones by adding the letter E (*Ec—Ei*). On this scheme is based the division of the diagrams from Faustynów and Leśna Niwa (Janczyk-Kopikowa 1971), Białki (Makowska 1979b), Bełchatów (Goździk & Jastrzębska-Mamełka 1982) and Nowiny (Makowska 1986).

The variable interpretation of Jessen's zone *i*, the application of zone *j* under the "scheme of Jessen and Milthers", in which such a zone does not exist at all and, what is more, the assignment of different pollen contents to this zone are other inconsistencies in the divisions applied to date. The still unsettled problem of the so-called "second climatic optimum" is also very difficult.

In view of the obvious need of unifying the problems connected with stratigraphic division of the Eemian an attempt was made to propose a pollen stratigraphy based on pollen assemblage zones distinguished with the help of uniform criteria used for the division of pollen diagrams. The pollen diagram from Imbramowice [1], presented in the first part of this work and covering the whole Eemian Interglacial with both, upper and lower boundaries, was adopted as the basis for the definition of pollen assemblage zones.

The similarities found between the local pollen assemblage zones in the diagrams from various sites allowed the definition of regional pollen assemblage zones. The scheme presented in Fig. 12 is based on the subjective comparison of all the diagrams from the territory of Poland, which were available up to 1985.

The regional pollen assemblage zones have been described, defined and named according to the rules given by Cushing (1964, 1967b), West (1970) and H. J. B. Birks (1973a) and in accordance with the principles of Polish stratigraphic classification (Alexandrowicz et al. 1975). They include bodies of sediments characterized by the occurrence of definite assemblages of pollen and spores, coming from the time when the given layers were being deposited (cf. Cushing 1964; H. J. B. Birks 1973a).

Imbramowice [1] is the type locality for several zones. Other type localities are proposed for the zones that are not so well developed or do not occur at all in the Imbramowice profile.

The names of the regional zones indicate the basic composition of the pollen spectra. The taxon after which the zone is named is not always the most abundant one in it, though here its values usually form a maximum for a higher stratigraphic unit. Pollen and spores for which there is any suspicion that they come from redeposition are not used to name the pollen assemblage zones (cf. Cushing 1964, 1967b; Alexandrowicz et al. 1975).

The pollen assemblage zones distinguished are linked together. They are characterized by common boundaries, the upper boundary of a zone being at the same time the lower boundary of the next one.

The regional zones have been described from oldest to youngest. The Eemian zones are marked with the letter E (E1—E7), the Early Vistulian zones with EV (EV1—EV5) and the late glacial ones with LG MPG, but they are not numbered.

REGIONAL POLLEN ASSEMBLAGE ZONES IN THE LATE GLACIAL OF THE MIDDLE POLISH GLACIATION S. L.

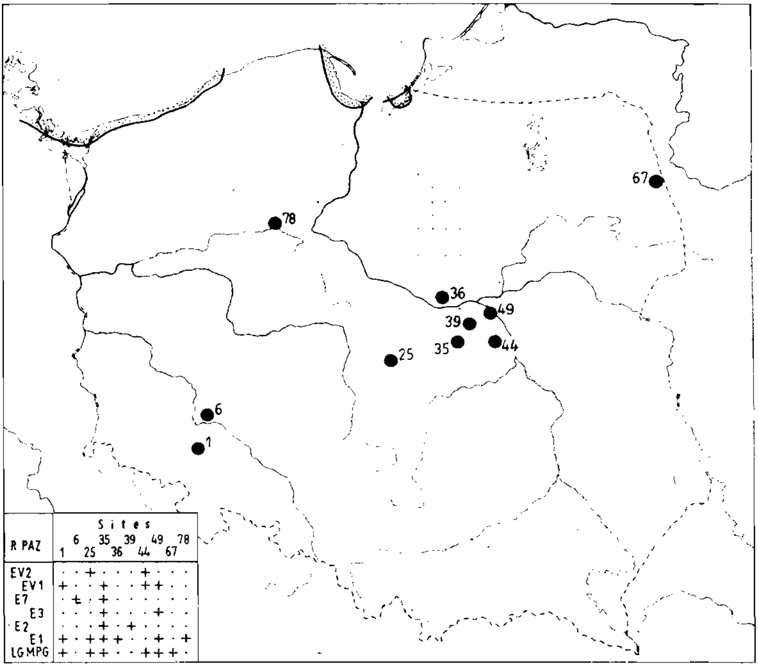
LG MPG — *Cyperaceae-Artemisia-Betula nana* R PAZ

Type locality and section. Imbramowice [1], zones IP-2 and IP-3 (Fig. 3).

Description. The NAP maximum comes to 52.4% in the diagram from the type locality and to 29.0 and 51.7% in the corresponding zone in two other profiles.

Cyperaceae, *Gramineae* and *Artemisia* are the main components. *Chenopodiaceae* are relatively important. Among the shrubs *Betula nana*, *Juniperus* and *Salix* are of essential importance. *Hippophaë* and *Ephedra* are sporadic. Pollen of *Pinus* and *Betula* occurs in moderate proportions. Pollen of other trees is present (redeposition possible). Redeposited pollen of pre-Quaternary plants is usually present.

Contacts. The lower boundary in the type locality is placed above local late-glacial zone IP-1, which has not been included in the zone under discussion because of its relatively low NAP values and very high values of redeposited pollen. At Zgierz-Rudunki II [25] and Bełchatów X [17], it is the lowest pollen zone above the glacial deposits of the Middle Polish Glaciation s. l. The upper boundary is placed where the NAP values fall below 25%.



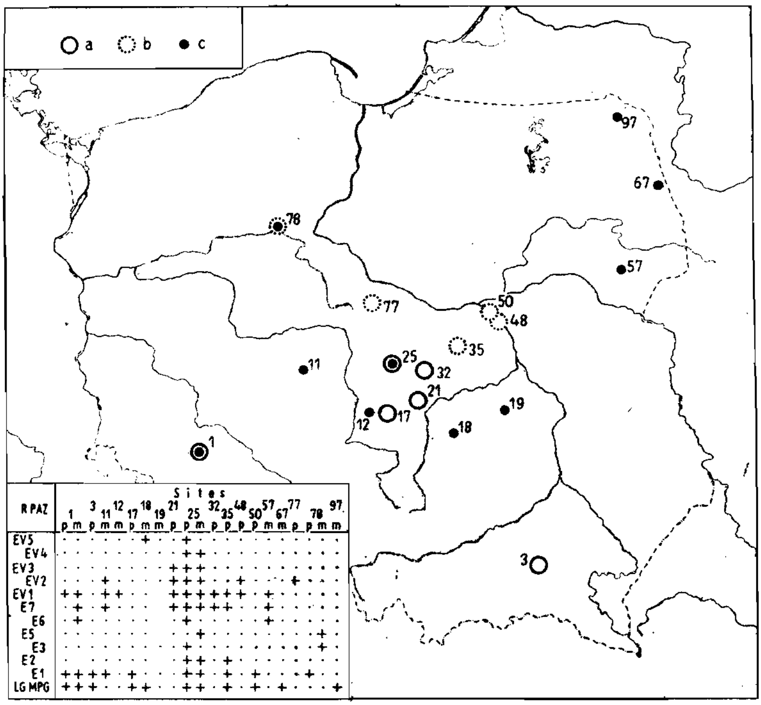
R PAZ	Sites 1	6	25	35	36	39	44	49	67	78
EV2	·	·	+	·	·	·	+	·	·	·
EV1	+	·	·	+	·	·	+	+	·	·
E7	·	+	·	+	·	·	·	·	·	·
E3	·	·	·	+	·	·	·	+	·	·
E2	·	·	·	+	·	+	·	·	·	·
E1	+	·	+	+	+	·	·	+	·	+
LG MPG	+	·	+	+	·	·	+	+	+	·

Fig. 13. Distribution of *Hippophaë* in Poland in the Late Glacial of Middle Polish Glaciation s. l. (LG MPG), in the Early Vistulian (EV) and in cool sections of the Eemian (E) on the basis of pollen records. The pollen occurrences in particular R PAZ-es are marked with + in the table. Site numbers as in the list (p. 93). The present occurrence area of *H. rhamnoides* L., acc. to Browicz et al. (1977), is shown by fine dots

Subdivisions. Two subzones have been distinguished at the type locality: the upper, *Juniperus* subzone, and the lower (IP-2), unnamed.

Juniperus subzone. The *Juniperus* values exceed those in the lower unnamed subzone (IP-2) and reach 6.5%.

Other occurrences. The *Juniperus* subzone is represented by local zone ZRII-1 at Zgierz-Rudunki II [25]; at Bełchatów X [17] samples B1 and B2 may be referred to it. At both sites, *Juniperus* pollen is associated with relatively high *Betula nana* pollen values. Sporadic *Hippophaë* pollen grains occur at Zgierz-Rudunki II (cf. Figs. 13 and 14).



R PAZ	1		3	11	12	17	18	19	21	25		32	35	48	50	57	67	77	78		97
	p	m	p	m	m	p	m	m	p	p	m	p	p	p	p	m	m	p	p	m	m
EV5	·	·	·	·	·	·	+	·	·	+	·	·	·	·	·	·	·	·	·	·	·
EV4	·	·	·	·	·	·	·	·	·	+	+	·	·	·	·	·	·	·	·	·	·
EV3	·	·	·	·	·	·	·	·	+	+	+	·	·	·	·	·	·	·	·	·	·
EV2	·	·	·	+	·	·	·	·	+	+	+	·	·	+	·	·	·	+	·	·	·
EV1	+	+	·	+	+	·	·	·	+	+	+	+	+	+	·	+	·	·	·	·	·
E7	·	+	·	+	·	·	·	·	+	+	+	+	+	·	·	+	·	·	·	·	·
E6	·	+	·	·	·	·	·	·	·	+	·	·	·	·	·	+	·	·	·	·	·
E5	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	+	·
E3	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	+	·
E2	·	·	·	·	·	·	·	·	·	+	+	·	+	·	·	·	·	·	·	·	·
E1	+	+	+	+	·	+	·	·	·	+	+	·	+	·	+	·	·	·	+	·	·
LG MPG	+	+	+	·	·	+	+	·	·	+	+	·	+	·	+	·	+	·	·	·	+

Fig. 14. Distribution of *Betula nana* in Poland in the Late Glacial of the Middle Polish Glaciation s. l. (LG MPG), Eemian (E) and Early Vistulian (EV) on the basis of pollen records (a), its presence suggested by pollen measurements (b) and macrofossils (c). The presence of *B. nana* in particular R PAZ-es is marked with + in the table: p — pollen, m — macrofossils. Site numbers as in the list (p. 93); site 48 acc. to Raniecka-Bobrowska 1954, profile 1a

Extent. On the basis of the present state of knowledge the complete zone range cannot be established. The sites at Imbramowice, Zgierz-Rudunki and Bełchatów, where the *Juniperus* subzone has been distinguished, indicate its occurrence in south-western and middle Poland up to the Łódź Upland.

Remarks. 1. The regional affiliation of the late-glacial sections from Bedlno [18] and Dąbrówka near Jasło [3] is left to be evaluated later. The site at Dąbrówka has only been studied in a preliminary way; its late-glacial section has 32% NAP and 2.5% *Betula nana* pollen, but its characteristic feature is the extremely high *Selaginella selaginoides* values (88% in relation to the total AP + NAP sum). One bottom sample from Bedlno, from a depth of 12.90 m, is characterized by relatively low NAP values (27.5%), but this zone abounds in macrofossils of *Betula nana* (cf. Fig. 14), while *Dryas octopetala* and *Salix herbacea* are present.

2. In the *Cyperaceae-Artemisia-Betula nana* zone of the type profile the macrofossils of *Betula nana* are abundant and macrospores of *Selaginella selaginoides* present (Fig. 4). *Betula nana* macrofossils also occur at Zgierz-Rudunki II [25] (cf. Fig. 14).

3. The presence of *Betula nana* macrofossils at the bottom of the profile from Kalisz I [11], below its part covered by the pollen analysis, suggests that this part may have formed in the Late Glacial of the Middle Polish Glaciation s. l. and probably corresponds to the *Cyperaceae-Artemisia-Betula nana* zone. Since it was not analysed palynologically, this part of the profile from Kalisz I has not been included in the stratigraphical table.

LG MPG — NAP-*Picea-Pinus* R PAZ

Type locality and section. Szwajcaria [97], profile 1, zones $a+b$, c, d — acc. to Borówko-Dłużakowa (Borówko-Dłużakowa & Halicki 1957). The section is presented in Fig. 15.

Description. In the type profile the herbaceous pollen values range from 43.7 to 25.8%, in other profiles they are even somewhat higher. *Cyperaceae* and *Gramineae* are dominant and *Artemisia* is an important taxon. *Pinus* is the most abundant pollen type but prominent amounts of *Picea* pollen are characteristic of the zone. *Betula* is relatively significant; pollen of other trees is sporadic except for the bottom sample from the type profile (redeposition). This zone is known in the literature as the "lower spruce" zone.

Contacts. This is the lowest pollen zone, overlying boulder clay of the Middle Polish Glaciation s. l. or sands and silts deposited on that clay (Borówko-Dłużakowa & Halicki 1957; Bitner 1956a, 1957). The upper boundary is placed at the fall of *Picea* pollen (in the type profile below 10%) and NAP values and the rise of *Betula* to more than 20%.

Subdivisions. NAP and *Picea* subzones have been distinguished.

NAP subzone. The herb pollen values exceed 40%. The diversity of herbaceous taxa is small, *Cyperaceae* and *Gramineae* prevailing. The values of *Artemisia* pollen in the type profile do not exceed 2% but in the profile 12a from Ludomirowo [67] they reach 13.4%. The upper boundary of this subzone is placed at the fall of NAP values and the rise in *Picea*.

Picea subzone. The maximum values of *Picea* in the type profile exceed 30%. The values of herb pollen fall; *Pinus* is still the most abundantly represented taxon.

Other occurrences. The zone with its two subzones is also present in profile 2 at Szwajcaria [97] — zones $a+b$, (c) acc. to Borówko-Dłużakowa (Borówko-Dłużakowa & Halicki 1957) — and at Ludomirowo 12a [67] — zones I and II acc. to Bitner (1957). At Otapy I [57] the bottom sample of phase II of Bitner (1956a), containing 4.3% *Picea* pollen, is presumably related to the decline of the *Picea* subzone.

Extent. The total geographical range of this zone is very extensive. The Polish sites form its south-western boundary. The nearest sites with this zone — Poniemuń (Dyakowska 1936), Nieciosy (Bremówna & Sobolewska 1950), Żukiewicze (Środoń 1950), Janiańce (Bremówna & Sobolewska 1950; Kondratiene 1965 after Vajtiekunas 1968; Chebotareva 1972-II) and Pyshki (Shalaboda & Yakubovskaya 1978) — are situated in the USSR close to the eastern boundary of Poland. Further to the east and north-east the zone of "lower spruce" has been distinguished in a great many profiles of the Russian Plain (Grichuk 1961; Gorlova 1968a, b, 1975; Kolesnikova & Khomutova 1970, Makhnach 1971; Liivrand 1974a).

Remarks. 1. Other Polish sites with *Picea* pollen in their late-glacial sections have not been referred to the NAP-*Picea-Pinus* zone, because *Picea* pollen is most probably redeposited in them, which is suggested by pollen of thermophilous trees and pre-Quaternary taxa present in their spectra. The bottom sample in the profile from Dzbanki Kościuszkowskie 1929 [12], in which *Picea* pollen reaches 7.4% of the AP sum, is omitted, for the lack of NAP makes the evaluation of its stratigraphic position difficult.

2. The occurrence of *Picea* obovata Ledeb. macrofossils is connected with the NAP-*Picea-Pinus* zone. At Szwajcaria [97] they come from profile 2 and are very abundant (Borówko-Dłużakowa & Halicki 1957; Borówko-Dłużakowa 1975b). Besides *Picea obovata* Borówko-Dłużakowa (1975b) mentioned also *Picea* cf. *excelsa* (Lam.) Lk. Some macrofossils of *Picea obovata* have also been found by Bitner (1957) at Ludomirowo [67]. As regards the sites situated beyond the eastern boundary of Poland,

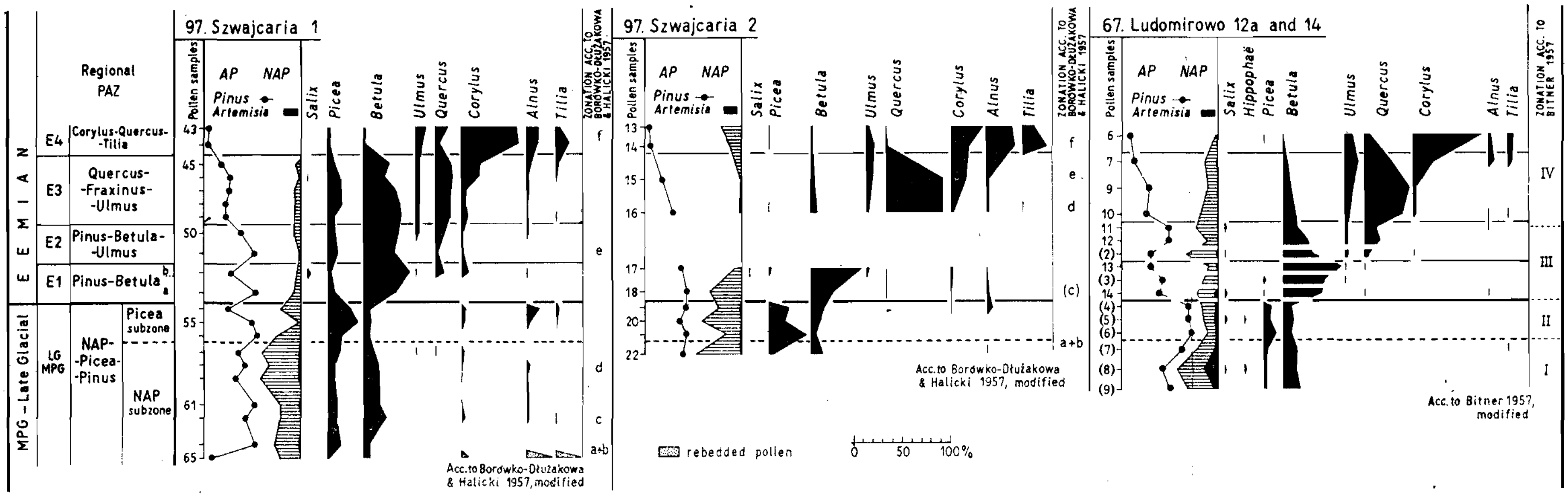


Fig. 15. The late-glacial NAP-*Picea-Pinus* R PAZ and the lower boundary of the Eemian in the diagrams with the so-called "lower spruce" from north-eastern Poland. Only the lower parts of diagrams are presented. They are recalculated (total sum = AP+NAP), simplified and modified in relation to the versions given by the authors. To facilitate a comparison of the zones depth scale is not preserved. The diagram from Ludomirowo is a compilation of the data from profiles 12a (sample numbers in brackets) and 14 (sample numbers not bracketed). Site numbers as in Figs. 11 and 12

macrofossils of *Picea obovata* have been found on the Niemen River at Żukiewicze (Środoń 1950; Litvinyuk 1979) and Nieciosy (Bremówna & Sobolewska 1950), on the Bug River at Koszary (Środoń 1957) and *Picea* sp. at Pyshki (Shalaboda & Yakubovskaya 1978). Macrofossils of *Picea obovata* are also known from sites lying further to the east, in the Moscow region (Sukachev 1954; Gorlova et al. 1962, after Środoń 1967b) and at Cheremoshnik about 200 km NE of Moscow (Gorlova 1968a). In this last locality the *Picea* pollen values reach about 80% in the "lower spruce" zone (Gorlova 1975). On the other hand, macrofossils of *Picea abies* or *Picea* sp. have been reported from the "lower spruce" zone at Tarasovo, about 400 km NE of Moscow (Kolesnikova & Khomutova 1970).

THE LATE-GLACIAL SEQUENCE OF LOCAL POLLEN ASSEMBLAGE ZONES AT WARSZAWA-WAWRZYSZEW

In the profile from Warszawa-Wawrzyszew XV [49] (Fig. 16) Dr. K. M. Krupiński found a tripartite late-glacial sequence of pollen assemblage zones for the first time in Poland. This locality has not been published yet. I have received permission from the author to publish a preliminary report on the late-glacial series and its simplified pollen diagram.

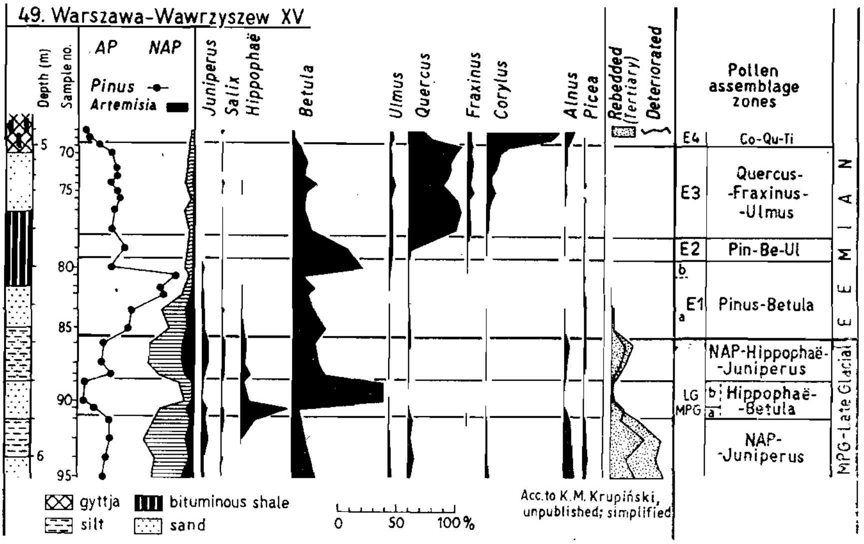


Fig. 16. Pollen assemblage zones in the Late Glacial of the Middle Polish Glaciation s. l. and the lower boundary of the Eemian in profile Warszawa-Wawrzyszew XV. Only the lower part of the diagram is presented. Published by courtesy of Dr. K. M. Krupiński. Site number as in Figs. 11 and 12

The profile has been obtained from a lake about 800 m in diameter, the bottom of which cuts into the clay of the maximum stadial of the Middle Polish Glaciation (Morawski 1976, 1978).

LG MPG — NAP-*Juniperus* L PAZ

Description. High values of herb pollen, with maximum 43.2%; *Juniperus* values reaching 4.7%. The zone is heavily disturbed by redeposited (Tertiary taxa and those common to the Tertiary and Quaternary) and deteriorated pollen.

Contacts. It is the lowest pollen zone occurring in sands and silts overlying boulder clay of the maximum range of the Middle Polish Glaciation. The upper boundary is placed at the decline of herb pollen values and the rise of *Hippophaë*.

LG MPG — *Hippophaë-Betula* L PAZ

Description. *Hippophaë* culminates in the lower part of the zone (40.4%,) whereas *Betula*, mainly *B.* sect. *Albae*, reaches high values in the upper part (max. 78.4%). At the same time the NAP falls to about 10% and there is hardly any redeposited and deteriorated pollen.

Contacts. The upper boundary of the previous zone makes the lower boundary of the *Hippophaë-Betula* zone. The upper boundary is placed where the *Betula* pollen values fall and the NAP frequencies rise again.

Subdivisions. The zone is divided into two subzones, the lower *Hippophaë* subzone a and the upper *Betula* subzone b.

LG MPG — NAP-*Hippophaë-Juniperus* L PAZ

Description. This zone is characterized by the recurrence of high herb values. *Juniperus* reaches 5.0% and *Hippophaë* does not exceed 6.7%. The proportion of redeposited and deteriorated pollen increases again, but it is lower than in the NAP-*Juniperus* zone.

Contacts. The upper boundary of the *Hippophaë-Betula* zone is the lower boundary of the NAP-*Hippophaë-Juniperus* zone. Its upper boundary is placed at the fall of NAP, *Juniperus* and *Hippophaë* and at the rise of *Pinus* and *Betula* frequencies (cf. Fig. 16).

Other occurrences. It may be supposed that sample 34 from Gołków [44], from a depth of 8.0 m, in the contact layer of bituminous shales and underlying sand, represents the NAP-*Hippophaë-Juniperus* zone. High frequencies of *Hippophaë* (3.8%) together with high values of NAP (41.0%, in which *Artemisia* 14.7%) permit this correlation. Gadomska (1966) and Janczyk-Kopikowa (1966a) refer the deposits represented by sample 34 to the Eemian. The bottom sample from profile 2/69 from Żyrardów [35], in which the *Hippophaë* value comes to 1.8% and NAP to 30% (zone bc? acc. to Krupiński 1978), should perhaps be assigned also to the decline of the NAP-*Hippophaë-Juniperus* zone.

Extent. The tripartite sequence of pollen assemblages is known only at Warszawa-Wawrzyszew. The data from Żyrardów and Gołków suggest that this phenomenon may be of wider significance than the local one.

Remarks. 1. As regards the area of Warsaw, the bottom sections of the profiles from Warszawa-Żoliborz 4 [50] and Warszawa-Wola, Młynarska/Wolska Str. [48] have also been ascribed to the Late Glacial. Although NAP is given only summarily for the Żoliborz profile (Raniecka-Bobrowska 1954), as can be seen from additional information provided by that author, in six bottom samples *Artemisia* occurs, reaching 4.2%, *Betula* pollen consists partly of *B. nana*, and *Selaginella selaginoides* is present in the spectra. This seems to justify the association of these samples with the decline of the Late Glacial, though, according to Raniecka-Bobrowska (1954), this part of the profile corresponds to the initial interglacial phase A.

Five bottom samples of the profile from Warszawa-Wola, Młynarska/Wolska Str. represent a section disturbed most probably by redeposition. Spectra with NAP values reaching 58.5% are mixed with those showing high values of *Picea* (to 12%), *Corylus* (to 26%), *Carpinus* (to 36%), *Alnus* (to 11%) and other trees. Borówko-Dłużakowa (1960) described this section as *?a+b, c*. The high NAP values permit the inclusion of these samples in the Late Glacial, but their attribution to the zone of "lower spruce" on account of the high values of *Picea* (Środoń 1967b) is unacceptable because of the distinct distortion caused by the redeposition. Unless an additional study has been carried out, it cannot be said whether the bottom sections of the two profiles in question are related to the NAP-*Hippophaë-Juniperus* zone, which is implied by the close neighbourhood of the site at Warszawa-Wawrzyszew [49].

2. The assigning of two bottom samples from the Elbląg-Bażantarnia [92] profile to the Late Glacial is disputable because the high NAP values (37.5 and 32.5%) are given only as sums of NAP. The location of this site in the coastal area allows us to presume that these samples may represent the NAP-*Hippophaë-Juniperus* zone.

CORRELATIONS OF LATE-GLACIAL ZONES

It is difficult to correlate the three types of late-glacial pollen assemblage zones that have been distinguished. The results of palaeobotanic studies concerning the part of the profile below that recognized as Late Glacial at Imbramowice [1] (Mamakowa unpubl.) permit the assumption that zones IP-1—IP-3 represent a full series of late-glacial deposits. They show no stadial-interstadial-type oscillations but reflect the increasing density of the vegetation, which reached its late-glacial optimum in the *Juniperus* subzone (IP-3, cf. Fig. 3). The very low pollen frequency and very low organic-matter content in the deposits of zones IP-1 and IP-2 indicate more open vegetation in these zones than in the *Juniperus* subzone despite lower NAP values. The large numbers of macrofossils of *Betula nana* in the zone IM-2 corresponding to IP-2 (cf. Fig. 4) indicate the domination of shrubby tundra at that time.

This being so, local zones IP-1 and IP-2 from Imbramowice [1] may correspond to the NAP-*Juniperus* zone at Warszawa-Wawrzyszew [49] and the NAP subzone of the NAP-*Picea-Pinus* zone at Szwajcaria [97], while the *Juniperus* subzone of the *Cyperaceae-Artemisia-Betula nana* zone to the *Hippophaë-Betula* and NAP-*Hippophaë-Juniperus* zones and to the *Picea* subzone of the NAP-*Picea-Pinus* zone (cf. Fig. 12).

In western Europe the Late Glacial of the Saalian (Riss), represented by poorly differentiated sections of diagrams with high NAP values and fairly high *Juniperus* values, has been distinguished at such sites in the north Alpine Foreland as Eurach (Beug 1973, 1979), Samerberg (Grüger 1979) and in some of Welten's (1981, 1982) profiles, as well as at Wardhausen in the German-Netherlands borderland (Meene & Zagwijn 1978). Declining sections of the Late Glacial have also been singled out at Kittlitz in Lower Lusatia (Erd 1973) and Bispingen in Lower Saxony (Müller 1974) and at Ganovce in northern Slovakia (Kneblova 1960).

More differentiated late-glacial series are shown by sub-Alpine profiles from Zeifen (Beug in Jung et al. 1972) and Mondsee (Klaus 1980) and in France from Grande Pile in the southern Vosges (Woillard 1978, 1979) and Les Echets near Lyon (Beaulieu & Reille 1984). In northern Europe they occur at Brokenlande in Schleswig-Holstein (Menke & Ross 1967) and Suur Prangli Island in the Gulf of Finland (Liivrand 1974a; Raukas 1978).

In those profiles, cold oscillations, similar in nature all over the area, and those of the interstadial type, varying in their pollen assemblages, can be found. This is, for the most part, a phase of open vegetation with thickets of *Hippophaë*, *Salix* and, especially, *Juniperus* (zone C at Brokenlande, 1b at Zeifen, 1B at Mondsee and A2b at Les Echets). A relatively high proportion of pine and birch (Suur Prangli — zone Ms2 — and Les Echets) or pine (Mondsee) occurred in diagrams from some sites.

A tripartite division of the Late Glacial into oscillations of the stadial-interstadial-stadial type, similar to the oscillations Older Dryas-Allerød-Younger Dryas in the Vistulian Late Glacial can be distinguished, in particular, at Mondsee, Les Echets, Grande Pile and Suur Prangli, thanks to which the sequence from Warszawa-Wawrzyszew [49] may be correlated with them, though none of them has high *Hippophaë* values.

However, the type of the late-glacial succession from Imbramowice [1] most resembles that at Zeifen and Brokenlande, with a characteristic peak of *Juniperus* in the zone bordering upon the interglacial.

The late-glacial sections from the sites of eastern Europe are chiefly represented by the zone of "lower spruce". This zone (= NAP-*Picea-Pinus*) was referred to the Late Glacial in Polish stratigraphic interpretations (Borówko-Dłużakowa & Halicki 1957; Bitner 1956a, 1957; Środoń 1967a, b, 1972, 1977), but it was approached in various ways in USSR literature. At first, Grichuk (1961) assigned the zone of lower spruce (= M1 in his scheme) to the Mikulino (Eemian) Interglacial and correlated it with zone *c* of Jessen's scheme (Jessen & Milthers 1928). Makhnach (1971, Makhnach et al. 1975) and Gorlova (1968b, 1975) also considered this zone to be the earliest developmental stage of the interglacial vegetation. On the other hand, Voznyachuk (1961, 1973, after Litvinyuk 1979) referred the "lower spruce" zone at Zhukevichi near Grodno to the Late Dnieper Glaciation (= Late Riss Glaciation).

Later, Grichuk (1972), too, withdrew his zone M1 from the Mikulino Interglacial and next correlated it with zone *a* of Jessen's scheme and zone 1 from Zeifen (Grichuk 1982).

The presence of a cold oscillation below the zone with remains of *Picea obovata* (= lower spruce zone) in the profile from Zhukevichi was demonstrated by Litvinyuk (1979) on the basis of macrofossils of *Selaginella selaginoides*, *Betula humilis*, *Dryas octopetala* and *Salix herbacea* found in it. This oscillation is also visible in the pollen diagrams from such localities in the north-western part of the USSR as Ulanovo (Makhnach 1971) or Toporikha (Chebotareva 1972-I). It correlates well with the NAP subzone of the NAP-*Picea-Pinus* zone.

THE LOWER BOUNDARY OF THE EEMIAN INTERGLACIAL

No breaks in sedimentation have been found between the late-glacial pollen sequence and the overlying Eemian sequence in the profiles from Imbramowice [1], Szwajcaria [97] and Warszawa-Wawrzyszew [49]. It may therefore be assumed that the upper boundary of the *Cyperaceae-Artemisia-Betula nana*, NAP-*Picea-Pinus* and NAP-*Hippophaë-Juniperus* pollen assemblage zones is, at the same time, the lower boundary of the Eemian Interglacial.

In the diagrams from Imbramowice and Warszawa-Wawrzyszew this boundary is placed at the fall of pollen values of herbs and shrubs and the rise of *Pinus* pollen values with simultaneous relatively high values of *Betula* pollen. These criteria resemble the criteria adopted for the boundary between the Late Glacial of the Vistulian and the Holocene, which is consistent with Zagwijn's (1961) postulates and also agrees with the principles of Jessen (Jessen & Milthers 1928), who found *Betula pubescens* and *Pinus sylvestris* spreading and *Betula nana* declining in zone *c*.

In the diagram from Szwajcaria this boundary is marked, in addition to the fall of NAP values, by the decline of the *Picea* pollen values and, temporarily, of *Pinus*, and the rise of *Betula* pollen. The *Pinus* values (despite their decrease) are still high. The boundary, established is this way, agrees with Grichuk's (1982) recent division of diagrams with the late-glacial "lower spruce".

In relation to the criteria for the establishment of the Late Glacial/Eemian boundary applied at Imbramowice and Warszawa-Wawrzyszew, the division applied by Jastrzębska-Mamełka (1985) at Zgierz-Rudunki II [25] and Noryśkiewicz (1978) at Nakło [78] is controversial. In diagrams from both of these latter sites sections with high *Pinus*, significant *Betula* and declining herb pollen values, defined as the domination of parkland landscape with clumps of trees (cf. Noryśkiewicz 1978; Jastrzębska-Mamełka 1985), were referred to the Late Glacial. In the present stratigraphic scheme these sections are related to interglacial E1 — *Pinus-Betula* zone. At Zgierz-Rudunki II this concerns the whole of local zone ZRII-2 and the upper sample from ZRII-1.

Similar divergencies with regard to the boundary between the Riss Late Glacial and the Eemian occur in the stratigraphic division at sites from the northern Foreland of the Alps. Beug (1973, 1979) and Grüger (1979, 1983) refer the zone defined as Kiefern-Zeit or Kiefern-Birken-Zeit to the Eemian Interglacial, whereas Klaus (1980) and Welten (1982) associate the zone of high *Betula* and *Pinus* values with the Riss Late Glacial.

REGIONAL POLLEN ASSEMBLAGE ZONES IN THE EEMIAN INTERGLACIAL

E1 — *Pinus-Betula* R PAZ

Type locality and section. Imbramowice [1], local zones IP-4 and IP-5 (Fig. 3).

Description. *Pinus* and *Betula* are the most abundantly represented taxa and, at the same time, are the characteristic taxa of the zone. At the type locality *Betula* undiff. pollen dominates only in the upper part of the zone (in IP-5); a similar situation occurs also in diagrams from most of the sites in which this zone has been distinguished (cf. Fig. 17). In the lower part of the zone the maximum *Pinus* values are 40—70% and *Betula* 20—40%, whereas in the upper part *Betula* reaches 40—60% and, exceptionally, at Warszawa-Wola, Młynarska/Wolska Str. [48] — 91.5%. At Dąbrówka [3] and Bobrówka Valley [30] *Pinus* prevails throughout the zone. In the diagrams with the late-glacial NAP-*Picea-Pinus* zone *Picea* values decrease in the course of the zone. *Juniperus* and *Salix* are still important taxa and *Populus*, *Hippophaë*, *Ephedra* and *Betula nana* are noted (Figs. 13 and 14). The NAP values are still relatively high: at the type locality their maximum reaches 30.1%, in the remaining sites it is 10—30% except at the profile from Warszawa-Wola, Młynarska/Wolska Str. — 37.5% and Szwajcaria 2 [97] — 33.9%, but NAP is represented in them exclusively by *Cyperaceae* + *Gramineae*. *Ulmus* and *Quercus* pollen appears more regularly at many sites (cf. Figs. 17 and 18). At some sites redeposition or contamination by deposits derived from the upper parts is not excluded.

Contacts. The lower boundary of this zone is at the same time the lower boundary of the Eemian and the upper boundary of the Late Glacial of the Middle Polish Glaciation s. l. and was described in the previous chapter. The upper boundary at the type locality is placed at the fall of *Betula* values and the rise in *Pinus* and a small increase in the *Ulmus* values. In the diagram from Otapy I [57] the upper boundary is marked only by the rise of *Ulmus* values, because the maximum values of *Betula* occur in zone E2 (cf. Fig. 17).

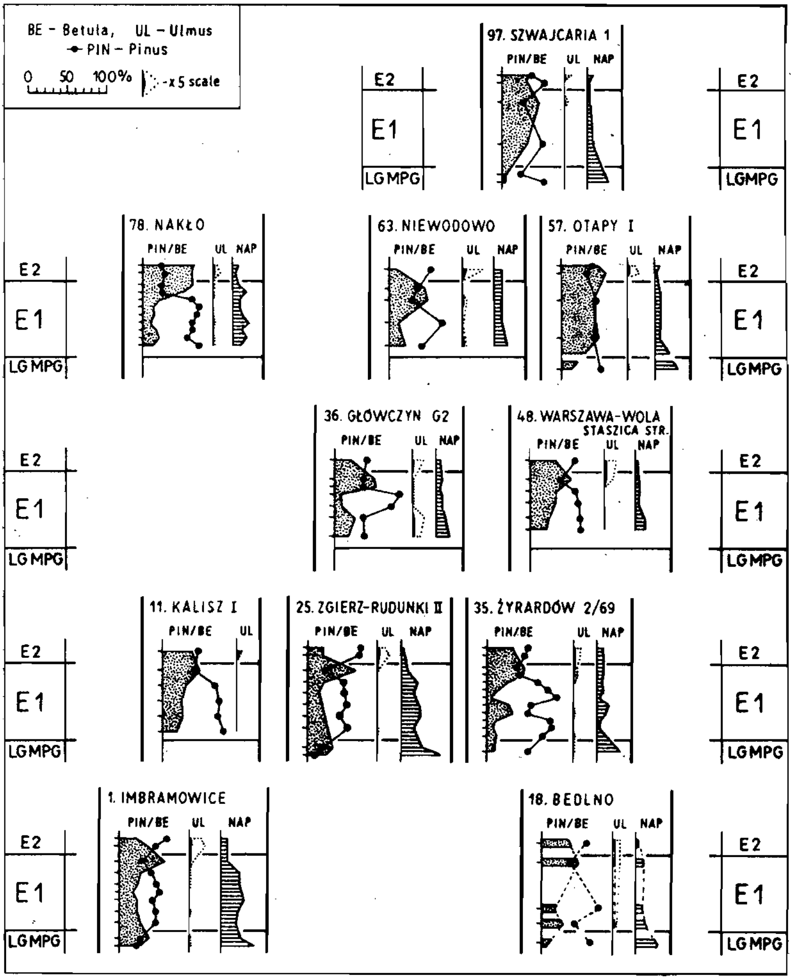


Fig. 17. Simplified curves for *Pinus*, *Betula*, *Ulmus* and NAP in the E1 — *Pinus-Betula* R PAZ in selected pollen diagrams. The characteristics of the zone and the bases for marking its boundaries are shown. The arrangement of sites agrees with their approximate geographical position. Site numbers as in Figs. 11 and 12

Subdivisions. Two subzones have been distinguished: a lower (unnamed) and an upper — *Betula* subzone.

Betula subzone. *Betula* pollen is most abundantly represented. This subzone is usually contained in a thin layer of deposit and it may be easily omitted in studies based on random samples. At the type locality it is represented by one sample (IP-5). According to Müller (1974), the section with the culmination of *Betula* lasted about 100 years. The characteristic features of the subzone are exemplified by some sites (Fig. 17).

Other occurrences. Besides the type locality, the *Pinus-Betula* zone or its part has been distinguished in diagrams from 30 sites (see Fig. 12). The well-developed zone, with both boundaries and the *Betula* subzone occurs at Żyrardów

2/69 [35], Warszawa-Wola, Młyn./Wolska Str. [48], Warszawa-Wawrzyszew XV [49], Warszawa-Żoliborz [50], Zgierz-Rudunki II [25] and Szwajcaria, profiles 1 and 2 [97]; with both boundaries but without the *Betula* subzone at Dąbrówka [3]; without the lower boundary but with the *Betula* subzone at Kalisz I [11], Nakło [78], Bobrówka Valley [30], Główczyn [36], Warszawa-Wola, Staszica Str. [48], Góra Kalwaria [42] and Niewodowo [63]; without the lower boundary and *Betula* subzone at Otapy I [57]. At the remaining 16 sites the zone is represented by single or few samples (cf. Fig. 12).

Extent. It may be assumed on the basis of the present data that the *Pinus-Betula* zone with a well-developed *Betula* subzone occurred nearly all over the area covered by studies. In north-eastern Poland a high proportion of birch was also observed in the older part of the zone. The extremely low values of *Betula* pollen (to 4%) throughout this zone at Dąbrówka [3] may indicate a local over-representation of *Pinus* or a different nature of the zone in southern Poland, but additional studies are needed to settle this question.

Remarks. 1. Macrofossils of *Pinus* and tree-birches occur in the *Pinus-Betula* zone at several sites: Imbramowice [1] — *Pinus sylvestris, Betula* sect. *Albae, B.* cf. *pubescens, B.* cf. *pendula*; Kalisz I [11] — *Pinus* sp., *B. pubescens, B. verrucosa, Betula* sp.; Dzbanki Kościuszkowskie [12] — *B. alba*; Zgierz-Rudunki II [25] — *P. sylvestris, B. tortuosa, B. pubescens, B. alba* type, *B. verrucosa*; Ludomirowo [67] — *B. alba*; Nakło [78] — *B.* sect. *Albae, B. tortuosa.*

2. Sections representing *Pinus-Betula* R PAZ are referred by the authors to Jessen's zones *bc, c, d* or even *e*.

3. The correlation of the zone distinguished that way has been discussed in the previous chapter.

E2 — *Pinus-Betula-Ulmus* R PAZ

Type locality and section. Imbramowice [1], local zone IP-6 (Fig. 3).

Description. *Pinus* and *Betula* pollen are most abundant. *Pinus* values occur with a maximum of 65.1% at the type locality and from 29 to about 85% at the other sites. The maximum of *Betula* at the type locality reaches 36.9%, being similar in most of the other sites except Otapy I [57], where this zone contains a culmination of *Betula* pollen, and Nakło [78], Józefów [32] and Warszawa-Wawrzyszew XV [49], in which the values of the preceding zone persist. *Ulmus* is the characteristic taxon of the zone. It reaches its absolute (interglacial) culmination in this zone at the type locality (4%) and apart from it also at Dąbrówka [3] — 7.5%, Zgierz-Rudunki II [25] — 2.9%, Warszawa-Wola [48] — 3.5%, Góra Kalwaria [42] — 3.9% and a nearly absolute culmination at Niewodowo [63] — 5.3%. At other sites the values of *Ulmus* are already high in this zone and its presence is continuous; nevertheless, the absolute culmination of *Ulmus* takes place later, at several sites even as late as E5 (cf. Fig. 18). *Quercus* has low pollen values at most of the sites (cf. Fig. 18) and in over a dozen of them *Fraxinus* and *Corylus* pollen already occurs. The proportions of NAP and heliophilous shrubs are very low.

Contacts. The lower boundary of the *Pinus-Betula-Ulmus* zone is formed by the upper boundary of the *Pinus-Betula* zone (see p. 106). At the type locality the upper boundary is placed where *Quercus* rises distinctly and *Pinus sylvestris* type falls. Somewhat above the boundary the values of *Betula* undiff. pollen decrease. At the remaining sites this boundary is placed similarly except for Szwajcaria 1 [97] and Pałczew [22], where *Betula* is on the increase, and Dzbanki Kościuszkowskie [12], Józefów [32], Otapy [57] and Konopki Leśne [59], where *Pinus* rises.

Other occurrences. In addition to the type locality, the *Pinus-Betula-Ulmus* zone or its part has been distinguished in 35 sites (see Fig. 12). It occurs well-

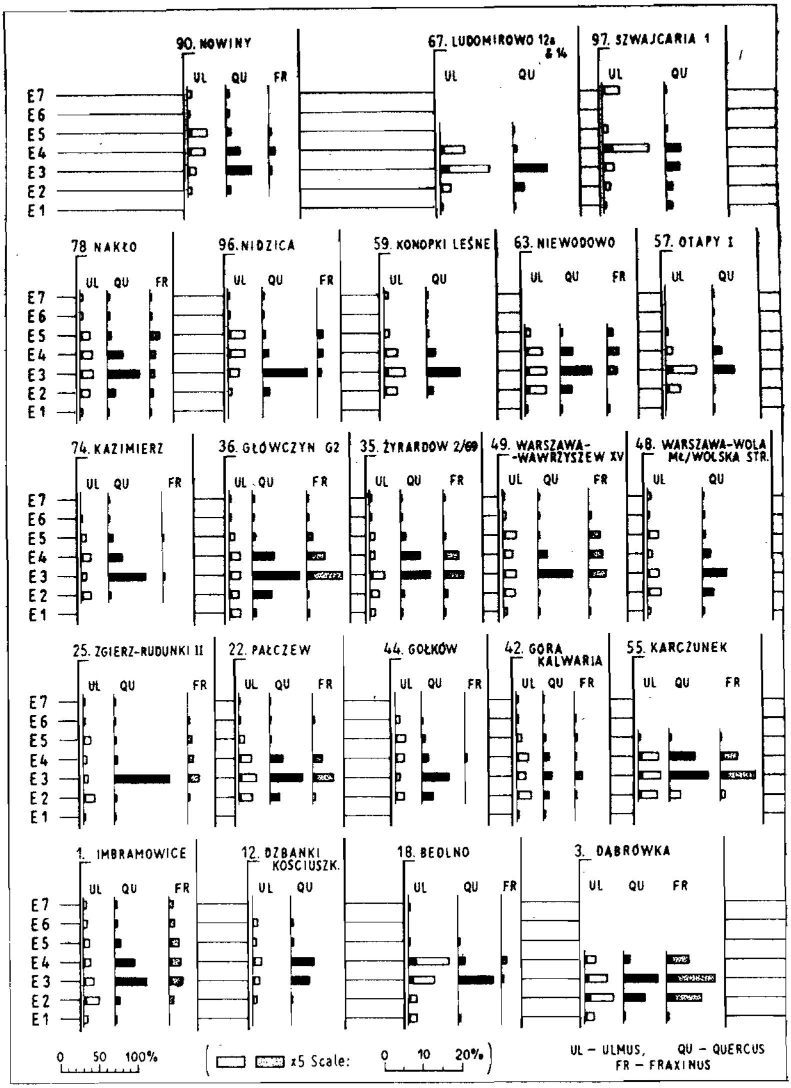


Fig. 18. Maximum pollen values of *Ulmus*, *Quercus* and *Fraxinus* through the regional pollen ass. zones of the Eemian in selected pollen diagrams. The arrangement of sites agrees with their approximate geographical position. Site numbers as in Figs. 11 and 12

-developed, with both boundaries at Dąbrówka [3], Kalisz I [11], Zgierz-Rudunki II [25], Bobrówka Valley [30], Żyrardów 2/69 [35], Główczyn G-28a [36], Warszawa-Wola [48], Warszawa-Wawrzyszew [49], Warszawa-Żoliborz [50], Niewodowo [63], Nakło [78], Szwajcaria 1 [97]; without the lower boundary at Nowiny [90]; with the lower boundary uncertain at Józefów [32]; with the upper boundary not quite certain at Główczyn G-2 [36], Góra Kalwaria [42] and Otapy I [57] and only with the declining part of the zone present at Szczerców [13], Bedlno [18], Sławno III [19], Pałczew [22] and Konopki Leśne [59]. Fourteen sites have only single samples from this zone (cf. Fig. 12).

Extent. The geographical extent of the *Pinus-Betula-Ulmus* zone agrees with

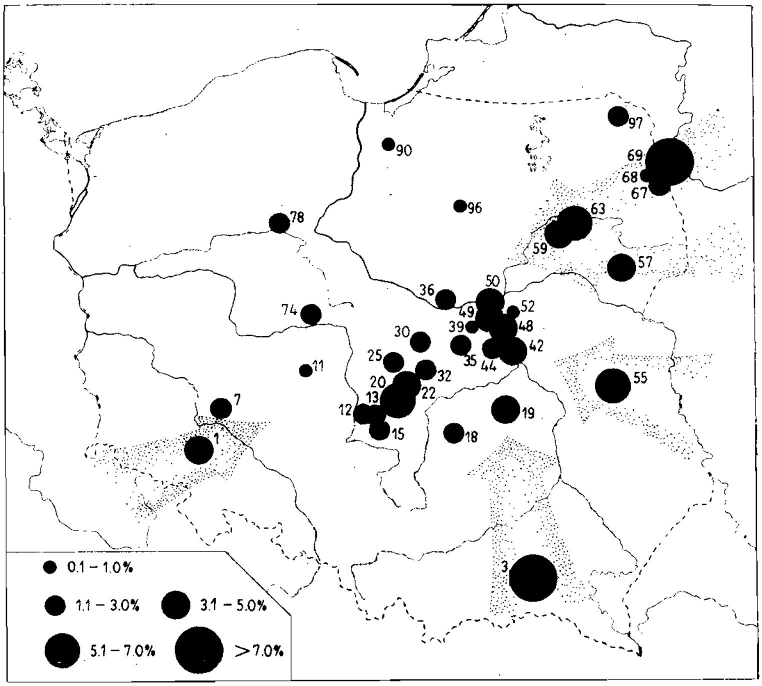


Fig. 19. Maximum pollen values of *Ulmus* in the E2 — *Pinus-Betula-Ulmus* R PAZ. The arrows indicate the presumable directions of migration. Site numbers as in the list (p. 93)

the range of the Eemian sites in Poland. High values of elm at Dąbrówka [3], Miklewszczyzna [69] and at Imbramowice may indicate three directions of elm migration: from the south, from the north-east and from the south-west (cf. Fig. 19).

Remarks. 1. In the original divisions carried out by the authors, sections representing the *Pinus-Betula-Ulmus* zone are referred to Jessen's (Jessen & Milthers 1928) zone *e* or *d* and sometimes even to *c*.

2. The *Pinus-Betula-Ulmus* zone may be easily overlooked in the profiles with widely spaced samples, because its formation took a short time. Müller (1974), having counted annual laminations in the profile at Bispingen, found that zone IIa (which may be correlated with the *Pinus-Betula-Ulmus* zone) had been deposited for 200 years and its thickness was only 20 cm.

3. The *Pinus-Betula-Ulmus* zone corresponds, in the west-German divisions, with zone IIa, according to Selle (1962), zone II, according to Behre (1962) and, in the sub-Alpine profiles, with the Kiefern-Birken-Ulmen Abschnitt (Jung et al. 1972; Beug 1973; Grüger 1979) and with zones 3 and 4 at Mondsee (Klaus 1980); in eastern Germany it corresponds with zone 2 at Kittlitz (Erd 1973), in Denmark with zone E2 — *Pinus-Betula-Ulmus* (Andersen 1964, 1966, 1975), in the Netherlands with E2a (Zagwijn 1961), in France at Les Echets with B2 (Beaulieu & Reille 1984) and in the east-European diagrams with zone M3 (Grichuk 1961).

E3 — *Quercus-Fraxinus-Ulmus* R PAZ

Type locality and section. Imbramowice [1], local zone IP-7 (Fig. 3).

Description. *Betula* and, especially, *Pinus* pollen values are still relatively high. The absolute peak of *Quercus* (cf. Fig. 18), the absolute or nearly absolute peak of *Fraxinus* and the continuous occurrence of *Ulmus* are characteristic features of this zone. The maximum values of *Quercus* lie within a wide range of 20—72%

(at type locality — 42%). Only at Bedlno [18], Dzbanki Kościuszkowskie [12] and Szwajcaria 1 [97], *Quercus* has somewhat lower values in this zone than in the next. The maximum of *Fraxinus* is 3.2% at the type locality and from about 1% to 12.4% (cf. Fig. 18) at the remaining sites in which its pollen has been determined. The *Ulmus* values are the highest in the diagrams from north-eastern Poland (Ludomirowo [67] — 13%) and the lowest from the west of the country (Imbramowice [1] — 2.3% and Rusinów [70] — 0.5%).

Of the other taxa, *Corylus* is already present in all the sites, its values rising rapidly in the younger part of the zone. Very high values (also in the older part) were noted at Kalisz [11] — 28%, Piaski Stare [28] — 20%, Rogów [31] — 41% and Karczunek [55] — 25%. Spruce pollen occurs in diagrams from most sites, but its maximum values are low except at Nowiny [90] — 10.5%, Kalisz [11] — 8.6% and Szwajcaria [97] — 14.4%. Maximum values of *Alnus* at the type locality are below 1% but in the diagrams from most sites they reach up to 7%. The alder behaves in a different way in the valley of the Lower Vistula, where it reaches higher values — up to 11% at Grudziądz-Mniszek [82] and 24% at Nakło [78]. Exceptionally high values of *Alnus* are noted also at Łódź-Polesie [24] — 41% and Bełchatów [17] — 15%. *Tilia* pollen values at most of the sites attain 2%. Higher values, 5—6%, are at Żyrardów [35], Karczunek [55], Ludomirowo [67], Nowiny [90] and Bedlno [18] and strikingly high ones at Bełchatów [17] — 14% and Pałczew [22] — 13%.

Contacts. The lower boundary of the *Quercus-Fraxinus-Ulmus* zone is the upper boundary of the *Pinus-Betula-Ulmus* zone (see p. 108). At the type locality the upper boundary is placed at the fall of *Quercus* values to about 25%, that of *Pinus* below 20% and the rise in *Corylus* to over 40%. The rise of *Corylus* values is the basic feature for establishing this boundary at all sites. It is correlated with the fall of *Pinus* with a few exceptions, namely, Góra Kalwaria [42] and Łódź-Polesie [24], and *Quercus* (exceptions: Jaworzyna Śląska [2], Kalisz [11], Dzbanki Kościuszkowskie [12], Ozorków [26], and Grudziądz-Mniszek [82]).

Subdivisions. Two subzones have been distinguished in the *Quercus-Fraxinus-Ulmus* zone, a lower — *Pinus* subzone — and an upper — *Corylus* subzone (cf. Fig. 3).

Pinus subzone. Although declining, the *Pinus* values are high (to 65%), often exceeding the *Quercus* values. *Corylus* pollen is sporadic or with low values (to 10%).

Corylus subzone. The *Corylus* values rise distinctly and simultaneously with the decline in values of *Pinus*. The percentages of *Corylus* usually lie within a range of 20—30% in the youngest part, the extreme values being 9 and 51%.

Other occurrences. Besides the type locality, the *Quercus-Fraxinus-Ulmus* zone or its part has been distinguished at 51 sites (see Fig. 12). It occurs with well-developed subzones and both boundaries at Bedlno [18], Pałczew [22], Zgierz-Rudunki II [25], Bobrówka Valley [30], Niewodowo [63], Nakło [78] and Nowiny [90]; with somewhat less distinct subzones but distinct boundaries at Dąbrówka [3], Żyrardów 2/69 [35], Warszawa-Wawrzyszew XV [49] and Szwajcaria 1 [97]; with a distinct division into subzones but without the lower boundary at Dzbanki Kościuszkowskie [12], Besiekierz [27], Rogów [31], Żyrardów 4/69 [35] and Otapy I [57] and with the lower boundary uncertain at Główczyn G-2 [36]. Out of the sites elaborated on the basis of random samples, Ossów [52], Ludomirowo 14 [67], Kazimierz [74], Nidzica [96], confirm the presence of two subzones. At 12 sites single samples have been referred on the basis of diagnostic characters to one of the subzones (Fig. 12). High values of *Pinus* occur throughout the zone at Jaworzyna Śląska [2], Kalisz I [11], Szczerców [13], Konopki Leśne [59] and Miklewszczyzna [69].

Extent. The geographical extent of the zone and both subzones agrees in principle with the range of the Eemian sites. Although *Fraxinus* pollen is missing in the pollen diagrams from more than ten sites studied in 1930—1960, their inclusion in the geographical extent of the *Quercus-Fraxinus-Ulmus* zone is permitted by the presence of *Fraxinus* pollen in diagrams from nearby sites examined in later years (cf. Fig. 18). The distribution of the sites with well-developed subzones shows that the division into the subzones is associated with the general trend of the *Pinus* recession and migration of *Corylus*. Deviations with high *Pinus* values are probably due to local over-representation, and the high values of *Corylus* at Imbramowice and several sites in the southern part of middle Poland indicate small local centres, presumably connected with an earlier migration of hazel from the south-west and south-east. A certain tendency towards a geographical differentiation of the zone is associated with the delayed culmination of elm and its highest values in north--eastern Poland (e.g. Szwajcaria [97]).

Remarks. 1. Macrofossils of the trees characteristic of the *Quercus-Fraxinus-Ulmus* zone occur in it only at three sites: wood of *Quercus* sp. at Imbramowice [1], Kalisz [11] and Główczyn [36], wood of *Fraxinus* sp. at Kalisz (profile I).

2. For previous divisions applied to the sections recognized as *Quercus-Fraxinus-Ulmus* R PAZ see p. 97.

3. It may well be that the high pollen values of *Picea* at Szwajcaria 1 [97] are connected not only with the expanding *Picea abies*, but also with the persistence of *Picea obovata*.

4. The marine sediments, studied palynologically, in the Lower Vistula Valley come from Elbląg [91], Elbląg-Bażantarnia [92], Nowiny [90], Dzierzgoń [89], Tychnowy [88], Kwidzyn-Nicponie [87] and Grabówka [86]. In the fullest of these profiles, at Nowiny, the pollen spectra from the oldest contact zone of marine-terrestrial deposits bear diagnostic characteristics of the older part of zone E3 — *Quercus-Fraxinus-Ulmus*. According to Makowska (1979b, 1986), it is the beginning of the transgression of the Eemian Sea called Tychnowy Sea. Samples analysed from other profiles were mostly few in number and taken wide apart; they did not permit the determination of the beginning of marine sedimentation (cf. Fig. 12). Pollen spectra from the profiles Tychnowy II and I, regarded (Halicki 1951) as older than the spectra grouped in the *Corylus-Quercus-Tilia* zone in the present work, carry no value for pollen stratigraphy.

E4 — *Corylus-Quercus-Tilia* R PAZ

Type locality and section. Imbramowice [1], local zones IP-8, IP-9, IP-10 (Fig. 3).

Description. The NAP values at the type locality are the lowest in the whole interglacial and do not exceed 6.5%. They are similar in most of the other sites. *Corylus* pollen is dominant throughout the zone. At the type locality its maximum is 71%, in most other sites it ranges from about 50% to more than 80%. Its maximum values, lower than 45%, were noted in continuous profiles only at Pałczew [22], Góra Kalwaria [42], Żyrardów 2/69 [35] and Nowiny [90] and in several profiles based on random samples. *Quercus* has higher values chiefly in the older part of the zone, 25% at the type locality, to 34% at other sites. At most sites *Tilia* attains an absolute interglacial culmination, with maximum values of 7% (type locality) to 31% (Warszawa-Żoliborz [50]); an extremely high maximum occurs at Szwajcaria [97] in profile 1 — 44%.

Taxus and *Carpinus* are also important taxa. *Taxus* culminates (11.8%) in the younger part of the zone at the type locality. At several other sites its highest values also occur in this zone (Fig. 20). At the type locality the pollen values of *Carpinus* reach 7.1%, at other sites even 30%. At most sites the highest pollen values of *Fraxinus* resemble those in the preceding zone. *Alnus* is represented in abundance, but it does not attain its highest pollen values until the younger part of the zone.

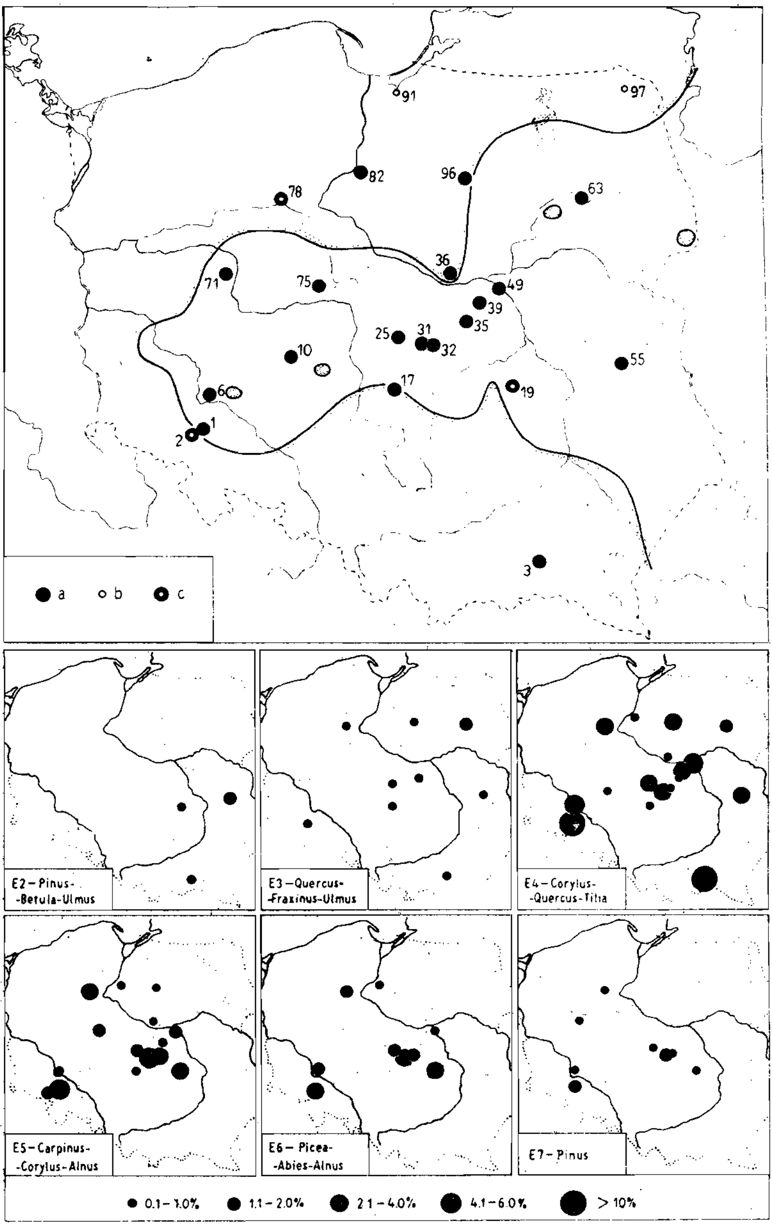
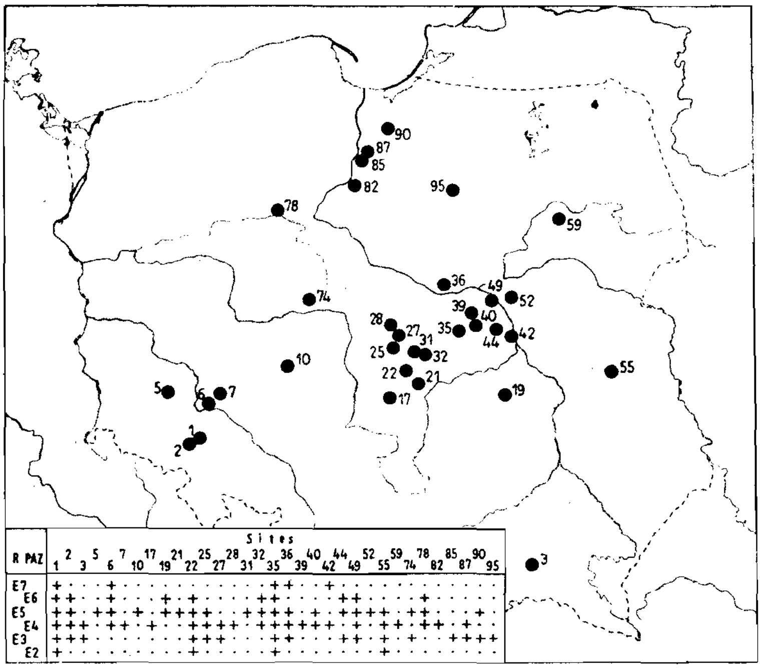


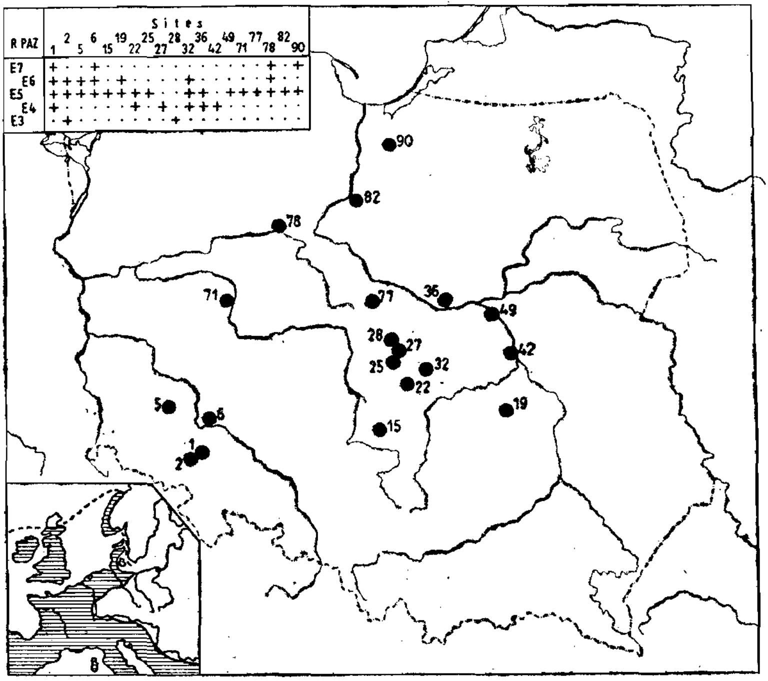
Fig. 20. Distribution of *Taxus* in the Eemian in Poland in relation to the present-day range of *T. baccata* L. and the maximum values of *Taxus* pollen through regional pollen ass. zones E2—E7: a — pollen, b — macrofossils, c — pollen and macrofossils. Site numbers as in the list (p. 93). The eastern boundary of the present range of *T. baccata* L. acc. to Browicz & Gostyńska-Jakuszewska 1969

At the type locality its maximum reaches 23.4%, elsewhere it does not exceed 30% except Szwajcaria [97] (see remark 7 on p. 119). At the type locality *Hedera*, *Ligustrum* and *Viscum* pollen occur in small amounts but fairly consistently and *Ilex aquifolium* type sporadically. The sites with these taxa, characteristic of climatic optimum, are given in Figs. 21—24.



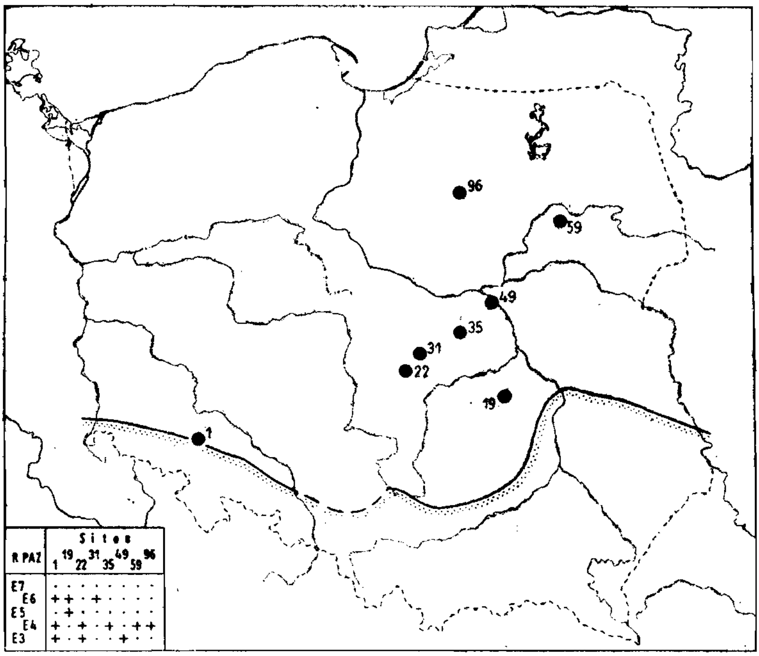
R PAZ	1	2	3	5	6	7	10	17	19	21	22	25	27	28	31	32	35	36	39	40	42	44	49	52	55	59	74	78	82	85	87	90	95
E7	+	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	+	+	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·
E6	+	+	·	·	+	·	·	·	+	·	+	·	·	·	·	+	+	·	·	·	·	+	+	·	·	·	·	+	·	·	·	·	·
E5	+	+	·	+	+	·	+	·	+	+	+	+	·	·	+	+	+	+	·	+	·	+	+	+	+	·	+	+	·	·	·	+	·
E4	+	+	+	·	+	+	·	+	·	·	+	+	+	+	·	+	+	+	+	+	+	·	+	·	+	+	·	+	+	·	+	·	·
E3	+	+	+	·	·	·	·	·	·	·	+	+	+	·	·	·	+	+	·	·	·	+	+	·	+	·	+	·	·	+	+	+	+
E2	+	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	+	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·

Fig. 21. Pollen records of *Hedera* in the Eemian in Poland. The pollen occurrences in particular R PAZ-es are marked with + in the table. Site numbers as in the list (p. 93); site 59 acc. to **Borówko-Dłużakowa** 1971a



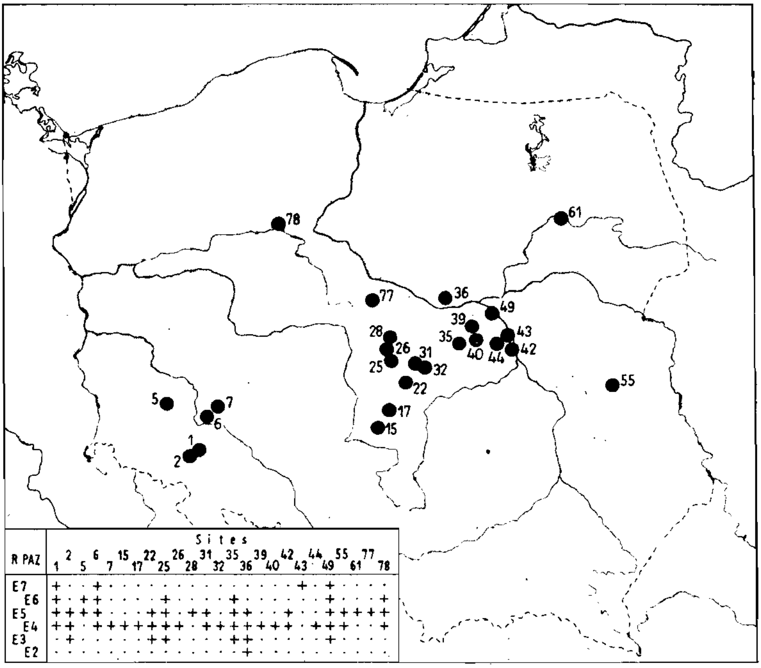
R PAZ	1	2	5	6	15	19	22	25	27	28	32	36	42	49	71	77	78	82	90
E7	+	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	+	·	+
E6	+	+	+	+	·	+	·	·	·	·	+	·	·	·	·	·	+	·	·
E5	+	+	+	+	+	+	+	+	·	·	+	+	·	+	+	+	+	+	+
E4	+	·	·	·	·	·	+	·	+	·	+	+	+	·	·	·	·	·	·
E3	·	+	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·

Fig. 22. Pollen records of *Ilex* in the Eemian in Poland and the present-day European range of *I. aquifolium* L., acc. to **Hegi** 1965. The pollen occurrences in particular R PAZ-es are marked with + in the table. Site numbers as in the list (p. 93)



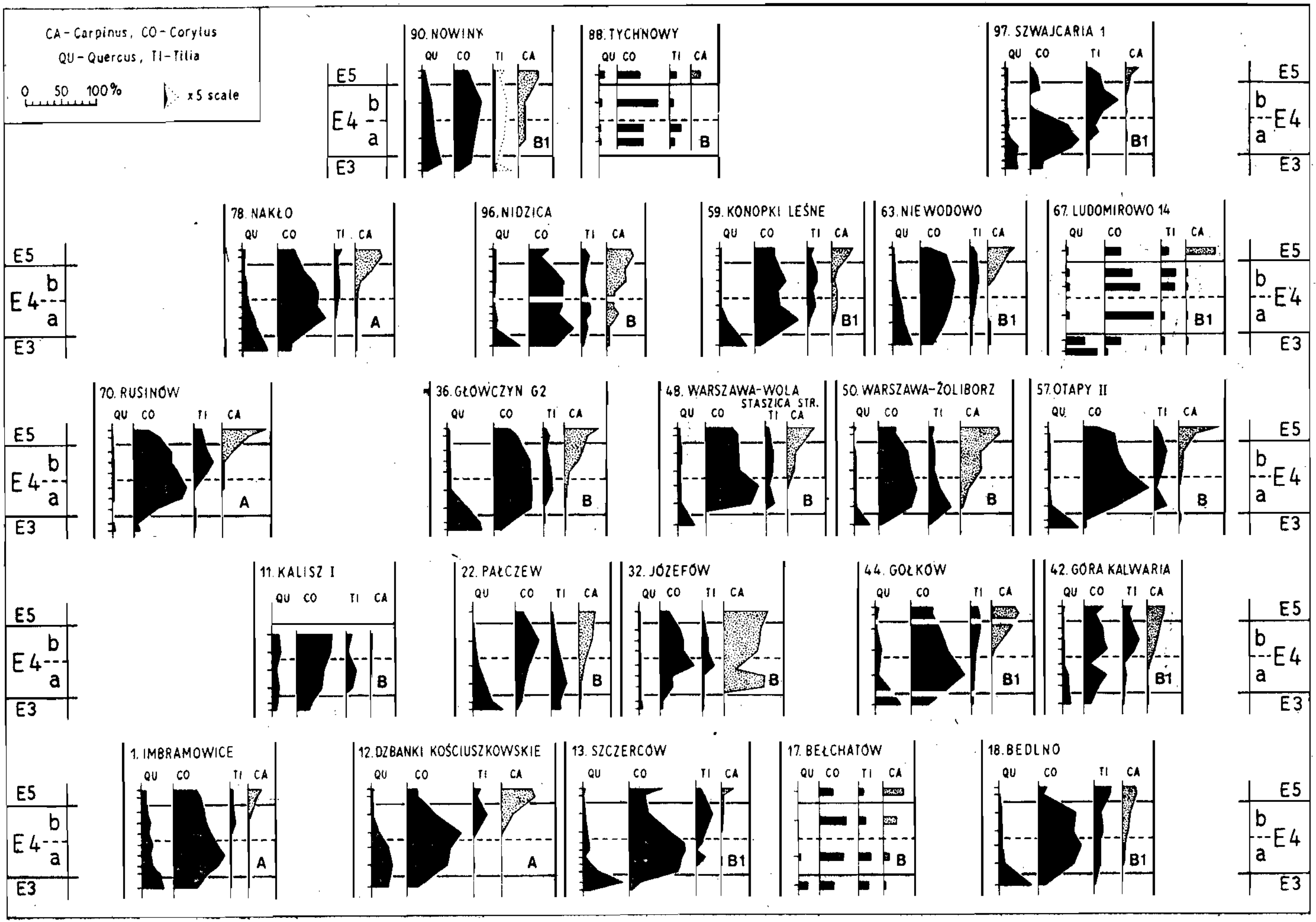
R PAZ	1	19	22	31	35	49	59	96
E7	·	·	·	·	·	·	·	·
E6	+	+	·	+	·	·	·	·
E5	·	+	·	·	·	·	·	·
E4	+	·	+	·	+	·	+	+
E3	+	·	+	·	·	+	·	·

Fig. 23. Pollen records of *Ligustrum* in the Eemian in Poland in relation to the present-day range of *L. vulgare* L. The pollen occurrences in particular R PAZ-es are marked with + in the table. Site numbers as in the list (p. 93). The northern boundary of the present range of *L. vulgare* L., acc. to Browicz & Gostyńska 1965



R PAZ	1	2	5	6	7	15	17	22	25	26	28	31	32	35	36	39	40	42	43	44	49	55	61	77	78
E7	+	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	+	·	·	·	·
E6	+	·	+	+	·	·	·	·	+	·	·	·	·	+	·	·	·	·	·	·	+	·	·	·	+
E5	+	+	+	+	·	·	·	+	+	·	+	+	·	+	+	·	·	+	·	·	+	+	+	+	+
E4	+	+	·	+	+	+	+	+	+	+	·	+	+	+	+	+	+	+	·	+	+	+	·	·	+
E3	·	+	·	·	·	·	·	+	+	·	·	·	·	+	+	·	·	·	·	·	+	·	·	·	·
E2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·

Fig. 24. Pollen records of *Viscum* in the Eemian in Poland. The pollen occurrences in particular R PAZ-es are marked with + in the table. Site numbers as in the list (p. 93)


CA - Carpinus, CO - Corylus
QU - Quercus, TI - Tilia
0 50 100%
x 5 scale
E5
E4
b
a
E3
90. NOWINY
QU CO TI CA
B1
88. TYCHNOWY
QU CO TI CA
B
97. SZWAJCARIA 1
QU CO TI CA
B1
78. NAKŁO
QU CO TI CA
A
96. NIDZICA
QU CO TI CA
B
59. KONOPKI LEŚNE
QU CO TI CA
B1
63. NIEWODOWO
QU CO TI CA
B1
67. LUDOMIROWO 14
QU CO TI CA
B1
70. RUSINÓW
QU CO TI CA
A
36. GŁOWCZYN G2
QU CO TI CA
B
48. WARSZAWA-WOLA STASZICA STR.
QU CO TI CA
B
50. WARSZAWA-ŻOLIBORZ
QU CO TI CA
B
57. OTAPY II
QU CO TI CA
B
11. KALISZ I
QU CO TI CA
B
22. PAŁCZEW
QU CO TI CA
B
32. JÓZEFÓW
QU CO TI CA
B
44. GOŁKÓW
QU CO TI CA
B1
42. GÓRA KALWARIA
QU CO TI CA
B1
1. IMBRAMOWICE
QU CO TI CA
A
12. DZBANKI KOŚCIUSZKOWSKIE
QU CO TI CA
A
13. SZCZERCÓW
QU CO TI CA
B1
17. BEŁCHATÓW
QU CO TI CA
B
18. BEDLNO
QU CO TI CA
B1

Contacts. The lower boundary of the *Corylus-Quercus-Tilia* zone is at the same time the upper boundary of the *Quercus-Fraxinus-Ulmus* zone (see p. 111). The upper boundary is placed above the rapid fall of *Corylus* values and the rise of *Carpinus* (cf. Fig. 25). At the type locality it is placed where the curve of *Corylus* falls below 40% and that of *Carpinus* rises above 10% (cf. Fig. 3).

Subdivisions. Two subzones have been distinguished in the *Corylus-Quercus-Tilia* zone: a lower with three variants, and an upper, *Tilia-Carpinus* (Fig. 25). The lower subzone is differentiated regionally, *Tilia* being the differentiating taxon. The following variants have been found in the lower subzone: A (so-called "late lime"), B ("early lime") and B1 — a weaker variety of "early lime".

Lower subzone. 1. Variant A (with "late lime") — *Corylus-Quercus* — distinguished at the type locality (cf. Fig. 3). *Corylus* and *Quercus* pollen attain maximum values in the zone here, whereas the values of *Tilia* pollen at the type locality are below 0.5% and at others below 3%. The upper boundary of the subzone lies at the rise in *Tilia* and *Carpinus* and the fall in *Quercus* (Figs. 3 and 25).

2. Variant B (with "early lime") — *Corylus-Tilia*. *Tilia* pollen reaches high values from the beginning of the zone or even earlier and culminates before or simultaneously with *Corylus*. *Corylus* and *Quercus* behave as in variant A, whereas *Carpinus* has often higher values than in variant A. The upper boundary is marked by the increase in values of *Carpinus* coinciding with a small fall in *Tilia* (Fig. 25).

3. Variant B1 — *Corylus-(Tilia)*. *Tilia* pollen occurs from the beginning of the zone, its values ranging from 3% to more than 10%, but it reaches maximum values in the upper subzone. The other taxa are as in variant B (Fig. 25).

Upper subzone — *Tilia-Carpinus*. In variants A and B1 *Tilia* pollen reaches maximum values in the whole zone, in variant B high but not maximum ones. The *Corylus* values are lower than in the lower subzone (in all three variants), but still high, 42—51% in the type profile. The *Carpinus* values increase distinctly. The exceptional behaviour of *Carpinus* at Józefów [32] is discussed in Remarks (p. 119).

Other occurrences. Apart from the type locality, the *Corylus-Quercus-Tilia* zone or its part has been distinguished at 73 sites (see Fig. 12). The characteristic features of variant A (with "late lime") were found — in addition to the type locality — in pollen diagrams from 14 sites, of which those with both boundaries and a distinct division into subzones were at Jaworzyna Śląska [2], Rusinów [70], Nakło [78], Dzbanki Kościuszkowskie [12], Faustynów 50/18a [15] and Żyrardów 4/69 [35], and those with distinctly separated subzones but without the boundaries of the zone well marked at Gawroniec [43], Karczunek [55] and Horoszki [56]. The features of variant B (with "early lime") were found in diagrams from 17 sites, of which those with both boundaries and two subzones were at Pałczew [22], Józefów [32], Główczyn [36], Warszawa-Wola [48], Warszawa-Żoliborz [50], Nidzica [96] and Otapy II [57] and with distinct subzones and only one boundary at Kalisz I [11] and Kaliska [77]. The features consistent with variant B1 occur at 19 sites: with two boundaries and well-developed subzones at Szczerców [13], Bedlno [18], Góra Kalwaria [42], Warszawa-Wawrzyszew XV [49], Konopki Leśne [59], Niewodowo [63] and Szwajcaria 1 [97] and with distinct subzones but without

←

Fig. 25. Simplified curves of *Quercus*, *Corylus*, *Tilia* and *Carpinus* in the E4 — *Corylus-Quercus-Tilia* R PAZ in selected pollen diagrams. They show the bases for marking the zone boundaries, the boundary between the subzones and for distinguishing three variants of the lower subzone (E4a): variant A — *Corylus-Quercus* ("late lime"), variant B — *Corylus-Tilia* ("early lime") and variant B1 — *Corylus-(Tilia)* ("early lime" with late culmination). The arrangement of sites agrees with their approximate geographical position. Site numbers as in Figs. 11 and 12

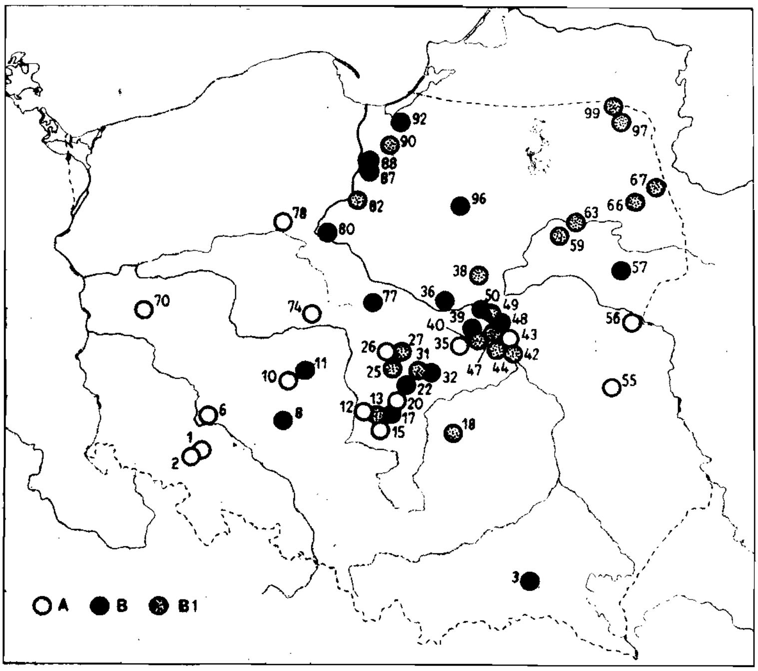


Fig. 26. Distribution of sites in which pollen ass. subzone E4a is differentiated into vaiiants A, B and B1. For the description of the variants see Fig. 25 and p. 117. Site numbers as in the list (p. 93)

the boundaries of the zone at Gołków [44], Ludomirowo 14 [67] and Grudziądz-Mniszek [82]. The remaining 23 sites have samples diagnostic of the *Corylus-Quercus-Tilia* zone but not allowing their inclusion in any of the variants distinguished. In the stratigraphical table (Fig. 12) they are placed — on the principle of greater probability — in the lower or upper subzone and in quite uncertain cases in the middle of the zone.

Extent. The *Corylus-Quercus-Tilia* zone extends all over the area of the occurrence of Eemian sites in Poland. The distribution of the sites in which the characteristics of the "early" or "late" lime were distinguishable (Fig. 26) suggest a geographical differentiation of the zone. The "late lime" characteristics most often occur in the diagrams from the sites in western and south-western Poland. Similar characteristics can be seen in most of the German profiles in which "Linden-Haselzeit" is the youngest part of the hazel zone, always after the maximum of *Corylus* (Woldstedt et al. 1951; Selle 1957, 1962; Averdieck 1967a, b, 1976; Averdieck et al. 1976; Hallik 1954, 1957; Menke 1967, 1970, 1975; Menke & Ross 1967; Menke & Tynni 1984; Behre 1962; Behre & Lade 1986; Erd 1960, 1973; Müller 1974; Ziemus 1980). The localities with characteristics of variant B1 resemble many sites in the north-west of the USSR (cf. Bremówna & Sobolewska 1950; Środoń 1950; Grichuk 1961; Vajtiekunas 1968; Chebotareva 1972-I/II; Liivrand 1974a; Shalaboda & Yakubovskaya 1978). A counterpart of variant B, with lime culminating before the maximum of hazel, is encountered at sites in Byelorussia (Makhnach 1971) and the Yaroslavl' region north-east of Moscow (Gorlova 1968a, b, 1975; Chebotareva et al. 1975). A similarly early maximum of lime occurs at Ganovce in Slovakia (Kneblova 1960), but here its values are very low (max. about 2%).

Remarks. 1. Sections representing *Corylus-Quercus-Tilia* R PAZ are referred by the authors concerned mostly to Jessen's zone *f* (Jessen & Milthers 1928) but at some sites to zone *de*, *e* or *g*.

2. Striking disturbances of the *Corylus-Quercus-Tilia* zone, similar in nature, can be observed in the diagrams from two sites. In the profile from Góra Kalwaria [42] (Sobolewska 1961, Fig. 3) the middle part of the zone shows a transient rapid fall in values of *Corylus* and rise in values of *Pinus*, *Betula* and NAP, notably *Gramineae*, *Artemisia*, *Compositae Tub.* and *Chenopodiaceae*. The changes resemble successions following fires observed in the Holocene and associated with the clearence of woods using fire by Neolithic people. Sobolewska (1961) discussed different factors that may have brought about the disturbance, including the possibility of a fire (started by Neanderthal man or by natural causes), to which interpretation she leant despite the absence of charcoal. Similarly, in profile 2/69 from Żyrardów [35] (cf. Krupiński 1978, Fig. 5, depth: 8.40—8.70 m), in the section of the transient but distinct fall of *Corylus* the values of *Tilia* and *Alnus* also decrease, while those of *Pinus*, *Quercus*, *Juniperus* and NAP rise. At the same time single pollen grains of heliophilous plants (*Ephedra*, *Helianthemum* and *Armeria*) and rebedded sporomorphs appear. Krupiński (1978) did not discuss this problem but in his doctoral thesis (Krupiński 1973) he was inclined to link these vegetational changes with a fire, which in this case would also be indicated by microscopic charcoals reported from that layer.

3. In the profile at Warszawa-Wola, Młyn./Wolska Str. [48], among the samples with *Corylus* values above 70% there is one in which the proportion of *Corylus* falls to 2.5% and that of *Carpinus* leaps up to 61%. Borówko-Dłużakowa (1960) did not interpret this disturbance. It seems, however, that the very high values of hornbeam in zone E5 in this profile suggest contamination of the zone E4 with some materials from above.

4. The *Corylus-Quercus-Tilia* zone in the profile of Józefów [32] is not at all typical; here a rapid and high-percentage culmination of hornbeam occurs before the maximum values of hazel and later on the hornbeam culminates for the second time in zone E5 (cf. Fig. 25 and Sobolewska 1966, Fig. 1). Disturbance at the time of sampling is hardly possible, because the profile comes from an outcrop. The early expansion of *Carpinus* in middle Poland and its very high values immediately after the culmination of *Corylus* in the nearest sites (Rogów [31], Zgierz-Rudunki II [25] and Bobrówka Valley [30] may suggest an earlier local over-representation of hornbeam at Józefów.

5. At Zacisze [68] the organic deposits are, according to Bitner (1957), disturbed by cryoturbation and in some layers pollen is selectively deteriorated. Such a situation occurs, among others, in profile 4, in which top sample 12 contains heavily corroded pollen. The proportion of *Tilia* in that sample is 77% (98% of total AP without *Corylus*), which in that author's opinion, is chiefly connected with the ease of identifying even very heavily corroded grains of lime pollen. This sample has been referred to the older part of the zone but it is not taken into consideration in the analysis of diagnostic features.

6. Kociszewska-Musiał (1978) notes that the geological position of the profile at Smolniki [99] is disputable, seeing that the deposits may have been displaced. The palynologically elaborated section of this profile (Borówko-Dłużakowa 1971c) has the diagnostic features of the *Corylus-Quercus-Tilia* zone free from disturbances and at the same time it shows a great resemblance to the older section of this zone in profile 1 at Szwajcaria [97]; this being so, a remote displacement of this deposit does not seem possible.

7. The exceptionally high leaps of the *Alnus* pollen values (90 and 47%) in profile 1 at Szwajcaria [97] (cf. Borówko-Dłużakowa & Halicki 1957, Fig. 7) are undoubtedly connected with a local over-representation of pollen. These values are not regarded as representative of the regional pollen stratigraphy.

E5 — *Carpinus-Corylus-Alnus* R PAZ

Type locality and section. Główczyn G-2 [36], depth: 2.5—3.7 m, zone *g* acc. to Niklewski (1968). A simplified section of the pollen diagram presenting this zone is given in Fig. 27.

Description. *Carpinus* is the distinctive taxon of the zone. At Główczyn it dominates with a maximum of 60.9%. Values ranging from 50 to 75% have been recorded from some dozen sites; the lower maximum values of *Carpinus*

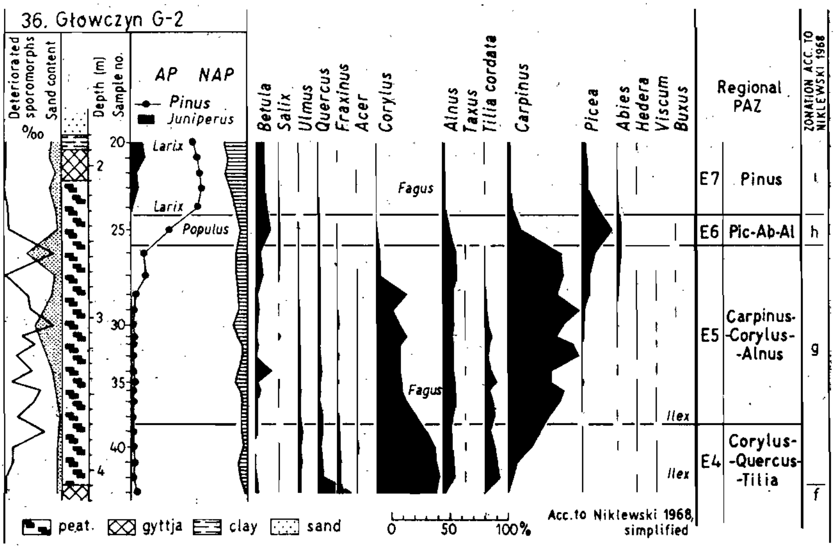


Fig. 27. The simplified top part of the pollen diagram from Główczyn, profile G-2, as the type locality for the E5 — *Carpinus-Corylus-Alnus* R PAZ. The sand content in the peat and the curve of deteriorated pollen grains, interpreted as the effect of hydrological disturbances in the peatbog, are given on the left side. Lithology simplified. Site number as in Figs. 11 and 12

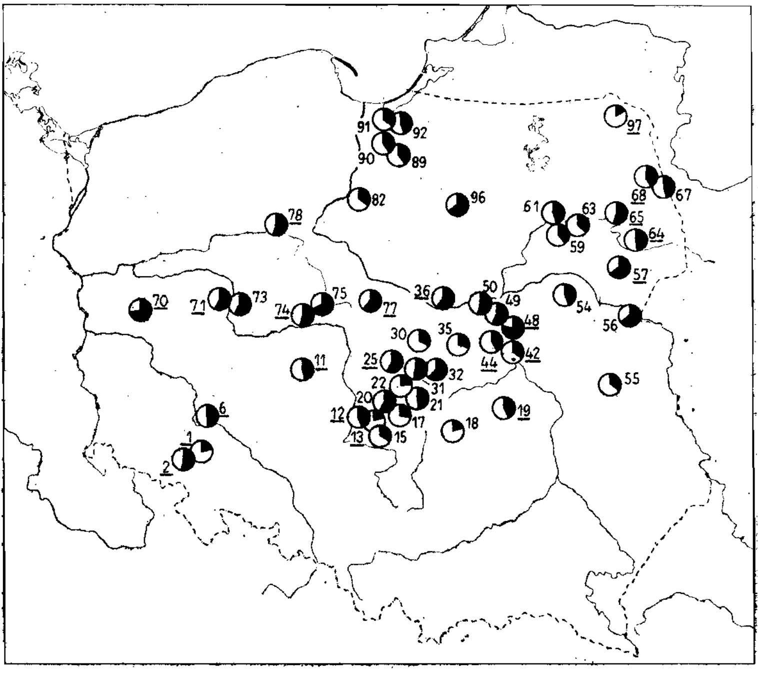
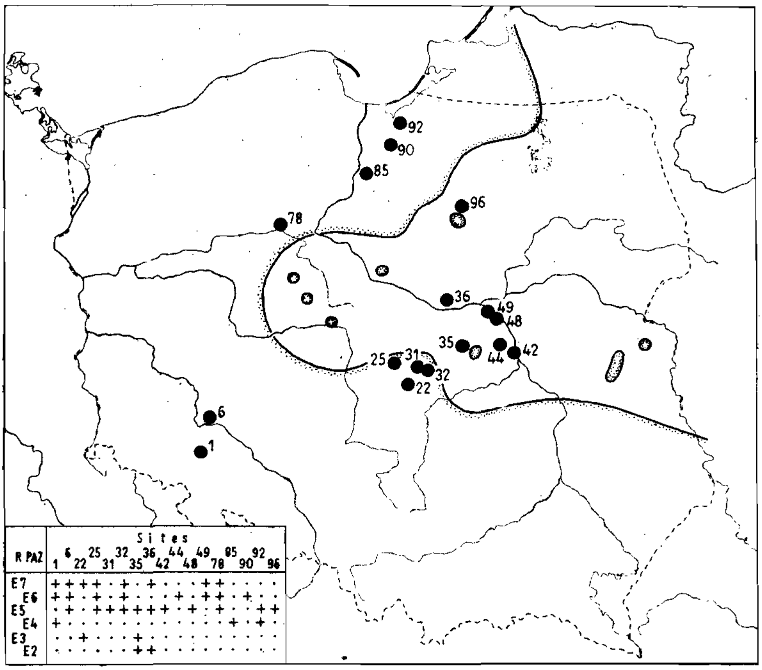


Fig. 28. Maximum values of *Carpinus* pollen and the occurrence of *C. betulus* macrofossils in the E5 — *Carpinus-Corylus-Alnus* R PAZ in Poland; the presence of macrofossils is marked by the underlining of the site number. Site numbers as in the list (p. 93). Some sites, which have single samples referred to this zone, have not been taken into consideration

occur at Imbramowice [1], Bedlno [18], Szczerców [13], Pałczew [22] and Szwajcaria [97] (Fig. 28). *Corylus* shows a downward trend over the span of the zone, at the type locality from the maximum of 34.4% in the lower part of the zone to about 4% in the upper. Maximum values of hazel lower than 20% are only recorded from several sites. At the type locality the maximum of *Alnus* comes to 12%, at other sites it does not exceed 30% except for Zgierz-Rudunki II [25] with 48% and Białki 5/VIII [85] with 75%. In this zone *Alnus* values are either maximum ones in the interglacial or they are high, increasing in the upper part of this zone to culminate in the next.

Tilia pollen is still relatively frequent in particular in the older part of the zone. The proportions of pollen of other thermophilous trees and shrubs are similar to or lower than those towards the close of the previous zone. *Picea* attains a significance in the younger part of the zone and *Abies* is fairly often noted for the first time (cf. Fig. 32). Sporadic pollen grains of *Fagus* appear in this zone at more sites (Fig. 29).

Contacts. The lower boundary of the *Carpinus-Corylus-Alnus* zone corresponds to the upper boundary of the *Corylus-Quercus-Tilia* zone (see p. 117). The upper boundary is placed where the *Carpinus* values decrease distinctly (at the type locality from 44 to 11%) and frequencies of *Picea* and *Abies* increase (at the type locality *Picea* from 11 to 25% and *Abies* from 3.2 to 3.8%). At some sites the values of *Pinus* and NAP rise also at the boundary level, which, however, is not a general phenomenon.



R PAZ	1	6	22	25	31	32	35	36	42	44	48	49	78	85	90	92	96
E7	+	+	+	+	·	+	·	+	·	·	·	+	+	·	·	·	·
E6	+	+	·	+	·	+	·	·	·	+	·	+	+	·	+	·	·
E5	·	+	·	+	+	+	+	+	+	·	+	·	+	·	·	+	+
E4	+	·	·	·	·	·	·	·	·	·	·	·	·	+	·	+	·
E3	·	·	+	·	·	·	+	·	·	·	·	·	·	·	·	·	·
E2	·	·	·	·	·	·	+	+	·	·	·	·	·	·	·	·	·

Fig. 29. Pollen records of *Fagus* in the Eemian in Poland in relation to the present-day range of *F. sylvatica* L. The pollen occurrences in particular R PAZ-es are marked with + in the table. Site numbers as in the list (p. 93); site 48 acc. to Raniecka-Bobrowska 1954, prof. 1a. The north-eastern boundary of the present range of *F. sylvatica* L., acc. to Gostyńska-Jakuszewska & Zieliński 1976

Other occurrences. In addition to the type locality, the *Carpinus-Corylus-Alnus* zone or its part has been distinguished at 66 sites (see Fig. 12). In nearly half of these sites this zone is well developed and with distinct boundaries. The well-developed zone without distinct boundaries (both or one) occurs at Wołów 4/b [6], Kalisz II [11], Krzepczów A [20], Świątniki [21], Karczunek [55], Józwin [75], Nowiny [90], Elbląg-Bażantarnia [92] and Nidzica [96]. Twenty-four sites are represented by one or two samples. In the stratigraphical table their position within the limits of the zone is determined on the basis of the pollen values of *Corylus*, *Picea* and possibly *Abies*. Samples with *Corylus* values about 20% or more are referred to the older part of the zone (Fig. 12).

Extent. The *Carpinus-Corylus-Alnus* zone occurs within the range of the Eemian sites with the exception of southern Poland, for the profile from Dąbrówka [3] ends within zone E4. The hornbeam zone at Ganovce in Slovakia (Kneblova 1960), very similar in nature, permits the assumption that the *Carpinus-Corylus-Alnus* zone extended also on southern Poland.

Remarks. 1. Nutlets of *Carpinus betulus* occur in this zone at 20 sites (cf. Fig. 28), most abundantly at Jaworzyna Śląska [2], Kalisz [11] and Dzbanki Kościuszkowskie [12] and fairly abundantly at Imbramowice [1], Główczyn [36] and Rusinów [70]. At several sites in southern and middle Poland and at Szwajcaria [97] and Zacisze [68] they appear (few in number) as early as zone E4. The occurrence of hornbeam nutlets at Bedlno [18] is puzzling; here, they are present in earlier zones (E1, E3 and E4) and in zone E6 but have not been recorded from the *Carpinus-Corylus-Alnus* zone at all.

2. Sections representing *Carpinus-Corylus-Alnus* R PAZ are referred by the authors mostly to Jessen's zone *g* (Jessen & Milthers 1928) and at several sites in part to zones *f* or *h*.

3. In the deposits of *Carpinus-Corylus-Alnus* zone hydrological disturbances indicative of increased climatic humidity and heavy rainfall are manifested in several profiles. An exceptionally rapid change of this sort can be seen in the profile from Imbramowice [1], in which the deposition of peaty gyttja is interrupted by sandy sediment towards the end of the zone, while the changes in aquatic vegetation indicate a rise of the lake water-level (cf. Fig. 3 and p. 75). A similar change was recorded from profile 10/69 at Grodzisk Mazowiecki [40] and a change of silt into sandy silt at Grudziądz-Mniszek [82]. Niklewski (1968) drew attention to the flooding of a peatbog at Główczyn [36] revealed by the deposits of sand and the appearance of pollen of aquatic plants (cf. Fig. 27) and so did Krupiński (1978) with regard to profile 4/69 at Żyrardów [35]. A change in sediments, from peat into organic silt with sand, occurred also at Rusinów [70] as early as the beginning of the zone (cf. Fig. 12).

The profiles from Kalisz [11] evidence another type of hydrological change in this zone. In profile I, taken on a high terrace, close to the edge of the Prosna valley, the *Carpinus-Corylus-Alnus* zone is missing utterly (cf. Fig. 12), while it is very well developed in profile II from a peatbog, situated higher on that terrace, 1 km away from the edge of the valley. Such a situation in conjunction with the fact that the next zone in profile I was deposited in strongly sandy detritus peat (to 40% sand — cf. Tołpa 1952) suggest that here river floods are responsible for this lack of the *Carpinus-Corylus-Alnus* zone. Disturbances in the *Carpinus-Corylus-Alnus* zone are also recorded from the profiles of Szwajcaria [97]. Profile 2 lacks almost the whole zone and in profile 1 there is a peat layer lacking pollen in the lower part. However, the lack of a description of the peat does not permit any interpretation of this phenomenon.

Similar disturbances in sedimentation caused by the influx of sand deposits were observed by Averdieck (1976) in the hornbeam zone in a profile from the Alster Valley in Schleswig.

4. The alternating rises and falls in the pollen values of *Carpinus* and *Picea* in the pollen diagram from Góra Kalwaria [42] were regarded by Sobolewska (1961) as the effect of fine climatic oscillations in the course of the hornbeam zone. She referred to the microstratigraphy of this zone, presented by Hallik (1953) on the basis of these very characteristics. This phenomenon was discussed in the same way by Niklewski (1968) at Główczyn [36] and by Krupiński (1978) at Żyrardów [35]. Similar oscillations can be also observed — though poorly marked — in profiles from Imbramowice [1], Jaworzyna Śląska [2], Jednaczewo [61], Niewodowo [63], Szwajcaria 1 [97], Nidzica [96] and Elbląg [91]. They are very distinct at Dzbanki Kościuszkowskie [12] and Szczerców [13]. The above data do not permit us to state un

questionably that the phenomenon under discussion is induced by climatic changes. It may well be that it is the effect of the short-lived prevalence of spruce over hornbeam induced by the podsolization of soils (cf. Andersen 1964, 1966; Sparks & West 1970).

E6 — *Picea-Abies-Alnus* R PAZ

Type locality and section. Bedlno [18], depth: 7.86—9.30 m, zone *h* and part of zone *i*, acc. to Środoń and Gołąbowa (1956). A simplified section of the pollen diagram presenting this zone is given in Fig. 30.

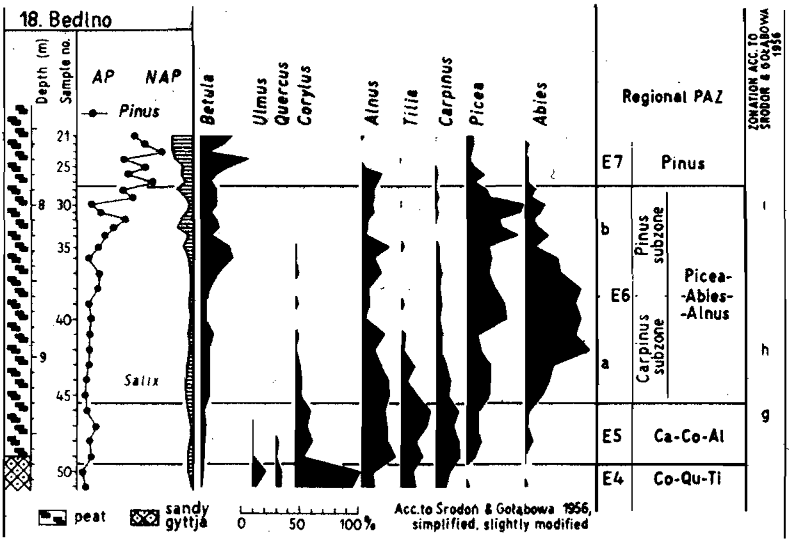
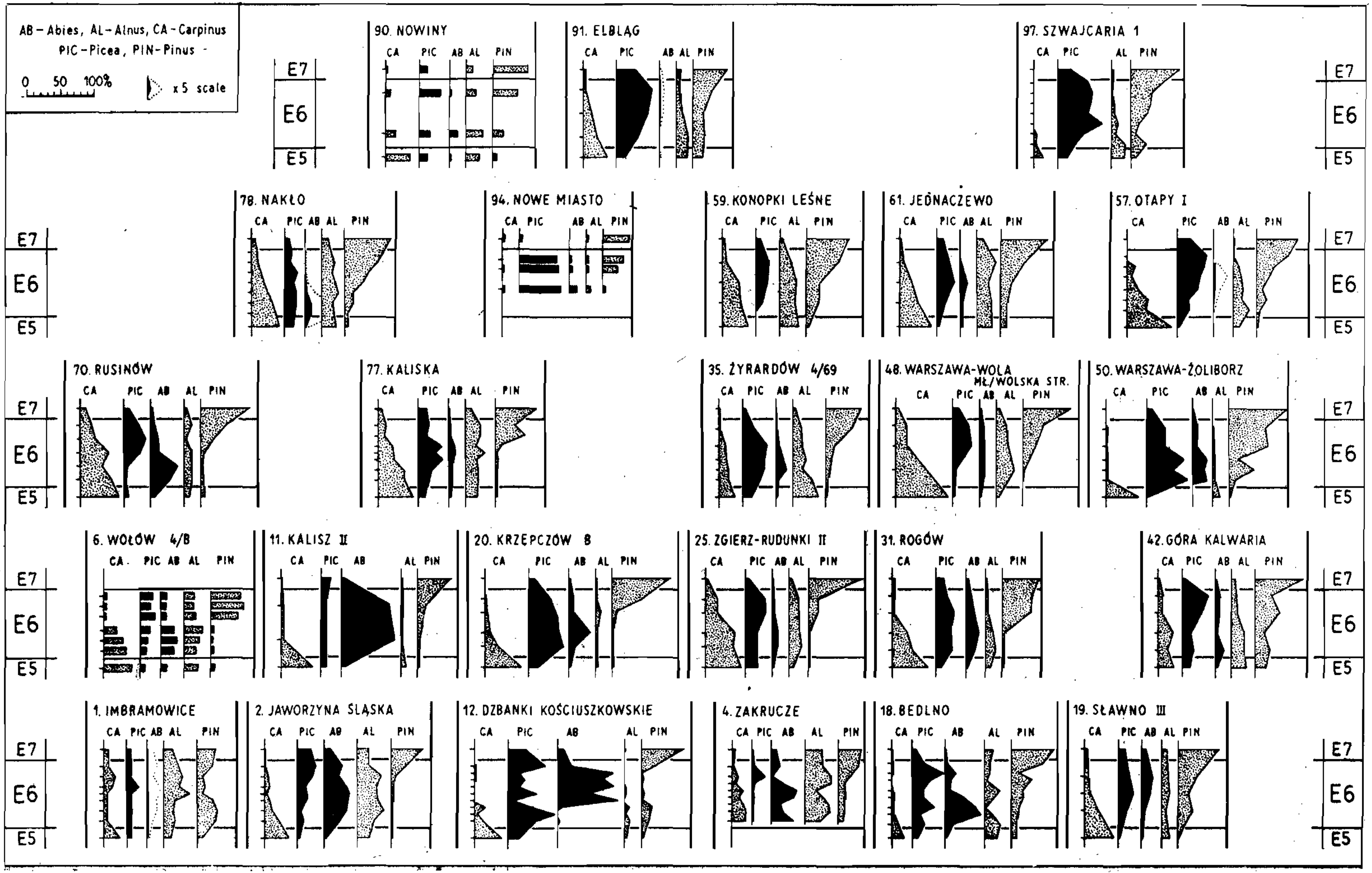


Fig. 30. A section of the pollen diagram from Bedlno, as the type locality for the E6 — *Picea-Abies-Alnus* R PAZ, simplified. Site number as in Figs. 11 and 12

Description. *Abies* is the distinctive taxon of the zone. In the type locality it reaches 53.1% and culminates early, before the culmination of *Picea*. Apart from the type locality, the highest values of *Abies* pollen occur at several sites in the southern upland part of middle Poland (cf. Fig. 32), with an absolute maximum of 90% at Dzbanki Kościuszkowskie [12]. *Picea*, too, reaches an interglacial maximum in this zone; at the type locality it is 47% and at other sites from 69% at Dzbanki Kościuszkowskie to 15% at Warszawa-Wawrzyszew XV [49]. The order of the culminations of *Abies* and *Picea* is different in particular sites (cf. Fig. 31). The maximum values of *Alnus* reach 23% at the type locality; at most other sites they range from 10 to 39%. *Carpinus* still has high pollen values.

At most sites pollen of thermophilous trees is either missing or has very low values. At the type locality only *Tilia* is noted in this zone (12.7%). Besides the type locality the exceptionally high proportions of *Tilia* pollen occur also at Dzbanki Kościuszkowskie [12] (13.1%), Szklary Dolne [5] (8.9%), Szwajcaria [97] (5.3%) and Imbramowice [1] (4.8%). High values of *Ulmus* pollen occur at Krzepczów A [20] (7.2%) and Zakrucze [4] (4.6%). *Taxus* decreases or disappears; only at Imbramowice, Sławno III [19] and Rogów [31] do its values reach 2—4% (Fig. 20). *Hedera*, *Ilex*, *Viscum* and *Ligustrum* are still present at several sites (Figs. 21—24).


AB – Abies, AL – Alnus, CA – Carpinus
PIC – Picea, PIN – Pinus
0 50 100%
x 5 scale
E7
E6
E5
90. NOWINY
CA PIC AB AL PIN
91. ELBLĄG
CA PIC AB AL PIN
97. SZWAJCARIA 1
CA PIC AL PIN
78. NAKŁO
CA PIC AB AL PIN
94. NOWE MIASTO
CA PIC AB AL PIN
59. KONOPKI LEŚNE
CA PIC AL PIN
61. JEDNACZEWO
CA PIC AB AL PIN
57. OTAPY I
CA PIC AB AL PIN
70. RUSINÓW
CA PIC AB AL PIN
77. KALISKA
CA PIC AB AL PIN
35. ŻYRARDÓW 4/69
CA PIC AB AL PIN
48. WARSZAWA-WOLA
MŁ./WOLSKA STR.
CA PIC AB AL PIN
50. WARSZAWA-ŻOLIBORZ
CA PIC AB AL PIN
6. WOŁÓW 4/B
CA PIC AB AL PIN
11. KALISZ II
CA PIC AB AL PIN
20. KRZEPCZÓW B
CA PIC AB AL PIN
25. ZGIERZ-RUDUNKI II
CA PIC AB AL PIN
31. ROGÓW
CA PIC AB AL PIN
42. GÓRA KALWARIA
CA PIC AB AL PIN
1. IMBRAMOWICE
CA PIC AB AL PIN
2. JAWORZYNA ŚLĄSKA
CA PIC AB AL PIN
12. DZBANKI KOŚCIUSZKOWSKIE
CA PIC AB AL PIN
4. ZAKRUCZE
CA PIC AB AL PIN
18. BEDLNO
CA PIC AB AL PIN
19. SŁAWNO III
CA PIC AB AL PIN

In the younger part of the zone the *Pinus* frequencies increase markedly and those of *Betula* and NAP rise less regularly (cf. Figs. 30 and 31). Sporadic pollen grains of *Fagus* have been recorded from eight sites (Fig. 29).

Contacts. The lower boundary of the *Picea-Abies-Alnus* zone coincides with the upper one of the *Carpinus-Corylus-Alnus* zone (see p. 121). The upper boundary is marked by the distinct fall in *Picea* and *Abies* values and the simultaneous rise in *Pinus* (cf. Figs. 30 and 31). This change is usually accompanied by a small increase in NAP and sometimes also an increase in *Betula* pollen values.

Subdivisions. Two subzones have been distinguished in the *Picea-Abies-Alnus* zone, a lower — *Carpinus* subzone and an upper — *Pinus* subzone.

Carpinus subzone. The maximum pollen values of *Carpinus* range between 10 and 48%, at the type locality 12%. Its proportion has a downward trend. The values of *Pinus* pollen do not exceed 15%. The upper boundary of this subzone is placed where the values of hornbeam pollen fall and those of pine rise.

Pinus subzone. The values of *Pinus* pollen increase successively to about 50% at the type locality and within a range of 20—60% in most other sites.

Other occurrences. In addition to the type locality, the *Picea-Abies-Alnus* zone or its part occurs at 52 sites (see Fig. 12). At 25 sites (apart from the type one) the zone is well developed and has both boundaries (cf. Fig. 31). The high *Pinus* values, starting as early as the older part of the zone and thwarting the division into subzones, occur at Imbramowice [1], Faustynów 50/18a [15], Warszawa-Żoliborz [50], Szwajcaria 1 [97], Błaskowizna [98] and Kalisz I [11]. 15 sites have the zone represented by one or two random samples. They have been referred to the subzones according to the higher values attained by *Carpinus* or *Pinus*. Less typical samples have been placed halfway through the zone in the stratigraphical table (Fig. 12).

Extent. The extent of the *Picea-Abies-Alnus* zone is conditioned by the north-eastern distribution limit of *Abies* in the Eemian Interglacial. On the basis of the palynological data so far obtained this limit is marked by the sites of Jednaczewo [61] with 10.7% *Abies* pollen (Borówko-Dłużakowa 1975a), Łomża [62] with 3.0% *Abies* (K. M. Krupiński, pers. comm.) and Otapy [57] with 3.7% *Abies* in zone E6 (cf. Figs. 32 and 11). Out of the sites situated farther to the north-east, three, namely, Czarna Wieś [66], Szwajcaria [97] and Błaskowizna [98] have no *Abies* pollen in this zone, in the pollen diagrams from the other ones either zone E6 is lacking (Bagno-Kalinówka [65] and Klewinowo [64]) or their pollen sequences end below this zone. Naturally, it may well be that the sites without *Abies* pollen in the *Picea-Abies-Alnus* zone represent another regional pollen zone, e.g. *Picea-Pinus*, as a western variant of the *Picea* zone (M7 of Grichuk 1961, 1982) extending in the western part of the USSR. The inclusion also of this part of north-eastern Poland in the range of the *Picea-Abies-Alnus* zone is, however, suggested by the presence of *Abies* pollen in the profiles from beyond the eastern frontier of Poland — sporadic at Nieciosy II (Bremówna & Sobolewska 1950) and continuous, with a maximum of 2%, at Samostrzelniki (Trela 1935) — as well as sporadic grains of *Abies* pollen at Błaskowizna [98] and Klewinowo [64] in the samples referred to the next zone (cf. Figs. 33 and 44). In the remaining area of

←

Fig. 31. Simplified curves for *Carpinus, Picea, Abies, Alnus* and *Pinus* in the E6 — *Picea-Abies-Alnus* R PAZ in selected pollen diagrams. The bases for marking the zone boundaries, the variable order of *Picea* and *Abies* culminations and the difference in percentage proportions of these taxa in neighbouring sites are illustrated. The arrangement of sites agrees with their approximate geographical position. Site numbers as in Figs. 11 and 12

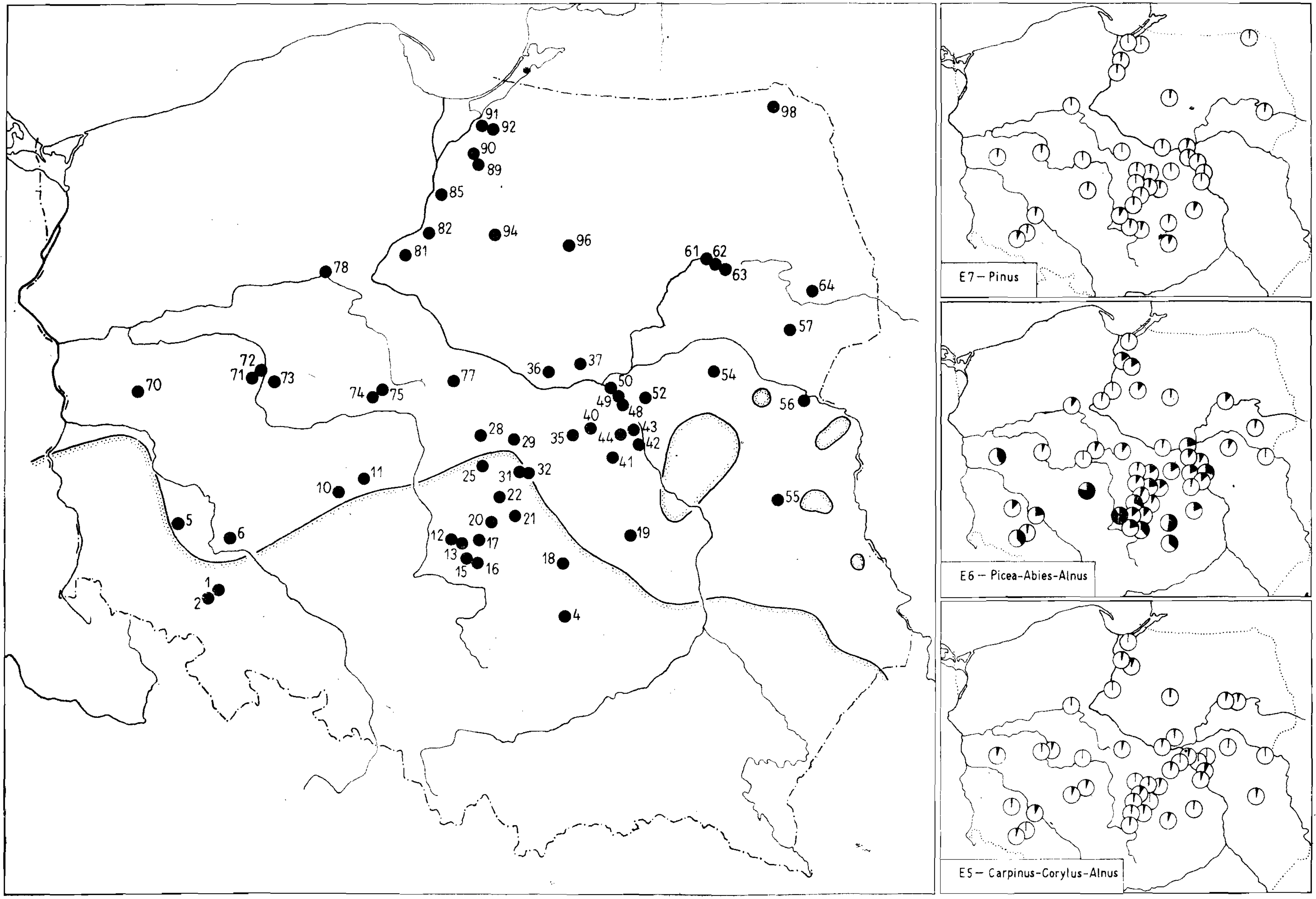


Fig. 32. Distribution of *Abies* in the Eemian in Poland on the basis of pollen records in relation to the present-day range of *A. alba* Mill. and the maximum values of *Abies* pollen through regional pollen ass. zones E5—E7. Site numbers as in the list (p. 93). The north-eastern boundary of the present range of *A. alba* Mill., acc. to **Browicz** 1972

Poland the range of the zone coincides with that of the Eemian sites except for Dąbrówka [3] and Karczunek [55] (cf. Fig. 11), at which pollen sequences end earlier. The highest values of fir pollen in the southern and western sites (cf. Figs. 32 and 31) indicate the geographical differentiation of the *Picea-Abies-Alnus* zone into the fir-dominated south-western part and the remaining part with a higher proportion of spruce.

Remarks. 1. This zone contains macrofossils of *Abies* only at five sites: Imbramowice [1] — wood, Bedlno [18] — needles, Sławno [19] — wood in profiles I—III, seeds in profile I, needles in profile II, Główczyn [36] — needle and Rusinów [70] — needle and fruit scale.

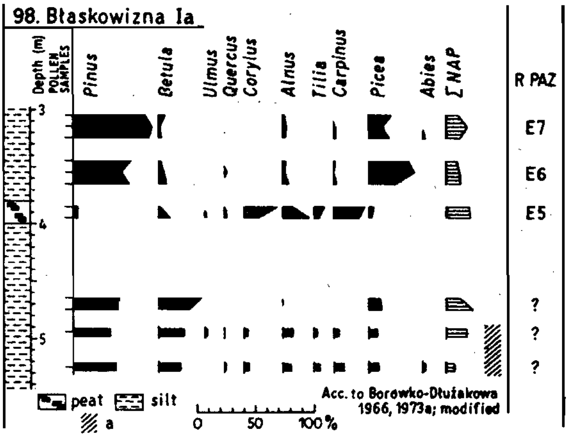


Fig. 33. Proposed division of the pollen diagram from the top section of deposits at Błaskowizna, modified in relation to Borówko-Dłużakowa (1973a) and supplemented with *Abies* values (see below). Percentages calculated from the AP+NAP sum. Site number as in Figs. 11 and 12

2. Sections representing *Picea-Abies-Alnus* R PAZ are referred by the authors to Jessen's zones *h* (h_1, h_2), *gh* (Jessen & Milthers 1928) but at several sites, in part to zones *g* or *i*.

3. *Abies* was omitted in the diagram published from Błaskowizna [98] (Borówko-Dłużakowa 1973a; Ber 1974), whereas *Abies* pollen was identified at this site by Borówko-Dłużakowa (1966), in two samples. A diagram (Fig. 33) constructed on the basis of the table given to me by the author, shows that 1.3% *Abies* in the sample from zone E7 may be the final value of *Abies* from zone E6, which has not been studied in detail. The occurrence of 2.7% *Abies* in the bottom sample is also striking. According to Borówko-Dłużakowa (1966) bottom samples are disturbed by the use of a spiral auger for sampling. On this basis it may be assumed that this profile has a zone with relatively abundant *Abies* pollen responsible for its 2.7% value. A detailed study of this locality on the basis of properly taken material may be of crucial importance to the problem of the maximum range of *Abies* in the Eemian Interglacial.

4. The upper sample from Błoniewo [54] with 9.4% *Abies* and 53.1% *Carpinus* has been alternatively included in this zone. It is presumably a disturbed sample (mixed). This possibility is also suggested by Halicki (Borówko-Dłużakowa & Halicki 1957), who takes into consideration a thorough exploitation of the upper peat layers.

5. To be sure, the pollen spectra of samples 3—5 from Nowe Miasto [94] agree with the characteristic features of the *Picea-Abies-Alnus* zone but they fail reliably to establish the stratigraphical position of this locality. At the present moment, the *Picea-Abies-Alnus* zone itself, particularly its upper part, which lacks the lower boundary, is not diagnostic for the Eemian, since a similarly developed zone occurs in the pollen zone sequence of the Zbójno-type Interglacial. Moreover, according to Churski (1966) the whole layer of this deposit has possibly been rebedded by glaciotectonic disturbances.

6. In the E6 zone a hiatus in the deposits of the profile from Klewinowo [64] and Bagno-Kalinówka [65] is postulated in the present interpretation (Figs. 12 and 44). The high values of *Carpinus* and *Corylus*, representing zone E5, are directly followed by high values of *Pinus*, indicating zone E7. There is no section with high values of *Picea* (and perhaps with *Abies* present), such as occurs at a depth of 3.50—3.95 m in the diagram from Konopki Leśne [59], with which Borówko-Dłużakowa (1974) compares the data from Klewinowo.

7. The *Picea-Abies-Alnus* zone at Imbramowice is slightly disturbed by redeposition (see p. 76).

E7 — *Pinus* R PAZ

Type localities and sections. Imbramowice [1], local zone IP-13 (Fig. 3) — for southern Poland; Zgierz-Rudunki II [25], depth: 9.20—10.15 m; acc. to Jastrzębska-Mamełka (1985) local zone ZRII-9 (Fig. 35) — for middle, western and north-eastern Poland.

Description. In this zone *Pinus* pollen (*sylvestris* type) is most abundant. Its maximum values are 28% at Imbramowice and 91% at Zgierz-Rudunki II and lie within this interval or are even higher at several other sites. In the pollen diagrams from many sites the values of *Betula* pollen increase as early as the lower boundary of the zone, in others only in its younger part (Fig. 34). The maximum values are strongly differentiated, from several to above 60%.

Of the other trees, *Picea* and *Alnus* are still important taxa, usually having the highest values in the older part of the zone (excluding sections with the so-called "second climatic optimum", see p. 146). At Imbramowice *Alnus* attains a maximum of 14.4% and *Picea* 6.4% (higher values are regarded as resulting from redeposition, see p. 80) and at Zgierz-Rudunki II their percentages are 3.3% and 5.1% respectively. The *Picea* values are higher at many sites; they range from 20 to 30% at Szwajcaria [97], Elbląg [91], Nowiny [90], Warszawa-Żoliborz [50], Dzbanki Kościuszkowskie [12] and Jaworzyna Śląska [2]. *Abies* still has significant values only in profiles of south-western Poland and middle-Polish uplands. Pollen of *Carpinus* and other trees and shrubs of higher climatic demands have low values with the exception of those at Imbramowice and Zakrucze, where they are represented by continuous curves of several percent. In other profiles the higher values are connected only with the phenomenon of "second climatic optimum" (see p. 146 and Fig. 34).

The successive rise in herbaceous pollen values is characteristic of the zone. At Zgierz-Rudunki II they attain 30% and at Imbramowice 34%. At most sites, however, they do not exceed 30% and this is so up to the end of the zone (cf. Fig. 34). The exceptions with higher NAP values are: Żyrardów 2/69 [35] — 39.3%, Warszawa-Wola, Młyn./Wolska Str. [48] — 36.4%, Warszawa-Wawrzyszew V [49] — 36.4%, Szwajcaria 1 [97] — 36.9% and Grudziądz-Mniszek G1/69 [82] — 63.0% (mainly *Cyperaceae* — see Remarks). Sporadic pollen grains of light-demanding herbs and shrubs begin to appear in some profiles.

Contacts. The lower boundary of the *Pinus* zone coincides with the upper boundary of the *Picea-Abies-Alnus* zone (see p. 125). The upper boundary is placed at the rise of NAP values usually to above 40% (cf. Fig. 34) — at Imbramowice to 43.2% and at Zgierz-Rudunki II to 57.7%. The increase in NAP is chiefly dependent upon *Gramineae*, *Artemisia* and *Cyperaceae* but it concerns also other herbaceous taxa, mainly heliophytes. The values of *Salix*, *Juniperus* and *Betula nana* also increase, where they have been identified. At Zgierz-Rudunki II and at other sites in middle and north-eastern Poland a distinct fall in *Pinus* values appears at the level of the boundary. At Imbramowice the proportion of *Pinus sylvestris*

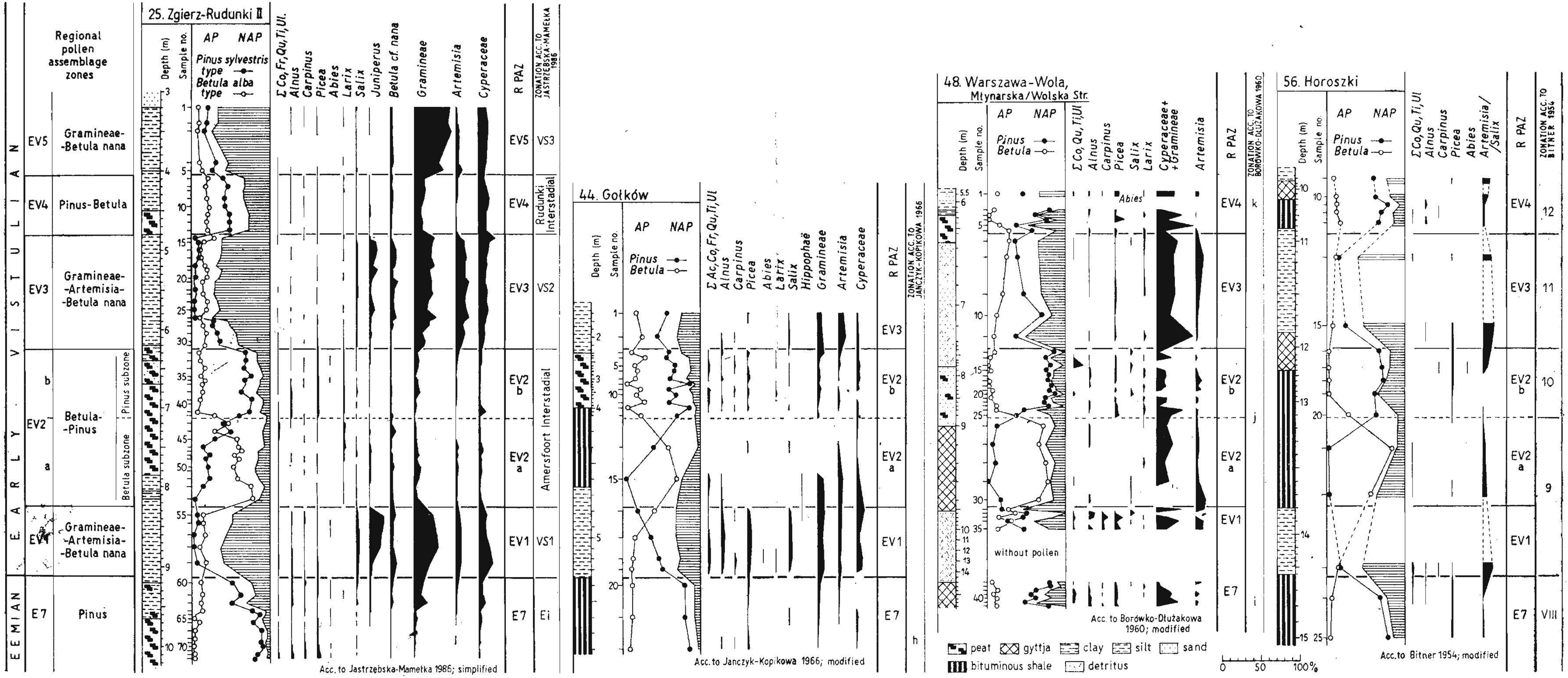


Fig. 35. The top sections of four pollen diagrams from Middle Poland (simplified), showing the basis for marking the Eemian/Early Vistulian boundary, the correlation of the pollen ass. zones of the Early Vistulian and the chronostratigraphy proposed. In the diagrams from Gołków, Warszawa-Wola and Horoszki the depth scale is changeable, adjusted to the thickness of the pollen zones distinguished at the type locality Zgierz-Rudunki II. Lithology somewhat simplified. Site numbers as in Figs. 11 and 12. Abbreviations: Ac — *Acer*, Co — *Corylus*, Fr — *Fraxinus*, Qu — *Quercus*, Ti — *Tilia*, Ul — Ulmus

type pollen decreases slightly and only temporarily, whereas we are concerned here with a definitive fall in pollen values of all thermophilous deciduous trees including *Corylus* and also of *Taxus*, *Abies* and *Picea*. In many profiles a change to more minerogenic sediments is observed. At Dzbanki Kościuszkowskie [12] and Otapy II [57], the upper boundary has been conventionally based on the occurrence of *Betula nana* macrofossils, as there is no possibility to fix it on the basis of NAP.

Other occurrences. Apart from the type localities the *Pinus* zone or its part occurs at 54 sites (see Fig. 12). At Gołków [44] the lower boundary is lacking because the samples were taken far apart. More than ten sites have this zone distinct and almost complete but it lacks its upper boundary (cf. Fig. 12). At Kalisz [11], Warszawa-Żoliborz [50], Rusinów [70], Elbląg [91] and Elbląg-Bażantarnia [92], zone E7 may include also a fragment of the Early Vistulian, but this cannot be stated reliably because of the lack of NAP.

In pollen diagrams from Wołów I/72 [6], Skaratki [29], Żyrardów 4/69 [35] and Nakło [78] the upper boundary of the zone has not been established, although the authors of the original division marked it (see p. 131). Without the upper boundary the *Pinus* zone has also been left at some sites containing the so-called "second climatic optimum", namely Konopki Leśne [59], Klewinowo [64] and Szwajcaria [97].

Of the sites studied on the basis of random samples, Faustynów 50/18a [15], Piaski Stare [28], Przyłubie 65/XIII [79], Nowiny [90], Elbląg-Bażantarnia [92] and Nidzica [96] show this zone most completely developed. In profiles from 16 sites the zone E7 is represented by one or two samples or by its very beginning (Fig. 12).

Extent. The zone extent agrees with the area of occurrences of the Eemian sites, excluding Dąbrówka [3] and Karczunek [55] in which the pollen zone sequences end earlier (cf. Fig. 11). It seems that this zone may be regionally divided into a south-western part with the strongly marked presence of *Abies* (Fig. 32), higher pollen values of thermophilous trees (cf. Fig. 34) and higher percentages of *Betula*, and a west-north-eastern part, lacking in these characteristics. The highest values of *Betula*, exceeding 30%, are reported from Wołów [6] — 49.7%, Kalisz I [11] — 35.0%, Aleksandrów 57/19 [16] — 54.1%, Bedlno [18] — 39.2%, Sławno III [19] — 65.1%, Skaratki [29] — 32.3% and Góra Kalwaria [42] — 63.6%.

Remarks. 1. The higher values of NAP, exceeding 30%, occur in the *Pinus* zone mainly in connection with hydrological changes and a particular type of sediment, and they probably express the over-representation of pollen originating from local vegetation. Zagwijn (1961) drew attention to such situations, recommending individual interpretation of NAP percentages in the Late Eemian. The connection of high NAP values with the over-representation of *Cyperaceae* pollen (in this section of the interglacial) has been pointed out on the basis of the macrofossil analysis at Imbramowice (see p. 82). It seems that the extremely high values of NAP at Grudziądz-Mniszek [82] — 63.0% — were induced by similar factors, as is evidenced by the proportion of *Cyperaceae* pollen (57.9%) and the change of deposits, from sandy silt to peaty silt, probably due to the quieter inflow of water and the development of swamp communities. In the profiles from Szwajcaria [97] an over-representation of *Cyperaceae* pollen is suggested by the abundance of nutlets of *Carex* sp. div. (Borówko-Dłużakowa 1975b). Interpretation of the other profiles with relatively high NAP values is difficult, chiefly because of the lack of a sufficiently detailed analysis of the sediment. Nevertheless, the transient and short-lived nature of these changes and the lack

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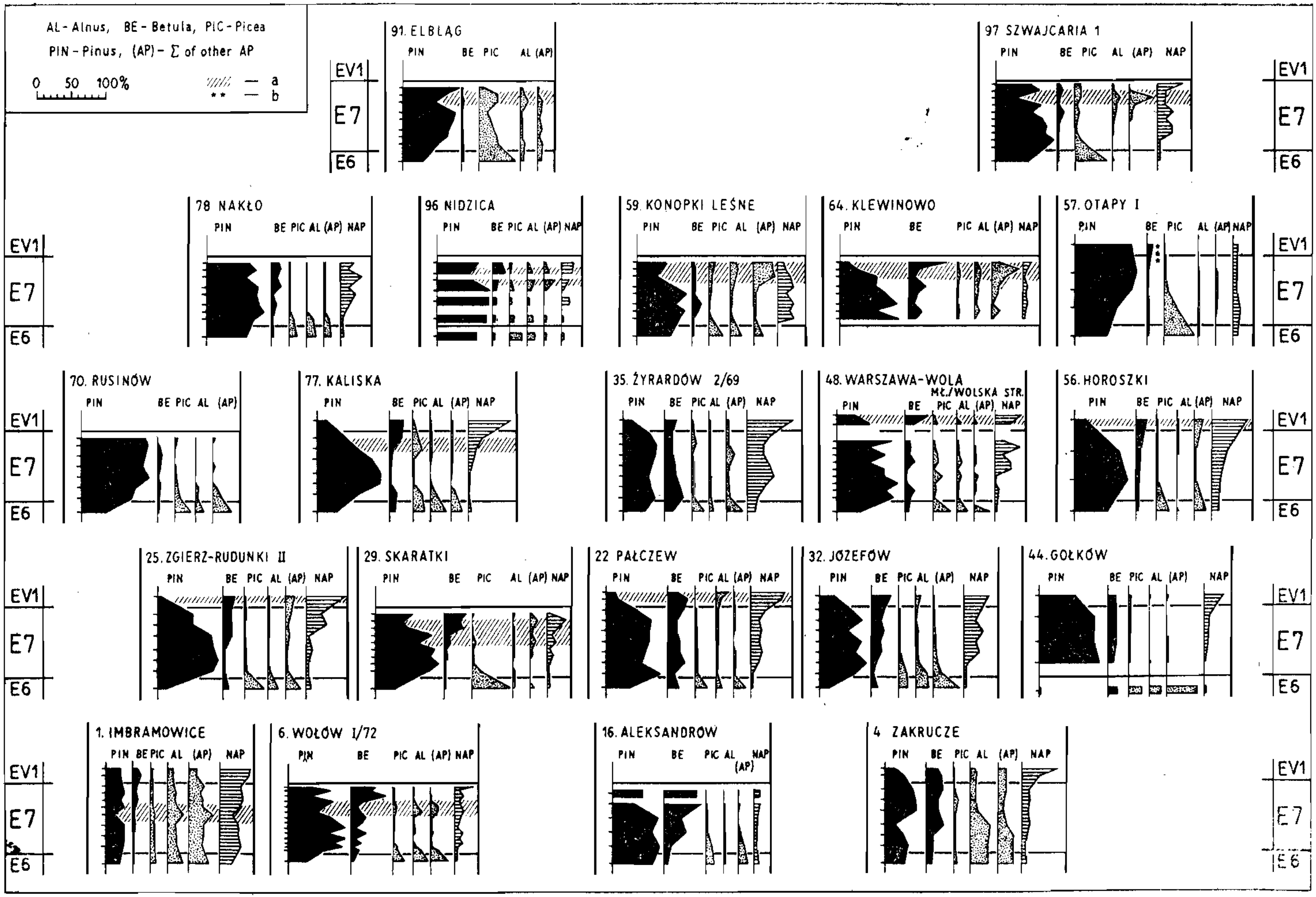
Fig. 34. Simplified curves for *Pinus*, *Betula*, *Picea*, *Alnus*, remaining AP and NAP in the E7 — *Pinus* R PAZ in selected pollen diagrams. The characteristics of the zone and the basis for marking the Eemian/Early Vistulian boundary are shown: a — sections with the redeposited pollen of thermophilous trees, b — macrofossils of *Betula nana* assumed as basis for marking the boundary. The arrangement of sites agrees with their approximate geographical position. Site numbers as in Figs. 11 and 12


AL - Alnus, BE - Betula, PIC - Picea
PIN - Pinus, (AP) - Σ of other AP
0 50 100%
a
b
91. ELBLĄG
97 SZWAJCARIA 1
78 NAKŁO
96 NIDZICA
59. KONOPKI LEŚNE
64. KLEWINOWO
57. OTAPY I
70. RUSINÓW
77. KALISKA
35. ŻYRARDÓW 2/69
48. WARSZAWA-WOLA MŁ./WOLSKA STR.
56. HOROSZKI
25. ZGIERZ-RUDUNKI II
29. SKARATKI
22 PAŁCZEW
32. JÓZEFÓW
44. GOŁKÓW
1. IMBRAMOWICE
6. WOŁÓW I/72
16. ALEKSANDRÓW
4 ZAKRUCZE
PIN
BE
PIC
AL
(AP)
NAP
EV1
E7
E6

of other characteristic features of the openness of the landscape at that time would indicate that the reasons for these culminations are mostly local (cf. also p. 153).

2. Three top samples (depth: 3.0—4.0 m) in the profile from Faustynów 50/18a [15] (Janczyk-Kopikowa 1971) have not been taken into consideration in the stratigraphical scheme. The large gap between those samples and the Eemian sequence (1.25 m of unanalysed peat and silt) undermines the basis for referring them to zone E*i* (= E7 — *Pinus*). It is not unlikely that they belonged to the Early Vistulian.

3. Previous divisions applied to the sections recognized as *Pinus* R PAZ are discussed in the next chapter.

UPPER BOUNDARY OF THE EEMIAN INTERGLACIAL

The upper boundary of E7 — *Pinus* R PAZ constitutes also the Eemian — Early Vistulian boundary (cf. p. 127). It was placed at such a rise in pollen values of herbs that it indicates a decline of closed forests and the formation of open subarctic communities, with a fairly high proportion and diversified composition of heliophytes. The change of deposits around the boundary into more minerogenic ones (cf. Fig. 12) points to an increase in the intensity of erosional processes connected with the increasing openness of the landscape and uncovering of soils.

The foregoing criteria agree with those applied by Andersen and Zagwijn in the re-interpretation of Jessen's stratigraphical scheme (Andersen 1957, 1961; Andersen et al. 1960; Zagwijn 1961). Basing himself on the re-analysed profiles from Jessen's sites (Jessen & Milthers 1928) and taking into consideration the NAP, Andersen interpreted zone *i* anew, including its part with rapidly rising proportions of herbs, especially *Ericales*, and also *Betula nana* and *Juniperus*, in the Early Vistulian (Andersen 1957, 1961). He recognized the section representing pine forests with birch, spruce and an admixture of thermophilous trees (top part of *h*) as the decline of the interglacial. In his later work, having applied the division into regional pollen assemblage zones, he defined this section as E7 — *Pinus* R PAZ (Andersen 1975).

Zagwijn (1961) applied similar criteria for establishing the upper boundary for the Eemian Interglacial in Dutch profiles and somewhat later the same criteria were used for this boundary in German diagrams (Averdieck 1967b; Menke 1967, 1970, 1975; Müller 1974; Averdieck et al. 1976; Erd 1973).

In Jessen's scheme, so far used in Poland, zone *i* is not separated uniformly. In some diagrams the sections designated with this symbol embrace only the pine zone (e.g. Sobolewska 1961; Niklewski 1968), in others the pine zone and a part of the Early Vistulian (e.g. Sobolewska 1966) and in still other diagrams zone *i* was removed from Jessen's scheme and zone *h* divided into an older — pine-spruce-part and a younger — pine-part (cf. Mamakowa 1976; Noryśkiewicz 1978). Środoń (1967a) postulated the maintenance of zone *i* in the interglacial and at the same time the adoption of criteria for the determination of the upper boundary after Andersen (1961).

The problem of the upper boundary of the Eemian in Polish diagrams was, in addition, complicated by the introduction of phase *j* into Jessen's scheme (Środoń & Gołąbowa 1956), which, as it was stated by these authors, does not exist in this scheme. It was defined by Środoń and Gołąbowa as a zone of forest vegetation at the transition to tundra i.e. as a cool section towards the close of the interglacial. Later, sections with features of the so-called "second climatic optimum" were mostly designated as phase *j* (Borówko-Dłużakowa & Halicki 1957;

Janczyk-Kopikowa 1964, 1965a; Marciniak & Kowalski 1978) and sometimes correlated with the Amersfoort Interstadial (Janczyk-Kopikowa 1965a). The scheme including phase *j* as the last phase of the interglacial was accepted by Mojski in his stratigraphical interpretations, but he regarded the sections defined as *j* by palaeobotanists as the Józefów interphase within the first stadial of the Vistulian (Mojski 1980, 1984a, b, 1985).

The criteria for establishing the Eemian/Early Vistulian boundary applied in the present work have led to changes in the divisions of the pollen diagrams from many sites. In this connection, zones *h*, *i* and *j* have different relations to the boundary (cf. Fig. 12). In some diagrams the upper boundary of the interglacial has been set up, although the author of the first publication did not define it (e.g. Pałczew [22], Gołków [44]). The reinterpreted zones of the so-called "second climatic optimum", distinguished as phase *j* or, *l*, *m*, found themselves at the decline of zone E7 — *Pinus* (see p. 152). In the profiles from Nakło [78], Skaratki [29], Wołów [6] and Żyrardów [35] the Interglacial/Early Vistulian boundary proposed by the respective authors has not been accepted, a decision which calls for some justification:

a) The distinction of zone W1 at Nakło as the first stadial of the Vistulian was based, according to Noryśkiewicz (1978), on the rise in NAP values (20—25% with single peak of 31.5%) and the relatively great diversity of herbs. The fact that it is chiefly *Cyperaceae* that contribute to the rise of NAP, while the *Artemisia* values constituting the main feature differentiating the first stadial, are low here, argue against that division. Compared with other sites, especially with the profile from Zgierz-Rudunki II [25], this section of the diagram presents a typical picture of the decline of the interglacial (cf. Fig. 34) with a growing proportion of NAP but indicative only of an inconsiderable thinning of forest. These changes did not reach, however, the level that forms a basis for establishing the lower boundary of the Early Vistulian.

b) The top part of the profile from Skaratki was referred to the Würm (Chmielewski 1961). Basing himself on changes observed in the deposits, Chmielewski distinguished — at the top of the profile — two cold oscillations separated by a warm spell. According to the present scheme it has been acknowledged that the whole top section of the pollen diagram from Skaratki represents only zone E7 — *Pinus*. This is decided by the low values of NAP with only one peak of 25.8% and the very small variety of herb taxa. A comparison of this section with the diagram from Zgierz-Rudunki II [25] shows a close similarity of the top part of the diagram from Skaratki to subzone ZRII-9b, representing the decline of the *Pinus* zone at Zgierz-Rudunki II (see also Fig. 34).

c) Out of the three profiles from Wołów (Kuszell 1980), only profile I/72 from the marginal part of the lake has a thicker series of deposits representing a cool section with a high proportion of *Pinus* and *Betula* pollen. Kuszell referred this series to the declining part of the interglacial (h_3) and the Early Vistulian, in which she distinguished two cold oscillations (W1 and W3), separated by an interstadial warming (W2) correlated by her with the Amersfoort Interstadial. In the stratigraphical scheme in the present work the whole sequence has been included in zone E7 — *Pinus* (cf. Figs. 12 and 34). This decision is based on the slight proportion of NAP in Kuszell's zone W1 (13.2%), which does not justify the positioning of the interglacial/glacial boundary. As a matter of fact, zone W2, recognized by Kuszell as a warming up, represents rather the beginning of a climatic worsening (the rise of NAP above 15% and the start of the continuous *Artemisia curve*) and hydrological changes signalled in the upper part by sandy clay (3.6—3.9 m). Hydrological disturbances were responsible here for the redeposition of older sediments, chiefly from the *Picea-Abies-Alnus* zone, with a whole set of indicator taxa of an interglacial climatic optimum (*Ilex*, *Hedera*, *Viscum*). The high values of *Artemisia* in the top section (W3) with a maximum of 5.8% may give rise to a dispute whether or not this part of the profile, despite its relatively low NAP values (28.3%) may possibly be connected with the very beginning of the first Vistulian stadial.

d) The modification of the division in the profiles from Żyrardów (Krupiński 1978) concerns the basic criteria for setting up the upper boundary of the Eemian Interglacial and the nature of the first Vistulian stadial and interstadial. The Eemian/Early Vistulian boundary, placed by Krupiński between phytophases *h* and *i* (= EWIa acc. to Zagwijn 1961), is based on the fall in *Picea* and *Abies* pollen values and the rise of *Pinus* (to 46.4% in profile 2/69 and 62.5% in profile 4/69) and the somewhat lower rise of *Betula*. The NAP values being quite low at the level of the boundary and in the "first stadial" distinguished on such a basis (15.9% in profile 2/69 and 13.4—18.8% in profile 4/69). These characteristics interfere with both the criteria adopted by Zagwijn (1961) and Andersen (1961) for the determination of the Eemian/Early Vistulian boundary and those adopted in the stratigraphical scheme in the present work. On the other hand, they are characteristic of the lower boundary of the pine zone towards the close of the interglacial and in this connection, the Eemian/Early Vistulian boundary according to Krupiński has been recognized — in the present scheme — as the lower boundary of E7 — *Pinus* R PAZ. The sections distinguished by Krupiński (1978) as phytophases *i* (= EWIa) and *j* (= EWIb, EWII) correlated by him with the Amersfoort Interstadial have been included in the zone E7 — *Pinus*. In the older part of this section (= phytophase *j*) the NAP values rise transiently (to 39.3% in profile 2/69 and 37.5% in profile 4/69) and the *Pinus* and *Betula* values decrease; *Pinus* rising again in the younger part (to 49.9% in profile 2/69 and 65.1% in profile 4/69). This oscillation in fact is a response to the worsening of the climate, mainly its humidity, as reflected by the increased sand content in the deposits (Fig. 12) and the development of reedswamp communities. The changes caused by it only slightly distorted the characteristic picture of the *Pinus* zone towards the close of the interglacial (high pine values, continuity of the *Picea* and *Alnus* curves uninterrupted from the *Picea-Abies-Alnus* zone; cf. Fig. 34 and Krupiński 1978, Fig. 5). The parallel increase in NAP and pollen representing reedswamp communities permits the inference that the rise of *Cyperaceae* and *Gramineae* within this oscillation was partly dependent upon a local source of pollen (cf. Mamakowa 1986). In such a reinterpretation the level of the NAP increase to above 67% in the top part of profile 2/69, corresponding to Krupiński's (1978) *j*/*k* (= EWIII) boundary, has been acknowledged in the present scheme to be the upper boundary of the E7 — *Pinus* R PAZ and, at the same time, of the interglacial.

REGIONAL POLLEN ASSEMBLAGE ZONES IN THE EARLY VISTULIAN

EV1 — *Gramineae-Artemisia-Betula nana* R PAZ

Type locality and section. Zgierz-Rudunki II [25]; acc. to Jastrzębska-Mamełka (1985), local zone ZRII-10 (Fig. 35).

Description. The proportion of herb pollen is distinctive in this zone. At the type locality it attains 63.4%. Out of the remaining sites, eleven have NAP values above 50%, whereas at Domasłów, profile 1 [8] (K. Tobolski, pers. comm.), Bedlno [18], Józefów B [32] and Nidzica-Sewerynów [95] they range between 40 and 50% and at Góra Kalwaria [42], Gołków [44] and Warszawa-Wawrzyszew V [49] between 30 and 40%. The high NAP values are mainly conditioned by *Gramineae*, *Cyperaceae* and *Artemisia*. The maximum values of *Artemisia*, the distinctive taxon of zone EV1, are fairly high. At the type locality they reach 7.2% and in most of the other sites they are similar or considerably higher (13.7% at Bedlno, 15.3% at Nidzica-Sewerynów, 21.7% at Piaski Stare [28] and 32.6% at Pałczew [22]). The values of other herbaceous taxa also increase, at Zgierz-Rudunki II they are *Chenopodiaceae*, *Compositae*, *Umbelliferae*, *Cruciferae*, *Rubiaceae*, *Rumex acetosa* type, *R. acetosella* type, *Thalictrum* and at Imbramowice [1], where the variety of taxa is very great, also *Rosaceae*, *Caryophyllaceae*, *Filipendula*, *Plantago maritima* s. str. and *P. maritima* s. l. In the pollen diagrams from the sites recently studied there is, in addition, a fairly great variety of indicator taxa of various types of open communities. Those noted more frequently are *Hippophaë*, *Ephedra distachya* type, *E. fragilis* type, *Helianthemum*, *Armeria*, *Polygonum bistorta/P. viviparum*, *Polemonium*, *Plantago major*, *Dianthus* type and at Imbramowice also *Sanguisorba officinalis* 2n = 28, *Saxifraga oppositifolia* type, *Polygonum aviculare* type, *Pleurospermum austriacum*, cf. *Koenigia islandica*, *Allium vineale* type, *Jasione*, *Gypsophila fastigiata* type, *Scleranthus perennis* and others (cf. Fig. 3). The rise of NAP at the type locality is also accompanied by the increasing pollen values of *Juniperus* (to 19.4%), *Betula nana* (to 7.5%) and *Salix* (to 3.4%). The presence of *Betula nana* in this zone is shown in Fig. 14. In some profiles *Larix* pollen appears.

Contacts. The lower boundary of the EV1 — *Gramineae-Artemisia-Betula nana* zone coincides with the upper boundary of the E7 — *Pinus* zone. At the type locality upper boundary is placed at the fall of NAP from 48.5 to 14.4%, the fall of shrub values and the steep rise of *Betula alba* type to 78.1%; in other profiles the values of *Betula* increase to about 60%.

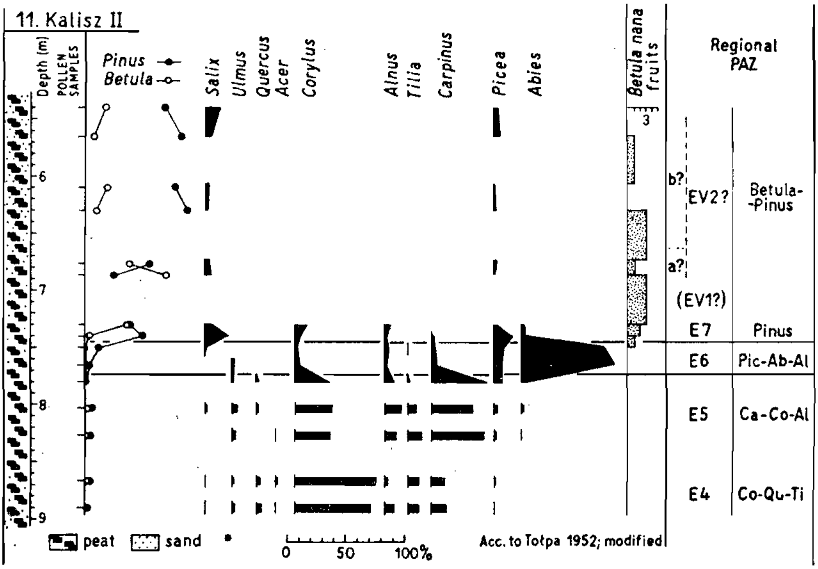


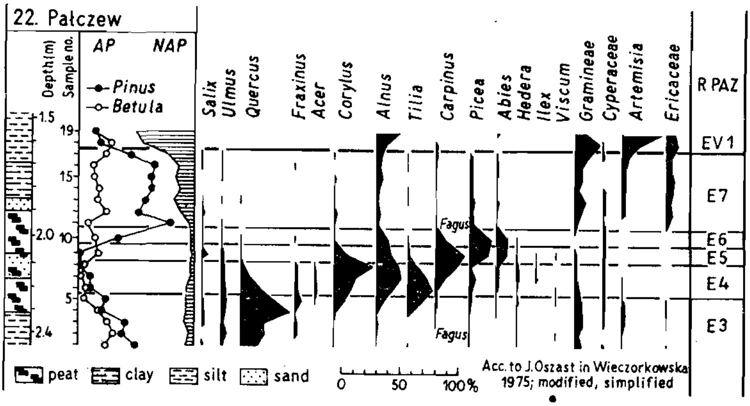
Fig. 36. Pollen diagram from Kalisz, profile II. The possibility of a stratigraphic division of the top section is shown despite the lack of NAP. It is based on the presence of *Betula nana* macrofossils. Percentage calculated from the AP sum. Site number as in Figs. 11 and 12

Other occurrences. Apart from the type locality, the EV1 — *Gramineae-Artemisia-Betula nana* zone or part of it occurs at 19 sites (see Fig. 12). Moreover, the top sediments of the profiles from Dzbanki Kościuszkowskie 1929 [12] and Otapy I and II [57] have been referred to this zone exclusively on the basis of the presence of *Betula nana* macrofossils. Besides the type locality the zone with both boundaries is present in the profiles from five sites (Fig. 12) but the upper boundary at Bedlno [18] is not quite certain. Relatively thick sections unbounded from above occur at Imbramowice [1], Sławno [19], Żyrardów 2/69 [35], Góra Kalwaria [42] and Warszawa-Wawrzyszew V [49]. The pollen spectra occurring above the pollen-free layers of sands at Bobrówka Valley [30] and Warszawa-Wola, Młyn./Wolska Str. [48] as well as the random samples from Raki [7], Świątniki [21], Piaski Stare [28] and Nidzica-Sewerynów [95] have been assigned to this zone, without establishing the lower boundary. Furthermore, the layers of pollen-free sands overlying the Eemian deposits at the Bobrówka Valley [30], Warszawa-Wola [48], Warszawa-Żoliborz [50] and Grudziądz-Mniszek [82] and perhaps also the peat layer with an admixture of sand at a depth of 688—730 cm in the profile from Kalisz II [11] (Fig. 36), palynologically uninvestigated, but containing fruits of *Betula nana*, are associated with this zone. In addition to the occurrences included in the stratigraphical table (Fig. 12), the first stadial of the Early Vistulian is reported from Domasłów, profile 1 [8], Władysławów [76], Kalinko [23], Komorów [45] and Łomża [62].

Extent. Imbramowice [1] and Raki [7] in the south-west, Nidzica-Sewerynów [95] in the north and Horoszki [56] and Otapy [57] in the east mark the range of this zone in the territory of Poland (cf. Fig. 11). A zone of similar stratigraphical significance is known from many West-European sites.

Remarks. 1. Macrofossils of *Betula nana* have been found in this zone at Imbramowice [1], Dzbanki Kościuszkowskie [12], Zgierz-Rudunki II [25] and Otapy [57] (cf. Fig. 14) and also in the profile from Kalisz II [11] (Fig. 36).

2. The diagram from Pałczew [22], published by Wieczorkowska (1975), does not contain the top part, representing zone EV1. The data concerning this section are derived from Dr. hab. J. Oszast's materials, deposited in the Archives of the Department of Paleobotany, W. Szafer Institute of Botany,



Acc. to J. Oszast in Wieczorkowska 1975; modified, simplified

Fig. 37. Pollen diagram from Pałczew (profile from the northern wall). Compared with the version published (Wieczorkowska 1975), it is supplemented with J. Oszast's (1972) unpublished materials, which make it possible to establish the Eemian/Early Vistulian boundary. It exemplifies a very strong compaction of deposits. Site number as in Figs. 11 and 12

PAScs in Cracow. A simplified pollen diagram of the supplemented upper part of the profile is given in Fig. 37.

3. In the profile from the Bobrówka Valley [30] the zone now equated with EV1 was regarded as the younger part of the Amersfoort (Klajnert & Piechocki 1972), which must be rejected in view of the too high values of NAP (above 50%) in comparison with subzone EV2b at Zgierz-Rudunki II [25] (cf. Fig. 35). One spectrum from a peaty silt lamina inserted at a depth of 9.80 m between pollen-free sands has not been taken into consideration in the present stratigraphical scheme. The assignment of this sample to the Brørup Interstadial by the authors is unjustified, for the spectrum contains 50% NAP and originates from a cold section, but its stratigraphic position is difficult to determine.

EV2 — *Betula-Pinus* R PAZ

Type locality and section. Zgierz-Rudunki II [25]; acc. to Jastrzębska-Mamełka (1985), local zones ZRII-11 and ZRII-12 (Fig. 35).

Description. *Betula* and *Pinus* are characteristic taxa of the zone and their pollen occurs in the largest amounts. *Betula* has maximum values in the lower part of the zone, and *Pinus* in the upper. The values of herb pollen are low. *Salix*, *Juniperus* and *Betula* cf. *nana* have considerably lower values than in zone EV1. The curve for *Larix* is continuous throughout the zone. At other sites this zone is similarly developed. It occurs within organic deposits.

Contacts. The lower boundary of the EV2 — *Betula-Pinus* zone coincides with the upper boundary of the EV1 — *Gramineae-Artemisia-Betula nana* zone (see p. 133). The upper boundary is marked by the sharp fall in the *Pinus* values and the rise in NAP from 15.5 to 40.0% at the boundary level at the type locality.

Subdivisions. The zone is divided into two subzones, a lower — *Betula* subzone and an upper — *Pinus* subzone.

Betula subzone (EV2a). At the type locality *Betula alba* type culminates (78%) at the beginning of the subzone, next its values decrease somewhat and there is a slight rise in NAP (to 18.4%) and *Betula* cf. *nana* (to 5.2%). At other sites the maximum values of *Betula* range from 65 to 85%. The upper boundary of the subzone is marked by the fall in *Betula* values and the rise of *Pinus*.

Pinus subzone (EV2b). At the type locality the *Pinus sylvestris* type curve ascends steeply and reaches 76.7%. The values of *Betula alba* type and NAP do not exceed 17% and those of *Betula* cf. *nana* — 3%. The values of *Larix* approach 3%, *Picea* 1.8% and *Alnus* are below 1%. In the pollen diagrams from other sites *Pinus* values range from 65 to 95% and those of NAP do not exceed 20% except for short oscillations at Horoszki [56] and Warszawa-Wola [48] and the values observed in single samples ascribed to this subzone. *Picea* values are between 2 and 5%, *Alnus* reaches 5.7% and *Corylus* occurs rather regularly but its values are low except at Warszawa-Wola — 12.5%.

Other occurrences. In addition to the type locality, the *Betula-Pinus* zone or its part occurs at 14 sites (see Fig. 12). The complete zone or its part but with diagnostic characteristics of both subzones is present at Józefów B [32], Gołków [44], Warszawa-Wola, Młyn./Wolska Str. [48], Horoszki [56] and Krzepczów [20] and, out of the sites with random samples, at Świątniki [21] and Raki [7]. In the diagram from Kalisz II [11] zone EV2 was delimited on the basis of the culminations of *Betula* and *Pinus*, following each other in the top part of the profile, above the 42-cm-thick layer of peat with sand, referred with reservations to the EV1 — *Gramineae-Artemisia-Betula nana* zone (see p. 134 and Fig. 36). Single samples from Piaski Stare [28], Warszawa-Żoliborz [50], Grudziądz-Mniszek [82] and Nidzica-Sewerynów [95] have been assigned to one of the subzones in accordance with their diagnostic characteristics. The numbering of single samples from Bedlno [18] (depth: 6.5—7.0 m) in this zone should be treated with much reserve.

Extent. The sites in which the EV2 — *Betula-Pinus* zone is well developed are grouped in middle Poland, from the Łódź Upland to the eastern edge of the South-Podlasie Lowland. Its maximum south-western range is reliably indicated by Raki [7], the locality based on random samples, while the north and south ranges are less reliably marked by single samples from Grudziądz-Mniszek [82], Nidzica-Sewerynów [95] and Bedlno [18] (cf. Fig. 11).

Remarks. 1. The pollen zone with characteristics of the *Betula-Pinus* R PAZ was first found at Horoszki [56] and interpreted as a "period of milder climate within the youngest glacial" (Bitner 1954) and correlated by Andersen (1961) with the Amersfoort Interstadial.

2. Macrofossils of tree-birches and common pine confirming the presence of these trees in the *Betula-Pinus* zone were found in the profiles at Kalisz II [11], Gołków [44], Warszawa-Wola [48] and Zgierz-Rudunki II [25]. Remains of *Larix* were also present at the last of these sites. Very many wood fragments of *Picea* vel *Larix* were noted at Kalisz II.

3. In the profile from Kaliska [77], the high values of *Betula* pollen above the cold oscillation referred — in the present scheme — to the first stadial (EV1) suggest, as in other sites, the beginning of the EV2 — *Betula-Pinus* zone. In this case, however, Janczyk-Kopikowa (1964, 1965a) identified *Betula* pollen, on the basis of measurements, chiefly as *Betula nana* (sample from a depth of 15.45 m). This is striking in view of the complete lack of macrofossils of *B. nana* in the deposit, a species that, in view of the great abundance of its pollen, should have occurred *in situ*.

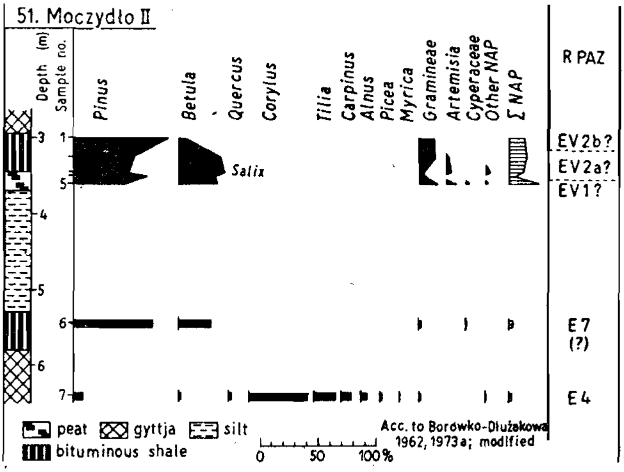


Fig. 38. Pollen diagram from Moczydło, profile II, showing the possible correlation of the top section of deposits. Percentages calculated from the AP+NAP sum. Site number as in Figs. 11 and 12

4. Five top samples from Moczydło [51] (Fig. 38) have not been included in the present stratigraphical scheme. The assignment of this profile to the Eemian (Borówko-Dłużakowa 1973a) is based on one diagnostic pollen sample (from a depth of 6.40 m), representing zone E4. The sample from a depth of 5.45 m probably represents E7 — *Pinus* zone. It seems, however, hardly probable that the samples from peat and bituminous shales at a depth of 3.0—3.6 m should also belong to zone E7. The relatively high NAP values (25.1%, in which *Artemisia* 7.5%) in the sample from a depth of 3.6 m suggest its possible reference to the decline of EV1 and the overlying samples to EV2a and EV2b. The mineral nature of the unanalysed deposits from a depth of 3.7—5.3 m may imply its relationship with the decline of the interglacial and the first stadial of the Early Vistulian. A lithological description of the profile from Moczydło (Mojski 1962) permits us to suppose that this locality may have provided a fairly long early-Vistulian series, for the shales are overlain by a 2-metre-thick layer of gyttja and gyttja silt.

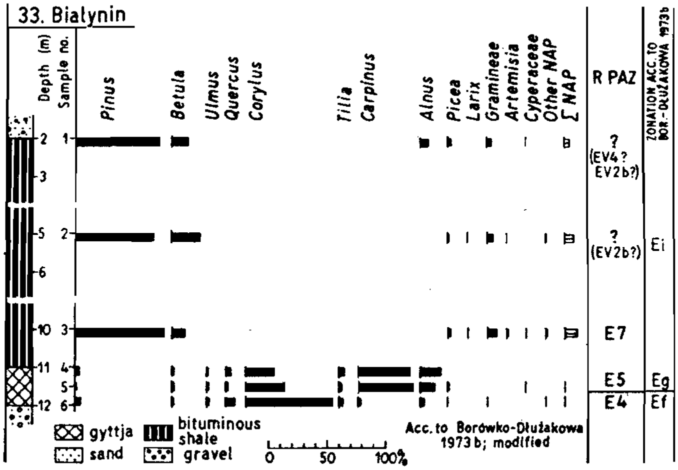


Fig. 39. Pollen diagram from Białynin, showing the possible correlation of the top section of deposits Percentages calculated from the AP+NAP sum. Site number as in Figs. 11 and 12

5. In the profile from Białynin [33] the samples linked to zones E4 and E5, which form a reliable basis for the determination of the Eemian age of this profile, are topped by a 9-metre-thick layer of bituminous shales. Only three samples of this layer (Fig. 39), referred to zone E*i* (Borówko-Dłużakowa 1973b), have been examined. The lower sample certainly represents zone E7, but the correlation of the two upper samples, taken at intervals of 3 and 5 m, to the same zone may be called in question. It seems probable that they correspond to the interstadial oscillations of the Early Vistulian, or at least to one of them. They have not been included in the present stratigraphical scheme, because the correctness of this supposition cannot be evaluated without additional studies, which this profile undoubtedly deserves.

EV3 — *Gramineae-Artemisia-Betula nana* R PAZ

Type locality and section. Zgierz-Rudunki II [25]; acc. to Jastrzębska-Mamełka (1985), local zone ZRII-13a, b (Fig. 35).

Description. The zone is characterized by the same features that served as the basis for the distinction of zone EV1 and so it was given the same name. At the type locality the NAP values reach 73.6%, at the other sites 30 to 62%. *Gramineae* and *Artemisia* are characteristic taxa of this zone. At Zgierz-Rudunki II *Artemisia* has higher values then in zone EV1, with a maximum of 17.3%. A number of other taxa also have somewhat higher values, e.g. *Helianthemum*, *Rumex acetosa* type, *R. acetosella* type and *Chenopodiaceae*. The variety of herbaceous taxa increases as well, several of them appear for the first time. The values of *Gramineae* and *Cyperaceae* resemble those in EV1. *Salix*, *Juniperus* and — characteristic of the zone — *Betula* cf. *nana* (Fig. 14), occur in abundance, but *Juniperus* has lower values than in zone EV1 (cf. Fig. 35). Both in the profile from the type locality and in the remaining profiles having this zone, the deposits change into minerogenic ones (cf. Figs. 35 and 12). This change takes place somewhat earlier at Warszawa-Wola [48]. The high values of NAP and the change of deposits indicate a successive opening of the landscape.

Contacts. The lower boundary of the EV3 — *Gramineae-Artemisia-Betula nana* zone coincides with the upper boundary of the EV2 — *Betula-Pinus* zone (see p. 135).

The upper boundary is marked by the fall of herb pollen values, at the type locality to 26.5% and to similar levels in the remaining sites, and the rise in *Pinus* values, which in pollen diagrams from the type locality and Warszawa-Wola is preceded by a small increase in *Betula* within the boundary range.

Other occurrences. Apart from the type locality this zone was distinguished earlier in the profiles from Horoszki [56], Gołków [44] Warszawa-Wola [48] and Krzepczów [20] (Mamakowa 1979). Recently, it has been recognized by one sample from Świątniki II [21] (Jastrzębska-Mamełka 1984).

Extent. On the basis of the data so far obtained the extent of the EV3 — *Gramineae-Artemisia-Betula nana* zone embraces middle Poland, from the Łódź Upland to the eastern edge of the South-Podlasie Lowland.

Remark. The presence of *Betula nana* is confirmed by macrofossils occurring in the profile from Zgierz-Rudunki II [25] and most abundant in this zone. The nutlets of *B. pubescens* and *B. alba* type at Zgierz-Rudunki II and the seeds of *Pinus* sp. at Gołków [44] prove the still continuous presence of trees in middle Poland during this zone.

EV4 — *Pinus-Betula* R PAZ

Type locality and section. Zgierz-Rudunki II [25]; acc. to Jastrzębska-Mamełka (1985), zone ZRII-14 (local Rudunki Interstadial) (Fig. 35).

Description. This zone, fully developed only in the profile from Zgierz-Rudunki II, is characterized by high values of *Pinus sylvestris* type, with a maximum of 48.5%, and relatively high values of *Betula alba* type, to 22.5%. *Larix* has values below 1%, but is noted all through the zone. The NAP values are relatively low (to 33.8%), which is chiefly conditioned by the fall in *Gramineae* and *Artemisia* pollen values. The percentages of other important herbaceous taxa in zone EV3 also decrease. The *Juniperus* and *Salix* curves are low throughout the zone and those of *Betula* cf. *nana* are lower than in EV3 but keep within the range 1.7—3.5%. Deposits become more organic in this zone (cf. Fig. 12).

Contacts. The lower boundary of the EV4 — *Pinus-Betula* zone coincides with the upper boundary of the EV3 — *Gramineae-Artemisia-Betula nana* zone (see above). The upper boundary lies where the values of *Pinus* and *Betula* pollen fall and the NAP values rise above 50%, which is chiefly due to the rise of *Gramineae* and the slight rise of *Artemisia*.

Other occurrences. This zone, first found at Horoszki [56] (Fig. 35), was interpreted by Bitner (1954) as a "period of milder climate during the glacial". Warszawa-Wola [48] is another locality in which it is present fragmentarily. These sites were reported at the Symposium on Vistulian Stratigraphy (Mamakowa 1979) as the only ones with two warm oscillations of an interstadial nature in the Early Vistulian.

Extent. As for zone EV3.

Remarks. 1. The macrofossils from Zgierz-Rudunki II [25] give evidence of the presence of *Betula pubescens*, *B. tortuosa*, *B. verrucosa*, *B. humilis* and *Pinus sylvestris* at that time. In the Middle-Polish Lowland the common pine was accompanied by *Pinus montana* (one cone at Warszawa-Wola [48]). Macrofossils of *Betula nana* were still noted.

2. The top sample from a depth of 1.5 m at Piaski Stare [28] was not taken into consideration in the present scheme. It was taken 4 m above the sample referred to zone EV2. It may well be that this sample represents EV4 — *Pinus-Betula* R PAZ and the underlying layer of silt and sand corresponds to a cold oscillation of EV3, but at the present state of study on the profile, this is only a supposition.

EV5 — *Gramineae-Betula nana* R PAZ

Type locality and section. Zgierz-Rudunki II [25]; acc. to Jastrzębska-Mamełka (1985), local zone ZRII-15 (Fig. 35).

Description. The zone is marked by high values of *Gramineae* (32—48%). The proportion of *Artemisia* is considerably lower than in zones EV1 and EV3, with a maximum of 7.5%. The maximum values of *Cyperaceae* are similar to those in zone EV4. The rise in values of other herbs is slight. The pollen values of ***Betula*** cf. *nana* are as in zone EV4. *Armeria* and, of the shrubs, *Ephedra fragilis* type pollen re-appears. The zone occurs within organic silts.

Contacts. The lower boundary of the EV5 — *Gramineae-Betula nana* zone agrees with the upper boundary of the EV4 — *Pinus-Betula* zone (see p. 138). The upper boundary is lacking.

Other occurrences. It may be assumed, with a certain degree of probability, that four samples from Bedlno [18], taken above the layer of pollen-free sand, represent this zone. In these samples herb pollen attains 62—98% and *Gramineae* pollen, with values of 31—86%, is dominant. *Betula nana* leaves and nutlets also occurred in this layer.

Extent. If the correlation given above is correct, these two localities indicate the presence of this zone in middle Poland, with its range from the Łódź Upland to the northern margin of the Little Poland Upland.

CHRONOSTRATIGRAPHY OF THE EARLY VISTULIAN INTERSTADIALS

Out of the five regional pollen assemblage zones distinguished above the upper boundary of the Eemian Interglacial, three represent the vegetation of open areas (EV1, EV3 and EV5) and correspond to the stadials of the Early Vistulian and two reveal forest vegetation (EV2 and EV4) of an interstadial nature. The oscillation distinguished in the present scheme as the EV2 — *Betula-Pinus* R PAZ was correlated with the Amersfoort Interstadial (Dylik 1968; Mamakowa 1979; Kuszell 1980; Jastrzębska-Mamełka 1979, 1984, 1985). The fragment of the second warm oscillation at Horoszki [56] and Warszawa-Wola [48] was then supposed to have been the beginning of the Brørup Interstadial (Mamakowa 1979).

The profile from Zgierz-Rudunki II [25] is the first from the territory of Poland that has the second warm oscillation fully developed and closed by the following cold oscillation (Fig. 35). Jastrzębska-Mamełka (1985) gave that interstadial the local name "Rudunki".

These new data permitted a change in ideas about the chronostratigraphical position of both interstadials (Mamakowa 1986). The first interstadial, represented by the EV2 — *Betula-Pinus* R PAZ, was considered to be contemporaneous with the Danish Brørup and Dutch Amersfoort and Brørup; the other, represented by the EV4 — *Pinus-Betula* R PAZ was recognized as a zone chronostratigraphical with the Odderade Interstadial.

This interpretation is, above all, justified by the nature of the second interstadial in the profile from Zgierz-Rudunki II [25]. It is considerably less well-developed than the first interstadial, EV2, and characterized by the continuous dominance of pine, a considerable proportion of NAP and the scanty occurrence of pollen of other trees, while a small rise in the *Betula* curve takes place only at the level of the EV3/EV4 boundary (Fig. 35). The correlation of this interstadial, so poorly developed, with the Danish Brørup (Andersen 1961), which has a well-developed birch zone (W3) and a pine zone (W4 and W5) with spruce, alder, larch and a small admixture of thermophilous tree pollen and, the more so, with the Dutch Brørup (zone EW IV — Zagwijn 1961), showing particularly high percentages of *Alnus* and *Picea*, seems to be out of the question. On the other hand, it may be readily correlated with the Odderade Interstadial (zone FW VI from Odderade — Averdieck 1967b) and with zones WF IV from Rederstall (Menke 1976b, 1982; Menke & Tynni 1984), W VI from Kittlitz (Erd 1973) and WF IV from Oerel (Behre & Lade 1986), regarded by those authors as the Odderade Interstadial. This being so, the first interstadial (EV2 — *Betula-Pinus* R PAZ) cannot be correlated other than with the Danish Brørup and with the Dutch Amersfoort and Brørup Interstadials both together.

The sequence of changes in the EV2 — *Betula-Pinus* R PAZ is very approximately similar to the sequence in the Danish Brørup. The long and distinct birch subzone, EV2a (cf. Fig. 35), may be correlated with the similarly developed W3 zone at Brørup Hotel Bog, and the pine subzone, EV2b, having a continuous *Larix* curve, somewhat higher values of *Picea* than in EV2a and lower values of *Juniperus* and *Betula nana*, with W4 and W5 at Brørup Hotel Bog. This is more so because the nature of the Danish Brørup has been changed by the re-interpretation of the occurrence of *Frangula alnus* as that of *Bruckenthalia spiculifolia* (Andersen 1973b). It should, however, be stated that in the pollen diagrams from Poland there is no earlier slight warm oscillation of the subzone W2c type within the Danish scheme, defined by Andersen (1961) as the Rodebaek Interstadial.

The EV2 — *Betula-Pinus* R PAZ may also be well correlated with the first early-Vistulian interstadial, regarded as the Brørup from German sites, which has also an older cooler birch section and a younger pine section with an admixture of *Alnus*, *Picea* and some thermophilous trees. In north-western Germany it is represented, among others, by zones A—D at Osterwanna (Behre 1974), FW II at Keller (Menke 1970, 1975), WF II at Rederstall (Menke 1976b; Menke & Tynni 1984) and WF II at Oerel (Behre & Lade 1986) and in the territory of the GDR by zones WII—WIV at Kittlitz (Erd 1973).

The recognition of the German Brørup as a time counterpart of the Amersfoort and Brørup in Dutch sites, suggested by Erd (1973), was supported by the distinction of traces of cooling in some German diagrams, expressed by the rise in NAP values in the upper part of the birch section of the interstadial. This weak cooling may be correlated with the cold oscillation EW III (Zagwijn 1961) in the Dutch diagrams (cf. Menke 1976b; Menke & Tynni 1984; Behre & Lade 1986; Grüger 1979, 1983; Welten 1982; Beaulieu & Reille 1984). A similar cooling is weakly marked at Zgierz-Rudunki II (section represented by samples 47—52, Fig. 35) by the rise in values of NAP, chiefly *Gramineae*, and of *Betula* cf. *nana* pollen, and the transient decrease in the *Betula alba* type curve. It is difficult to find such an oscillation in the pollen diagrams from other Polish sites in view of the lack of detailed studies of the early-Vistulian sections of the profiles. The increase in NAP values at the EV2a/EV2b boundary at Warszawa-Wola [48] and that at the beginning of subzone EV2b at Horoszki [56] (cf. Fig. 35) may be counterparts. The lack of a distinct occurrence of this phenomenon in the Polish diagrams does not deny or weaken the correlation of the EV2 — *Betula-Pinus* R PAZ with Zagwijn's (1961) Amersfoort and Brørup Interstadials, because this correlation is based on a different principle. Besides, the oscillation in question is not always present, which is exemplified by Welten's (1982) subalpine profiles.

The third cold oscillation, EV5 — *Gramineae-Betula nana* R PAZ (= VS3 at the type locality — Fig. 35) is left, as in the previous scheme (Mamakowa 1986), within the Early Vistulian. Recently Behre and Lade (1986) refer the Schalkholz

Stadial, following the Odderade, and the subsequent Keller Interstadial to the Middle Vistulian. Likewise, in his new stratigraphic division (paper presented at Poznań 1986), Grüger included cold zone DA 26 from Samerberg (Grüger 1979) in the Middle Vistulian. On the other hand, Menke (1982) proposed to place the boundary between the Early and the Middle Vistulian above the Keller Interstadial and retained this scheme in his latest work on the Rederstall locality (Menke & Tynni 1984).

Thus the leaving of the EV5 — *Gramineae-Betula nana* R PAZ in the Early Vistulian may be considered controversial.

SITES EXCLUDED FROM THE EEMIAN INTERGLACIAL

The list of Eemian sites in the present work does not include 12 sites which were classified in this category on the basis of the results from pollen analyses. In my view, these results do not justify such a decision. In this assessment I based my decisions on the diagnostic characteristics and the sequence of the distinguishable regional pollen assemblage zones of the Eemian Interglacial and their comparison with the pollen sequences of other stratigraphical units of the Pleistocene.

Out of the sites accepted as representing the Eemian by Środoń (1960, 1972), the following ones have been excluded: Śmielin (Środoń 1954b), Zawichost (Pożaryski 1955, poll. anal. M. Gołąbowa), Styków (Wąs 1956), Nadbrzeże (Halicki & Brodniewicz 1961, poll. anal. T. Przybylski), Polanica-Zdrój (Walczak & Szczypek 1966; Szczypek 1974) and out of the sites determined as Eemian by Borówko-Dłużakowa (1973a): Kalsk and Goczałków. Of the other sites, Klękówek (Bitner 1956b), Kurzętnik (Churski 1966, poll. anal. T. Przybylski), Żmigród (Szczepankiewicz 1969, 1976a, b; Szczypek 1976), Karolino (Borówko-Dłużakowa 1958; Nowak 1974) and Czarne (Cielińska & Szczypek 1974) have been excluded. In their survey of Quaternary sites, Straszewska and Stupnicka (1980) included these sites except Nadbrzeże, Żmigród and Czarne in the Eemian Interglacial.

Five of the sites mentioned, namely Zawichost, Kalsk, Klękówek, Kurzętnik and Karolino, have exclusively pine-birch pollen spectra (with a small admixture of thermophilous trees), which by themselves are not diagnostic for any Pleistocene unit. The profile from Kurzętnik was questionably determined by Churski (1966) as the decline of the Eemian or an interstadial, and Bitner (1956b) defined Klękówek "rather as an interstadial of the Varsovien II".

The exclusion of the remaining sites calls for more detailed justifications.

Styków on Kamienna River (Little Poland Upland)

The age of this locality was discussed (Wąs 1956) on the basis of one pollen spectrum with a fairly great proportion of *Pinus*, *Picea* and *Alnus*. The author, assuming the possibility of its reference to the Mazovian or the Eemian Interglacial, inclined rather towards the former. Środoń (1960, 1972), basing himself on the geological data, included Styków (with reservations) in the Eemian.

The pine-spruce-alder sample isolated here cannot be stratigraphically diagnostic. It might come from either of these interglacials. Similar spectra can be found in the pollen diagrams representing the Mazovian Interglacial (from the neighbourhood of e.g. Olszewice II, 9.10 m depth — Sobolewska 1956 or Radziechowice, 16.30 m depth — Borówko-Dłużakowa 1981) and also the Eemian (e.g. Bedlno, 7.80 m depth — Środoń & Gołąbowa 1956). It is, however, easier to find sections with samples of this type in the Mazovian Interglacial.

The interglacial age of the peat from Styków was questioned in general by Bartosik (1972) on the basis of geological data.

Polanica-Zdrój, Kłodzko Sudetes

The Eemian age of this profile (Walczak & Szczypek 1966; Szczypek 1974) has already been called in question by Mamakowa and Środoń (Mamakowa et al. 1975; Mamakowa 1976). Compared with the Eemian sequence of pollen assemblage zones, the diagram from Polanica-Zdrój shows significant differences. It lacks the features of the E3 — *Quercus-Fraxinus-Ulmus* and E5 — *Carpinus-Corylus-Alnus* zones in their proper stratigraphic position; the maximum values of *Corylus* (29.3%) are too low for the Eemian in this part of Poland, and so it also lacks a proper climatic optimum — zone E4. The fact that the culmination of *Quercus* follows the culmination of *Corylus* is another significant difference. The *Picea-Abies-Alnus* zone, existing in the Eemian sequence of pollen assemblage zones, is admittedly not diagnostic in itself for this interglacial (cf. p. 126).

In the light of the known interglacial successions from the territory of Poland it is impossible to correlate the pollen succession from Polanica-Zdrój with any interglacial pollen sequence.

Czarne near Jelenia Góra (Western Sudetes)

It is difficult to appraise the data presented by the diagram from Czarne (Cielińska & Szczypek 1974). It certainly does not represent the sequence of Jessen's zones, from *e* to *i*, of the Eemian Interglacial, as assumed by Szczypek, since it lacks characteristics associated with a succession of trees in the climatic optimum, i.e., the zones with successive culminations of *Quercus*, *Corylus* and *Carpinus*. The picture presented by the section above the bottom samples 24 and 23 from sandy silt, might, at the most, correspond with the E6 — *Picea-Abies-Alnus* zone developed atypically (samples 22 to 3) and the beginning of the E7 — *Pinus* zone (samples 2 and 1, cf. Cielińska & Szczypek 1974, Fig. 3). Such an interpretation is, however, complicated by the spectra from the bottom samples, which have more than 40% NAP (of total AP+NAP sum), high values of *Salix*, *Hippophaë* pollen present and at the same time a pretty marked proportion of thermophilous trees and *Corylus* pollen. It is hard to decide whether these are spectra mixed with redeposited pollen from both a cool and a warm period and partly with local elements or whether they come from the decline of a cool period with redeposited pollen of thermophilous trees and *Corylus*. In the first case it might be presumed that the bottom of this profile represents a hydrological disturbance, possibly even at the decline of the Eemian zone E5 (cf. p. 122). The other possibility would indicate that these samples are at the beginning of part of the Pleistocene in the form of a warm interstadial rather than an interglacial. These doubts as well as the non-diagnostic nature of the *Picea-Abies-Alnus* zone as regards the Eemian (cf. p. 126) do not permit the inclusion of this locality in the present stratigraphic scheme.

Goczałków near Strzegom (Sudety Foreland)

On the basis of two pollen spectra this locality was admitted to be undoubtedly the Eemian Interglacial (Borówko-Dłużakowa 1973a). This age of the locality was also accepted by the geologist (Karaszewski 1973).

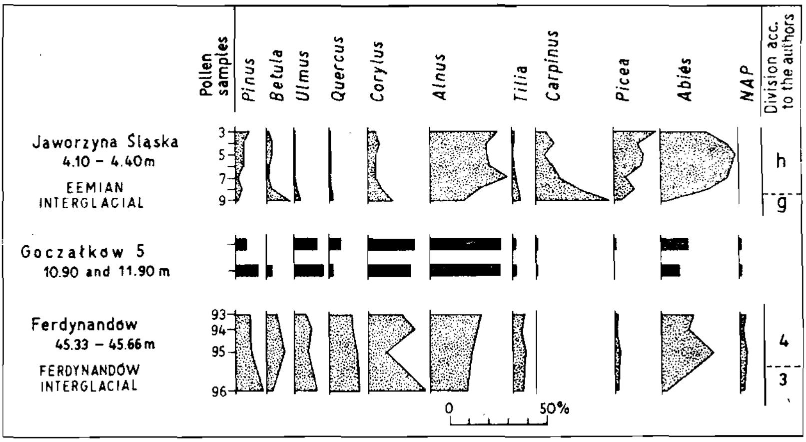


Fig. 40. A comparison of the pollen spectra from Goczałków 5 (acc. to Borówko-Dłużakowa 1972, 1973a) with the selected sections of the pollen diagrams from the Eemian (Jaworzyna Śląska, acc. to Kuszell 1980) and Ferdynandów Interglacial (Ferdynandów, acc. to Janczyk-Kopikowa 1975a). Percentages calculated from the AP+NAP sum

The spectra from Goczałków 5 (Fig. 40) are characterized by high proportions of *Alnus*, *Corylus*, *Ulmus* and *Abies*. *Picea* and *Carpinus* are represented only by single pollen grains. These characteristics alone make it impossible to place the spectra from Goczałków 5 in the Eemian sequence of pollen zones. In the Eemian Interglacial the high values of *Abies* (zone E6) either somewhat precede the maximum values of *Picea*, or are synchronous with them. In either case relatively high values of *Picea* are recorded together with *Abies* (cf. Fig. 31). Moreover, in the Eemian *Picea-Abies-Alnus* R PAZ relatively high *Carpinus* values ought to be found in the pollen spectra if frequencies of *Pinus* are as low as they are at Goczałków.

Another argument undermining the Eemian age of this profile are the very high values of *Ulmus* pollen (14.7 and 12.1%) accompanied by high values of *Abies*. To be sure, in several Eemian profiles the values of *Ulmus* exceed 10%, but only in the older part of the interglacial in middle and north-eastern Poland (cf. Fig. 18).

A comparison of the spectra from Goczałków 5 with the pollen sequences from the profiles referred to older interglacials shows that spectra with the most similar pollen assemblages can be found in the diagram from Ferdynandów (Janczyk-Kopikowa 1975a) and Podgórze (Jurkiewiczowa et al. 1973), representing the Ferdynandów Interglacial with a stratigraphic position between the Cracovian Glaciation (= Elster Glaciation) and the Wilga Glaciation (Janczyk-Kopikowa et al. 1981; Mojski 1985). And so the samples from Goczałków may signal another occurrence of this interglacial (cf. Fig. 40).

In the light of this hypothesis Karaszewski's remark (1973) on the solifluction deposits covering the lacustrine deposits is striking. According to him they resemble boulder clay but are quite different from the typical boulder clay occurring in this area. In this context the question emerges whether or not they are solifluction deposits arising from boulder clay of the Wilga Glaciation.

Żmigród, north of Wrocław (Silesia Lowland)

Sandy deposits with a mollusc fauna were first described from this locality by Schwarzbach (1942) as the Saale-Warthe Interglacial. On the basis of new borings, the organic deposits with floral and faunal fossils were referred to the

Eemian Interglacial (Szczepankiewicz 1969, 1976a, b; Szczypek 1976), as shown by palynological studies performed by Szczypek (Szczepankiewicz & Szczypek, in prep.).

The literature quoted does not provide a description of the vegetational succession. Prof. S. Szczepankiewicz and Dr. P. Szczypek gave the author access to the results of their palynological study, but since the work has not as yet been published, they will not be discussed here. Nevertheless, in the author's opinion, these data do not allow the assignment of the deposits from this site to the Eemian.

Śmielin near Nakło (Western Pomerania)

Two samples from a peat layer (70 cm thick) underlying two layers of boulder clay (Rühle 1954b) were studied by means of pollen and macroscopic analyses (Środoń 1954b). The boulder clay was referred by Rühle to two stages of the last glaciation. Although the results of the pollen analysis were not diagnostic for the Eemian, Środoń (1954b) admitted, on the principle of exclusion of other possibilities, that the peat comes from the older part of that period.

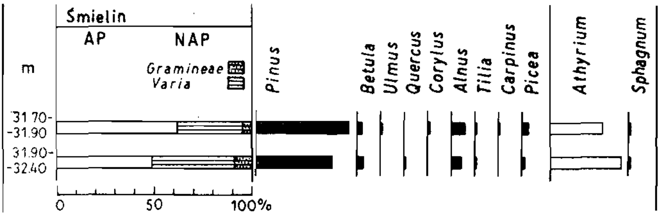


Fig. 41. Pollen spectra from Śmielin, based on Środoń's (1954) data, recalculated in relation to the total sum (AP+NAP)

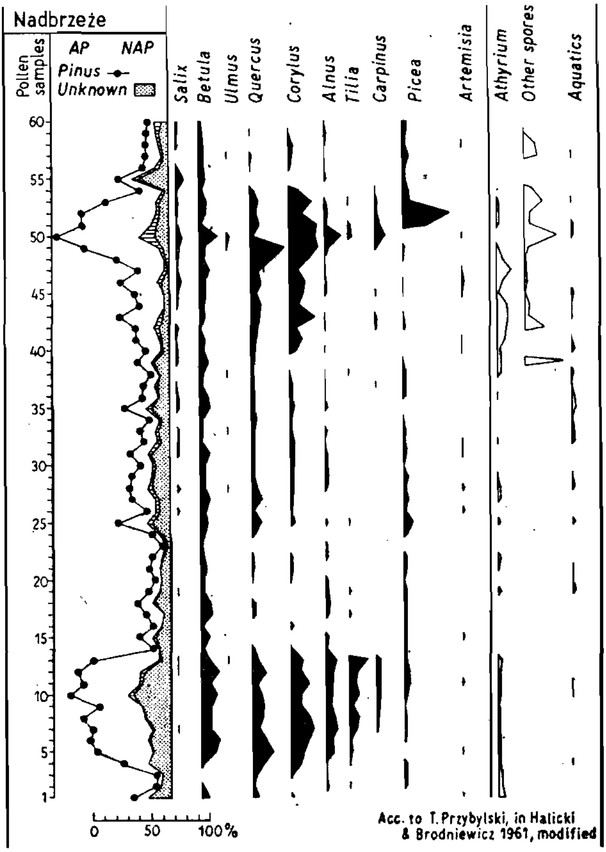
Having access to the original reports by courtesy of Prof. A. Środoń, I recalculated the spectra from Śmielin using the total (AP+NAP) sum (Fig. 41). *Pinus* and herb pollen represented by *Gramineae* and *Varia* are dominant. On the assumption that *Varia* in fact represent various herbaceous taxa (Środoń, 1954b, ruled out the presence of exotic pollen), such high NAP values (50.5 and 38.1%) do not allow equating these samples with the Eemian either in its lower part or in the upper. Moreover, the presence of *Picea* in the oldest section of the Eemian is quite sporadic in this part of Poland (cf. Noryśkiewicz 1978) and there are no grounds to suggest the occurrence of the so-called "lower spruce" zone here. Next, in spite of the relatively high pollen values of *Alnus* and the presence of *Alnus glutinosa* macrofossils, it is difficult to link these spectra to the boundary between zones E6 and E7; this is denied by the lack of *Carpinus* pollen, whose proportion in this area is fairly high even at the beginning of the pine zone (cf. Stark et al. 1932; Środoń 1956; Noryśkiewicz 1978).

Instead, in the light of the present data, equating this peat to an interstadial of the last glaciation, excluded by Środoń (1954b), becomes a real possibility. Despite certain differences in connection with the higher NAP values, the samples from Śmielin may be referred to the pine subzone of the EV2 — *Betula-Pinus* R PAZ, correlated with the Brørup Interstadial. Organic deposits at Kurów (about 100 km west of Śmielin), occurring in a stratigraphic position similar to that at Śmielin, were also initially determined to be Eemian age (Wrotek 1978), and now they are referred to the Brørup Interstadial (Kozarski et al. 1980).

Nadbrzeże near Elbląg (Lower Vistula region)

The pollen diagram from Nadbrzeże was interpreted as the Eemian Interglacial with the "second climatic optimum" (Halicki & Brodniewicz 1961). In later stratigraphical discussions the younger "warm" section was regarded either as the second climatic optimum of the Eemian (S. Z. Różycki 1972; Borówko-Dłużakowa 1974; Mojski 1974) or as an Early Vistulian interstadial, e.g. the Brørup (Borówko-Dłużakowa 1967; Środoń 1967a), or the Konin Interstadial (Mojski 1984b).

Changes represented in the pollen diagram from Nadbrzeże invoke reservations as to the stratigraphic position established for both "warm" sections, among others, on the basis of the behaviour of the NAP curve (P. N. D. in Halicki & Brodniewicz 1961). Thanks to Prof. T. Przybylski, who gave me the use of the original tables, it became possible to find the composition of the NAP sum (mainly indeterminate pollen, *Gramineae*, slight proportions of *Artemisia*, *Cyperaceae* and *Ericaceae*), and to present a diagram calculated according to the methods applied in this work (Fig. 42).



Acc. to T. Przybylski, in Halicki & Brodniewicz 1961, modified

Fig. 42. Pollen diagram from the Elbląg clays at Nadbrzeże, recalculated on the basis of the total sum (AP+NAP) and modified

The behaviour of the NAP curve, which attains its highest values just in the periods of "warm oscillations" and in the upper section also parallel the increase in *Salix* values, is the crucial point in the interpretation of the diagram from Nadbrzeże, so far omitted in the dispute. This behaviour proves that these sections of sediments were deposited at the time when the occurrences of herbs in the surroundings were higher than in the pine section dividing them or the pine sections opening and closing this cycle of changes.

In the lower warm section, recognized as Eemian, the proportions of *Pinus* and *Betula* pollen are also very high, the sum of these two taxa exceeding 40% in the zone with maximum values of hazel. On the other hand, *Ulmus* pollen is here completely lacking, values of *Corylus* are below 20% and this sequence lacks sections which might correspond with the *Carpinus-Corylus-Alnus* and *Picea-Abies-Alnus* zones.

The upper warm section, "second optimum", has high values of *Quercus* (29.2%) and *Picea* (to 39.5%) and somewhat higher values of *Corylus* (23.6%) and *Carpinus* (7.6%) than in the lower section, and so it is as a rule "warmer" than the lower one, recognized as the Eemian Interglacial.

The above-quoted data prove that none of these sections represents the pollen assemblage zone sequence characteristic of the Eemian Interglacial, while the synchronous occurrence of high pollen values of thermophilous trees and the highest pollen values of herbs in both "climatic optima" indicates that the profile from Nadbrzeże is disturbed. In all probability the sedimentation of "both warm sections" took place in a cold period and was contaminated by redeposited material, most probably of Eemian origin. A cold period is also indicated by the cold-loving malacofauna found in this profile (cf. Halicki & Brodniewicz 1961).

The high proportion of indeterminate (unknown) NAP pollen may also represent Tertiary taxa. If the hypothesis of sediment disturbances is left quite unchanged, it might indicate the non-interglacial origin of a part of the redeposited sediments. The possible presence of Tertiary pollen in this profile is suggested indirectly by the pollen analytical results of another profile at Nadbrzeże obtained from the boring (Janczyk-Kopikowa 1976b), in which most samples had spectra characteristic of Tertiary deposits.

Makowska (1986) considers Halicki's profile from an outcrop and the upper part of the boring profile to be younger than the Eemian Interglacial and refers them to the transgression of the cold arctic-boreal Elbląg Sea. Makowska's opinion concerning the heavy disturbances observed in Elbląg clay is very important to the evaluation of the profile from Nadbrzeże presented in this work. In her opinion (Makowska 1986, p. 36), the picture of changes, both in the pollen diagram from Nadbrzeże (Halicki & Brodniewicz 1961) and in the fauna (Brodniewicz 1969, 1972), may be due to the mixing of the same layers and their overlying each other.

THE PROBLEM OF THE "SECOND CLIMATIC OPTIMUM" IN THE EEMIAN IN POLAND

The phenomenon of the so-called "second climatic optimum" in some Eemian pollen diagrams from Poland refers to the re-appearance (or rise in values) of thermophilous tree pollen, chiefly *Carpinus*, *Tilia* and *Alnus*, and also *Corylus*, *Picea* and *Abies*, in the cool section at the decline of the interglacial. This phenomenon, defined in literature as "the second warming", "the first post-optimal wave of warmth", "the upper warming", etc., according to the author, does not actually represent the characteristics attributed to it. This is indicated by the frequently parallel occurrence of the relatively high or rising values of NAP, the indicator taxa of cold periods or by the change of deposits into more minerogenic ones. The common feature of this phenomenon is some similarity to the zones described by Jessen (Jessen & Milthers 1928) as the "upper temperate flora" and the fact that they were interpreted by the authors as a warm oscillation chiefly on the basis of changes taking place in the composition of arboreal pollen.

This problem has been running through the Polish literature since the mid-fifties, that is, since Raniecka-Bobrowska (1954) correlated two samples (21 and 22) in profile 1a from Warszawa-Wola with the "upper temperate flora" zone in the Danish profiles of the Herning type. She suggested also the possibility of their assignment to the Aurignacian Interstadial.

Konopki Leśne (Borówko-Dłużakowa & Halicki 1957) was another locality with the "second climatic optimum". Its authors regarded the repeated rise in pollen values of thermophilous trees and *Corylus* occurring here towards the close of the pine zone as an indication of a milder climate and correlated it with Jessen's zones *l—m* i.e. with the "upper temperate flora".

Later the "second warming" of the same or similar nature was postulated in the diagrams from sites at Nadbrzeże (Halicki & Brodniewicz 1961), Kaliska [77], Szwajcaria [97], Warszawa-Żoliborz [50], Warszawa-Wola, Młyn./Wolska Str. [48], Gołków [44], Klewinowo [64] and Nidzica (Marciniak & Kowalski 1978). The problem of the "second warming" emerged in addition in the interpretation of the palaeobotanic data concerning Góra Kalwaria [42] and Sławno [19] made by S. Z. Różycki (1967a), but the phenomena recognized in these profiles as a second warming occur at different stages in the vegetational succession (see further, pp. 155, 156). In some of the above-mentioned sites the problem of the "second warming" was posed by the authors of the first publications. As regards Warszawa-Wola Młyn./Wolska Str., Góra Kalwaria, Sławno, Gołków and Szwajcaria, such an interpretation was introduced by geologists or other discussants.

In correlations the phenomenon of the "second climatic optimum" was sometimes — at the same locality — referred to various stratigraphic positions. The concept of the correlation often underwent a change in one and the same author at that. This may be exemplified by the "warming" at Konopki Leśne [59], which, interpreted originally by Borówko-Dłużakowa and Halicki (1957) as the second interglacial climatic optimum, was later recognized by Borówko-Dłużakowa (1967) as the Brørup Interstadial and correlated with the warm oscillation from Konin-Marantów. Earlier, Środoń assigned such a position to this "warming" (Środoń 1960, 1961, 1967a; Birkenmajer & Środoń 1960) and so did later Dylik (1968) and Mojski (1969). In her publication on the Klewinowo profile Borówko-Dłużakowa (1974) returned to the concept of the Eemian Interglacial with two climatic optima; then, she no longer correlated the "second warming" with the Brørup Interstadial and admitted "the problem of the bipartition of the Eemian to be proved".

In his stratigraphic scheme S. Z. Różycki (1961) accepted the phenomenon of the "second climatic optimum" as the first post-optimal warming of substage rank, termed "the warm Drna wave". He found it in the pollen diagrams from Warsaw sites (Raniecka-Bobrowska 1954 and Borówko-Dłużakowa 1960) and from Sławno (Tołpa 1961). Then, S. Z. Różycki correlated this warming with the Amersfoort Interstadial but he regarded it as a oscillation within the Eemian Interglacial. He held the birch-pine section preceding the "second warming" to be the first post-optimal cold substage. As the second cold substage in his scheme he regarded the *Betula* culmination (= EV2a in the present paper) following the phenomenon of the "second climatic optimum". The *Pinus* culmination (= EV2b in the present work) was recognized by S. Z. Różycki as the subsequent "warm Drzasna substage". Only in the top part of the diagram from Warszawa-Wola Młyn./Wolska Str. [48] with high NAP values and *Pinus montana* present he distinguished the beginning of the first cold substage of the Lower Vistulian. In the present work this section is considered to be the second Early Vistulian Stadial EV3.

Later, S. Z. Różycki (1967a, b, 1972) distinguished the Drna warming (calidostadial), besides the foregoing sites, also in Góra Kalwaria [42], Gołków [44], Bedlno [18], Konopki Leśne [59] and Nadbrzeże, but he did not correlate it any longer with the Danish and Dutch divisions. He has recently presented his view on the question of two warm oscillations following the main Eemian climatic optimum, as exemplified by Gołków (S. Z. Różycki 1978a, b). In this diagram he referred a section from the silt layer at a depth of 4.3—5.3 m to "the second late optimum of the Eemian Interglacial" (cf. Janczyk-Kopikowa 1966a and Fig. 35 in the present work).

In Mojski's approach to this problem the warming of the type of the "second climatic optimum" was also given definite and distinct though changing stratigraphic positions. Originally he assigned (Mojski 1968) the "warming" in zone $i+j$ in the profile from Kaliska [77] and at the top of profile 1 from Szwajcaria [97] to the Amersfoort-Rodebaek Interstadial and he acknowledged the "warm oscillation" from Konopki Leśne [59] and Klewinowo [64], which had just been detected to be the second climatic optimum of the Eemian Interglacial. Later he recognized the "upper warming" at Konopki Leśne [59], Nadbrzeże (Halicki & Brodniewicz 1961), Warszawa-Wola [48], Warszawa-Żoliborz [50] and — with reservation — Horoszki [56] as the Brørup Interstadial (Mojski 1969). After a few years he again identified the warming at Konopki Leśne and Klewinowo as the second climatic optimum of the Eemian (Mojski 1974) and as further typical profiles with this phenomenon mentioned Warszawa-Wola, Nadbrzeże and Horoszki.

In the latest stratigraphical scheme Mojski (1984b, 1985) ascribes the "second warming" at Szwajcaria, Kaliska, Sławno I, Konopki Leśne and Klewinowo as well as the "first postoptimal Drna warming" distinguished by S. Z. Różycki (1972) in Warszawa and Bedlno to the Józefów Interphase within the first Early Vistulian Kaszuby Substage and correlates it with the Amersfoort. On the other hand, he refers the profile sections above the pollen-free sands from Warszawa-Żoliborz [50] and Warszawa-Wola [48] and the "upper warming" at Nadbrzeże to the Konin Interstadial (with the stratotype profile from Konin-Marantów).

References to the phenomenon of the "second climatic optimum" appear also in other works (Makowska 1979b; Marciniak & Kowalski 1978; Chmielewski in Chmielewski et al. 1975; Baraniecka et al. 1978). In the ensuing discussions and stratigraphical schemes presented the position of the zone with the "second climatic optimum" underwent, as can be seen, various changes, but the substance of this problem has remained unchanged until recently. It is based on the fact that the appearance of thermophilous tree pollen and *Corylus*, *Picea* and sometimes *Abies* in the cool post-optimal section, in several Eemian diagrams, is interpreted as a recurring warming.

In the pollen stratigraphic scheme presented by the author in this work (cf. Fig. 12), the zones interpreted as the "second climatic optimum" or "post-optimal warming" were not given any distinct stratigraphic rank that could be based on the occurrence of taxa suggestive of warming. This is so because the author called in question the criteria for the distinction of this phenomenon as a separate palynostratigraphical unit. This standpoint is justified by the interpretation that the taxa indicative of "warming" are, for the most part, associated with redeposition or other disturbances, which excludes their use as the basis for stratigraphic determinations. Consequently such a zone cannot be the basis for correlating and distinguishing chronostratigraphic units (cf. Cushing 1964; Alexandrowicz et al. 1975). An additional argument for questioning the zone with the "second climatic optimum" as a definite and separate unit is the occurrence of this phenomenon in various positions relative to the vegetational succession, even in profiles from sites located close to each other (e.g. Gołków—Góra Kalwaria—Sławno).

In most cases the interpretation of the zones with the "second climatic optimum" as isolated warm oscillations was based on their correlation with Jessen's *l* and *m* zones of stage IV with the "upper temperate flora" (Jessen & Milthers 1928). It should, however, be noted here that the "warm" nature of this stage in Jessen's scheme was questioned as early as the fifties, when the suggestion was made that it had arisen as a result of periglacial erosional processes and the deposition of interglacial material in the water-bodies (Thomson 1951; Woldstedt 1947; West 1956). Later, the stage with the "upper temperate flora" in Danish profiles was re-interpreted by Andersen (1957, 1961).

Already Jessen drew attention to the fact that the rise in values of *Quercus*, *Corylus*, *Carpinus* and, particularly, *Alnus* towards the close of zone *i* in the Brørup-type peatbogs is presumably due to the shifting of these layers and their mixing with material from earlier deposits (cf. Jessen & Milthers 1928, p. 358).

On the basis of the re-analysed Herning-type profiles and various additional studies, Andersen (1961) found a change of the deposits into more mineral sediments and an increase in the herb pollen values in the "upper temperate flora" zones, which no doubt indicates a worsening climate. Basing his interpretation on the correlation between the summary curve of thermophilous tree and shrub pollen and the mineral and organic content of the sediments, he concluded that this pollen had been deposited together with allochthonous mineral material originating from intense erosion at that time. In this connection zones *l*—*m* of the "upper temperate flora" were acknowledged by him to be a cold substage of the Early Vistulian (Andersen 1961).

The re-interpretation of the "upper temperate flora" zones in Danish profiles pointed to the necessity of repeating studies on Polish profiles with the "second climatic optimum" as well. This is true not only of the pollen diagrams in which zones *l*—*m* were distinguished by their authors but also of those where these zones, often designated differently (e.g. *j*), were regarded as corresponding to the "upper temperate flora" zones. Such studies have not yet been undertaken.

Additionally, the author wishes to draw attention to some other facts and opinions referring to the sediment disturbances towards the close of the last interglacial and at the beginning of the Early Vistulian.

1. Dylik (1967) paid attention to the activation of the downwash in the period of the Early Vistulian. He attached particular significance to this phenomenon in periglacial environments (Dylik 1972).

2. The erosional boundary between peat and sandy deposits (over certain sections) and the washing of the top peats have been found by Dyjor (Dyjor & Kuszell 1977) at Jaworzyna Śląska. He put forward similar interpretations for the locality at Wołów (pers. comm.).

3. In his description of the deposits from the outcrop of an Eemian lake at Warszawa-Wawrzyszew, Morawski (1978) noticed that the frost fissure structures "are infilled with redeposited lacustrine deposits derived from their margins, as well as with sand poured from above and usually infilling their central parts. Upper part of the lacustrine series is sometimes eroded. Fluvial sands infilling the holes are sometimes intercalated by redeposited Eemian peats". And so various profiles from the same lake may have various types of disturbances over the transition

of interglacial/glacial contact in the results of pollen analysis. In such a situation the recurrence of pollen spectra from the older sections of the interglacial seems quite obvious and understandable.

4. It is worthwhile recalling that a similar phenomenon of "second warming", distinguished in some pollen diagrams of the Mikulino Interglacial in the north-western part of the Russian Plain was reinterpreted by Grichuk (1961) as redeposition as early as 25 years ago. He stated then that in the zone in which the deciduous tree pollen reappeared above the Mikulino sequence there were also sporomorphs which represented a tundra element. This concerns, among other sites, the Mikulino locality.

5. Liivrand (1977) found contamination of the Early Valday deposits with redeposited Mikulino sediments at several Estonian sites. She had already given much attention before to studies aiming at the separation of mixed pollen spectra, which had their origin in cold periods but were contaminated with interglacial material (Liivrand 1974b; Liivrand & Pirrus 1973; Liivrand & Saarse 1976).

6. Beaulieu and Reille (1984) have recently noted a very strong redeposition of tree pollen from the Eemian Interglacial in the first and second stadials of the Early Würm in the profile from Les Echets near Lyon. In the first cooling this was according to the authors "a mixture of pollen of all trees and all herbs". They also observed "dy granules encased in silty sediments".

7. Similarly abundant redeposition took place in the Early Vistulian in the profile from Fjøsanger in Norway (Mangerud et al. 1981), where the proportion of *Corylus* and *Alnus* pollen together reached about 40% of the total sum.

REINTERPRETATION OF THE "SECOND CLIMATIC OPTIMUM" AT SEVERAL SITES

Most of the crucial Polish sites with the "second climatic optimum" do not fulfil the requirements needed to frame an authoritative opinion whether the zones under discussion arose from redeposition or different periglacial disturbances or whether they do indeed represent a warm section. They lack thorough descriptions of deposits, analyses of the grain-size distribution and loss on ignition, and observations concerning the state of pollen preservation, and some of them lack also a proper study of herbaceous pollen. This makes the formulation of any well-supported conclusions impossible.

In connection with the foregoing, any attempt made by the author of this work to reinterpret the zones of the so-called "second climatic optimum" in Polish diagrams connected with this problem, has — by necessity — a very limited extent.

The diagram from Nadbrzeże (Halicki & Brodniewicz 1961) goes beyond the scope of this discussion, since, in my opinion, it does not represent the vegetational succession of the Eemian Interglacial. The justification for this view was given in the previous chapter (see p. 145).

Warsaw sites

In the profiles from Warszawa-Wola and Warszawa-Żoliborz Raniecka-Bobrowska (1954) found a "warming" reflected by the rise of pollen values of thermophilous trees, *Corylus* and *Picea*, in the samples from sandy deposits above the Eemian pollen sequence. The "second climatic optimum" was best reflected at a depth of 7.5—7.7 m in profile 1a from Warszawa-Wola (Fig. 43).

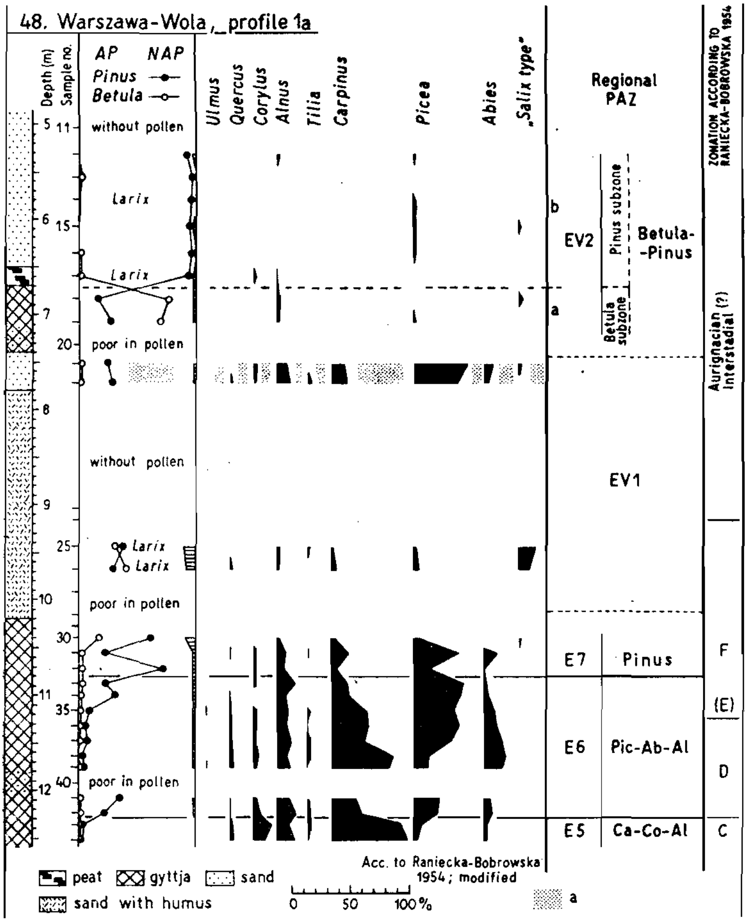


Fig. 43. Pollen diagram of the top part of profile 1a from Warszawa-Wola. The proposed stratigraphic division and the reinterpretation of the "second climatic optimum" are illustrated; a — section disturbed by redeposited pollen of thermophilous trees. Percentages calculated from the AP+NAP sum. Site numbe as in Figs. 11 and 12

According to the present author the pollen picture of these samples and analogous zones in the other profiles from Warsaw is due to the effect of sediment redeposition from older interglacial zones, mostly from E6 — *Picea-Abies-Alnus* zone, in a cold period. Low values of NAP in these samples (in profile 1a) cannot weaken this hypothesis because the knowledge of NAP was insufficient at that time and no suitable laboratory techniques for preparing mineral sediments were available.

The hypothesis of redeposition is supported, not only by the very type of deposit (sand with traces of humus), but also by the intercalation of this layer in pollen-free sands and the very changeable sedimentation in the lake in this section (cf. Fig. 9 in Rühle 1954a).

Indirect evidence is provided by the pollen diagram from Warszawa-Wola Młyn./Wolska Str. [48] worked out by Borówko-Dłużakowa (1960). In this pollen diagram (see Fig. 35) relatively high values of *Picea*, *Carpinus* and *Alnus* pollen are also present in the top part of the sand layer that overlies interglacial gyttja (before the maximum increase in *Betula* values). High values of NAP (to 53.5%) and *Artemisia* (to 11.1%), changing over to high values of thermophilous tree pollen from sample to sample, suggest very turbulent sedimentation and are a distinct indication of redeposition of thermophilous tree pollen in the cold period.

This zone, together with the whole sand layer, was admitted (Mamakowa 1986) to be the first cold oscillation of the Early Vistulian, with redeposited pollen of thermophilous trees. The samples representing the "second optimum" in profile 1a from Warszawa-Wola (Fig. 43) are in the same position relative to the layer of pollen-free sand and to the overlying zone with high values of *Betula*. This proves indirectly that they, too, come from the first cold Early Vistulian oscillation (EV1) and result from nothing but the effects of redeposition, manifesting itself more strongly because of the poorly represented herb pollen. The presence of *Betula nana* in the samples above (no. 18) and below (no. 25) the "second climatic optimum" zone, suggested on the basis of pollen measurements (Raniecka-Bobrowska 1954), support this argument.

Gołków

In the diagram from Gołków [44] the zone considered by S. Z. Różycki (1967b, 1972, 1978a, b) to be the postoptimal Drna warming (at a depth of 4.8—5.3 m), was described by Janczyk-Kopikowa (1966a) as a section reflecting an open forest cover and the cool climate at the decline of the Eemian. This is evidenced, in her opinion, by "the re-appearance of the light-demanding sea buckthorn (*Hippophaë rhamnoides* L.) and the greater proportion of herbs that demand open areas (*Artemisia*, *Gramineae*, *Helianthemum* etc.)".

In the present paper the interpretation regarding the inferred vegetation of this section is similar, but it is recognized to be the first stadial of the Early Vistulian, EV1 (cf. Fig. 35). High values of herbaceous pollen and its diverse composition of taxa indicate a fairly high proportion of open habitats. It is also confirmed by the change of deposits, from bituminous shale to silts, implying increased erosion of exposed soils. These changes in sedimentation explain the recurrence of pollen of thermophilous trees and *Picea*, whose presence under such conditions must have been brought about by redeposition. Immediately above this zone (cf. Fig. 35) there is a pollen sequence with distinct characteristics of the EV2 — *Betula-Pinus* zone, evidently divided into two subzones.

Kaliska

The repeated rise in pollen values of thermophilous trees, *Corylus* and *Picea* in the diagram from Kaliska [77] at a depth of 16.1—15.5 m was assumed by Janczyk-Kopikowa (1965b) to be a sign of warming and this section was correlated with the Rodebaek-Amersfoort Interstadial.

An analysis of changes in the pollen diagram (cf. Janczyk-Kopikowa 1965a, Fig. 1) shows that in the section preceding "the re-warming" there are no signs of cooling comparable to the first Vistulian stadial, neither are there any signs of a hiatus. On the other hand, the rise in pollen values of herbs (to 20.6% of the AP+NAP sum) with a high proportion of *Artemisia* (to 3.7%) coincides with the start of an increase in values of thermophilous trees and a change in the deposits, from peaty gyttja, silty in places, to silty gyttja with plant detritus.

The significance of this situation resembles that at Gołków, but redeposition, somewhat more marked here, manifests itself as early as the decline of the E7 — *Pinus* zone. It is only above this zone that the rise in NAP values to 62.3% signals the upper boundary of the interglacial (see Fig. 34).

Szwajcaria

The rise in pollen values of thermophilous trees within phase (*j*)? in the top part of profile 1 from Szwajcaria [97] (cf. Borówko-Dłużakowa & Halicki 1957, Fig. 7), was interpreted as a warming by Janczyk-Kopikowa (1965a) and correlated with the "warming" at Kaliska.

In the profile from Szwajcaria the deposit described only as "peat" gives no grounds for suggesting that the "re-warming" resulted from solifluctional processes. There are, however, several features which permit the proposition that in this case, too, the "re-warming" is the effect of disturbances. According to Halicki's description (Borówko-Dłużakowa & Halicki 1957), "the peat deposit is compact and shaly at the bottom and becomes looser above" which may indicate that the peat might have had an admixture of mineral matter at the top. Moreover, Halicki drew attention to a micro-glaciotectonic phenomena at the top of the interglacial deposits at Szwajcaria ("...fine horizontal scalings and tears ... instillation of silt into peat and vice versa..."). On the basis of this description it is possible to say that in the presence of such periglacial disturbances even a small addition of foreign matter incorporated in could result in a "warming" in the top part of the profile.

It should be stated that in the pollen diagram from profile 1 the rise in values of thermophilous trees is not preceded by any signs of cooling or the occurrence of tundra vegetation, as suggested by Mojski (1968). The rise in NAP values was almost exclusively determined by *Cyperaceae* + *Gramineae* pollen, which may have derived in great part from various peat-forming species of *Carex*. This is suggested by numerous nutlets of *Carex* sp. div. occurring in profile 2 (Borówko-Dłużakowa 1975b) in the part corresponding to the same zone in profile 1. *Artemisia* occurs quite sporadically and, what is very significant, not below the horizon of the rising pollen values of thermophilous trees. The above characteristics occurring in profile 1 and the absolute lack of the "second climatic optimum" phenomenon in the well-developed pine zone in profile 2 (Borówko-Dłużakowa & Halicki 1957, Fig. 8; Borówko-Dłużakowa 1975b) seem an adequate reason for interpreting this phenomenon in profile 1 as a disturbance and for including the section in question in the top part of the E7 — *Pinus* R PAZ (cf. Figs. 12 and 34).

Konopki Leśne

In the diagram from Konopki Leśne [59] the recurring rise in pollen values of *Picea*, *Corylus*, *Alnus*, *Carpinus* and, to a small degree, also *Quercus* and *Tilia* — after the culmination of *Pinus* — is undoubtedly the most distinct and suggestive picture of the "second climatic optimum" (Fig. 44). Borówko-Dłużakowa (1967) rejected Andersen's (1961) hypothesis that this warming results from the redeposition of interglacial deposits, stating that nearly the whole profile consists of peat free from sandy insertions and its contamination at sampling was impossible because it was obtained from an outcrop. These are no doubt strong arguments, but they cannot be verified unless a close analysis of the peat has been carried out. Circumstantial evidence that some disturbances also occur in the peat is, e.g., the mixing of deposits observed in the marginal part of the Cheremoshnik peatbog, shown by the simultaneous occurrence of *Brasenia schreberi* and *Betula nana* and interpreted by Sukachev (1954) as "the result of the activity of exogenic processes leading to redeposition".

In the picture from the pollen analysis, the hypothesis of redeposition is supported by the occurrence of sporadic *Artemisia* pollen grains just parallel to the very beginning of the "second climatic optimum" (see Fig. 44) and by exactly the same position of this "warming" in relation to the culmination of pine as in Kaliska and also on other profiles (see Fig. 34).

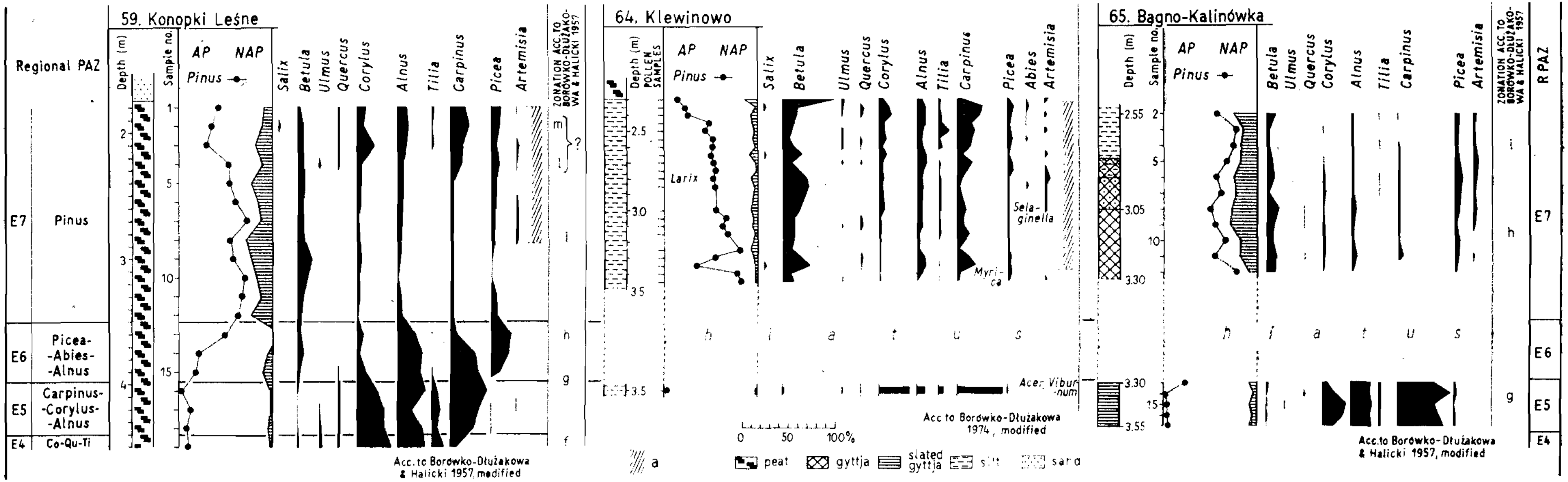


Fig. 44. Simplified pollen diagrams from Konopki Leśne (top part), Klewinowo and Bagno-Kalinówka, recalculated on the uniform basis (sum AP+NAP) and modified. The proposed stratigraphic division, the possible correlation of the distinguished pollen ass. zones and the reinterpretation of the "second climatic optimum" are illustrated; a — sections disturbed by redeposited pollen of thermophilous trees. Site numbers as in Figs. 11 and 12

Klewinowo

On the basis of the diagram from Klewinowo [64] and its comparison with the pollen data from Konopki Leśne [59], Borówko-Dłużakowa (1974) assumed that the question of the bipartition within the Eemian is settled. A series of samples (see Fig. 44) from the silt layer, 1.20 m thick, registers — in her opinion — changes in vegetation from the decline of the hornbeam phase (bottom sample), through pine-birch forests, re-warming at a depth of 2.80—2.35 m (correlated with phase *l*—*m*) at Konopki Leśne, to the recurrence of the cooling represented by the top birch sample (Borówko-Dłużakowa 1974).

The diagram from Klewinowo can be, however, interpreted in a different way. Only the bottom sample from a depth of 3.5 m is diagnostic for the Eemian. It may be correlated with the E5 — *Carpinus-Corylus-Alnus* zone (cf. Fig. 44), but the low values of *Picea* and *Pinus*, with 32.3% *Corylus*, indicate the older part and not the decline of that zone. The whole upper part of the diagram represents the final section of the Eemian, zone E7, as evidenced by the high *Pinus* values. And so the younger part of zone E5 and the whole E6 — *Picea-Abies-Alnus* zone are missing as there are no high *Picea* values. This, compared with the diagram from Konopki Leśne (Fig. 44), proves that a distinct hiatus occurs between the section with the bottom sample and the rest of the profile from Klewinowo.

The presence of the hiatus may indicate that the upper part of the silt, deposited after a long break, in the period when boreal pine-birch forest prevailed, also contains pollen from eroded older deposits dating from the hornbeam zone, from which the pre-hiatus bottom sample comes. In this case the mineral deposit unreservedly permits such a hypothesis. Moreover, presence of *Selaginella selaginoides* and the start of the continuous *Artemisia* curve distinctly indicate a worsening of the climate during the deposition of the section regarded as the "second climatic optimum".

Nidzica

Phytophase *j* distinguished in the profile from Nidzica was interpreted (Marciniak & Kowalski 1978) as "a spectrum pointing to a warmer climate than that of preceding phytophase *i*". It was based on the decrease of *Pinus* values and an increase of elements of deciduous forests (see Marciniak & Kowalski 1978, Fig. 2). On the other hand, the results of a diatom analysis carried out simultaneously, according to Marciniak, show a general cooling of the climate in the section corresponding to phytophase *j*, which disagrees with the data obtained from the pollen analysis.

The results of the diatom analysis concerning this profile are, according my opinion, a perfect proof and argument for reinterpreting the "second climatic optimum", for they support the signs of a worsening climate, also occurring in the picture that emerges from the pollen analysis but that is not taken into account in the interpretation of the pollen data. These are: the rise in NAP and *Salix* values parallel the appearance of thermophilous tree pollen (cf. Marciniak & Kowalski 1978, Fig. 2), pointing to the openness of the landscape at that time and the appearance of pollen of exotic plants which together with the change in the deposits, from calcareous gyttja to silt, signals erosion and deposition of allochthonous sediments in the basin. The eroded material from warm sections of the interglacial and from older (Tertiary?) deposits provides a picture improperly interpreted as "re-warming".

Sławno

In the diagrams from Sławno [19] studied by Tołpa (1961), S. Z. Różycki (1961) distinguished two post-optimal warmings. In his later papers (S. Z. Różycki 1967a, b, 1972) he recognized Sławno as one of the main Eemian sites having two warm oscillations above the main climatic optimum. Unluckily, none of the diagrams from Sławno has been divided according to Różycki's scheme, which makes the discussion difficult. On the basis of descriptions alone it may be assumed after S. Z. Różycki that at Sławno I the section at a depth of 7.82—7.45 m (Fig. 45) represents the first post-optimal "wave of warmth (Drna)". The underlying zone with high values of *Pinus*, *Betula* and *Picea* (samples 60—75) corresponds, according to him, to the first post-optimal cooling. By analogy, in the diagrams from Sławno II and III (Fig. 45) the "first post-optimal cooling" is reflected by the bottom spectra with relatively high values of *Pinus* and *Betula*, and the first post-optimal "wave of warmth (Drna)" by the section with a high share of thermophilous trees and *Picea* and *Abies*, up to the repeated *Pinus* rise.

According to the interpretation of Tołpa (1961), the profiles from Sławno represent the Eemian Interglacial, but are distorted by very strong disturbances in some zones (mostly at Sławno I). He emphasized the frequent alternation of mineral deposits with peat, which are also strongly sandy in many layers. Rühle (1961), too, drew attention to heavy disturbances in this lake. Both authors found the occurrence of slope wash processes and a great fluctuation in the water-level throughout the period of existence of the lake.

The arrangement of layers in the deposits in the middle and marginal parts of the lake, visible in the cross-section (Rühle 1961, Fig. 1), shows that in the marginal part the older deposits which were formed simultaneously with the lower gyttja and peat in the middle part, must have been destroyed and mixed at the time of the repeated rise of water-level responsible for the formation of the second, thick, gyttja layer above the peat. The profile of Sławno III comes from this marginal part of the lake. The other two profiles, Sławno I and II, also most probably come from the marginal part (cf. Tołpa 1961). The profiles from the middle part, with twice as great thickness of deposits and considerably less disturbed (cf. Rühle 1961, Fig. 1) have not, till now, been studied by means of pollen analysis.

In the present author's opinion, all three diagrams reflect various disturbances of deposits. In the diagram of Sławno I it can be seen (cf. Fig. 45) that the whole lower section, obtained from "sand with gravel and a small admixture of plant detritus" consists of mixed pollen spectra. They are alternately either almost pure spectra representing zone E4 (e.g. samples 96, 91, 89) with maximum *Corylus* values in the zone or similarly pure spectra representing zone E5 (samples 95—92, 90) with maximum *Carpinus* values in this zone and also with high values of *Abies* (to 7.8%). After many changes *Corylus* has its highest value (66.7%) at the top of this section. It corresponds with the highest *Corylus* values in the E4 — *Corylus-Quercus-Tilia* zone in Poland (cf. p. 112 and Fig. 25).

The high values of *Abies* as early as the bottom of this profile suggest that the disturbance connected with the rise of the water level in the lake must have occurred in the transitional period between the E5 — *Carpinus-Corylus-Alnus* and E6 — *Picea-Abies-Alnus* zones, that is at the time when hydrological disturbances were recorded also at other sites (cf. p. 122).

The following section, deposited in sedge peat, may present a somewhat less disturbed part of zone E6 (Fig. 45). The next horizon, regarded by S. Z. Różycki as the "first postoptimal Drna warming", is, in all probability, the effect of a new wave of increased slope wash which reworked older sediments from *Carpinus-*

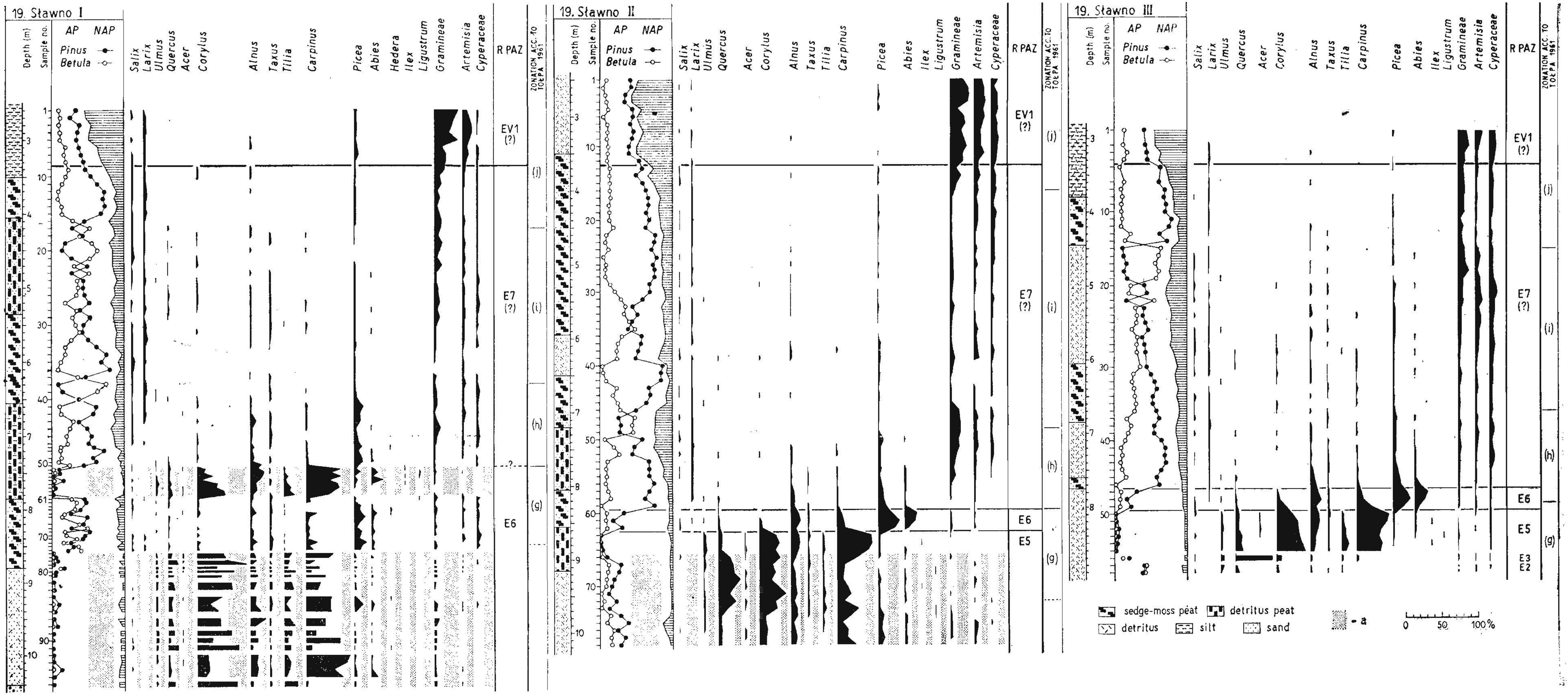


Fig. 45. Simplified pollen diagrams from Sławno (acc. to **Tołpa** 1961, modified); they show the proposed pollen-stratigraphic division taking into consideration sediment disturbances; a — disturbed sections. Site number as in Figs. 11 and 12

Corylus-Alnus zone and redeposited them in the younger section of zone E6. This interpretation is justified by both the change of sediment in this zone to detritus peat with sandy, loamy and clayey admixtures and the highest values of *Abies* pollen, which occur only in these spectra (15.6%) and are indicative of E6 — *Picea-Abies-Alnus* R PAZ.

The bottom pollen spectra from Sławno II (Fig. 45), obtained from varigrained sand with an admixture of detritus, indicate the similar nature of disturbances to those in the profile from Sławno I. Also the period in which sand sedimentation started here is similar, as indicated by the presence of relatively high values of *Abies* pollen, whereas the high values of *Quercus* with a maximum of 29.8%, occurring above, suggest redeposition of sediments of zone E3 — *Quercus-Fraxinus-Ulmus*, which were not present in the diagram from Sławno I. In the diagrams with an undisturbed sequence of pollen zones neither the *Corylus-Quercus-Tilia* zone nor the *Carpinus-Corylus-Alnus* zone has such high values of *Quercus*.

The upper section of zone E5 occurring in detritus peat with sand and the whole zone E6 show no more disturbances and are developed similarly to those in the diagram from Sławno III.

In the diagram from Sławno III (Fig. 45), two lower pine-birch spectra with a small admixture of *Ulmus*, *Quercus* and *Corylus* and sporadic pollen grains of *Taxus*, *Alnus* and *Tilia* resemble the characteristics of the E2 — *Pinus-Betula-Ulmus* zone. Further upwards the spectrum with the extremaly high *Quercus* value (50.0%) no doubt represents the E3 — *Quercus-Fraxinus-Ulmus* zone. On the other hand, still higher, there is not a single sample with the characteristics of the E4 — *Corylus-Quercus-Tilia* zone. Sample 55 and the next ones, with high values of *Carpinus*, represent the E5 — *Carpinus-Corylus-Alnus* zone straight off. The successively increasing values of *Picea* and *Abies* in the course of this zone lead to the well-developed E6 — *Picea-Abies-Alnus* zone, with a maximum of *Abies* (16.9%), that is, resembling that at Sławno I in the disturbed upper part of *Picea-Abies-Alnus* zone.

Thus the picture presented by the diagram from Sławno III suggests a big hiatus between samples 56 and 55, but there are no mixed pollen spectra in this profile.

In the interpretation given above the "warm Drna wave" (= the Drna calidostadial) was acknowledged to be a disturbance within zone E6 — *Picea-Abies-Alnus* in profile I, whereas in the diagrams from profiles II and III zones E5 and E6 are not disturbed and have characteristics of normal zones appropriate to the younger part of the Eemian vegetational succession. Neither are there any grounds to regard them as a phenomenon of recurring warming, i.e., the Drna calidostadial (= the "second climatic optimum" in other interpretations).

Góra Kalwaria

The "warm Drna wave" found by S. Z. Różycki (1967a) in the diagram from Góra Kalwaria [42] differs in nature from the above-discussed cases. Irrespective of the cause of the fall in *Corylus* pollen values in sample 29 (9.75 m), the birch-pine oscillation following that fall is not a post-optimal cooling, but occurs in the middle part of the *Corylus-Quercus-Tilia* zone, i.e. in the climatic optimum. Above this disturbance the continuation of the Eemian vegetational succession starts from the same stage at which it was interrupted. Further, there is a normal development of the forest communities, characteristic of the younger part of the Eemian (cf. Sobolewska 1961, Fig. 3).

This succession cannot therefore be a counterpart of the phenomenon distinguished as the "warm Drna wave", since this last phenomenon consists in the re-appearance of pollen of thermophilous trees, spruce and fir after their earlier culminations, whereas at Góra Kalwaria both *Carpinus* and *Picea* and *Abies* have their first interglacial culminations above the disturbance occurring within the climatic optimum.

CHRONOSTRATIGRAPHICAL POSITION OF THE EEMIAN INTERGLACIAL IN POLAND

Geological data from the territory of Poland permit the statement that most sites with the Eemian pollen sequence include sediments lying above the boulder clays of the Middle Polish Glaciation s. l. (Maximum, Warta and Wkra Stadials). At several sites within the range of the Vistulian Glaciation the interglacial deposits are overlain by moraine clays of that glaciation. From the geological point of view, Krzepczów [20] and Besiekierz [27] belong to controversial sites, which despite an Eemian pollen sequence are located by Klatkowa (1972) between the deposits of the Maximum Stadial of the Middle Polish Glaciation and those referred by her to the Warta Stadial.

Despite a large number of sites acknowledged to be Eemian on the basis of palaeobotanic data, only a few have been dated by chronometric methods. Tl datings were obtained for the profiles from Błonie 3 [39] and Bełchatów X [17], both studied on the basis of random samples *. A layer of sand with an admixture of organic matter underlying the organic deposits was dated in profile 3 from Błonie. Its age was determined at 108—125 ka B. P. (Karaszewski 1975). This dating indirectly indicates the beginning of the organic series sedimentation, provided there is no hiatus between the sand and the overlying layer of silt, from which the lowest pollen spectrum representing the E2 — *Pinus-Betula-Ulmus* zone comes.

The Tl dates from Bełchatów X suggest an age of 136±16 ka B. P. (Lu 97) for the sand layer under the Eemian peat and 139±17 ka B. P. (Lu 98) for that between two layers of silt lying below (Butrym et al. 1982). They concern the section from which two pollen spectra have been referred to the decline of the Middle Polish Glaciation (Goździk & Jastrzębska-Mamełka 1982).

The older date from Błonie comes nearest to the datings which place the beginning of the warm oscillation correlated with the Eemian Interglacial s. str. between 125 and 130 ka B. P. (Matthews 1972, 1973; Mc Intyre & Rudiman 1972; Sancetta et al. 1972; Shackleton & Opdyke 1973).

The profiles included in the present stratigraphic table (Fig. 12) have no datings within the range of the Eemian/Early Vistulian boundary.

An attempt to determine the approximate duration of the Eemian Interglacial was made by Dąbrowski (1971) on the basis of the Główczyn [36] profile. In his calculation "a constant of tree pollen grain deposition per cm^2 in a year was established, based on recent data of pollen rain in various forest types of the Białowieża National Park". On this basis he fixed the relative duration of the Eemian Interglacial at about 18000 palynochrones or autonomous time units, which may be regarded as equal to years. The duration of the Eemian Interglacial determined by him is longer than that calculated by Müller (1974) on the basis of the annual lamination in the Bispingen profile (±10000 years).

The older Tl date — 125 ka B. P. — obtained for the beginning of the Eemian at Błonie 3 together with the duration of the Eemian Interglacial calculated by Dąbrowski would place the Eemian/Early Vistulian boundary at 107 ka B. P. and in combination with the time computed by Müller at 115 ka B. P. These calculations agree with data presented by Shackleton (1969), Matthews

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* When this paper was being printed several new sites obtained Tl dates.

(1972, 1973), Shackleton and Opdyke (1973), Sancetta et al. (1972, 1973), Fairbridge (1972) and other authors, according to whom the Eemian ended at 110 ka B. P. and not with the data of the authors who date the end of the interglacial at 70 ka B. P. And so, the full Eemian sequence of the regional pollen assemblage zones, E1—E7, may correspond to the deep-sea oxygen-isotope substage 5e and not to a greater part of stage 5.

The dates from Błonie and Bełchatów and the calculated end of the Eemian pollen sequence permit a correlation to the chronostratigraphy of loesses in Poland. Maruszczak (1980, 1985) assumes the age of Eemian soils at 130/125—115/110 ka B. P. on the basis of Tl datings and the occurrence of Blake's event in the lowest beds of younger loesses overlying the Eemian soil at Komarów Górny and Orzechowce (Tuchołka 1977). Blake's event at Komarów Górny has also been supported by Tl datings (Prószyńska-Bordas & Prószyński 1983).

The chronostratigraphic position of marine sediments in the Lower Vistula region referred by Makowska (1986) to the Eemian Interglacial on the basis of the Tl dates is not univocal. Basing her conclusions on comparisons and stratigraphical considerations, Makowska concluded that "the beginning of the glaciation... giving rise to the Malborg lobe, may have taken place not later than at about 115 ka B. P." (Makowska 1986), which, in her opinion, is also the estimated age of the upper boundary of the Eemian Interglacial. Its lower boundary is, in Makowska's interpretation, placed considerably earlier than it is generally admitted, because in this stage she includes two marine sequences, the older one — Sztum and the younger — Tychnowy. The Eemian Interglacial in its palaeobotanic aspect is correlated only with the Tychnowy sequence, the beginning of which is placed at about 130 ka B. P.

REMARKS CONCERNING THE STRATIGRAPHICAL POSITION OF THE EEMIAN INTERGLACIAL

Studies of oceanic sediments have led to the distinction of a larger number of climatic oscillations of interglacial rank than was assumed in the classical continental models of the Quaternary stratigraphy. Attempts have been made for many years to correlate the continental data with oceanic ones, which results in the new continental models becoming increasingly complicated.

In north-western Europe, apart from a great many changes in the Quaternary stratigraphy, the position of the Eemian Interglacial, as the Last Interglacial, was relatively uncontroversial until the seventies. On the other hand, in the Soviet Union the Moskvitin's (1950) opinion about the existence of an interglacial younger than the Eemian, still had its adherents (Raukas & Serebryanny 1971; Krasnov & Zarrina 1974 and Auslender & Vigdorchik 1974 — after Erd 1978). Grichuk (1961) also leant towards this opinion, although somewhat differently formulated. In Poland it was put forward by Halicki (1950) and recently by Makowska (1986), who postulated such an opinion on the basis of marine sediments.

In recent years the stratigraphic position of the Eemian as the Last Interglacial, has also been discussed in western Europe. Frenzel (1973) assumed that the Riss/Würm Interglacial is younger than the Eemian. On the basis of the profile from Grande Pile in the southern Vosges Woillard (1975, 1978) postulated the occurrence of two other interglacials — St. Germain I and II — above the Eemian. This opinion was rejected, among other authors, by Grüger (1979), Mangerud et al. (1979a, 1981), Menke (1980) and Menke and Tynni (1984) who argued that the warm oscillations of St. Germain I and II correlate with the Amersfoort, Brørup and Odderade interstadials. Later, Woillard (1979), too, discussed the possibility of this latter alternative.

The theory has lately been put forward that the classical Eemian pollen sequence may represent various interglacials (Kukla 1977; Bowen 1979a, b). In Poland Klatkowa (1972) considered such an assumption to be plausible. It is, however, not accepted by the palaeobotanists who think that the typical Eemian pollen sequence in Europe in well-developed and undisturbed deposits represents only one interglacial, and that is the last interglacial. Grüger (1979), Mangerud (Mangerud et al. 1979a, b, 1981), Menke (Menke 1980; Menke & Tynni 1984) and other authors share this opinion and so does the author of the present work.

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REFERENCES

Alexandrowicz S., Birkenmajer K., Burchart J., Cieśliński S., Dadlez R., Kutek J., Nowak W., Orłowski S., Szulczewski M. & Teller L. 1975. Zasady polskiej klasyfikacji, terminologii i nomenklatury stratygraficznej. Instrukcje i metody badań geologicznych, 33. Wyd. Geol., Warszawa.

Andersen S. Th. 1957. New investigations of interglacial fresh-water deposits in Jutland. A preliminary report. Eiszeitalter u. Gegenwart, 8: 181—186.

— 1961. Vegetation and its environment in Denmark in the Early Weichselian Glacial (Last Glacial). Danm. Geol. Unders., 2, 75.

— 1964. Interglacial plant successions in the light of environmental changes. Rep. VI. Int. Congr. Quatern. Warsaw 1961, 2: 359—368.

— 1966. Interglacial vegetational succession and lake development in Denmark. Palaeobotanist, 15: 117—127.

— 1970. The relative pollen productivity and pollen representation of north European trees, and correction factors for tree pollen spectra. Danm. Geol. Unders., 2, 96.

— 1973a. The differential pollen productivity of trees and its significance for the interpretation of a pollen diagram from a forested region. In: Birks H. J. B. & West R. G. (eds.), Quaternary Plant Ecology. Blackwell Sci. Publ., Oxford—London—Edinburgh—Melbourne.

— 1973b. On the occurrence of pollen similar to Bruckenthalia spiculifolia (Salisb.) Reichenb. in Danish Quaternary deposits. Danm. Geol. Unders., Årbog 1972: 5—6.

— 1975. The Eemian fresh-water deposit at Egernsund, South Jylland, and the Eemian landscape development in Denmark. Danm. Geol. Unders., Årbog 1974: 49—70.

—, de Vries H. & Zagwijn W. H. 1960. Climatic change and radiocarbon dating in the Weichselian Glacial of Denmark and the Netherlands. Geol. en Mijnb., 39: 38—42.

Andrew R. 1971. Exine pattern in the pollen of British species of *Tilia*. New Phytol., 70: 683—686.

Mc Andrews J. H., Berti A. A. & Norris G. 1973. Key to the Quaternary pollen and spores of the Great Lakes Region. Life Sci. Misc. Publ., R. Ont. Mus., Toronto.

Averdieck F. R. 1967a. Botanisch-moorgeologische Untersuchungen am "Tuul" von Westerland (Sylt). Berichte u. Mitteil., 24: 84—100.

— 1967b. Die Vegetationsentwicklung des Eem-Interglazials und der Frühwürm-Interstadiale von Odderade/Schleswig-Holstein. Fundamenta, B. 2: 101—125.

— 1976. Palynologische Untersuchungen zur Alterbestimmung und Vegetationsgeschichte des Alstertals. Mitt. Geol.-Paläont. Inst. Univ. Hamburg, Sonderband Alster: 81—89.

—, Friedrichsen O., Ullrich W. & Vogel H. 1976. Geobotanische und -zoologische Untersuchungen an Eeminterglazialen in SW-Holstein. Meyniana, 28: 1—18.

Backman A. L. 1941. *Najas marina* in Finnland während der Postglazialzeit. Acta Bot. Fenn., 30: 1—38.

Bałuk A. 1973. Objaśnienia do Mapy Geologicznej Polski, ark. Łomża. Inst. Geol., Warszawa.

— 1975. Czwartorzęd i morfogeneza okolic Łomży (summary: The Quaternary and morphogenesis of the Łomża area). Kwart. Geol., 19 (2): 349—369.

— 1978. Objaśnienia do Mapy Geologicznej Polski, ark. Ostrołęka. Inst. Geol., Warszawa.

Baraniecka M. D. 1974. Plejstocen nad dolną Wkrą (summary: The Pleistocene on the Lower Wkra River). Biul. Inst. Geol., 268: 5—89.

— 1980. Objaśnienia do Mapy Geologicznej Polski, ark. Grójec. Inst. Geol., Warszawa.

—, Makowska A., Mojski J. E., Nowak J., Sarnacka Z. & Skompski S. 1978. Stratygrafia osadów czwartorzędowych Niziny Mazowieckiej oraz jej południowego i zachodniego obrzeżenia (summary: Stratigraphy of the Quaternary of Mazovian Lowland and of its southern and western peripheries). Biul. Inst. Geol., 306: 5—113.

Bartosik J. 1972. Geomorfologia obrzeżenia Gór Świętokrzyskich w okolicach Iłży (sommaire: Morphologie du rebord des montagnes de la S-te Croix aux environs d'Iłża). Acta Geogr. Lodz., 29: 1—87.

Beaulieu J. L. de & Reille M. 1984. A long Upper Pleistocene pollen record from Les Echets, near Lyon, France. Boreas, 13: 111—131.

Behre K. E. 1962. Pollen- und diatomeenanalytische Untersuchungen an letztinterglazialen Kieselgurlagern der Lüneburger Heide (Schwindebeck und Grevenhof im oberen Luhetal). Flora, 152: 325—370.

— 1970. Die Flora des Helgoländer Süsswasser-"Töcks", eines Eem-Interglazials unter der Nordsee. Flora, 159: 133—146.

— 1974. Die Vegetation im Spätpleistozän von Osterwanna/Niedersachsen. Geol. Jb., A 18: 3—48.

— & Lade U. 1986. Eine Folge von Eem und 4 Weichsel-Interstadialen in Oerel/Niedersachsen und ihr Vegetationsablauf. Eiszeitalter u. Gegenwart, 36: 11—36.

Ber A. 1974. Czwartorzęd Pojezierza Suwalskiego (summary: The Quaternary of the Suwałki Lake District). Biul. Inst. Geol., 269: 23—106.

Beug H. J. 1961. Leitfaden der Pollenbestimmung. G. Fischer Verlag, Stuttgart.

— 1973. Die Bedeutung der interglazialen Ablagerungen von Zeifen und Eurach (Oberbayern, BRD) für die Vegetationsgeschichte der Eem-Warmzeit am Nordrand der Alpen. In: Grichuk V. P. (ed.), Palynology of the Pleistocene and Pliocene. Proc. IIIrd Intern. Palynol. Conf., Novosibirsk 1971.

— 1979. Vegetationsgeschichtlich-pollenanalytische Untersuchungen am Riss/Würm-Interglazial von Eurach am Starnberger See/Obb. Geol. Bavarica, 80: 91—106.

Białobrzeska M. & Truchanowiczówna J. 1960. Zmienność kształtu owoców i łusek europejskich brzóz (*Betula* L.) oraz oznaczanie ich w stanie kopalnym (summary: The variability of shape of fruits and scales of the European birches (*Betula* L.) and their determination in fossil materials). Monogr. Bot., 9: 1—95.

Birkenmajer K. & Środoń A. 1960. Interstadiał oryniacki w Karpatach (summary: Aurignacian Interstadial in the Carpathians). Biul. Inst. Geol., 150: 9—70.

Birks H. J. B. 1973a. Past and present vegetation of the Isle of Skye. A palaeobotanical study. Cambridge Univ. Press, London.

— 1973b. Modern pollen rain studies in some arctic and alpine environments. In: Birks H. J. B. & West R. G. (eds.), Quaternary Plant Ecology. Blackwell Sci. Publ., Oxford—London—Edinburgh—Melbourne.

Bitner K. 1954. Charakterystyka paleobotaniczna utworów interglacjalnych w Horoszkach koło Mielnika na Podlasiu (summary: The palaeobotanic characteristic of the interglacial deposits at Horoszki near Mielnik in Podlasie). Biul. Inst. Geol., 69: 79—91.

— 1956a. Flora interglacjalna w Otapach (summary: Interglacial flora in Otapy/District Białystok). Biul. Inst. Geol., 100: 61—142.

— 1956b. Nowe stanowiska trzech plejstoceńskich flor kopalnych (summary: Three new localities of Pleistocene flora). Biul. Inst. Geol., 100: 247—262.

— 1957. Trzy stanowiska flory interglacjalnej w okolicach Sidry (summary: Three localities of interglacial flora of Sidra, northly of Sokółka in Polesie). Biul. Inst. Geol., 118: 109—154.

Borówko-Dłużakowa Z. 1956. Ekspertyza palinologiczna 6-ciu próbek z Łodzi-Polesia i Leżnicy pow. Łęczyca. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1958. Orzeczenie w sprawie analizy pyłkowej próbek z miejscowości Karolino. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1959. Wyniki analizy pyłkowej próbek z profilu Bylice. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1960. Dwa nowe profile interglacjalne z Warszawy w świetle badań paleobotanicznych (summary: Two new Interglacial stratigraphical columns from Warsaw in the light of palaeobotanical investigations). Biul. Inst. Geol., 150: 105—130.

— 1962. Orzeczenie palinologiczne dotyczące próbek z wierc. I i II w Moczydle, ark. Serock. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1966. Ekspertyza palinologiczna próbek w profilu Błaskowizna, ark. Olecko. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1967. Badania paleobotaniczne osadów młodoplejstoceńskich (Brørup) w Koninie-Marantowie (summary: Palaeobotanical studies of Late Pleistocene deposits (Brørup) in the Konin-Marantów area). Prace Inst. Geol., 48: 81—136.

— 1971a. Orzeczenie dotyczące 5 prób z profilu Ciechanowiec, ark. Ciechanowiec, 3 prób z Konopek Leśnych, ark. Łomża, 1 próby ze Zdrodów Starych, ark. Bielsk Podlaski. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1971b. Ekspertyza palinologiczna z prób z profilu Mystki, ark. Wysokie Mazowieckie. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1971c. Kopalna flora interglacjału eemskiego w Smolnikach koło Suwałk (summary: Fossil flora from Eemian Interglacial at Smolniki near Suwałki). Przegl. Geogr., 43 (4): 591—600.

— 1972. Analiza palinologiczna interglacjału eemskiego w Goczałkowie. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1973a. New localities with Eemian flora in the Polish Lowland. In: Palinologiya Pleystotsena i Pliotsena. Nauka, Moskva.

— 1973b. Analiza pyłkowa profilów interglacjału eemskiego w Skierniewicach, Białyninie i Wyszkowie (summary: Pollen analysis of profiles of the Eemian Interglacial at Skierniewice, at Białynin and at Wyszków). Przegl. Geogr., 45 (4): 771—779.

— 1973c. Wyniki wstępnych badań palinologicznych w Gawrońcu koło Warszawy (doniesienie tymczasowe). Przewodnik Zjazdu Naukowego pod hasłem "Geneza gleb wytworzonych z utworów przekształconych peryglacjalnie na Niżu Polskim". Pol. Tow. Gleboznawcze, Warszawa.

— 1974. Eemska flora z Klewinowa na Nizinie Podlaskiej (summary: Eemian flora at Klewinowo in the Podlasie Lowlands). Biul. Inst. Geol., 269: 11—22.

— 1975a. Ekspertyza palinologiczna dotycząca 13 prób z miejscowości Jednaczewo, 5 prób z miejscowości Kupiski, ark. Łomża. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1975b. Interglacjalna makroflora z osadów w Szwajcarii koło Suwałk (summary: Interglacial macroflora of the Szwajcaria sediments near Suwałki). Prace Muzeum Ziemi, 24: 145—161.

— 1976. Wyniki analizy palinologicznej osadów z profilu Nidzica nr 12, ark. Olsztyn. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1977a. Ekspertyza palinologiczna 2 prób z profilu Borzęcin, ark. Żyrardów i 2 prób z profilu Włochy, ark. Warszawa-Zachód. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1977b. Ekspertyza palinologiczna z prób z Rząśnika, ark. Wyszków i Ossowa, ark. Warszawa-Wschód. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1978. Ekspertyza palinologiczna 3 próbek z sondy 345 — profilu Zębców, ark. Krotoszyn (1:100 000) oraz 1 próbki z sondy 1066 profilu Rososzyca, ark. Opatówek (1:100 000). MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1979. Młodoplejstoceńskie i postglacjalne stanowiska flor kopalnych w Koninie (summary: Late Pleistocene and Post-Glacial floral localities in Konin). Kwart. Geol., 23 (1): 247—257.

— 1981. Interglacjał mazowiecki na Wyżynie Wieluńskiej (summary: The Mazovian Interglacial in the Wieluń Upland). Biul. Inst. Geol., 321: 259—275.

— 1985. Orzeczenie palinologiczne w sprawie próbek ze stanowiska Siekierki (dolina Wisły). MS. Arch. Geol. Surv. of Poland, Warsaw.

— & Halicki B. 1957. Interglacjały Suwalszczyzny i terenów sąsiednich (summary: Interglacial sections of the Suwałki region and of the adjacent territory). Acta Geol. Polon., 7: 361—401.

— & Janczyk-Kopikowa Z. 1963. Orzeczenie dotyczące próbek ze Szklar Dolnych i Górnych, ark. Lubin. MS. Arch. Geol. Surv. of Poland, Warsaw.

Bowen D. Q. 1979a. Quaternary correlations. Nature, 277: 171—172.

— 1979b. Reply on J. Mangerud: "One or more Eemian interglacials?". Nature, 279: 108.

Bremówna M. & Sobolewska M. 1950. Wyniki badań botanicznych osadów interglacjalnych w dorzeczu Niemna (Summary: The results of botanical investigations of interglacial deposits in the Niemen Basin). Acta Geol. Polon., 1: 335—364.

Brodniewicz I. 1969. Mięczaki z interglacjalnych iłów z Elbląga i Nadbrzeża (summary: Molluscs of interglacial clays from Elbląg and Nadbrzeże). Acta Palaeont. Polon., 14 (2): 253—290.

— 1972. Pleistocene foraminifers of the area of the Lower Vistula River (Northern Poland). Acta Palaeont. Polon., 17 (4): 423—518.

Browicz K. 1968. *Tilia* L. In: Tutin T. G. et al. (eds.), Flora Europaea, 2. Cambridge Univ. Press, London.

— 1972. *Abies alba* Mill. In: Browicz K. (ed.), Atlas rozmieszczenia drzew i krzewów w Polsce (Atlas of distribution of trees and shrubs in Poland), 12. PWN, Warszawa—Poznań.

— & Gostyńska M. 1965. *Ligustrum vulgare* L. In: Białobok S. & Czubiński Z. (eds.), Atlas rozmieszczenia drzew i krzewów w Polsce (Atlas of distribution of trees and shrubs in Poland), 4. PWN, Poznań.

— & Gostyńska-Jakuszewska M. 1969. *Taxus baccata* L. In: Białobok S. & Browicz K. (eds.), Atlas rozmieszczenia drzew i krzewów w Polsce (Atlas of distribution of trees and shrubs in Poland) 8. PWN, Poznań.

—, —, Hantz J. & Kapuściński R. 1977. *Hippophaë rhamnoides* L. In: Browicz K. (ed.), Atlas rozmieszczenia drzew i krzewów w Polsce (Atlas of distribution of trees and shrubs in Poland), 24. PWN, Warszawa—Poznań.

Butrym J., Baraniecka M. D., Kasza L., Brodzikowski K., Hałuszczak A., Gotowała R., & Janczyk-Kopikowa Z. 1982. Datowanie bezwzględne osadów czwartorzędowych górnego piętra strukturalnego w strefach Piaski—Buczyna—Chojny odkrywki bełchatowskiej. Czwartorzęd rejonu Bełchatowa, I Sympozjum. Wyd. Geol., Wrocław—Warszawa.

Casper S. J. 1974. Familie *Plantaginaceae*. In: Hegi G., Illustrierte Flora von Mitteleuropa. Bd. VI/1, Lief. 7/8. C. Hauser Verl., München.

Chebotareva N. S. 1972-I/II. Die interglazialen Mikulino-Schichten im Nordwesten der Russischen Tafel. Ber. Deutsch. Ges. Geol. Wiss., A. Geol.-Paläont.: (I) — 17: 101—118, (II) — 3: 377—389.

—, Adadzhanyan A. K., Gorlova R. N., Paramonova N. N., Sokolova N. S., Sudakova N. G. & Cukurova A. M. 1975. Vicinity of Rostov Yaroslavsky. In: Excursion Moscow — the Upper Volga. Biul. Perygl., 24: 130—151.

Chmielewski W. 1961. Skaratki. Guide-book of Excursion C — The Łódź Region. INQUA VIth Congress. PWN, O/Łódź.

—, Schild R. & Więckowska H. 1975. Prahistoria Ziem Polskich. I — Paleolit i Mezolit. Ossolineum, Wrocław—Warszawa—Kraków—Gdańsk.

Churski Z. 1966. Młodoplejstoceńskie (międzymorenowe) osady jeziorne z okolic Kurzętnika nad Drwęcą (summary: Young-Pleistocene (intermorainic) lacustrine deposits from the region of Kurzętnik, near Nowe Miasto on river Drwęca). Zesz. Nauk. UMK Toruń, Nauki Mat.-Przyr., 14: 5—15.

Cielińska M. & Szczypek P. 1974. Nowe interglacjalne stanowisko w Sudetach Zachodnich (summary: A new interglacial locality in Western Sudets Mts.). Acta Univ. Wratisl., 236: 25—38.

Cushing E. J. 1964. Application of the Code of Stratigraphic Nomenclature to Pollen Stratigraphy. Unpubl. MS.

— 1967a. Evidence for differential pollen preservation in Late Quaternary sediments in Minnesota. Rev. Palaeobot. Palynol., 4: 87—101.

— 1967b. Late-Wisconsin pollen stratigraphy and the glacial sequence in Minnesota. In: Cushing E. J. & Wright H. E. (eds.), Quaternary Paleoecology. Yale Univ. Press, New Haven and London.

Dąbrowski M. J. 1971. Palynochronological Materials — Eemian Interglacial. Bull. l'Acad. Pol. d. Sc., 19 (1): 29—36.

Dąmbska I. 1961. Roślinne zbiorowiska jeziorne okolic Sierakowa i Międzychodu (summary: Plant communities of lakes in the region of Sieraków and Międzychód). Prace Kom. Biol. Pozn. Tow. Przyj. Nauk, 23 (4): 1—120.

— 1964. *Charophyta* — Ramienice. In: Starmach K. (ed.), Flora słodkowodna Polski, 13. PWN, Warszawa.

Drozdowski E. & Tobolski K. 1972. Stanowiska interglacjału eemskiego w Basenie Grudziądzkim (wiadomość wstępna) (summary: Sites of Eem Interglacial in Grudziądz Basin (preliminary information)). Bad. Fizjogr. nad Polską Zach., 25 A: 75—91.

Dyakowska J. 1936. Interglacjał w Poniemuniu pod Grodnem (summary: Interglacial in Poniemuń near Grodno). Starunia, 14: 1—11.

Dyjor S. & Kuszell T. 1977. Neogeńska i czwartorzędowa ewolucja rowu tektonicznego Roztoki-Mokrzeszowa (summary: Development of the Roztoka-Mokrzeszów Graben in the Neogene and Quaternary). Geol. Sudetica, 12 (2): 113—132.

Dylik J. 1967. The main elements of Upper Pleistocene paleogeography in Central Poland. Biul. Perygl., 16: 85—116.

— 1968. The earliest warmer substage of the Würm (Amersfoort) in Poland. Bull. Soc. Sci. et Lettr. de Łódź, 19 (4): 1—15.

— 1972. Znaczenie spłukiwania w morfogenezie peryglacjalnej. Sprawozdania Łódzk. Tow. Nauk., 26 (2): 1—13.

Ehrendorfer F. 1973. Liste der Gefässpflanzen Mitteleuropas. G. Fischer Verlag, Stuttgart.

Ellenberg H. 1974. Zeigewerte der Gefässpflanzen Mitteleuropas. Scripta Geobot., 9: 1—97.

Engler A. 1964. Syllabus der Pflanzenfamilien. B. II. Angiospermen. Gebrüder Borntraeger, Berlin.

Erd K. 1960. Das Eem-Interglazial von Kerkwitz-Atterwasch bei Guben. Wiss. Zeitschr. Päd. Hochsch. Potsdam, Math.-Nat. R., 6: 107—118.

— 1973. Pollenanalytische Gliederung des Pleistozäns der Deutschen Demokratischen Republik. Z. Geol. Wiss. Berlin, 1 (9): 1087—1103.

— 1978. Pollenstratigraphie im Gebiet der skandinavischen Vereisungen. Schrifter. Geol. Wiss. Berlin, 9: 99—119.

Erdtman G., Berglund B. & Praglowski J. 1961. An introduction to a Scandinavian Pollen Flora. Grana Palynol., 2 (3): 3—92.

Faegri K. 1950. Studies on the Pleistocene of western Norway IV. On the immigration of *Picea abies*. Univ. Bergen Årbog 1949, R. 1.

— & Iversen J. 1978. Textbook of pollen analysis. Munksgaard, Copenhagen.

Fairbridge R. W. 1972. Climatology of a glacial cycle. Quater. Research, 2: 283—302.

Firbas F. 1934. Über die Bestimmung der Walddichte und der Vegetation Waldloser Gebiete mit Hilfe der Pollenanalyse. Planta, 22: 109—145.

— 1949. Spät- und nacheiszeitliche Waldgeschichte Mitteleuropas nördlich der Alpen. 1. G. Fischer Verl., Jena.

Frenzel B. 1967. Die Klimaschwankungen des Eiszeitalters. Braunschweig.

— 1973. Some remarks on the Pleistocene vegetation. Eiszeitalter u. Gegenwart, 23/24: 281—292.

Gadomska S. 1966. Sytuacja geologiczna osadów interglacjału eemskiego w Gołkowie koło Warszawy (summary: Geological situation of the Eemian Interglacial deposits at Gołków near Warsaw). Kwart. Geol., 10: 425—442.

Gajewski W. 1931. Szczątki flory pierwotnej w jarze Dniestru. Ochrona Przyrody, 11.

Galon R. & Roszkówna L. 1967. Zasięgi zlodowaceń skandynawskich i ich stadiów recesyjnych na obszarze Polski. In: Galon R. & Dylik J. (eds.), Czwartorzęd Polski. PWN, Warszawa.

Gawłowska M. 1935. Jezierze (*Najas*) w dyluwium polskim (summary: *Najas* in the Polish Diluvium). Starunia, 6: 1—13.

Godwin H. 1975. The history of the British Flora. Cambridge Univ. Press., London.

Gołąb J. & Urbański J. 1938. Nowa odkrywka interglacjału na Winiarach koło Poznania (Zusammenfassung: Neuer Aufschluss des Interglazials in Winiary bei Poznań). Rocz. Pol. Tow. Geol., 12: 104—143.

Gorlova R. N. 1968a. Smena rastitelnogo pokrova v Mikulinskoye mezhlednikovye po issledovaniyam torfyannikov Yaroslavskoy oblasti. Nauka, Moskva.

— 1968b. Smena rastitelnosti kak komponenta biogeotsenozov v predposledneye mezhlednikovye. Nauka, Moskva.

— 1975. Some results of paleobiocoenosic studies of Mikulino (MGIN) deposits in the Rostov Basin, region of Yaroslavl. Biul. Perygl., 24: 25—31.

Gostyńska-Jakuszewska M. & Zieliński J. 1976. *Fagus silvatica* L. In: Browicz K. (ed.), Atlas rozmieszczenia drzew i krzewów w Polsce (Atlas of distribution of trees and shrubs in Poland), 18. PWN, Warszawa—Poznań.

Goździk J. & Jastrzębska-Mamełka M. 1982. Osady eemskie w kopalni węgla brunatnego "Bełchatów". Czwartorzęd rejonu Bełchatowa, I Sympozjum. Wyd. Geol., Wrocław—Warszawa.

Grichuk V. P. 1950. Rastitelnost Russkoy ravniny v nizhne i srednechetvertichnoye vremya. Tr. In-ta Geogr., 46.

— 1961. Iskopaemye flory kak paleontologicheskaya osnova stratigrafii chetvertichnykh otlozheniy. In: Relief i stratigrafiya chetvertichnykh otlozheniy severo-zapada Russkoy ravniny. Izd. Akad. Nauk SSSR, Moskva.

— 1972. Osnovnye etapy istorii rastitelnosti yugo-zapada Russkoy ravniny v pozdnem pleystotsenie (summary: Main stages in the vegetational evolution of the south-western part of the Russian plain during the Late Pleistocene). In: Grichuk V. P., Palinologiya Pleystotsena. AN SSSR, Novosibirsk— Moskva.

— 1982. Rastitelnost Evropy v pozdnem pleystotsene. In: Gerasimov I. P. & Velichko A. A. (eds.), Paleogeografiya Evropy za posledniye sto tysyach let (Atlas — monografiya). Nauka, Moskva.

Grüger E. 1968. Vegetationsgeschichtliche Untersuchungen an cromerzeitlichen Ablagerungen im nördlichen Randgebiet der deutschen Mittelgebirge. Eiszeitalter u. Gegenwart, 18: 204—235.

— 1979. Spätriss, Riss/Würm und Frühwürm am Samerberg in Oberbayern — ein vegetationsgeschichtlicher Beitrag zur Gliederung des Jungpleistozäns. Geol. Bavarica, 80: 5—64.

— 1983. Samerberg. Symposium "Würm-Stratigraphie" München 1983. Führer zu den Excursionen der Subkommission für Europäische Quartärstratigraphie: 88—92.

Gürich G. 1905. Der Schneckenmergel von Ingramsdorf und andere Quartärfunde in Schlesien. Jb. Preuss. Geol. Land. u. Bergakad., 26: 43—57.

Hafsten U. 1969. A proposal for a synchronous subdivision of the Late Pleistocene Period having global and universal applicability. Nytt Mag. Bot., 16: 1—13.

Halicki B. 1946. Stratygrafia polskiego plejstocenu (Stratigraphy of the Pleistocene in Poland). Starunia, 21: 21—25.

— 1950. Z zagadnień stratygrafii plejstocenu na Niżu Europejskim (summary: Some problems concerning the stratigraphy of the Pleistocene of the European Lowland). Acta Geol. Polon., 1: 106—142.

— 1951. Z historii plejstoceńskiego Bałtyku. Acta Geol. Polon., 2: 595—615.

— 1953. O geomorfologicznej metodzie wykrywania organogenicznych osadów interglacjalnych i jej konsekwencjach (summary: A geomorphologic method detection of interglacial organogenic sediments). Acta Geol. Polon., 3: 147—157.

— & Brodniewicz I. 1961. La stratigraphie du Pléistocène supérieur dans la région péribaltique méridionale. Bull. l'Acad. Pol. d. Sc., Sér. Sc. Géol. Géogr., 9 (3): 163—168.

Hallik R. 1953. Zur Feinstratigraphie des Eem-Interglazials. Geol. Jb., 68: 179—183.

— 1957. Material zur Vegetationsentwicklung während der Eem-Warmzeit in Nordwestdeutschland. Mitt. Geol. Staatsinst. Hamburg, 26: 31—38.

Hartmann F. 1907. Die fossile Flora von Ingramsdorf. Inaug. Diss. Univ. Breslau.

Heck H. L. 1929. Über ein neues Vorkommen interglazialer Torfe und Tone bei Rinnersdorf (nahe Schwiebus) in der östlichen Mark Brandenburg. Jb. Preuss. Geol. Land. Berlin, 49: 1117—1126.

Hegi G. 1965. Illustrierte Flora von Mitteleurope. C. Hauser Verlag, München, 5 (1): 678.

Hultén E. 1950. Atlas över växternas utbredning i Norden (Atlas of the distribution of vascular plants in NW. Europe). Gen. Lit. Aust. Förl., Stockholm.

Hustich I. 1948. The Scotch pine in northernmost Finland and its dependence on the climate in the last decads. Acta Bot. Fenn., 42: 1—75.

McIntyre A. & Ruddiman W. F. 1972. Northeast Atlantic Post-Eemian paleooceanography: a predictive analog of the future. Quater. Research, 2: 350—354.

Iversen J. 1944. Viscum, Hedera and Ilex as climate indicators. A contribution to the study of the Post-Glacial temperature climate. Geol. Fören. Förhlandl., 66 (3): 463—483.

— 1945. Conditions of life for the large herbivorous mammals in the Late-glacial Period. In: Dagerbøl M. & Iversen J. (eds.), The Bison in Denmark. Danm. Geol. Unders., 2 (73): 49—57.

— 1954. The Late-glacial flora of Denmark and its relation to climate and soil. Danm. Geol. Unders., 2 (80): 87—119.

Janczyk-Kopikowa Z. 1964. Eemskaya mezhlednikovaya flora v Kaliskoy. Report of the VIth Int. Congr. on Quatern., Warsaw 1961, 2: 429—431.

— 1965a. Flora interglacjału eemskiego w Kaliskiej koło Chodcza na Kujawach (summary: Eemian interglacial flora at Kaliska near Chodecz in Kujawy). Biul. Inst. Geol., 187: 107—117.

— 1965b. Orzeczenie dotyczące próbek czwartorzędowych z miejscowości Bajerze. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1966a. Interglacjał eemski w Gołkowie koło Warszawy (summary: Eemian Interglacial at Gołków near Warsaw). Kwart. Geol., 10 (2): 453—461.

— 1966b. Stratygraficzno-paleobotaniczne opracowanie czwartorzędu rejonu Bełchatowa. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1968. Orzeczenie dotyczące próbek czwartorzędowych z miejscowości Białki, Obory i Grabówka. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1970. Analiza pyłkowa osadów z obszaru doliny dolnej Wisły. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1971. Analiza pyłkowa nowych stanowisk interglacjału eemskiego z dorzecza Widawki (summary: Pollen analysis of new sites of the Eemian Interglacial in the drainage basin of the Widawka). Biul. Inst. Geol., 254: 65—88.

— 1973. Analiza pyłkowa osadów interglacjału eemskiego w Grodzisku Mazowieckim (summary: Pollen analysis of the Eemian Interglacial in Grodzisk Mazowiecki). Kwart. Geol., 17 (4): 821—827.

— 1975a. Flora interglacjału mazowieckiego w Ferdynandowie (summary: Flora of the Mazovian Interglacial at Ferdynandów). Biul. Inst. Geol., 290: 5—94.

— 1975b. The Eemian Interglacial sediments at Błonie near Warsaw. Bull. l'Acad. Pol. d. Sc., Sér. Sc. d. la Terre, 22 (3/4): 147—150.

— 1976a. Analiza pyłkowa osadów w Nowinach. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1976b. Opracowanie palinologiczne prób z profilu wiertniczego Nadbrzeża. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1985. Analiza pyłkowa osadów interglacjału eemskiego w Rogowie (summary: Pollen analysis of sediments of Eem Interglacial at Rogów). Roczniki Gleboznawcze, 36 (2): 143—148.

—, Mojski J. E. & Rzechowski J. 1981. Position of the Ferdynandów Interglacial, Middle Poland, in the Quaternary stratigraphy of the European Plain. Biul. Inst. Geol., 335: 65—79.

Jastrzębska-Mamełka M. 1979. Eemian and Early Vistulian organic sediments at Zgierz-Rudunki near Łódź. Bull. Soc. Sci. et Lettr. de Łódź, 29 (3): 1—6.

— 1984. Interglacjał eemski i wczesny Vistulian w Świątnikach. In: Konf. robocza — Rozwój sieci dolinnej w późnym plejstocenie i holocenie na Wyżynie Łódzkiej. Wyd. Uniw. Łódzkiego, Łódź.

— 1985. Interglacjał eemski i wczesny Vistulian w Zgierzu-Rudunkach na Wyżynie Łódzkiej (summary: The Eemian Interglacial and the Early Vistulian at Zgierz-Rudunki in the Łódź Plateau). Acta Geogr. Lodz., 53: 1—75.

Jessen K. & Milthers V. 1928. Stratigraphical and paleontological studies of interglacial fresh-water deposits in Jutland and Northwest Germany. Danm. Geol. Unders., 2 (48): 1—379.

Jewtuchowicz S. 1970. Rozwój rzeźby okolic Łęczycy po zlodowaceniu środkowopolskim (summary: Evolution of land-forms in the region of Łęczyca since the Middle-Polish Glaciation). Prace Geogr., 85: 1—79.

Jonassen H. 1950. Recent pollen sedimentation and Jutland heath diagrams. Dansk Bot. Arkiv., 13 (7): 1—168.

Jung W., Beug H. J. & Dehm R. 1972. Das Riss/Würm-Interglazial von Zeifen, Landkreis Laufen a. d. Salzach. Bayer. Akad. Wiss., Math.-Naturw. Kl., Abh., N. F., 151: 1—131.

Jurkiewiczowa I., Mamakowa K. & Rühle E. 1973. Utwory środkowego plejstocenu na południe od Wyśmierzyc (obok Nowego Miasta nad Pilicą) (summary: Middle Pleistocene deposits south of Wyśmierzyce near Nowe Miasto on the Pilica river). Folia Quater., 43: 1—26.

Kac N. J., Kac S. V. & Kipyani M. G. 1965. Atlas i opredelitel plodov i semyan vstrechayushchikhsya v chetvertichnykh otlozheniayakh SSSR (Atlas and keys of fruits and seeds occurring in the Quaternary deposits of the USSR). Nauka, Moskva.

Kaczmarska I. 1976. Diatom analysis of Eemian profile in fresh-water deposits at Imbramowice near Wrocław. Acta Palaeobot., 17 (2): 3—34.

Kalniet A. 1955. Międzylodowcowe jeziora kopalne w południowej części Niżu Polskiego. Acta Geol. Polon., 5 (3): 405—426.

Karaszewski W. 1973. Jeziorny interglacjał eemski w Goczałkowie pod Strzegomiem (summary: Lacustrine Eemian Interglacial at Goczałków near Strzegom (Lower Silesia)). Kwart. Geol., 17 (1): 139—142.

— 1975. Age of the Warsaw ice dammed lake sediments. Bull. l'Acad. Pol. d. Sc., Sér. Sc. Terre, 22 (3/4): 151—155.

Karczmarz K. (this volume). Fossil mosses and stoneworts at Imbramowice near Wrocław. Acta Palaeobot., 29 (1): 179—186.

Klajnert Z. & Piechocki A. 1972. Górnoplejstoceńskie osady doliny Bobrówki koło Łowicza i ich zawartość malakologiczna (summary: The Upper-Pleistocene deposits with molluscan fauna in the Bobrówka valley near Łowicz). Folia Quater., 40: 1—36.

Klatkowa H. 1972. Paleogeografia Wyżyny Łódzkiej i obszarów sąsiednich podczas zlodowacenia Warciańskiego (sommaire: Paleogéographie du Plateau de Łódź et de terrain avoisinant pendant la glaciation de Warta). Acta Geogr. Lodz., 28: 1—228.

Klaus W. 1980. Riss/Würm Interglazial und Würm-Frühglazial von Mondsee. In: Führer zum X. Internationalen Treffen Europäischer Quartärbotaniker in Österreich. Innsbruck 1980.

Kneblova V. 1960. Paleobotanický výzkum interglaciálních travertinu v Gánovcích (Zusammenfassung: Paleobotanische Forschung interglazialer Travertine in Gánovce). Biologické práce, VI/4.

Kociszewska-Musiał G. 1978. Czwartorzędowe surowce okruchowe Suwalszczyzny na tle budowy geologicznej (summary: Quaternary aggregates of the Suwałki Region against its geological background). Prace Muzeum Ziemi, Pr. Geol., 29: 3—79.

Kolesnikova T. D. & Khomutova V. I. 1970. O mezhlednikovikh florakh Vologodskoy oblasti (po dannym palinologicheskogo i paleokarpologicheskogo analizov). Botan. Zhurn., 55 (2): 222—232.

Kondracki J. 1978. Geografia fizyczna Polski. PWN, Warszawa.

Körber-Grohne U. 1967. Geobotanische Untersuchungen auf der Feddersen Wierde. In: Haarnagel W. (ed.), Feddersen Wierde. 1. F. Steiner Verl., Wiesbaden.

Kozarski S., Nowaczyk B. & Tobolski K. 1980. Wstępne wyniki badań osadów stanowiska interstadiału Brørup w Starym Kurowie koło Drezdenka (summary: Results of studies of deposits from Stary Kurów near Drezdenko assigned to the Brørup Interstadial). Przegl. Geol., 4: 210—214.

Kral F. 1971. Pollenanalytische Untersuchungen zur Waldgeschichte des Dachsteinmassivs. Österr. Agrarvlg., Wien.

Kräusel R. 1920. Ein Beitrag zur Kenntnis der Diluvialflora von Ingramsdorf in Schlesien. N. Jb. Miner. Geol. Paläont., 1. Stuttgart.

— 1955. Die Interglazialflora von Lehringen. Palaeontographica, 97: 47—73.

Król S. 1975. Zarys ekologii (summary: An ecological outline). In: Białobok S. (ed.), Cis pospolity — *Taxus baccata* L. Nasze drzewa leśne. Monogr. Inst. Dendr. PAN, 3. PWN, Warszawa—Poznań.

Krupiński K. M. 1973. Studium paleogeograficzne okolic Żyrardowa w młodszym plejstocenie. Praca doktorska. Arch. Inst. Geogr. UW, Warszawa.

— 1978. Historia, dynamika rozwoju i zaniku zbiornika interglacjalnego w Żyrardowie (summary: History and dynamics of the development and disappearance of an interglacial basin in Żyrardów). Biul. Inst. Geol., 300: 153—178.

—, Rytel A. & Saliński P. 1982. Stanowisko eemskich osadów jeziornych w Karczunku na Wysoczyźnie Lubartowskiej (summary: The locality of Eemian lacustrine deposits at Karczunek, Lubartów Upland). Kwart. Geol., 26 (1): 147—158.

Kukla G. J. 1977. Pleistocene land-sea correlations. I. Europe. Earth Sci. Rev., 13: 307—374.

Kunkel A. & Tobolski K. 1977. Interglacjał eemski w Swarzędzu koło Poznania (summary: Eemian Interglacial from Swarzędz near Poznań). Przegl. Geol., 5: 249—250.

Kuszell T. 1980. Trzy nowe stanowiska flory z interglacjału eemskiego na Dolnym Śląsku (summary: Three new localities of Eemian flora in Lower Silesia). Geol. Sudetica, 15 (1): 143—167.

Liivrand E. 1974a. Mikuulini jäävaheaja taimestik Eestis (summary: Flora of the Mikulino Interglacial in Estonia). Eesti Loodus, 9: 537—542.

— 1974b. O vozraste valgutaskikh mezhmorennykh otlozheniy Yugo-Vostochnoy Estonii po palinologicheskim dannym (Zusammenfassung: Zur Alterbestimmung der Ablagerungen des Bohrprofils von Valguta nach Pollenanalyse). Izvestiya AN ESSR, 23 (1): 54—58.

— 1977. Zaleganie mikulinskikh mezhlednikovykh otlozheniy v Yugo-Vostochnoy Estonii (summary: The bedding of Miculian Interglacial deposits in South-East Estonia). Izvestiya AN ESSR, 26 (4):289—303.

Liivrand E. & Pirrus R. 1973. Primenenie ekologo-geograficheskogo analiza i metoda variogramm pri izuchenii sporovo-pyltsevykh spektrov otlozheniy lednikovykh epokh na territorii Estonii (summary: Application of the ecological-geographical analysis and the method variograms to the study of spore-pollen spectra from glacial deposits on the territory of Estonia). In: Palinologiya Pleystotsena i Pliotsena, Izd. Nauka, Moskva.

— & Saarse L. 1976. Geologicheskaya i palinologicheskaya kharakteristika verkhnepleystotsenovykh otlozheniy mestonakhozhdeniya Peedu (summary: Geological and palynological investigation of Upper Pleistocene intermorainic deposits at Peedu). Izvestiya AN ESSR, 25 (4): 334—342.

Lilienfeldówna F. 1919. *Najadaceae*. In: Raciborski M. & Szafer W. (eds.), Flora Polska. Rośliny naczyniowe Polski i ziem ościennych. 1. Akademia Umiejętności, Kraków.

Lilpop J. 1925. Charakterystyka paleobotaniczna profilu dyluwialnego pod Koszarami. Posiedz. Nauk. Państw. Inst. Geol., 11: 10—11.

Lindner L. & Ziembińska-Tworzydło M. 1974. Osady interglacjału eemskiego w Zakruczu koło Małogoszcza. Komunikat wstępny (summary: The Eemian Interglacial deposits at Zakrucze near Małogoszcz, western part of the Świętokrzyskie Mts. Preliminary report). Kwart. Geol., 18 (3): 636—646.

Litvinyuk G. I. 1979. Novye dannye o flore Zhukevichey (r. Gornitsa) na Nemane. In: Goretskiy G. I. & Grichuk V. P. (eds.), Sovetskaya Paleokarpologiya. Izd. Nauka, Moskva.

Ławrynowicz M. 1983. *Cenococcum graniformae* w Polsce (summary: *Cenococcum graniformae* in Poland). Acta Mycol., 19 (1): 31—40.

Makhnach N. A. 1971. Etapy razvitiya rastitelnosti Byelorussii v antropogene (Stages of the development of the vegetation of the Byelorussia during Anthropogen). Izd. Nauka i Tekhnika, Minsk.

—, Mander K. P., Rylova T. B., Krutous E. A., Loginava L. P. & Khursevich G. K. 1975. Paleabatanichniya dasledavanni muravinskikh (mikulinskikh) azernykh adkladav Byelarusi. Vestsi AN BSSR, 6: 53—58.

Makowska A. 1979a. Stratigraphy of Vistulian Glaciation deposits in the Lower Vistula valley at the background of marine and continental key series of Eemian Interglacial. Gniew. Symposium on Vistulian Stratigraphy, Poland. Guide-book of Excursion 5: 18—20.

— 1979b. Interglacjał eemski w dolinie dolnej Wisły (summary: Eemian Interglacial in valley of Lower Vistula River). Studia Geol. Polon., 63: 1—90.

— 1986. Morza plejstoceńskie w Polsce — osady, wiek i paleogeografia (summary: Pleistocene seas in Poland — sediments, age and palaeogeography). Prace Inst. Geol., 70: 1—74.

Mamakowa K. 1962. Roślinność Kotliny Sandomierskiej w późnym glacjale i holocenie (summary: The vegetation of the Basin of Sandomierz in the Late-Glacial and Holocene). Acta Palaeobot., 3 (2): 1—56.

— 1976. Vegetation of the Eemian Interglacial at Imbramowice near Wrocław. Preliminary report. Acta Palaeobot., 17 (1): 27—38.

— 1979. Die Stratigraphie des Spät-Eem und Beginn der Vistulianzeit auf der pollenanalytische Grundlage. Summary of the lecture presented at the Intern. Symposium on Vistulian Stratigraphy, Poland.

— 1986. Lower boundary of the Vistulian and the Early Vistulian pollen stratigraphy in continuous Eemian-Early Vistulian pollen sequences in Poland. Quater. Studies in Poland, 7: 51—63.

—, Mook W. G. & Środoń A. 1975. Late Pleistocene at Kąty (Pieniny Mts., West Carpathians). Acta Palaeobot., 16 (2): 147—172.

— & Starkel L. 1974. New data about the profile of Young Quaternary deposits at Brzeźnica on the Wisłoka River. Stud. Geomorph. Carpatho-Balcan., 8: 47—59.

— & — 1977. Stratigraphy of Late Glacial and Early Holocene alluvia at Podgrodzie on the Wisłoka River (SE Poland). Stud. Geomorph. Carpatho-Balcan., 11: 101—110.

— & Wójcik A. 1987. Stanowisko osadów interglacjału eemskiego w Dąbrówce koło Jasła. Kwart. Geol., 1: 213—214.

Mangerud J. 1970. Late Weichselian vegetation and ice-front oscillations in the Bergen District, Western Norway. Norsk geogr. Tidsskr., 24: 121—148.

—, Andersen S. T., Berglund B. E. & Donner J. J. 1974. Quaternary stratigraphy of Norden, a proposal for terminology and classification. Boreas, 3: 109—128.

—, Sønstegaard E. & Sejrup H. P. 1979a. Correlation of the Eemian (interglacial) Stage and the deep-sea oxygen-isotope stratigraphy. Nature, 277: 189—192.

— 1979b. One or more Eemian interglacials?. Nature, 279: 108.

—, Larsen E., Longva O. & Sønstegaard E. 1979c. Glacial history of western Norway 15.000—10.000 B. P. Boreas, 8: 179—187.

—, Sønstegaard E., Sejrup H. P. & Haldorsen S. 1981. A continuous Eemian-Early Weichselian sequence containing pollen and marine fossils at Fjøsanger, western Norway. Boreas, 10: 137—208.

Marciniak B. & Kowalski W. W. 1978. Dominant diatoms, pollen, chemistry and mineralogy of the Eemian lacustrine sediments from Nidzica (northern Poland): a preliminary report. Pol. Arch. Hydrobiol., 25 (1/2): 269—281.

Marek S. 1954. Cechy morfologiczne i anatomiczne owoców rodzajów *Polygonum* L. i *Rumex* L. oraz klucze do ich oznaczania (summary: Morphological and anatomical features of the fruits of genera *Polygonum* L., *Rumex* L. and keys for their determination). Monogr. Bot., 2: 77—161.

Markgraf F. 1981. Familie *Najadaceae*. In: Hegi G., Illustrierte Flora von Mitteleuropa. Bd. 1/2. Verl. P. Parey, Berlin—Hamburg.

Maruszczak H. 1980. Stratigraphy and chronology of the Vistulian loesses in Poland. Quater. Studies in Poland, 2: 57—76.

— 1985. Problems of stratigraphy and palaeogeography of loesses in Poland. In: Guide-book of the Intern. Symp. — Problems of the stratigraphy and paleogeography of loesses. UMCS, Lublin.

Matthews R. K. 1972. Dynamics of the ocean-cryosphere system: Barbados data. Quater. Research, 2 (3): 368—373.

— 1973. Relative elevation of Late Pleistocene high sea level stands: Barbados uplift rates and their implications. Quater. Research, 3: 147—153.

Matuszkiewicz W. 1981. Przewodnik do oznaczania zbiorowisk roślinnych Polski. PWN, Warszawa.

— & Matuszkiewicz J. 1973. Przegląd fitosocjologiczny zbiorowisk leśnych Polski. Cz. 2. Bory sosnowe (Zusammenfassung: Pflanzensoziologische Übersicht der Waldgesellschaften von Polen. Teil 2. Die Kiefernwälder). Phytocoenosis, 2 (4): 273—356.

Mądalski J. 1961. Uwagi do pracy F. Hartmanna "Die fossile Flora von Ingramsdorf" (Zusammenfassung: Die Bemerkungen zur F. Hartmanns "Die fossile Flora von Ingramsdorf"). Kwart. Opolski, Zesz. Przyr. 1: 53—54.

Medwecka-Kornaś A., Kornaś J., Pawłowski B. & Zarzycki K. 1972. Przegląd ważniejszych zespołów roślinnych Polski. In: Szafer W. & Zarzycki K. (eds.), Szata Roślinna Polski. 1. PWN, Warszawa.

Meene E. A. van de & Zagwijn W. H. 1978. Die Rheinläufe im deutsch-niederländischen Grenzgebiet seit der Saale-Kaltzeit. Überblick neuer geologischer und pollenanalytischer Untersuchungen. Fortschr. Geol. Rheinld. u. West., 28: 345—359.

Menke B. 1967. Ein Beitrag zur eemzeitlichen Vegetations- und Klimageschichte nach dem Profil von Ostrohe/Schleswig-Holstein. Fundamenta, R. B, 2: 126—135.

— 1970. Ergebnisse der Pollenanalyse zur Pleistozän-Stratigraphie und zur Pliozän-Pleistozän-Grenze in Schleswig-Holstein. Eiszeitalter u. Gegenwart, 21: 5—21.

— 1975. Vegetationsgeschichte und Florenstratigraphie Nordwestdeutschlands im Pliozän und Frühquartär. Mit einem Beitrag zur Biostratigraphie des Weichselfrühglazials. Geol. Jb., A 26: 3—151.

— 1976a. Pliozäne und ältestquartäre Sporen- und Pollenflora von Schleswig-Holstein. Geol. Jb., A 32: 3—197.

— 1976b. Neue Ergebnisse zur Stratigraphie und Landschaftsentwicklung im Jungpleistozän Westholsteins. Eiszeitalter u. Gegenwart, 27: 53—68.

— 1980. Vegetationskundlich-ökologisches Modell eines Interglazial-Glazial-Zyklus in Nordwestdeutschland. Phytocoenol., 7: 100—120.

— 1982. On the Eemian Interglacial and the Weichselian Glacial in Northwestern Germany (vegetation, stratigraphy paleosols, sediments). Quater. Studies in Poland, 3: 61—68.

— & Ross P. H. 1967. Der erste Fund von Kieselgur in Schleswig-Holstein bei Brokenlande, südlich von Neumünster. Eiszeitalter u. Gegenwart, 18: 113—126.

— & Tynni R. 1984. Das Eeminterglazial und des Weichselfrühglazial von Rederstall/Dithmarschen und ihre Bedeutung für die mitteleuropäische Jungpleistozän-Gliederung. Geol. Jb., A 76: 3—120.

Meusel H., Jäger E. & Weinert E. 1965. Vergleichende Chorologie der Zentraleuropäischen Flora. VEB G. Fischer Verl., Jena.

Mikulski J. S. 1982. Biologia wód śródlądowych. PWN, Warszawa.

Moe D. 1970. The Post-Glacial immigration of *Picea abies* into Fennoscandia. Bot. Notiser, 123: 61—66,

Mojski J. E. 1962. Opis litologiczny profilu II z miejscowości Moczydło. MS. Arch. Geol. Surv. of Poland, Warsaw.

— 1968. Podstawy podziału zlodowacenia północnopolskiego (summary: Principles for division of the North-Polish Glaciation). Kwart. Geol., 12 (3): 665—679.

— 1969. Stratygrafia zlodowacenia północnopolskiego na obszarze Niżu Polskiego i wyżyn środkowopolskich (summary: Stratigraphy of the North-Polish Glaciation (Würm, Vistula, Kalinin) in the Polish Lowland and the Middle Polish Uplands). Biul. Inst. Geol., 220: 115—173.

— 1974. Sytuacja geologiczna utworów interglacjału eemskiego w Klewinowie na Nizinie Podlaskiej (summary: Geological position of the Eemian Interglacial sediments at Klewinowo in the Podlasie Lowlands). Biul. Inst. Geol., 269: 5—8.

— 1980. Vistulian stratigraphy in the glaciated area of the Polish Lowlands. Quater. Studies in Poland, 2: 77—98.

— 1984a. Osady rzeczne, jeziorne, gleby kopalne i utwory jaskiniowe na pozostałej części Niżu Polskiego i na wyżynach środkowopolskich. In: Sokołowski S. & Mojski J. E. (eds.), Budowa Geologiczna Polski, 1, 3b. Wyd. Geol., Warszawa.

— 1984b. Zlodowacenie północnopolskie. In: Sokołowski S. & Mojski J. E. (eds.), Budowa Geologiczna Polski, 1 3b. Wyd. Geol. Warszawa.

— 1985. Geology of Poland, 1, 3 b. Quaternary. Wyd. Geol., Warszawa.

Morawski W. 1976. Osady jeziorne interglacjału eemskiego na Wawrzyszewie. Kwart. Geol., 20 (4): 920—922.

— 1978. Buried Eemian lake from the northern Warsaw. Pol. Arch. Hydrobiol., 25 (1/2): 297—299.

Moskvitin A. I. 1950. Würmskaya epokha (paleopleistocen) v Evropeyskoy chasti SSSR. Izd. Akad. Nauk SSSR, Moskva.

Müller H. 1953. Zur spät- und nacheiszeitlichen Vegetationsgeschichte des mitteldeutschen Trockengebietes. Nova Acta Leopold., 16 (110): 1—67.

— 1974. Pollenanalytische Untersuchungen und Jahresschichtenzählungen an der eem-zeitlichen Kieselgur von Bispingen/Luhe. Geol. Jb., A 21: 149—169.

Musiał A., Straszewska K. & Ziembińska-Tworzydło M. 1982. Interglacjalny zbiornik jeziorny w Niewodowie na Wysoczyźnie Kolneńskiej (summary: Interglacial lacustrine reservoir at Niewodowo, Kolno Upland). Kwart. Geol., 26 (1): 159—176.

Neustadt M. I. 1953. Rasseleniye leshchiny obyknovennoy po territorii Evropeyskoy chasti SSSR v poslednikovoye vremia. Botan. Zhurn., 38 (3): 330—349.

— 1959. Geschichte der Vegetation der UdSSR im Holozän. Grana Palynol., 2 (1): 69—76.

Niklewski J. 1968. Interglacjał eemski w Główczynie koło Wyszogrodu (summary: The Eemian Interglacial at Główczyn near Wyszogród (Central Poland)). Monogr. Bot., 27: 125—192.

— & Dąbrowski M. J. 1974. Analiza pyłkowa interglacjału eemskiego w Łomżycy. MS. Arch. Zakł. Nauk Geol. PAN, Warszawa.

Noryśkiewicz B. 1978. Interglacjał eemski w Nakle nad Notecią (summary: The Eemian Interglacial at Nakło on the River Noteć (N Poland)). Acta Palaeobot., 19 (1): 67—112.

Nowak J. 1974. Stratygrafia plejstocenu północnej części Kotliny Warszawskiej (summary: Stratigraphy of the Pleistocene in the Northern Part of the Warsaw Depression). Biul. Inst. Geol., 268: 91—164.

Oberdorfer E. 1957. Süddeutsche Pflanzengesellschaften. Pflanzensoziologie, 10. VEB G. Fischer Verl., Jena.

Oszast J. 1972. Wyniki analizy palinologicznej z Pałczewa. Tabele, protok. MS. Arch. Dep. Paleobot., W. Szafer Inst. of Bot. PAScs., Cracow.

— & Stuchlik L. 1977. Roślinność Podhala w neogenie (summary: The Neogene vegetation of the Podhale (West Carpathians, Poland)). Acta Palaeobot., 18 (1): 45—86.

Paszewski A. 1927. Analiza pyłkowa torfu międzylodowcowego z Szeląga pod Poznaniem. Przyroda i Technika, 3: 135—136.

— 1950. Ślady interglacjału w Łańcuchowie nad Wieprzem (summary: Traces of Interglacial sediments at Łańcuchów on Wieprz). Ann. UMCS, B 4 (11): 271—286.

Pawłowski B. 1927. Rodzina: *Ceratophyllaceae*, Rogatkowate. In: Szafer W. (ed.), Flora Polska, 3: 75—77.

Phillips L. 1974. Vegetational history of the Ipswichian/Eemian Interglacial in Britain and continental Europe. New Phytol., 73: 589—604.

Piech K. 1930a. Flora warstw międzylodowcowych okolicy Szczercowa, Dzbanek Kościuszkowskich i niektórych innych miejscowości w dorzeczu środkowej Warty. Rocz. Pol. Tow. Geol., 6: 14—20.

— 1930b. The flora of the interglacial strata in the environs of Szczerców, Dzbanki Kościuszkowskie and some other places in the basin of the river Warta. Summary of the communications on the Diluvial Epoch of Poland at the session of the Polish Geological Society in Cracow on March 2. 1930. Rocz. Pol. Tow. Geol., 6: 8—11.

— 1932. Zur Kenntnis des Diluviums im süd-westlichen Mittelpolen. Das Interglazial von Szczerców (östlich v. Wieluń, Wojewodschaft Łódź). Rocz. Pol. Tow. Geol., 8 (2): 51—132.

Pilger R. 1937. *Plantaginaceae*. In: Engler A. (ed.), Das Pflanzenreich, 4, 269. Verl. W. Engelmann, Leipzig.

Podobielkowski Z. & Tomaszewicz H. 1982. Zarys hydrobotaniki. PWN, Warszawa.

Pożaryski W. 1955. Osady rzeczne w przełomie Wisły przez wyżyny południowe. Prace Inst. Geol., 12c: 1—96.

Praglowski J. R. 1962. Notes on the pollen morphology of Swedish trees and shrubs. Grana Palynol., 3 (2): 45—65.

— & Erdtman G. 1969. On the morphology of the pollen grains in *Armeria sibirica* in specimens from between longitude 30° W and 60° E. Grana Palynol., 9: 72—91.

Premik J. 1925. Sprawozdanie z badań geologicznych wykonanych w roku 1924 w powiecie Wieluńskim oraz nad górną i środkową Widawką (Compte-rendu des recherches géologiques, exécutées en 1924 dans le district de Wieluń et sur la haute et moyenne Widawka). Pos. Nauk. Państw. Inst. Geol., 10: 8—11.

Prószyńska-Bordas H. & Prószyński M. 1983. Termoluminescencyjne datowanie anomalii magnetycznych występujących w profilach lessowych południowej Polski. Sprawozd. z Bad. Nauk. Kom. Bad. Czwartorzędu, 5: 105—113.

Ralska-Jasiewiczowa M. 1980. Late-Glacial and Holocene vegetation of the Bieszczady Mts. (Polish Eastern Carpathians). PWN, Kraków.

— 1983. Isopolen maps for Poland: 0—11 000 Years B. P. New Phytol., 94: 133—175.

Raniecka J. 1930. Pollenanalytische Untersuchungen des Interglazials von Żoliborz in Warschau. Acta Soc. Bot. Pol., 7 (2): 169—182.

Raniecka-Bobrowska J. 1954. Analiza pyłkowa profilów czwartorzędowych Woli i Żoliborza w Warszawie (summary: Pollen analysis of Quaternary profiles at Wola and Żoliborz, Warsaw). Biul. Inst. Geol., 69: 107—140.

Raukas A. 1978. Pleystotsenovye otlozheniya Estonskoy SSR (summary: Pleistocene deposits of the Estonian SSR). Valgus, Tallin.

— & Serebryanny L. P. 1971. Aktualnye problemy geokhronologicheskikh issledovanii pozdniego pleistotsena Russkoy Ravniny. In: Problemy periodizatsii pleistotsena.

Rendle A. B. 1901. *Najadaceae*. In: Engler A. (ed.), Das Pflanzenreich, 4. 12/7. Verl. W. Engelmann, Leipzig.

Rotnicki K. & Tobolski K. 1965. Stanowisko interglacjału eemskiego w Domasłowie pod Kępnem (summary: Locality of Eem Interglacial at Domasłów near Kępno — Southern Great Poland). Bad. Fizjogr. nad Polską Zach., 15: 177—186.

Różycki F. 1979. Plejstoceńska flora kopalna na obszarze Łodzi (dzielnica Polesie). Przegl. Geol., 10: 566—567.

Różycki S. Z. 1961. Middle Poland. Guide-book of Excursion. From the Baltic to the Tatras, 2, 1. VIth INQUA Congress. PWN, Łódź.

— 1967a. Zarys stratygrafii plejstocenu Polski Środkowej. In: Galon R. & Dylik J. (eds.), Czwartorzęd Polski, PWN, Warszawa.

— 1967b. Plejstocen Polski Środkowej na tle przeszłości w górnym trzeciorzędzie (summary: The Pleistocene of Middle Poland). PWN, Warszawa.

— 1972. Plejstocen Polski Środkowej na tle przeszłości w górnym trzeciorzędzie. PWN, Warszawa.

— 1978a. Use of complex paleogeographic method to recognize the history of distrophic lakes and high bogs as exemplified by an interglacial lake at Gołków near Warszawa. Pol. Arch. Hydrobiol., 25 (1/2): 361—371.

— 1978b. Od "Mocht" do syntezy stratygrafii plejstocenu Polski (summary: From Mochty to a synthesis of the Polish Pleistocene). Rocz. Pol. Tow. Geol., 48 (3/4): 445—478.

Rühle E. 1954a. Utwory interglacjalne Żoliborza i Woli w Warszawie (summary: Interglacial sediments of Żoliborz and Wola in Warsaw). Biul. Inst. Geol., 69: 93—105.

— 1954b. Profil geologiczny utworów czwartorzędowych w Śmielinie koło Nakła na Pomorzu (summary: The geological profile of Quaternary formations at Śmielin near Nakło, Pomerania). Biul. Inst. Geol., 69: 149—152.

— 1957. Mapa utworów czwartorzędowych Polski w skali 1: 2 000 000 (summary: Map of Quaternary deposits in Poland on the scale of 1: 2 000 000). Biul. Inst. Geol., 118: 489—550.

— 1961. Przekrój geologiczny osadów czwartorzędowych w Sławnie koło Radomia (summary: Geological section of Quaternary sediments at Sławno near Radom (Central Poland)). Biul. Inst. Geol., 169: 5—13.

Sancetta C., Imbrie J., Kipp N. G., McIntyre A. & Ruddiman W. F. 1972. Climatic record in North Atlantic deep-sea core V23—82: Comparison of the last and present Interglacials based on quantitative time series. Quater. Research, 2: 363—367.

—, Imbrie J. & Kipp N. G. 1973. Climatic record of the past 130.000 years in North Atlantic deep-sea core V23—82: Correlation with the terrestrial record. Quater. Research, 3: 110—116.

Schwarzbach M. 1942. Ein Interglazial aus Nordschlesien. Zentralblatt f. Min. Geol. u. Paläont., Abt. B: 215—220.

Selle W. 1957. Das letzte Interglazial in Niedersachsen. Ber. Naturhist. Ges. zu Hannover, 103: 77—89.

— 1962. Geologische und vegetationskundliche Untersuchungen an einigen wichtigen Vorkommen des letzten Interglazials in Nordwestdeutschland. Geol. Jb., 79: 295—352.

Shackleton N. J. 1969. The last interglacial in the marine and terrestrial records. Proc. Roy. Soc. London, 174: 135—154.

— & Opdyke N. D. 1973. Oxygen isotope and palaeomagnetic stratigraphy of Equatorial Pacific core V28—238: Oxygen isotope temperatures and ice volumes on a 10^5 year and 10^6 year scale. Quater. Research, 3: 39—55.

Shalaboda V. L. & Yakubovskaya T. V. 1978. Paleabatanichnaya kharaktarystyka muravinskikh adkladav v. Pyshki lya Grodna. In: Kuznyetsov U. A. (ed.), Issledovaniya Antropogena Byelorussii. Nauka i Tekhnika, Minsk.

Sobolewska M. 1956. Wyniki analizy pyłkowej osadów interglacjalnych z Olszewic (summary Pollen analysis of the interglacial deposits of Olszewice on the Wieprz river). Biul. Inst. Geol., 100: 271—289.

— 1961. Flora interglacjału eemskiego z Góry Kalwarii (summary: Flora of the Eemian Interglacial from Góra Kalwaria (Central Poland)). Biul. Inst. Geol., 169: 73—90.

— 1966. Wyniki badań paleobotanicznych nad eemskimi osadami z Józefowa na Wyżynie Łódzkiej (summary: Results of palaeobotanic researches of Eemian deposits from Józefów, Łódź Upland). Biul. Perygl., 15: 303—312.

Sorsa P. 1964. Studies on the spore morphology of Fennoscandian fern species. Ann. Bot. Fenn., 1: 179—201.

Sparks B. W. & West R. G. 1970. Late Pleistocene deposits at Wretton, Norfolk. I. Ipswichian interglacial deposits. Phil. Trans. Roy. Soc. London, Ser. B, 258: 1—30.

Stachurska A. 1957. Roślinność interglacjalna z Włodawy nad Bugiem (summary: Interglacial flora from Włodawa on the Bug river (Lublin Upland)). Biul. Inst. Geol., 118: 61—89.

— 1961. Schyłek interglacjału mazowieckiego w Susznie koło Włodawy nad Bugiem w świetle analizy botanicznej (summary: Decline of the Masovian Interglacial at Suszno near Włodawa on the Bug river in the light of botanical analysis). Biul. Inst. Geol., 169: 155—173.

Stankowski W. & Tobolski K. 1981. Osady torfowe i limniczne wieku eemskiego z odkrywki Kazimierz Kopalni Węgla Brunatnego w Koninie (doniesienie wstępne) (summary: Eemian peat and lacustrine deposits from the Kazimierz exposure of the Brown Coal Mine in Konin (preliminary report)). Bad. Fizjogr. nad Polską Zach., 34: 171—178.

Stark P., Firbas F. & Overbeck F. 1932. Die Vegetationsentwicklung des Interglazials von Rinnersdorf in der östlichen Mark Brandenburg. Abh. Naturwiss. Ver. Bremen, 28: 105—130.

Staszkiewicz J. & Wójcicki J. J. 1979. Analiza biometryczna orzechów rodzaju *Trapa* L. z Polski. (summary: Biometrical analysis of *Trapa* L. nuts from Poland). Fragm. Flor. et Geobot. 25 (1): 33—59.

Stix E. 1960. Pollenmorphologische Untersuchungen an Compositen. Grana Palynol. 2 (2): 41—104.

Stockmarr J. 1970. Species identification of Ulmus pollen. Danm. Geol. Unders., 4, 11: 1—19.

— 1974. Scanning electron micrographs of pollen from two *Tilia* species. Danm. Geol. Unders., Årbog 1973: 107—109.

Straszewska K. & Goździk J. 1978. Final period of development and decline of "Łomżyca" lacustrine basin. Pol. Arch. Hydrobiol., 25 (1/2): 403—412.

— & Stupnicka E. 1980. Sites of the Quaternary lacustrine and peaty deposits in Poland. Bull. l'Acad. Pol. d. Sc., Sér. Sc. Terre, 27 (3—4): 169—177.

Stuchlik L. 1964. Pollen analysis of the Miocene deposits at Rypin. Acta Palaeobot., 5 (2): 1—111.

Sukachev V. N. 1954. O sovmestnom nakhozhdenii ostatkov karlikovoy beryozy i brazenii v mezhlednikovykh otlozheniyakh. Doklady Akad. Nauk SSSR, 94 (3): 561—563.

Suszka B. 1983. Rozmnażanie generatywne (summary: Generative propagation). In: Białobok S. (ed.), Jodła pospolita — *Abies alba* Mill. Nasze drzewa leśne, Monogr. Inst. Dendr. PAN, 4. PWN, Warszawa—Poznań.

Szafer W. 1912. Eine Dryas-Flora bei Krystynopol in Galizien. Bull. Acad. Sc. L. Cl. Math.-Nat. Cracovie, Sér. B, 8: 1103—1123.

— 1925. Über den Charakter der Flora und des Klimas der letzten Interglazialzeit bei Grodno in Polen. Spraw. Kom. Fizjogr. PAU, 60: 277—314.

— 1928. Entwurf einer Stratigraphie des polnischen Diluviums auf floristischer Grundlage. Rocz. Pol. Tow. Geol., 5: 1—15.

— 1945. Kopalna *Armeria* w plejstocenie europejskim ze szczególnym uwzględnieniem plejstocenu w Polsce (summary: The fossil *Armeria* in the European Pleistocene especially in Poland). Starunia, 20: 1—31.

— 1953. Stratygrafia plejstocenu w Polsce na podstawie florystycznej (summary: Pleistocene Stratigraphy of Poland from the Floristical Point of View). Rocz. Pol. Tow. Geol., 22 (1): 1—99.

— & Jaroń B. 1935. Plejstoceńskie jezioro pod Jasłem (summary: Pleistocene lake near Jasło in Poland). Starunia, 8: 1—20.

—, Kulczyński S. & Pawłowski B. 1953. Rośliny Polskie. PWN, Warszawa.

— & Trela J. 1928. Interglacjał w Szelągu pod Poznaniem (Zusammenfassung: Interglazial in Szeląg (Schilling) bei Posen). Spraw. Kom. Fizjogr. PAU, 63: 71—82.

—, — & Ziembianka M. 1931. Flora interglacjalna z Bedlna koło Końskich (Zusammenfassung: Die interglaziale Flora von Bedlno bei Końskie). Rocz. Pol. Tow. Geol., 7: 402—414.

Szczepanek K. 1962. Stanowisko flory interglacjalnej w Nidzicy (woj. olsztyńskie). Przegl. Geol., 10: 609—611.

Szczepankiewicz S. 1962. Kilka uwag o przebiegu sedymentacji czwartorzędowej na Równinie Świdnickiej (summary: Comment on the course of Quaternary sedimentation in the Świdnica Plain). Czasopismo Geograficzne, 33: 45—61.

— 1969. Sediments and forms of the far extents of Scandinavian Glaciations in SW Poland. Geogr. Polon., 17: 149—159.

— 1976a. Niektóre zagadnienia czwartorzędu południowo-zachodniej Polski. In: Czwartorzęd Polski Południowo-Zachodniej. Mat. sesji nauk. Kom. N. o Ziemi PAN O/Wrocław, 1974—1975: 7—17.

— 1976b. Cechy stratygrafii, litologii i paleogeografii Polski Zachodniej w świetle wybranych profilów. In: Czwartorzęd Polski Południowo-Zachodniej. Mat. sesji nauk. Kom. N. o Ziemi PAN O/Wrocław, 1974—1975: 55—65.

— & Szczypek P. (in prep.). Stratygrafia osadów czwartorzędowych w Żmigrodzie.

Szczypek P. 1974. Flora interglacjału eemskiego w Polanicy-Zdroju (summary: Eemian-Interglacial flora in Polanica Zdrój). Acta Univ. Wratisl., 219: 1—44.

— 1976. Zagadnienia paleobotaniczne czwartorzędu Polski Południowo-Zachodniej. In: Czwartorzęd Polski Południowo-Zachodniej. Mat. sesji nauk. Kom. N. o Ziemi PAN O/Wrocław, 1974—1975: 99—102.

Szponar A. 1965. Etapy deglacjacji na przedpolu moren stadiału warciańskiego (summary: The phases of deglaciation on the morainic foreland of Warta Stadium). Czasopismo Geograficzne, 36: 245—260.

Środoń A. 1950. Rozwój roślinności pod Grodnem w czasie ostatniego interglacjału (summary: The development of vegetation in the Grodno area during the last interglacial period (Masovien II)). Acta Geol. Polon., 1 (4): 365—400.

— 1954a. Flory plejstoceńskie z Tarzymiechów nad Wieprzem (summary: Pleistocene floras from Tarzymiechy on the river Wieprz). Biul. Inst. Geol., 69: 5—78.

— 1954b. Interglacjalny torf ze Śmielina koło Nakła na Pomorzu (summary: Interglacial peat from Śmielin near Nakło, Pomerania). Biul. Inst. Geol., 69: 153—158.

— 1956. W sprawie interglacjału w Szelągu pod Poznaniem (summary: Interglacial in Szeląg near Poznań). Biul. Inst. Geol., 100: 45—60.

— 1957. Wiek interglacjału w Koszarach nad Bugiem (summary: The age of the interglacial deposits at Koszary on the river Bug). Acta Soc. Bot. Pol., 26 (3): 569—581.

— 1960. Tabela stratygraficzna plejstoceńskich flor Polski (summary: Stratigraphic Table of the Pleistocene Floras of Poland). Rocz. Pol. Tow. Geol., 29 (4): 299—316.

— 1961. Palaeobotanical studies on the Quaternary in Poland. Prace Inst. Geol., 34: 667—674.

— 1967a. Stratygrafia późnego plejstocenu Polski niżowej na podstawie paleobotanicznej. In: Galon R. & Dylik J. (eds.), Czwartorzęd Polski. PWN, Warszawa.

— 1967b. Świerk pospolity w czwartorzędzie Polski (summary: The common spruce in the Quaternary of Poland). Acta Palaeobot., 8 (2): 1—59.

— 1972. Roślinność Polski w czwartorzędzie. In: Szafer W. & Zarzycki K. (eds.), Szata Roślinna Polski, 1. PWN, Warszawa.

— 1974. Glacial flora of the Saalian age from Góra Kalwaria near Warsaw. Acta Palaeobot., 15 (1): 17—41.

— 1977. Świerk w historii naszych lasów (summary: Spruce in the history of our forests). In: Białobok S. (ed.), Świerk pospolity — *Picea abies* (L.) Karst. Nasze Drzewa Leśne, Monogr. Inst. Dendr. PAN, 5. PWN, Warszawa—Poznań.

— 1981. Karta do historii badań nad czwartorzędem Polski (summary: A contribution to the history of research on the Quaternary in Poland). Biul. Inst. Geol., 321: 13—17.

— & Gołąbowa M. 1956. Plejstoceńska flora z Bedlna (summary: Pleistocene flora of Bedlno, Central Poland). Biul. Inst. Geol., 100: 7—44.

Tacik T. 1963. Rodzina: *Hydrocaryaceae* (*Trapaceae*), Kotewkowate. In: B. Pawłowski (ed.), Flora Polska, 10. PWN, Warszawa—Kraków.

— 1967. Rodzina: *Plantaginaceae*, Babkowate. In: Pawlowski B. (ed.), Flora Polska, 11. PWN, Warszawa—Kraków.

Tallantire P. A. 1977. A further contribution to the problem of the spread of spruce (*Picea abies* (L.) Karst.) in Fennoscandia. J. Biogeogr., 4: 219—227.

Thomson P. W. 1951. Das Interglazial von Wallensen im Hils. Eiszeitalter u. Gegenwart, 1: 96—102.

Tobolski K. 1986. Paleobotanical studies of the Eemian Interglacial and Early Vistulian, Władysławów in the vicinity of Turek (preliminary report). Quater. Studies in Poland, 7: 91—101.

Tołpa S. 1952. Flora interglacjalna w Kaliszu (summary: Interglacial flora at Kalisz). Biul. Inst. Geol., 68: 73—120.

— 1961. Flora interglacjalna ze Sławna koło Radomia (summary: Interglacial flora from Sławno near Radom, Central Poland). Biul. Inst. Geol., 169: 15—56.

Tomaszewicz H. 1977. Dynamics and systematic position of *Thelypteridi-Phragmitetum* Kuiper 1957. Acta Soc. Bot. Pol., 46 (2): 331—338.

— 1979. Roślinność wodna i szuwarowa Polski (klasy: *Lemnetea*, *Charetea*, *Potamogetonetea*, *Phragmitetea*) wg stanu zbadania na rok 1975. Rozprawy Uniw. Warsz., Warszawa.

Traczyk T. 1962. Materiały do geograficznego zróżnicowania grądów w Polsce (sommaire: Matériaux pour la différentiation des groupements *Querco-Carpinetum* en Pologne). Acta Soc. Bot. Pol., 31 (2): 275—304.

Trela J. 1928. Zur Morphologie der Pollenkörner der einheimischen *Tilia*-Arten. Bull. Acad. Pol. Sc. et Lettr. Sér. B.

— 1935. Interglacjał w Samostrzelnikach pod Grodnem (Zusammenfassung: Interglazial in Samostrzelniki bei Grodno in Polen). Starunia, 9: 1—8.

Troels-Smith J. 1955. Characterization of unconsolidated sediments. Danm. Geol. Unders., IV, 3 (10): 1—73.

Tuchołka P. 1977. Magnetic polarity events in Polish loess profiles. Biul. Inst. Geol., 305: 117—123.

Turner C. & West R. G. 1968. The subdivision and zonation of interglacial periods. Eiszeitalter u. Gegenwart, 19: 93—101.

Ueno J. 1958. Some palynological observations of Pinaceae. Jour. Inst. Polytechn. Osaka City Univ., Ser. D, 9: 163—186.

Vajtiekunas P. 1968. Problemy stratygrafii neoplejstocenu Litwy (summary: Stratigraphical problems of Neopleistocene in Lithuania). Kwart. Geol., 12 (3): 646—664.

Walczak W. & Szczypek P. 1966. Nowe stanowisko interglacjału eemskiego w Sudetach Kłodzkich (summary: A new stand of the Eems Interglacial stage in the Kłodzko Sudetes). Czasopismo Geograficzne, 37 (3): 305—310.

Walter H. & Straka H. 1970. Arealkunde — Floristisch-historische Geobotanik. Einführung in die Phytologie, 3, 2. Eugen Ulmer, Stuttgart.

Wasylikowa K. 1964. Roślinność i klimat późnego glacjału w środkowej Polsce na podstawie badań w Witowie koło Łęczycy (summary: Vegetation and climate of the Late-Glacial in Central Poland based on investigations made at Witów near Łęczyca). Biul. Perygl., 13: 261—382.

— 1978. Plant remains from Early and Late Medieval time found on the Wawel Hill in Cracow. Acta Palaeobot., 19 (2): 115—200.

Watts W. A. 1959. Interglacial deposits at Kilbberg and Newtown, Co. Waterford. Proc. R. Ir. Acad., B, 60: 79—134.

Wąs M. 1956. Nowe stanowisko interglacjału i gliny zwałowej. Przegl. Geol., 4: 323—325.

Webb D. A. 1968. *Ilex* L. In: Tutin T. G. et al. (eds.), Flora Europaea. 2. Cambridge Univ. Press, London.

Wegmüller S. 1986. Recherches palynologiques sur les charbons feuilletés de la région de Gondiswil/Ufhusen (Plateau Suisse). Bull. Ass. Fr. Et. Quat., 1/2: 29—34.

Welten M. 1950. Beobachtungen über den rezenten Polleniederschlag in alpiner Vegetation. Ber. Geob. Forsch. Inst. Rübel, Zürich.

— 1957. Über das glaziale und spätglaziale Vorkommen von *Ephedra* am nordwestlichen Alpenrand. Ber. d. Schw. Bot. Ges., 67: 33—54.

— 1981. Gletscher und Vegetation im Lauf der letzten hunderttausend Jahre. Vorläufige Mitteilung. Jb. Schweiz. Natf. Ges., Wiss. Teil 1978: 5—18.

— 1982. Pollenanalytische Untersuchungen im Jüngeren Quartär des nördlichen Alpenvorlandes der Schweiz. Beitr. Geol. Karte der Schweiz, N. F., Lief. 156: 1—174.

West R. G. 1956. The Quaternary deposits at Hoxne, Suffolk. Phil. Trans. Roy. Soc. London, Ser. B, 239: 265—356.

— 1969. Pleistocene geology and biology. Longmans, London.

— 1970. Pollen zones in the Pleistocene of Great Britain and their correlation. New Phytol., 69: 1179—1183.

Wieczorkowska J. 1975. Rozwój stoków Pagórków Romanowskich na tle paleogeografii obszaru, (sommaire: L'évolution des versants des Collines de Romanów à la lumière de la paléogéographie de la région). Acta Geogr. Lodz., 35: 1—118.

Wieser J. 1982. Makroskopowe szczątki roślinne z Drogomyśla nad górną Wisłą. MS. Arch. Dep. Paleobot., W. Szafer. Inst. of Bot. PAScs., Cracow.

Wiśniewski E. & Pietkiewicz A. 1985. Stanowisko interglacjału eemskiego w Podleśnem koło Braniewa (summary: Stand of the Eemian Interglacial in Podleśne near Braniewo). Przegl. Geogr., 57 (4): 611—619.

Woillard G. 1975. Recherches palynologiques sur le pléistocène dans l'Est de la Belgique et dans les Vosges Lorraine. Acta Geogr. Lovaniensia, 14: 1—168.

— 1978. Grande Pile peat bog: A continuous pollen record for the last 140.000 years. Quater. Research, 9: 1—21.

— 1979. The last interglacial-glacial cycle at Grande Pile in northeastern France. Bull. Soc. Belge de Géol., 88: 51—69.

Woldstedt P. 1947. Über die stratigraphische Stellung einiger wichtiger Interglazialbildungen im Randgebiet der nordeuropäischen Vergletscherung. Ztschr. d. Deutsch. Geolog. Ges., 99: 96—123.

— 1950. Norddeutschland und angrenzende Gebiete im Eiszeitalter. Verl. Koechler, Stuttgart.

—, Rein U. & Selle W. 1951. Untersuchungen an nordwestdeutschen Interglazialen. Eiszeitalter u. Gegenwart, 1: 83—96.

Wrotek K. 1978. Nowe stanowisko osadów organicznych w krawędziowej stiefie pradoliny Noteci-Warty w Łęgowie. Przegl. Geol., 5: 304—306.

Zachowicz J., Przybyłowska-Lange W. & Nagler J. 1982. The Late-Glacial and Holocene vegetational history of the Żuławy region, N. Poland. A biostratigraphic study of Lake Druzno sediments. Acta Palaeobot., 22 (1): 141—161.

Zagwijn W. H. 1961. Vegetation, climate and radiocarbon datings in the Late Pleistocene of the Netherlands. I. Eemian and Early Weichselian. Mem. Geol. Found. Netherl., N. S. 14: 15—45.

— & Staalduinen C. J. van. 1975. Toelichting bij geologische oversichtskaarten van Nederland. Rijks Geol. Dienst., Harlem.

Zarzycki K. 1984. Ekologiczne liczby wskaźnikowe roślin naczyniowych Polski (Indicator values of vascular plants in Poland). Instytut Botaniki PAN, Kraków.

Ziemus H. 1980. Palynologische Untersuchungen am limnischen Jungpleistozän von Haalmoor bei Burg/Dithmarschen (Schleswig-Holstein). Schr. Naturw. Ver. Schleswig-Holst., 50, 71—80.

Zwanden H. 1977. Zur Unterscheidung des Blütenstaubes der vier heimischen Kiefernarten. Carinthia II, 167/87: 227—238.

Żukowski W. 1965. Rodzaj *Eleocharis* R. Br. w Polsce (summary: Genus *Eleocharis* R. Br. in Poland). Prace Kom. Biol. Pozn. Tow. Przyj. Nauk, 30 (2): 1—113.

PLATES

Plate I

1. *Dryopteris thelypteris* (see description on p. 33), × 1000
2, 3. *Salvinia natans*, fragments of microsporangium with spores (one with visible tetrad scar), × 1000
4. *Tilia platyphyllos* type, × 1000
5—7. *T. cordata* type, × 1000
    5. Most likely *T. cordata*
    6. 7. Acknowledged as *T. tomentosa* (see description on p. 36)

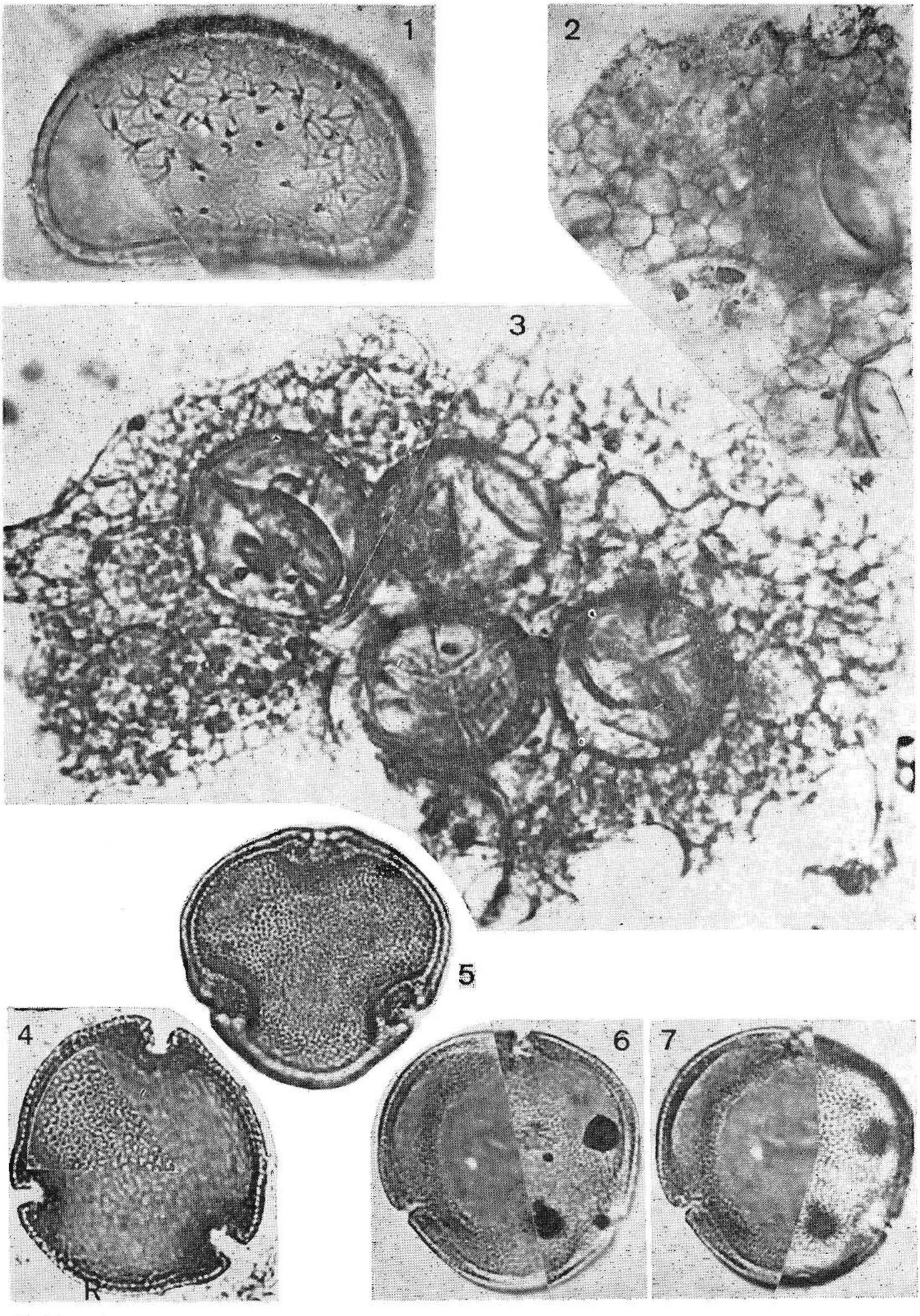

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Plate II

1, 2. *Betula* cf. *pubescens*, nutlets, × 10
3. *B.* cf. *pendula*, nutlet, × 10
4, 5. *B.* sect. *Albae*
    4. Fragment of staminate catkin, × 8
    5. Catkin bract with three anthers, × 12
6, 7. *Gypsophila* cf. *fastigiata*, seeds, × 30
8, 9. *Silene otites*, seed, × 30
    8. Lateral side
    9. Dorsal side
10. *Carex aquatilis*, fruit with utricle, × 15
11. *C. nigra*, fruit, × 15
12. *C. elata*, fruit, × 15
13. *C. gracilis*, fruit, × 15
14. *C.* cf. *oederi* ssp. *pulchella*, fruit, × 15
15—17. *C. pseudocyperus*, × 15
    15. Utricle
    16. Fruit
    17. Fruit with utricle
18—24. *C. rostrata*, × 15
    18. Utricle
    19—21. Fruits — elongate form
    22—24. Fruits — broad and shorter form (22 — fruit with utricle)

Plate II


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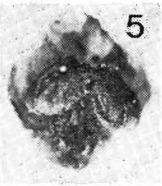
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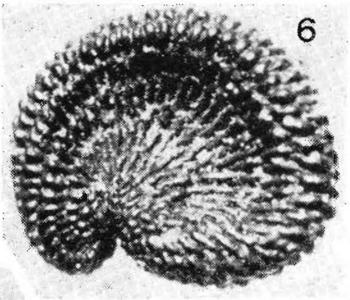
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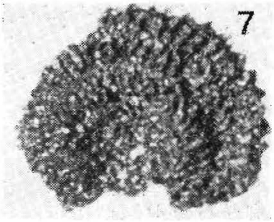
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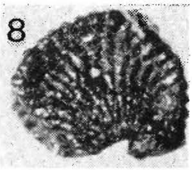
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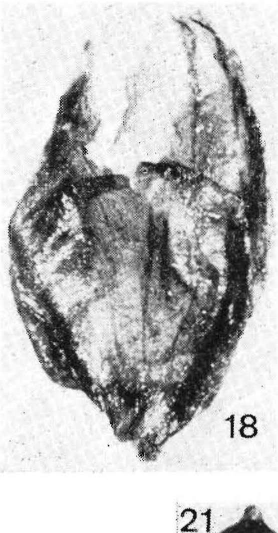
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Plate III

1. *Ilex aquifolium*, fruit-stone, dorsal side, × 9
2. *Knautia arvensis*, fruit, × 10
3. *Alchemilla*, fruit, × 20
4. *Papaver rhoeas* type, seed, × 16
5. *Ceratophyllum demersum*, fruit with tubercles (see description on p. 40), × 7
6. *Rumex maritimus*, inner perianth sepals, × 15
7. *Lythrum salicaria/L. virgatum*, seed, dorsal side, × 35
8. *Stratiotes aloides*, spine, × 15

9, 10. *Viscum*, wood, × 25
  9. Transversal section: extremely diffuse porous; difficult to differentiate vessels, parenchyma cells and ray cells; indistinct growth ring limit
  10. Tangential section: storied vessel elements

Plate III


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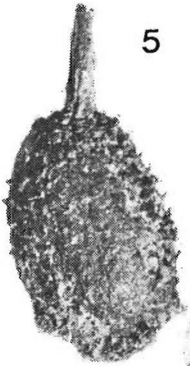
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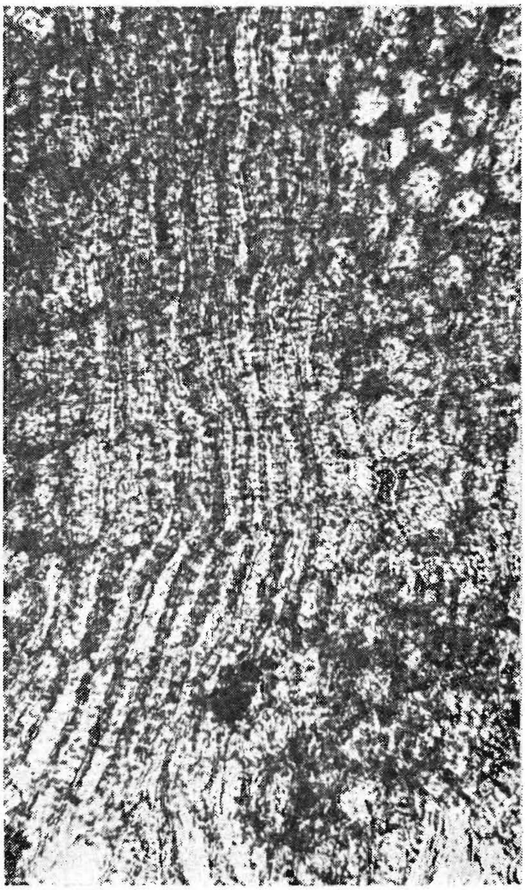

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Plate IV

1–11. *Najas marina,* fruits, × 10
    1—6. Big-fruit form
    7—11. Small-fruit form
12. *Lemna* cf. *trisulca,* fruit, × 25
13. *Lysimachia thyrsiflora,* seed, × 20
14—16. *Trapa natans,* × 4
    14. Fragment of nut
    15. Apical corona from above
    16. Lower horn, concave
17—20. *T.* cf. *conocarpa,* × 4
    17, 18. Fragment of nut with smooth horns and tubercle
    19. Horn with ribs
    20. Smooth and thin horn

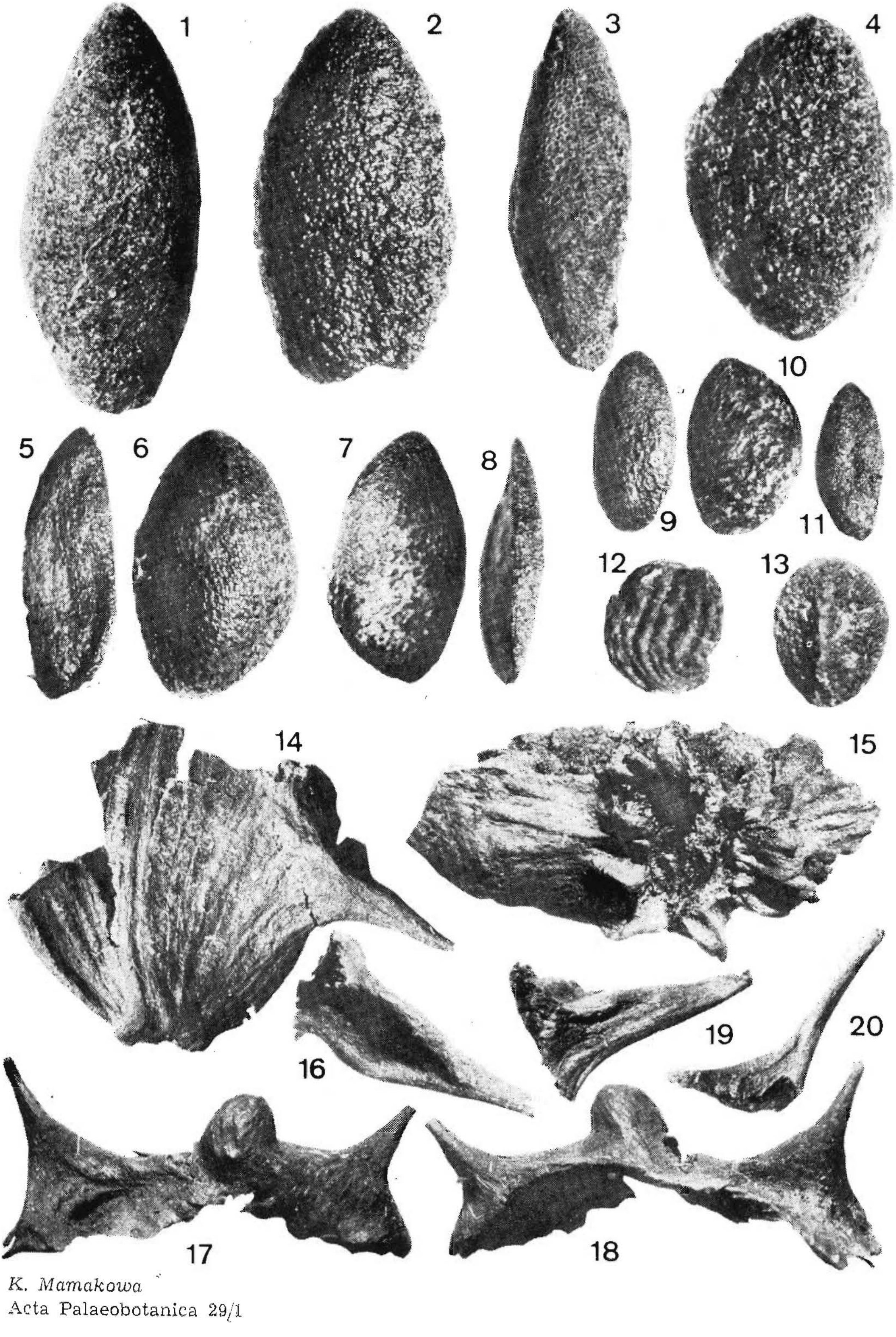
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Fig. 3. Percentage pollen diagram from Imbramowice. Scale at top of diagram gives percentages for black silhouettes; white silhouettes are exaggerated × 10 scale. Nomenclatural conventions follow H. J. B. Birks (1973a) — see p. 21. The sediment lithology is presented using the symbols of Troels-Smith (1955): Ld¹ — slightly humified gyttja, Ld² — humified gyttja, Lso — diatomaceous gyttja, Lc — calcareous gyttja, Dg — fine plant detritus, Th² — herbaceous peat, Ag — silt, Ga — fine sand, Gs — coarse sand, Gg^{min} — fine gravel (up to [illegible] mm), Gg^{maj} — coarse gravel (6—20 mm), part. test. mol. — fragments mollusca shells, anth. — charcoals. The pollen sum, ΣP, includes trees, shrubs dwarf-shrubs and herbs; for other explanations see p. 20. Taxa and other groups excluded from the basic sum (ΣP) are calculated on the basis of ΣP + taxon or ΣP + Σ group as indicated. 1) — rebedded pollen of thermophilous trees and shrubs not excluded from the basic sum
]

Fig. 4. Macrofossil diagram from Imbramowice. Nomenclatural conventions follow H. J. B. Birks (1973a) — see p. 21. Names of plants without additional explanations mean the presence of reproductive bodies. For other explanations see p. 20. Symbols of the sediment lithology as in Fig. 3

Fig. 12. Pollen stratigraphy of the Eemian Interglacial and the adjacent glacial deposits in continuous pollen sequences in Poland. Site numbers as in Fig.11 and in the list (p. 93); a — sections or single samples worked out by means of pollen analysis, b — sediment unknown or where there are no grounds to present it, c — hiatus; numbers in brackets (1), (2), (3) at the late-glacial sections of profiles indicate their reference to the respective type of late-glacial vegetational succession