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GEOLOGICAL POSITION AND POLLEN ANALYSIS OF EEMIAN INTERGLACIAL SEDIMENTS OF WARSAW – WAWRZYSZEW

Sytuacja geologiczna i analiza pyłkowa osadów interglacjału eemskiego z Warszawy Wawrzyszewa

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ABSTRACT. Organogenic sediments filling the basin of a fossil reservoir in the through-like depression in the surface clay of the Warta Stadial are preserved in the north-western part of the Warsaw-Wawrzyszew. Distinct traces of active periglacial processes and erosional dissections are well marked in the top part of these sediments. The sediments are overlain by sands. Palynological results concerning five profiles of lacustrine and post-lacustrine sediments of Warsaw-Wawrzyszew permit us to distinguish and characterized 22 local zones. An analysis of the floristic elements and the features of the succession reflect of the environmental changes in the Late Glacial of the Middle Polish Glaciation and represent the full developmental cycle of interglacial vegetation and the beginning of the Early Vistulian.

KEY WORDS: pollen analysis, Eemian, Interglacial, vegetation succession

CONTENTS

INTRODUCTION

At Wawrzyszew, one of the northern parts of Warsaw (Fig. 1) occurs a buried post-lacustrine sub-circular basin (Fig. 3) 700 to 800 m in diameter. This is a depression in the Middle Polish Glaciation till series and filled with the organic sediments several to more than 10 m thick and covered with fluvial sands of the highest Vistula terrace. Lacustrine organic sediments were recognized in the Wawrzyszew area from geological

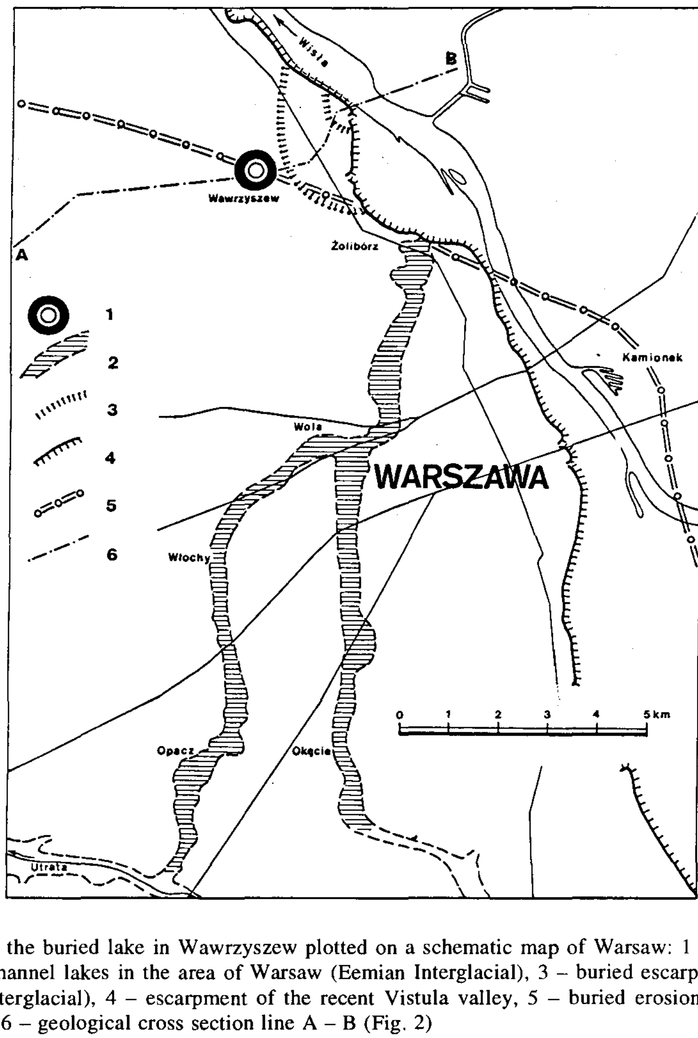

Fig. 1. Location of the buried lake in Wawrzyszew plotted on a schematic map of Warsaw: 1 – Lake at Wawrzyszew, 2 – buried channel lakes in the area of Warsaw (Eemian Interglacial), 3 – buried escarpment of the Vistula terrace (Eemian Interglacial), 4 – escarpment of the recent Vistula valley, 5 – buried erosional channel (Middle Polish Glaciation), 6 – geological cross section line A – B (Fig. 2)

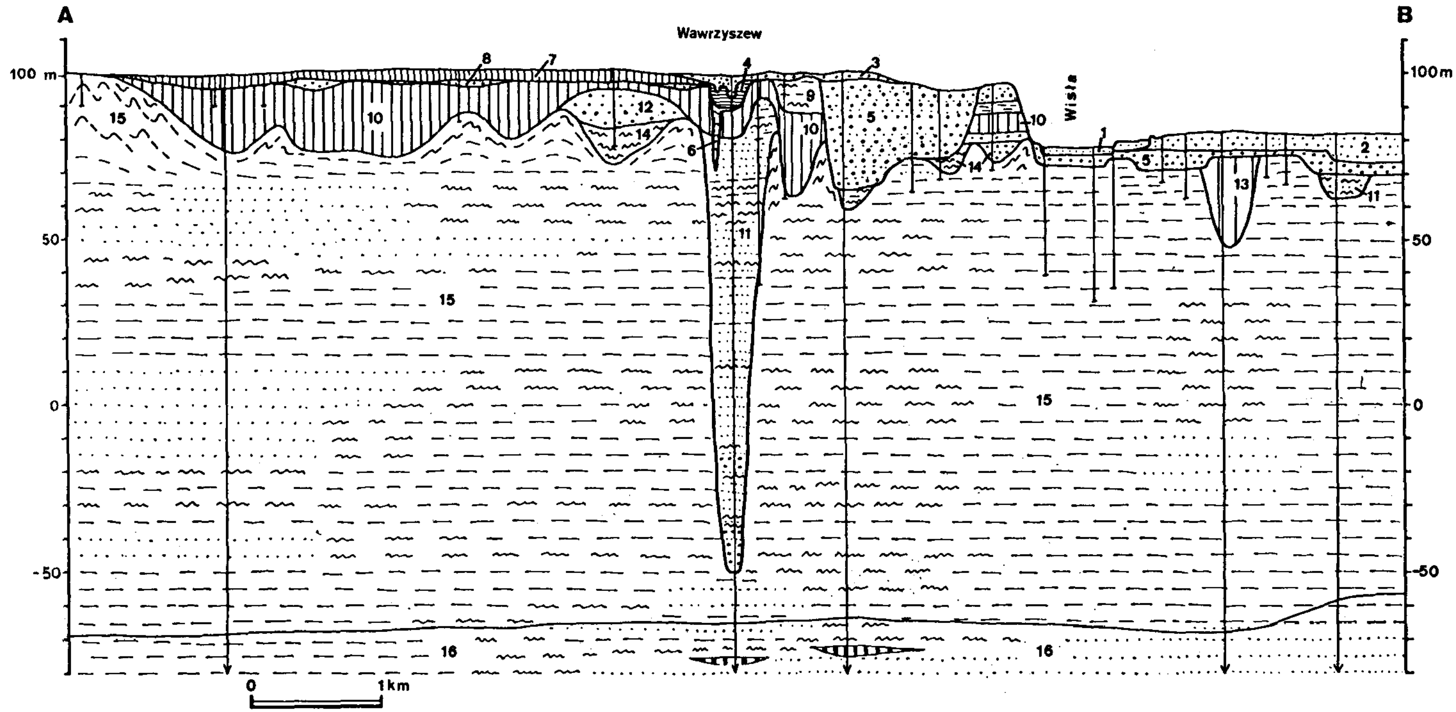

Fig. 2. Geological section across the northern part of Warsaw: Quaternary: Holocene: 1 – fluvial sands and gravel of the Vistula lower flood plains; Vistulian Glaciation: 2 – fluvial sands and gravel of the Vistula upper flood plains, 3 – fluvial sands and gravel of the Warsaw – Błonie terrace; Eemian Interglacial: 4 – organic lacustrine sediments, 5 – gravel and fluvial sands; Middle Polish Glaciation: North Mazovian (Wkra) Stadial: 6 – silts and dammed-lake, partly lacustrine interglacial, clays; Mazovia-Podlasie (Warta) Stadial: 7 – till, 8 – fluvioglacial sands, 9 – silts, sands and dammed-lake clays; Maximum Stadial: 10 – till, 11 – sands and dammed-lake clays, partly fluvioglacial, 12 – gravel and fluvioglacial sands; South Polish Glaciation: 13 – till; Pre-Pleistocene (Preglacial): 14 – sands, gravel and silts. Tertiary: Pliocene: 15 – clays, silts and sands; Miocene: 16 – sands, silts and lignite

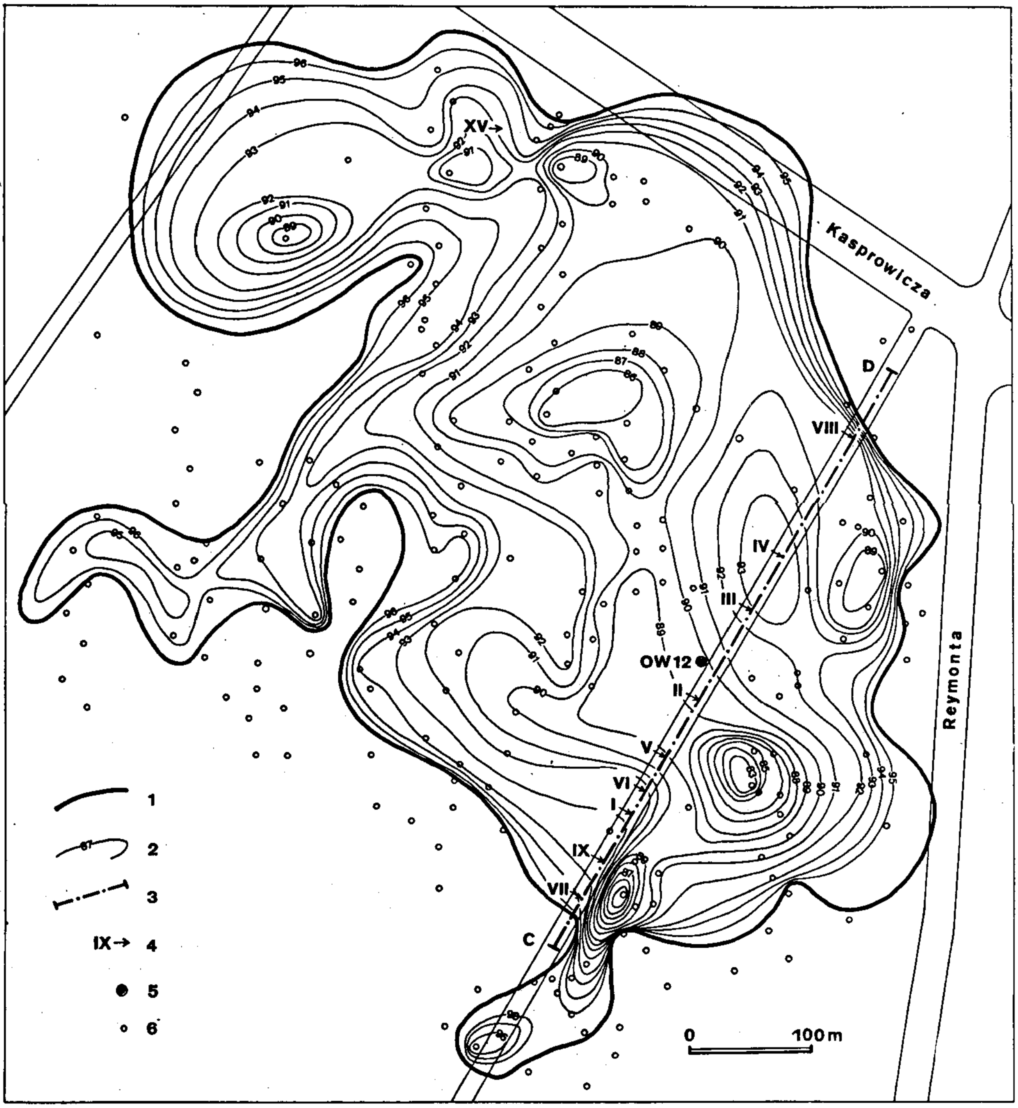

Fig. 3. Sketch showing the bottom relief of the organic sediments of the buried lake in Wawrzyszew (Eemian Interglacial): 1 – extent of the organic lacustrine sediments, 2 – isolines of the organic sediments bottom (in m a.s.l.), 3 – geological cross section line – Fig. 5 (trench axis), 4 – distribution of the sampled sections and their numbers, 5 – location of the OW – 12 borehole, 6 – location of the engineering geological boreholes

engineering work conducted by the "Geoproject" enterprice in 1971–1973 for a future residential area and supervised by Z. Stala. Over 300 holes were drilled out of which about 100 pierced the organic sediments. All this rich material, kindly made available to the Polish Geological Institute, served to compile the sheet Warszawa Zachód of the Detailed Geological Map of Poland (Szczegółowa Mapa Geologiczna Polski) on 1: 50 000 scale (Morawski 1979, 1980) and was also used in the present work. In 1974 a number of sewage and foundation trenches were dug and large-dimensional holes were drilled for piling purposes. Of particular scientific interest proved to be the sewage trench dug across the lake basin along Wolumen street to the depth of 5 to 6 m (Fig. 3). In the course of excavation work the exposed formations were thoroughly described. To extend the stratigraphical column and complement previous drilling data a number of auger tests were carried out from the bottom of the sewage trench. Fifteen geological sequences were described and sampled out of which ten included organic sediments. Mapping for the Detailed Geological Map of Poland was supplemented by resistivity profiling completed in 1975 along Wolumen street by the Enterprise for Geophysical Exploration on commission from the Polish Geological Institute (Morawski 1977). Later the fully cored bore hole OW – 12 was drilled to the depth of 190 m (to Miocene formations). Altogether 600 palynological samples, were taken every 5 cm from walls of various excavations. For 59 samples comprehensive chemical analyses were completed at the Chemical Laboratory of the Polish Geological Institute. Lithological-petrographic studies at the laboratory of the Polish Geological Institute included 12 sand and gravel samples, 16 till samples and samples taken every 1 m from the whole column of bore hole OW – 12. In addition, two ^{14}C datings were carried out on peats. A preliminary palynological analysis was completed in 1975 on 8 samples selected from section IX by Z. Baranowska-Zarzycka and revealed a vegetational succession characteristic of the Eemian Interglacial. Preliminary contributions to the question of Eemian sediments of the Wawrzyszew area were published previously (Morawski 1975, 1976a, 1978, 1980). The present paper is a recapitulation of geological and paleobotanical data on this site: the geological part has been prepared by W. Morawski, the palynological one by K. M. Krupiński.

POSITION OF THE EEMIAN LACUSTRINE SEDIMENTS IN THE QUATERNARY SEQUENCE OF THE NORTHERN PART OF WARSAW

The position of the Eemian organic sediments in the Quaternary sequence is shown in the geological section across the northern part of Warsaw (Fig. 2). The relatively flat-lying Miocene sediments, the top of which was encountered in holes at the depth of 162.5 m (64.0 m a.s.l.) are overlain by a series of strongly folded Pliocene clays, silts and sands. Upon this series rest patches of Preglacial sands and silts preserves mainly in synclines. In the Wawrzyszew area the Pliocene sediments are cut by a deep channel in literature refered to as the "Kamionek – Żolibórz valley". Its origin and trend against the topography of the Sub-Quaternary bedrock in Warsaw and adjacent areas is discussed in separate papers (Morawski 1980, Morawski & Sarnacka 1989). The trend of this channel is defined precisely from electrical survey and drilling records provided by the hole OW – 12 drilled in its axial part. Drilling data revealed that erosional processes cut the Tertiary formations to the depth of 148.5 m (50 m a.s.l.) producing the deepest recess reported so far from the Warsaw area. The infill of the channel is a 130 m thick sandy series with silt and clay intercalations. These sediments are classified into the transgression period of the Maximum Stadial of the Middle Polish Glaciation. Above the channel infill, but outside its extent, directly on Pliocene or Preglacial sediments rests a compact till horizon of the Maximum Stadial of the Middle Polish Glaciation. This till forms the bottom of the Eemian basin of the Wawrzyszew area (Figs 2, 5). In this area its thickness varies from 6 to 21 m. It is covered by variously thick patches of dammed-lake and fluvioglacial sediments which in turn are overlain by thin till of the Mazovia-Podlasie (Warta) Stadial of the Middle Polish Glaciation. In the vicinity of the Wawrzyszew basin described above this till is about 2 m thick and separated from the Maximum Stadial till by several centimeter thick sands with gravel and silt. The Wawrzyszew basin itself constitutes a closed trough at the bottom of which a series of grey silt with local intercalations of fine-grained sands and clays in upper portion occurs beneath Eemian organic sediments. The thickness of these sediments varies significantly from several centimeters to several or even more than 10 m. In the course of foundation work local grey silts were found to occur to depth exceeding 30 m. These sediments are classified into the North Mazovia (Wkra) Stadial (Morawski 1978, 1980).

The organic infill series of the Wawrzyszew basin is the subject of botanical studies. The top of this series is cut by frost fissure structures (Morawski 1976a) indicative of periglacial processes during the Vistulian Glaciation. Locally, the Eemian organic sediments are cut by erossion to a depth of less than 3 m and covered by a usually 1 to 6 m thick sand series with gravel at the top. These are channel facies sands which constitute the Warsaw – Błonie terrace, the highest Vistula terrace of the Vistulian period. In the middle and northern part of the Wawrzyszew basin the upper portion of sands covering the Eemian organic sediments forms an eolian cover not exceeding 2 m in thickness. Studies of aerial photographs taken in the fifties before the area was covered by rubble mounds reveal, that the eolian sediment belt marks the route along which the dune now situated nearby the Bielany hospital was shifted from west to east.

LITHOLOGY OF THE WAWRZYSZEW ORGANIC SEDIMENTS

The upper portion of silts with sand intercalations underlying the organic series (Fig. 5) shows organic matter admixtures sometimes expressed in a change of color to dark grey or even black. Locally, at the top of these sediments, a 10 cm thick gyttja layer occurs which, when dried, is very porous and shows vivianite coatings. Occasionally in the marginal part of the basin the upper portion of silts contains plant remains visible in hand specimen or grades into fine-grained sands of the same grey color with brown peat streaks and wood fragments. Chemical determinations show up to 4% of organic matter in the upper portion of grey silts where this matter does not show megascopically.

The extent of the individual lithological varieties of the organic series in the Wawrzyszew area (Fig. 4) was established from drilling and auger records as well as from observations in trenches and holes. It should be noted that the image established applies to the current state of geological formations that is to one disturbed by partial

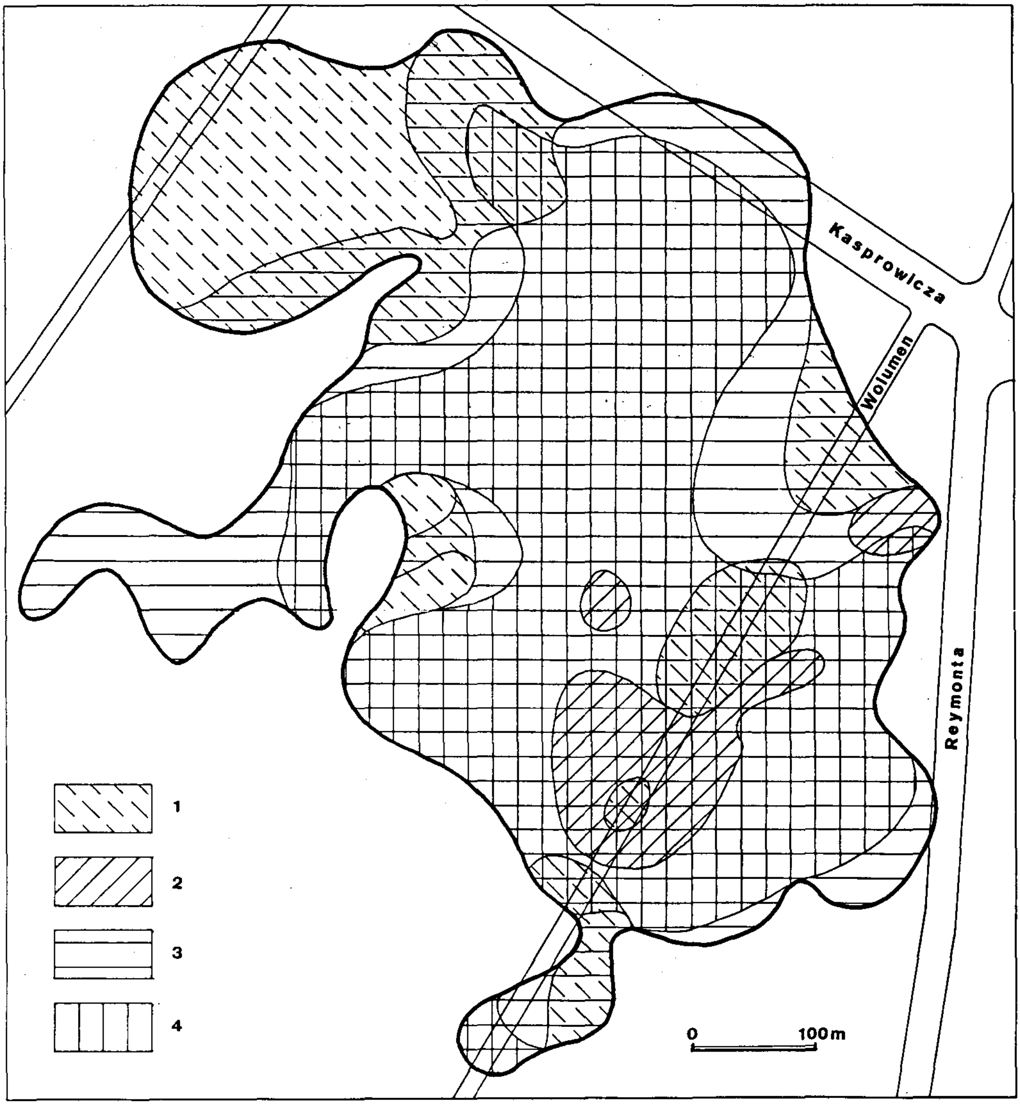

Fig. 4. Sketch showing the extent of various lithological types of the organic sediments of the Eemian buried lake in Wawrzyszew: 1 – lacustrine chalk, 2 – peats, 3 – gyttja, 4 – bituminous shales

erosion of the upper portions of sediments, chiefly peats which probably occurred over considerably larger parts of the basin. For simplification purposes all the gyttjas present in the basin were given only one symbol.

In nearly all sequences examined the organic series commences with a bituminous shale layer. Usually, the basal part of this layer is an approximately 5 cm thick "block" of organic-mineral sediment without a distinct shaly parting, very compact and hard when dried. This sediment contains up to 10% of organic matter. Further up in the sequence lie black bituminous shales distinctive by their scaly parting. Fresh and moist

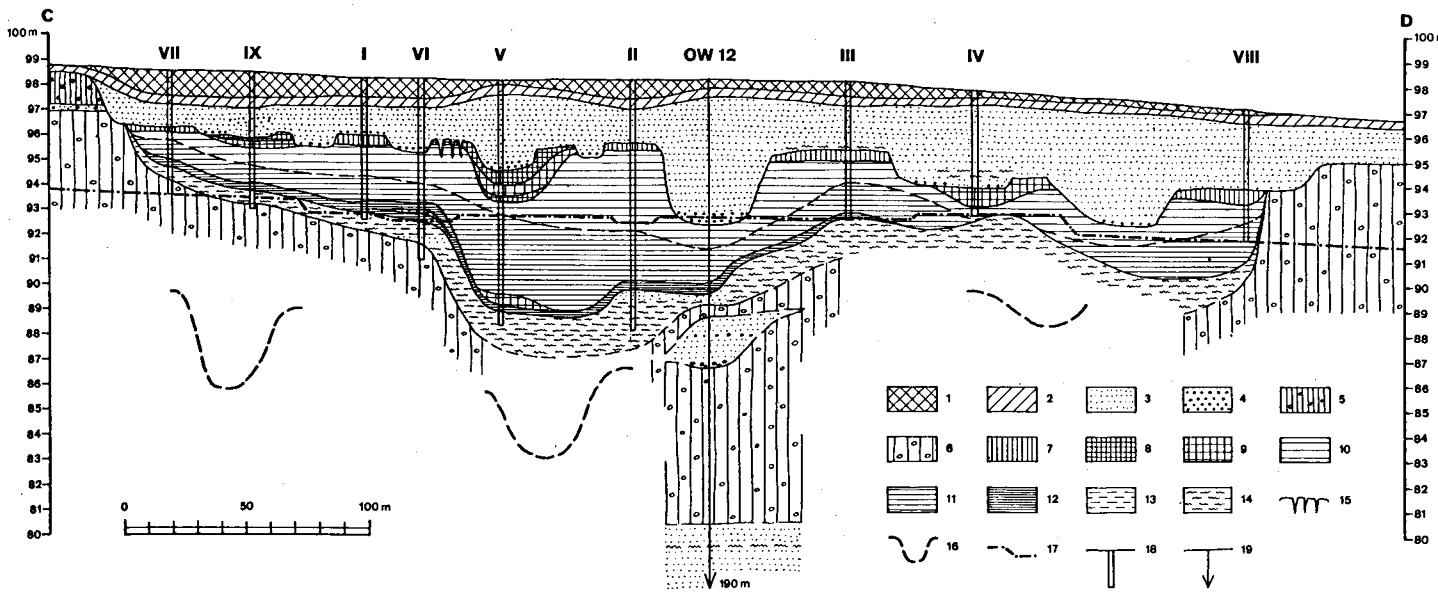

Fig. 5. Geological section across the buried Eemian lake in Wawrzyszew (along the trench): 1 – mound, 2 – soil, 3 – sands, 4 – gravel, 5 – till – Mazovia-Podlasie (Warta) Stadial, 6 – till – Maximum Stadial, 7 – lacustrine chalk, 8 – peat, 9 – structureless, spongy, grey-green gyttja, 10 – light-beige limy gyttja, 11 – beige-brown shaly gyttja, 12 – bituminous shales, 13 – clays, 14 – silts, 15 – frost fissure structures, 16 – bottom of the organic sediments in deepened parts of the basin beside the cross-section line, 17 – trench bottom, 18 – distribution of sampled sections, in circles palynologically examined sections, 19 – borehole

they are elastic but become hard when dried. Burning, they produce a heavy smoke. The organic matter content in these shales reaches up to 27% and $CaCO_3$ content increases upwards from 7% at the bottom to 15% at the top. Within the shale occur sporadical grey-green gyttja intercalations with megascopically visible plant detritus, strongly compressed and laminated with single scaly shale fragments. The total thickness of the shale layer varies from several to about 70 cm.

There is a fairly distinct boundary between the bituminous shales and the overlaying gyttja series making up the major part of the organic series described. In absence of a clear boundary within the latter series it is divided into the lower – brown-beige and the upper – light-beige – part. From the bottom the dark gyttja grades upwards into a brown and subsequently into a beige variety. The same gradual transition applies to the structural features of the sediment. In the basal part of the gyttja is compressed, displays tabular parting and, when dried, disintegrates into cubes. Upwards this parting gradually disappears. In the basal part the parting surfaces are covered by a black coating. in the gyttja series discussed mollusc shells and fish scales were found to occur in addition to macroscopic plant remains. Generally speaking, the organic matter content in the gyttja series gradually drops upwards from about 21% at the bottom to about 8% at the top, while the $CaCO_3$ content increases upwards from about 35% at the bottom to about 60% at the top. In some parts of the basin there is a gradual transition between the gyttja series and the overlying lacustrine chalk – white beige or grey at the bottom and white at the top. This sediment contains 4 – 2% of organic matter and 60 to 80% of $CaCO_3$.

In other parts of the basin the gyttja series is overlain by peats and porous peaty gyttja. The peat series with gyttja intercalations is best developed in the vicinity of section V (Fig. 5). The beige gyttja with gastropod shells is followed by a 10 cm thick layer of limy porous gyttja with plant detritus containing 12% of organic matter and 80% of $CaCO_3$. Higher up in the sequence lies a 7 cm thick dark brown peat layer with compressed tree leaves, plant remains and gastropod shells. Its organic matter content is 57% and $CaCO_3$ content 5%. Next comes a 43 cm thick layer of porous spongy green-grey gyttja peaty and green-brown towards the top. It is intercalated with several streaks of light beige dust – probably loess. The organic matter and $CaCO_3$ content in the gyttja layer are about 20% and 40 to 60% respectively. The gyttja is overlain by sandy peats (27 cm thick) with minute laminae of fine sand and loess. Here the amount of organic matter ranges from 28 to 24%. Higher up occurs a 16 cm thick layer of alternating peat dust laminae and very fine-grained sand.

PALAEOGEOGRAPHY

The literature concerning buried Eemian lakes of Warsaw and its neighborhood is throughly discussed in the explanations for the Geological Atlas of Warsaw – Atlas Geologiczny Warszawy and in the explanations for the sheet Warszawa Zachód of the Detailed Geological Map of Poland – Szczegółowa Mapa Geologiczna Polski, 1: 50 000

(Morawski 1980). Over nearly 100 years researchers were devoting special attention to the channel lake belt extending from Żolobórz in the north of Warsaw to Okęcie in the south. It seems highly probable that a western branch of this channel follows the line Wola – Włochy – Opacz (Morawski 1980). The channels (Fig. 1) connected the Vistula valley in the north with the Utrata – Wilanówka valley in the south and during the Eemian undoubtedly provided conduits for the water flow, which resulted in an incomplete development of the organic sediments and their partial washing.

The Wawrzyszew basin constitutes a trough in a closed depression left may be by a dead-ice block of the Mazovia- Podlasie (Warta) Stadial. The reduced thickness of the Maximum Stadial till forming the bottom of the trough may also suggest that this depression was initiated by exaration or erosion of subglacial waters of the Mazovia-Podlasie ice sheet and was later filled with ice or water. The latter possibility seems to be confirmed by the lack of morainic material melted from the hypothetical dead-ice block as well as by the existence of a silt series covering the basin bottom and filling up local depressions. Presumably, from the close of the Mazovia-Podlasie Stadial till the close of the Late Mazovia Stadial mineral sedimentation prevailed in this basin. A high moisture content in silts underlying Eemian sediments prevented the collection of samples which might have provided evidence of a climatic warming in connection with the Pilica Interstadial.

Of particular interest is the location of the basin coincident with the axis of the buried Kamionek – Żolibórz channel probably derived from the Maximum Stadial of the Middle Polish Glaciation. A thorough analysis of the Maximum Stadial till bottom in numerous bore holes indicates the bottom to be inflected along the trend of the channel. Presumedly, the sandy-silty sediments filling the channel cut in the Pliocene clay and strongly saturated with water in the course of deposition were affected by gradual compaction which might have resulted in subsidence, particularly along the channel axis. Data from numerous bore holes drilled in the channel revealed the existence of considerable undulations of its bottom of which the Wawrzyszew area seems to be the lowest part. Consequently, both in the preceding period and during the Eemian Interglacial itself when organic sediment were deposited in the basin, its bottom gradually subsided, assumedly by several meters. This process could be responsible for the fact that the organic sediments exceed 12 m in thickness and the bottom shows local subsidence features (Fig. 3). Sections from some piling excavations show that the most subsided parts of the basin coincide with "holes" in the underlying till, which presumedly favoured subsidence. The bottom surface of the organic sediments (Fig. 3) which, cover the major part of the basin, corresponds to the bottom of the bituminous shales. As only a part of the bore holes reached the basin bottom which is assumed to be till, it is not possible to

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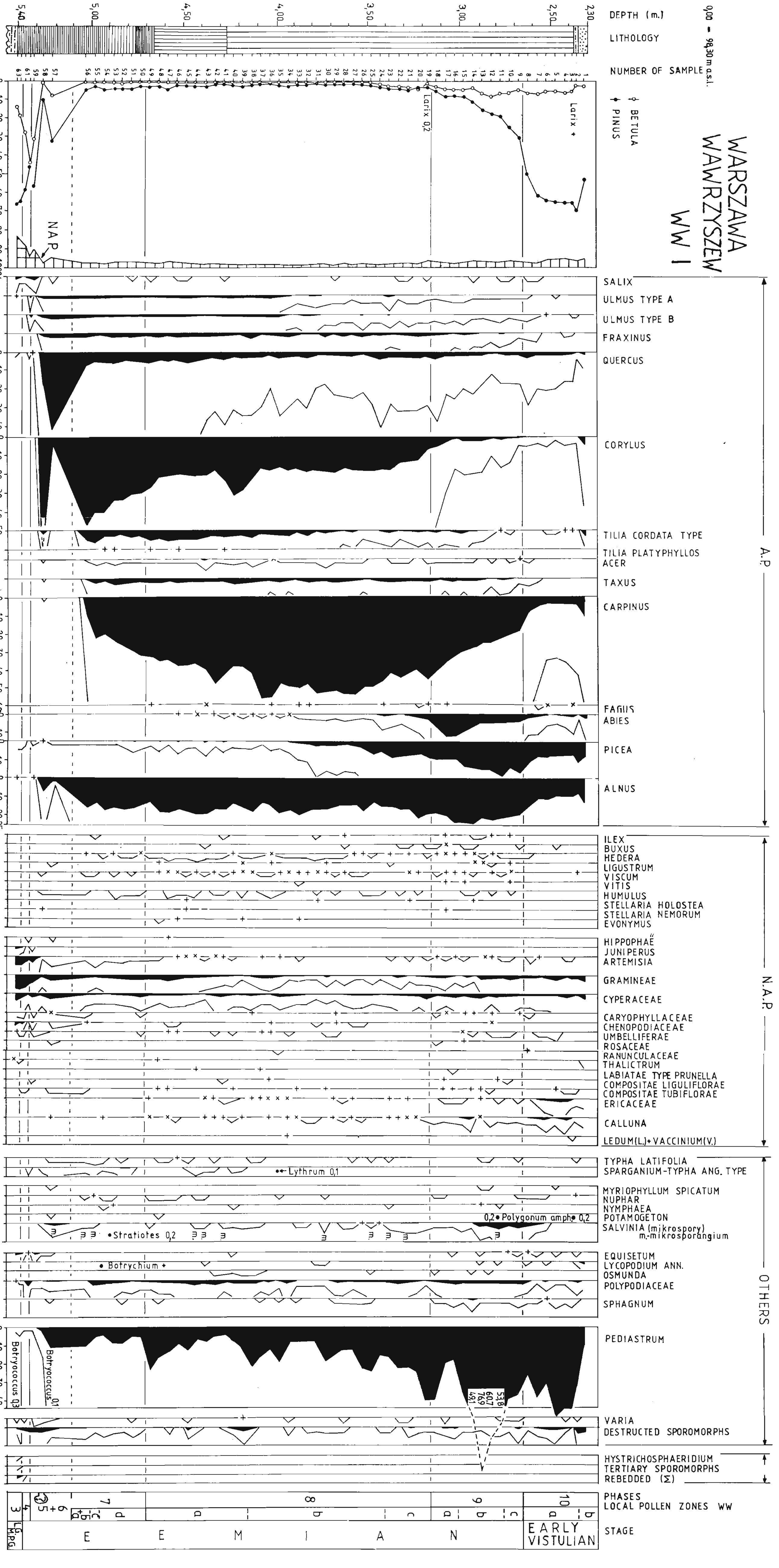
Fig. 6. Warszawa Wawrzyszew. Pollen diagram of the profile WW I. Taxa which are not marked in the diagram: sample No (%) *Cruciferae* 3(+) *Ephedra distachya* type 3(+) *Ephedra fragilis* type 63(0.2) *Frangula alnus* 10(+) *Helianthemum nummularium* type 6(0.2) *Helianthemum oelandicum* type 63(0.2) *Papilionaceae* 5(+) *Polygonum persicaria* type 39(+) *Ranunculus acer* type 4(+) *Rubiaceae* 16(+) *Rumex* sec. *Acetosa* 57(0.1): 50(0.2) *Urtica* 62(0.2): *Viburnum* 56(0.1): 21(0.2): *Lycopodium inundatum* 10(0.2): *Pteridium* 3(0.2); Denotations as in Figs 10, 11


WARSZAWA WAWRZYSZEW WW I
DEPTH (m.)
0,00 = 98,30 m a.s.l.
LITHOLOGY
NUMBER OF SAMPLE
BETULA
PINUS
Larix 0,2
Larix +
NAP
SALIX
ULMUS TYPE A
ULMUS TYPE B
FRAXINUS
QUERCUS
CORYLUS
TILIA CORDATA TYPE
TILIA PLATYPHYLLOS
ACER
TAXUS
CARPINUS
FAGUS
ABIES
PICEA
ALNUS
A.P.
ILEX
BUXUS
HEDERA
LIGUSTRUM
VISCUM
VITIS
HUMULUS
STELLARIA HOLOSTEA
STELLARIA NEMORUM
EVONYMUS
HIPPOPHAË
JUNIPERUS
ARTEMISIA
GRAMINEAE
CYPERACEAE
CARYOPHYLLACEAE
CHENOPODIACEAE
UMBELLIFERAE
ROSACEAE
RANUNCULACEAE
THALICTRUM
LABIATAE TYPE PRUNELLA
COMPOSITAE LIGULIFLORAE
COMPOSITAE TUBIFLORAE
ERICACEAE
CALLUNA
LEDUM(L.)+VACCINIUM(V.)
N.A.P.
TYPHA LATIFOLIA
SPARGANIUM-TYPHA ANG. TYPE
Lythrum 0,1
MYRIOPHYLLUM SPICATUM
NUPHAR
NYMPHAEA
POTAMOGETON
SALVINIA (mikrospory) m.-mikrosporangium
Stratiotes 0,2
0,2 Polygonum amph. 0,2
EQUISETUM
LYCOPODIUM ANN.
OSMUNDA
POLYPODIACEAE
SPHAGNUM
Botrychium +
PEDIASTRUM
Botryococcus 0,3
Botryococcus 0,1
VARIA
DESTRUCTED SPOROMORPHS
OTHERS
HYSTRICHOSPHAERIDIUM
TERTIARY SPOROMORPHS
REBEDDED (Σ)
PHASES
LOCAL POLLEN ZONES WW
STAGE
LG MPG.
E E M I A N
EARLY VISTULIAN

construct a topographical sketch of this surface. Nevertheless, the existing data indicate that areas where the bottom of the organic sediments is lowered approximately coincide with the subsided parts or "holes" described from the basin bottom.

Palynological results reveal that deposition in the Wawrzyszew basin continued uninterruptedly throughout the Eemian Interglacial till the North Polish Glaciation. The silt series underlying the proper Eemian organic cycle shows a gradual increase in the organic matter amount in it upper portion. Almost throughout the entire basin the lacustrine organic sediments represent a uniform depositional cycle differing only in its upper portion. In the final depositional stage in various parts of the basin peat, gyttja or lacustrine chalk were laid down side by side. Then deposition was interrupted due to a climatic cooling related to the North Polish Glaciation. During this period in the moisture-saturated lacustrine sediments ice wedges were formed and subsequently filled with material derived from the then originated fissures as well as with sand supplied mainly by eolian processes. The advance of the North Polish ice sheet probably caused a complete burial of the Vistula valley the western part of which was situated several hundred meters east of the Wawrzyszew lake. On this site in the Eemian Interglacial the Vistula valley formed a meander lobe. At that time the valley bottom was at about 65 m a.s.l. The burial of the valley produced the now buried Bielany terrace (Morawski 1980). The valley itself was buried up to the level of the plateau and the Vistula river gradually shifted its shallow channel to the west forming the erosional Warsaw-Błonie terrace. Only in the lower areas thin fluvial sands were deposited. In the Wawrzyszew lacustrine basin with already deposited organic sediments erosional processes produced a shallow cut, subsequently filled with sands with gravel appearing at the top. A minor depression, partly filled with eolian sands, survived till the Holocene. In small shallow swamps organic sediments were formed. ^{14}C dating of peats resting with fluvial sands and covered with eolian sands yielded 720±120 years BP. (GD-343) Swampy depressions visible on prewar topographic maps survived till the present time.

PALYNOLOGICAL STUDIES

METHODS

A total of 261 samples of lacustrine and post-lacustrine sediments from 5 profiles were provided for palynological studies. The samples were air-dried.

Profiles WW I, WW V, WW VI and WW IX are located close to one another (25–45 m) in the southeastern part of the buried lake basin. The profile WW XV is about 500 m apart, to the northwest (Figs 1, 3). Profile WW V represents deep part of the basin, whereas the remaining profiles come from considerably shallower zones (Fig. 5). The upper part of the profile WW VI and the lower section of profile WW V have not been sampled (Figs 5, 11).

Different separation and preparation procedures were applied depending on the variable nature of sediments. Samples of calcareous sediments distinguished by high pollen frequency were decalcified with 10% HCl solution prior to Erdtman's acetolysis. As regards sediments with a significantly lower proportion of sporomorphs and higher amounts of mineral constituents (silt, sand), acetolysis was preceded by decantation and flotation ($KJ+CdJ_2$, '$\tau = 2.26–2.28$ g/cm^3) or by the hydrogen fluoride method (WW I, IX).

The pollen spectra were counted in at least two slides but for samples with lower pollen frequency a larger number of slides were used. The material was studied in 1975–1988.

In samples with high pollen frequency at least 500 tree pollen grains (AP) were counted along with all sporomorphs of other plants. The percentages of particular taxa were calculated in relation to the total of tree pollen (AP) as well as shrub and herb pollen (NAP). Single spororomorph out of total pollen sum are "+"; two or more sporomorphs out of total pollen sum are "x" indicated on the pollen diagrams.

The objective of the present work is to provide a thorough analysis of the local pollen zones and to describe the differentiation of their pollen spectra in five profiles from the Warsaw – Wawrzyszew area. A detailed history of the local and regional vegetation during this interglacial in the Warsaw area will be a subject of a separate paper (Krupiński 1993).

LOCAL POLLEN ZONES

Results of palynological studies of five profiles in the Warsaw-Wawrzyszew area (Figs 3, 5) permit a distinction of 22 local pollen zones corresponding to 11, phases of the vegetational development. The oldest phases represented by a single pollen zone – WW 1, WW 2 and WW 3 – refer to the late glacial of the glaciation preceding the Eemian Interglacial. In the examined profiles most sediments derive from the Eemian Interglacial (phases WW 4 – WW 9). Sediments the origin of which can be related to the post- Eemian climatic cooling (Early Vistulian, phases WW 10 and WW 11), are poorly preserved.

Palynological studies of the bottom part of these profiles included also sediments with a considerable number of Tertiary sporomorphs. This zone has been called a bed with secondary pollen and it forms a bed from a geological point of view. At the top of the zone WW XV (Fig. 10) there are the Late Holocene sediments.

Development and preservation state of sediments of individual pollen zones are markedly different (Fig. 1). Only the profile WW XV is relatively complete (Fig. 10). Sediments of the pollen zone WW 11 did not form at all or are not preserved and only fragments of the zones WW 10a and WW 10b are present. This is also true to a certain degree of the pollen zone WW 4 is concerned.

In the profile WW IX (Fig. 9) fragments of the Early Vistulian along with the pre Eemian and Eemian sediments are preserved. The profile WW VI (Fig. 8) has best preserved Late Glacial Eemian Interglacial sediments (up to the *Corylus* phase inclusive) of all the studied profiles. The upper part of this profile has not been sampled. Profile WW I (Fig. 6) includes the whole interglacial with particularly well-preserved sediments of the zone WW 8. At its bottom barely traces of the Late Glacial deposits are noted with the some Early Vistulian fragments at the top. Profile WW V (Fig. 7) embraces the upper part of the Eemian and the beginning of the Early Vistulian deposits. The lower part of the profile has not been sampled (Figs 5, 11).

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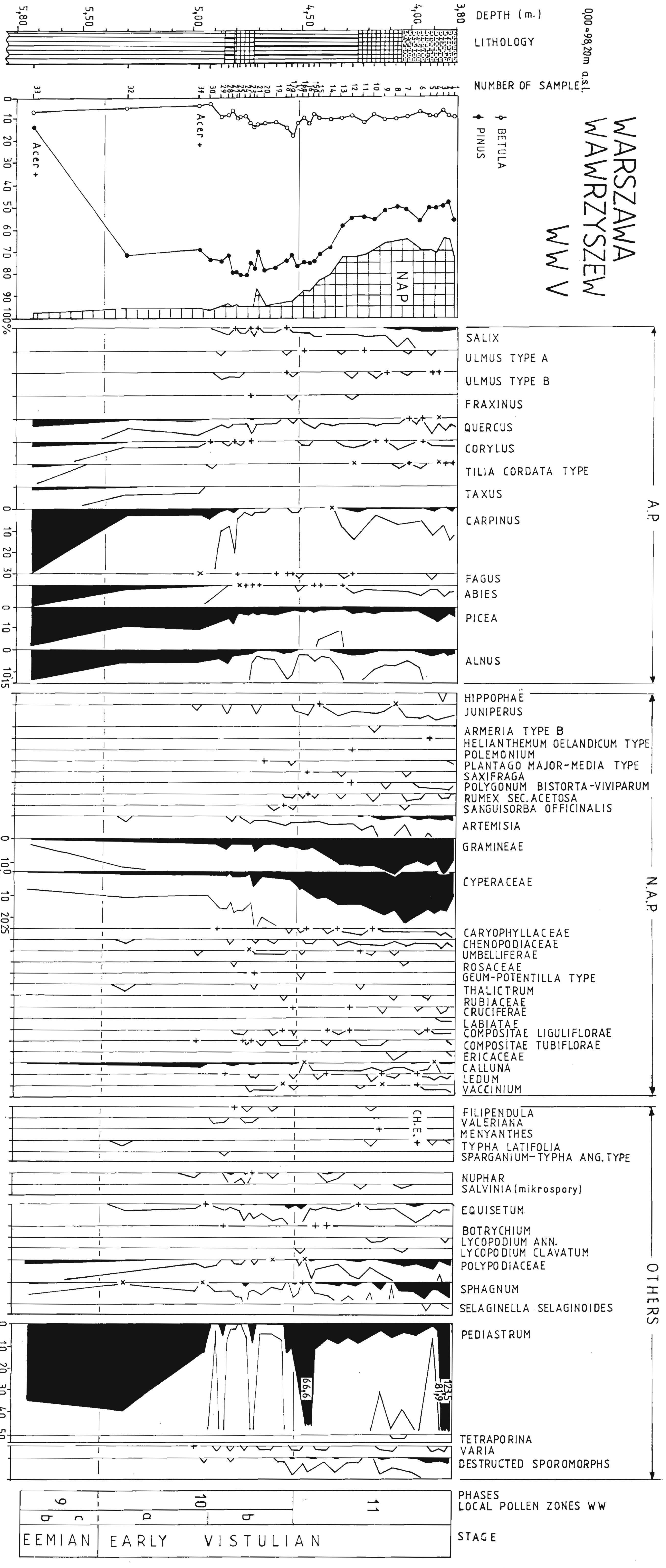
Fig. 7. Warszawa Wawrzyszew. Pollen diagram of the profile WW V. Taxa which are not marked in the diagram: sample No (%): *Arctostaphylos* 6(+): *Humulus* 33(0.2): *Urtica* 17a(0.2): *Caltha* 17a(0.2): 16(+): 10(0.1): *Chamaenerion-Epilobium* type 6(+): *Parnassia* 14(+): *Myriophyllum alterniflorum* 4(+); Denotations as in Figs 10, 11


WARSZAWA WAWRZYSZEW WW V
DEPTH (m.)
LITHOLOGY
NUMBER OF SAMPLE
0,00 = 98,20 m a.s.l.
BETULA
PINUS
Acer +
NAP
SALIX
ULMUS TYPE A
ULMUS TYPE B
FRAXINUS
QUERCUS
CORYLUS
TILIA CORDATA TYPE
TAXUS
CARPINUS
FAGUS
ABIES
PICEA
ALNUS
A.P.
HIPPOPHAË
JUNIPERUS
ARMERIA TYPE B
HELIANTHEMUM OELANDICUM TYPE
POLEMONIUM
PLANTAGO MAJOR-MEDIA TYPE
SAXIFRAGA
POLYGONUM BISTORTA-VIVIPARUM
RUMEX SEC. ACETOSA
SANGUISORBA OFFICINALIS
ARTEMISIA
GRAMINEAE
CYPERACEAE
CARYOPHYLLACEAE
CHENOPODIACEAE
UMBELLIFERAE
ROSACEAE
GEUM-POTENTILLA TYPE
THALICTRUM
RUBIACEAE
CRUCIFERAE
LABIATAE
COMPOSITAE LIGULIFLORAE
COMPOSITAE TUBIFLORAE
ERICACEAE
CALLUNA
LEDUM
VACCINIUM
N.A.P.
FILIPENDULA
VALERIANA
MENYANTHES
TYPHA LATIFOLIA
SPARGANIUM-TYPHA ANG. TYPE
CH. E.
NUPHAR
SALVINIA (mikrospory)
EQUISETUM
BOTRYCHIUM
LYCOPODIUM ANN.
LYCOPODIUM CLAVATUM
POLYPODIACEAE
SPHAGNUM
SELAGINELLA SELAGINOIDES
PEDIASTRUM
66,6
123,5
81,9
TETRAPORINA
VARIA
DESTRUCTED SPOROMORPHS
OTHERS
PHASES
LOCAL POLLEN ZONES WW
STAGE
9
10
11
b
c
a
b
EEMIAN
EARLY VISTULIAN

"A bed with secondary pollen" (NAP + secondary pollen) has been distinguished in three profiles: WW VI (samples nos. 15–17, 5.90–6.60 m), WW IX (nos. 52–53, 4.90–5.00 m) and WW XV (nos. 92–95, 5.87–6.05 m). It is marked by its components: silts and silty sands. The pollen spectra contain tree pollen of cool (*Pinus, Betula, Salix*) and temperate (*Quercus, Tilia, Fraxinus, Corylus, Carpinus, Abies, Ulmus, Picea*) climate. The pollen percentages of shrubs and herbaceous plants with heliophilous floristic elements (*Empetrum, Helianthemum, Armeria, Polemonium, Saxifraga, Polygonum bistorta-viviparum, Selaginella selaginoides, Artemisia, Juniperus, Hippophaë* etc.) justify the supposition that the pollen of meso- and oligocratic elements has been here redeposited. This conclusion is certified by abundant Tertiary sporomorphs (15–45%) and *Hystrichosphaeridium* (0.3–5.4%). The proportion of redeposited material must be much higher because of pollen of trees and shrubs with greater climatic demands, common to the Tertiary and Quaternary (and so its minimal values have been estimated at 37–58%). Significant pollen are damaged seriously preventing their identification (3–28%). *Botryococcus* is found to be exceptionally abundant (11–13%).

The pollen zone WW 1 — *Hippophaë-Salix*-NAP. In three profiles it corresponds with silt and sand: WW VI (no 14, 5.80–5.90 m), WW IX (no 51, 4.85–4.90 m) and WW XV (no 91, 5.85–5.87 m) – see Figs 8 and 11. It is best pronounced in the profile WW VI. The high NAP percentage, mainly *Hippophaë* is a characteristic feature of this zone. Maximum values of shrub and herb pollen come up to 88% (56–88%). *Hippophaë* being decidedly predominant (WW IX – 73.4%, WW VI – 45.1% and WW XV – 40.4%). Apart from the pollen grains of *Hippophaë*, its hair is also noted in 84 specimens of 70 cm3 of sand from the profile WW IX (sample No 51, 4.85–4.90 m).

In addition to *Hippophaë* in the pollen of *Artemisia* (up to 6%), *Juniperus* (up to 5%), *Gramineae* (4–16%) and *Cyperaceae* (2–8%) is abundante. Pollen of heliophilous plant e.g. of *Empetrum nigrum* and *E. hermaphroditum, Helianthemum oelandicum* type, *Ephedra distachya* type (WW XI), *Pleurospermum austriacum (WW VI) and Polygonum bistorta-viviparum* (WW IX) is constantly or nearly constantly present. As a rule, the proportion of AP does not exceed 26% and only in the profile WW IX it is slightly higher (44%). It is mainly pollen of *Pinus* (5–23%) and *Betula* (1–13%). Pollen of *Salix* reach 5%. As compared with the previous zone, a pollen of exotic plants (1.6–8.9%) and meso- and oligocratic dendroflora is clearly losing significance. Distinctly lower are the values of redeposited sporomorphs (up to 11%). *Hystrichosphaeridium* is still present(up to 0.5%). There is a distinct drop in the quantity of damaged and unidentified sporomorphs (11%), as well as that of *Botryococcus* (1–11%) and *Pediastrum.*

The pollen zone WW 2 — *Betula-Hippophaë-Artemisia* – includes the layers of silts WW VI (no 13, 5.75–5.80 m) and sands with admixture of peat WW XV (nos. 89–90, 5.78–5.85 m). The sediments of this zone are decidedly best preserved in the profile WW XV. In the profile WW IX these layers (silts) are very thin (Fig. 9). It is very difficult to settle the upper boundary of the zone because of, among other things, its very small thickness resulting perhaps from a low deposition rate, scarce sampling in view of their deposition rate, the considerable compaction of the sediments and possibly their incompleteness. The pollen zone WW 2 is characterized by very high values of *Betula* (25–78%). Shrub and herb pollen are much lower (15–47%). Nevertheless, numerous heliophilous plants, such as *Empetrum, Ephedra distachya* type, *Pleurospermum austriacum, Armeria, Polygonum bistorta-viviparum, Saxifraga, Juniperus* and *Artemisia*, are still present (Figs 8 and 9). In the profile WW XV a number of heliophytes is smaller. The *Hippophaë* percentages fall drastically (7.4–1.5%). The values of *Salix* are relatively high and those of *Pinus* remain similar to its values in the preceding zone.

In the profile WW IX there is a temporary increase in percentage of exotic sporomorphs (2–5%) and *Botryococcus* (up to 12%). Such proportion of Tertiary sporomorphs however permits us to regard pollen spectra of this zone as the Quaternary, the more so since neither *Hystrichosphaeridium* nor meso- or oligocratic tree pollen has been noted in profile WW XV.

The pollen zone WW 3 — *Pinus-Juniperus-(Artemisia-Hippophaë)* starts with silts followed by sapropel which, having undergone a diagenesis, was transformed into bituminous shale (see Krupiński 1984–85). Its deposits are preserved in four profiles: WW I (nos. 62–63, 5.37–5.40 m), WW VI (nos. 10–12/13, 5.63–5.75 m), WW XV (nos. 81–88, 5.50–5.78 m) and WW IX (nos. 49A-50B, 4.77–4.85 m including the zone WW 2).

This zone is characterized by high *Pinus* pollen values (60–83%), relatively high values of *Betula* (10–29%) and, in its initial part, also by high proportions of shrub and herb pollen (47–5%), with still frequent *Hippopha* (17.0–0.3%) and heliophilous plants reported from the previous zone, such as *Juniperus* (0.2–7.2%), *Empetrum* (up to 0.7%), *Artemisia* (up to 10%), *Helianthemum* (up to 0.5%), *Saxifraga, Selaginella selaginoides, Armeria, Ephedra distachya* type, *Geranium, Euphorbia, Centaurea montana* type, *Linum* and *Polygonum bistorta-viviparum.*

A rise is noted in percentages of Tertiary sporomorphs, redeposited sporomorphs of other taxa and damaged sporomorphs as well as those of *Hystrichosphaeridium, Pediastrum* (20–40%) and *Botryococcus* (to ca. 20%). The upper boundary of this zone coincides with disappearance of redeposited elements and decline of high values of damaged sporomorphs.

The pollen zone WW 4 — *Betula-Pinus*-NAP-*(Ulmus)* appears in 4 profiles: WW I (nos. 60–61, 5.32–5.37 m), WW VI (nos. 8–9, 5.50–5.63 m), WW IX (nos. 47–48, 4.70–4.77 m) and WW XV (no 80, 5.48–5.50 m). It includes bituminous shales, best preserved in the profile WW VI. In profiles WW XV and WW I the sediments could be partly destroyed or the zone itself could be reduced in thickness due to compaction.

The zone WW 4 is characterized by high *Betula* pollen (29–60%), *Pinus* slightly lower than in the preceding zone (29–59%) and a relatively low though differentiated shrub and herb pollen (5–15%). There is a distinct fall in pollen values of heliophilous

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Fig. 8. Warszawa Wawrzyszew. Pollen diagram of the profile WW VI. Taxa which are not marked in the diagram: sample No(%): *Acrostaphylos* 17(+): *Hypericum* 16(0.3): *Iridaceae* 14(0.1): 12(0.1): *Ligustrum* 5(+): *Polygonum persicaria* type 12(+): *Rumex* sec *Acetosa* 3(0.1): *Vaccinium* 14(+): *Caltha* 15(0.3): *Parnassia* 14(0.1): *Myriophyllum spicatum* 13(0.3): *Nuphar* 3(0.1) *Nymphaea* 3(0.1); Denotations as in Figs 10, 11

WARSZAWA WAWRZYSZEW WW VI
0,00 = 98,25 m a.s.l.
DEPTH (m.)
LITHOLOGY
NUMBER OF SAMPLE
BETULA
PINUS
Populus 0,1
NAP
Fagus +
SALIX
ULMUS TYPE A
ULMUS TYPE B
FRAXINUS
QUERCUS
CORYLUS
TILIA CORDATA TYPE
TILIA PLATYPHYLLOS
TAXUS
ACER
CARPINUS
ABIES
PICEA
ALNUS
A.P.
HEDERA
VISCUM
HUMULUS
HIPPOPHAË
JUNIPERUS
PLEUROSPERMUM
EPHEDRA DISTACHYA TYPE
EPHEDRA FRAGILIS TYPE
ARMERIA TYPE A
HELIANTHEMUM NUMMULARIUM TYPE
HELIANTHEMUM OELANDICUM TYPE
EMPETRUM HERMAPHRODITUM
EMPETRUM NIGRUM
SAXIFRAGA
ARTEMISIA
GRAMINEAE
CYPERACEAE
CARYOPHYLLACEAE
CHENOPODIACEAE
UMBELLIFERAE
ROSACEAE
ROSA TYPE
POLYGONUM
RANUNCULUS ACER TYPE
THALICTRUM
RUBIACEAE
CRUCIFERAE
LABIATAE
COMPOSITAE LIGULIFLORAE
COMPOSITAE TUBIFLORAE
CALLUNA
LEDUM
N.A.P.
TYPHA LATIFOLIA
SPARGANIUM-TYPHA ANGUST. TYPE
POTAMOGETON
SALVINIA
EQUISETUM
BOTRYCHIUM
LYCOPODIUM ANN.
POLYPODIACEAE
SPHAGNUM
SELAGINELLA SELAGINOIDES
PEDIASTRUM
BOTRYOCOCCUS
1373
842
TETRAPORINA
VARIA
DESTRUCTED SPOROMORPHS
OTHERS
HYSTRICHOSPHAERIDIUM
TERTIARY SPOROMORPHS
REBEDDED (Σ)
REBEDDED
PHASES
LOCAL POLLEN ZONES WW
STAGE
BED with SECONDARY POLLEN
L.G. M.P.G.
E E M I A N

plants, whereas surviving taxon (*Juniperus* and *Hippophaë*) occur irregularly. The *Artemisia* values are still relatively high (0.7–2.8%).

The appearance and subsequent rise of the *Ulmus* curve to the value of about 1% is characteristic for this zone. The zone should be referred to the first development phase of an interglacial vegetation.

The pollen zone WW 5a — *Pinus-Betula-Ulmus-(Quercus)* has been distinguished in 4 profiles: WW VI (no 7, 5.45–5.50 m), WW IX (no 46, 4.66–4.70 m), WW I and WW XV. In the last two profiles these sections were poorly sampled and thus the zones WW 5a and WW 5b could be hardly separated from each other. In all the profiles this very thin zone (about 0.05 m) is distinguishable due to its primary sapropel type deposits (see Krupiński 1984–85).

The zone WW 5a is characterized by high *Pinus* pollen (41–57 %), relatively high though distinctly decreasing *Betula* (32–45%), rise of the *Ulmus* curve (up to 3%) and the appearance of rational curves of *Quercus* (up to 2.2%) and *Fraxinus* (up to 0.4%). Values of shrub and herb pollen do not exceed 10% as a rule. These are mainly *Gramineae* and *Cyperaceae*. Relatively high *Artemisia* values are persistent (up to 0.9%).

The pollen zone WW 5b — *Pinus-Quercus-Ulmus-(Fraxinus)* as a separate biostratigraphic unit is distinguished in 2 profiles: WW VI (no 6, 5.35–5. 45 m) and WW IX (nos. 44–45, 4.62–4.66 m). In profiles WW I and WW XV it is treated jointly with the zone WW 5a. In WW I, WW VI and WW XV it is made up of bituminous shales and in the profile WW IX of bituminous shales and sands. In all the profiles its thickness is very similar and does not exceed 0.10 m.

It differs from the zone WW 5a in lower values of *Pinus* (34–51%), *Betula* (9–25%) and NAP (5–7%) and in distinctly higher and clearly differentiated values of *Quercus* (12–41%) and a relatively high frequency of *Fraxinus* (1–4%). This zone has comparatively high *Ulmus* values (1.8–3.1%). Pollen of *Alnus* (0.1–0.3%), *Corylus* (0.2–0.6%), *Humulus* (0.2–1.4%), and of swamp and water plants of slightly higher climatic demands, e.g. *Typha latifolia* (up to 0.3%), *Salvinia* (up to 0.7%), and sporadically *Hedera*, begins to run regularly.

Palynological results concerning the WW 5a and WW 5b zones of these profiles suggest that changes in a natural environment of that time were very rapid or a deposition was rate very low, compaction very remarcable and the time interval might have been very short.

The pollen spectrum for the sample no 58 in profile WW I (Fig. 6) is interpreted by the author as resulting from shifting of sediments within the same lake basin, which might have caused a partial inversion of the Eemian succession in this section.

The pollen zone WW 6a — *Quercus-Pinus-Fraxinus* – is noted in 4 profiles. It is best documented by pollen spectra from the profiles: WW XV (nos. 76–78, 5.30–5.42 m) and WW IX (despite the difficulties in setting the upper boundary). In profiles WW I and WW XV the zone is distinguished as simple one together with the zones WW 6b and WW 6c. In the profile WW XV the sediments consist of bituminous shales, silts and sands, while in all the remaining profiles of bituminous shales.

The zone WW 6a is characterized by high values of *Quercus* (40–43 %), considerable proportions of *Ulmus* (1.3–3.2%) and *Fraxinus* (1.6–3.2%), a distinct fall of *Pinus*

(30–36%), *Betula* (10–17%) and NAP (4.3–8.6%) curves and the appearance of the rational curve of *Corylus* (0.6–4.0%) and the empiric curve of *Alnus* (0.2–0.4%). From among shrubs and herbaceous plants of slightly higher climatic demands there is *Viscum* and the ones occurring previously become more frequent: *Hedera, Humulus* (0.1–0.8%). There is also an increase in the frequency of *Typha latifolia* and *Salvinia*.

The pollen zone WW 6b — *Quercus-Fraxinus-(Corylus)* – has been distinguished as a separate stratigraphic unit in one profile only – WW XV (nos. 70–75, 5.02–5.30 m) whereas it is difficult to distinguish in the profiles WW IX, WW VI and WW I, although its presence is unquestionable. Its sediments are composed of grey sand and bituminous shales at the top in the profile WW XV and of bituminous shales in the remaining profiles. Probably owing to nature of the sediment in the profile WW XV, a thickness of this zone is marked (about 0.28 m), being smaller in the remaining profiles (Fig. 11).

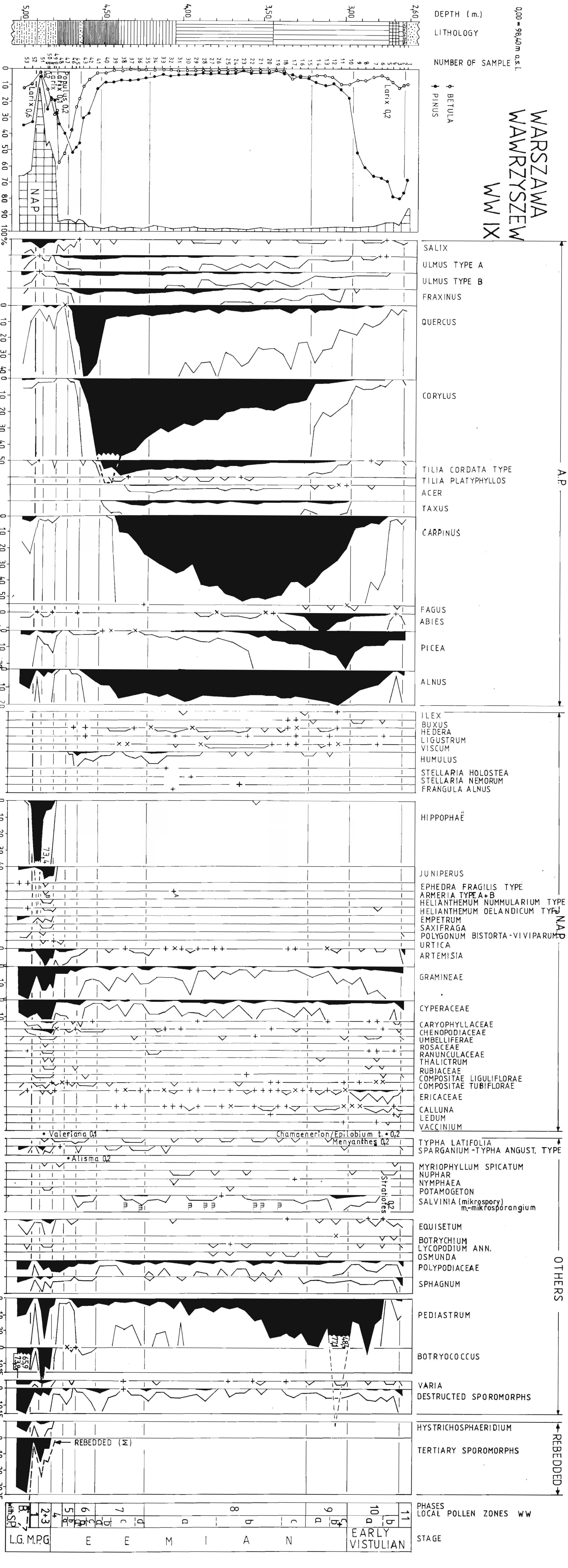
The pollen zone WW 6b is characterized by high values of *Quercus* (29–43%), rise of *Corylus* (4–12%), *Alnus* (0.5–2.0%) and *Fraxinus* (2.7–4.3%) curves, high *Ulmus* (1.5–3.5%) and the appearance of the first *Tilia* and *Acer* pollen. *Pinus* (33–28%) and *Betula* (20–6%) continue to decrease. The NAP values do not exceed 8%; pollen of plants with great climatic demands – *Hedera, Viscum* and *Ligustrum* – occurs almost constantly. Maximum values of *Humulus* (0.5–1.2%) appearing in the final part of this zone are clearly correlated with those of *Fraxinus* (cf. Niklewski 1968, Krupiński 1978). This zone shows the first maximum of *Salvinia* (up to 0.7%) and the almost constant presence of *Typha latifolia*. In the profile WW XV the *Frangula alnus* pollen grain has been noted.

The pollen zone WW 6c — *Quercus-Corylus-(Alnus)* – is distinguished as a separate zone in the profiles WW XV (no 69, 4.97–5.02 m) and WW IX (no 41, 4.50–4.55 m), but hardly distinguishable at all in the profiles WW I and WW VI. The zone is built of bituminous shales.

It is characterized by high *Quercus* (35–45%) and *Corylus* (20–34%) values and very close to the *Fraxinus* maximum (2.5–4.0%). *Pinus* (15–20%) and *Betula* (2–6%) values are low while the *Alnus* pollen curve rises (to 6%) and some *Taxus* pollen grains appear for the first time (Figs 6, 8). Here there are the very beginnings of *Tilia* and *Carpinus* curves. There is a distinct decrease of *Humulus* to about 0.5%. Pollen of shrub and water plants with higher climatic demands – *Hedera, Ligustrum, Viscum, Typha latifolia* and *Salvinia* is present.

The presence of single *Hippophaë* pollen in the zones WW 5a, WW 5b and in particular WW 6a, b, c, in the profile WW I seems to result from shifting of sediments of earlier phases, rich in *Hippophaë*. The difficulty in separating phases WW 5 and WW 6

Fig. 9. Warszawa Wawrzyszew. Pollen diagram of the profile WW IX. Taxa which are not marked in the diagram: sample No(%): *Centaurea montana* type 49a(0.1): *Cornus sanguinea* 37(+): *Ephedra distachya* type 49a(0.1): *Linum* 49a(0.1): *Plantago lanceolata* type 2(+): *Polygonum persicaria* type 50b(0.2): 45(+): 39(+): 8(+): *Ranunculus acer* type 49a(+): *Rumex* sec *Acetosa* 49a(0.2): *Butomus* 49a(+): *Filipendula* 49b(0.2): *Lycopodium clavatum* 16(0.2): *Lycopodium selago* 25(0.2): *Ophioglossum* 46(+): *Pteridium* 1(0.2): *Tetraporina* 49b(0.2); Denotations as in Figs 10, 11



WARSZAWA WAWRZYSZEW WW IX
0,00 = 98,40 m a.s.l.
DEPTH (m.)
LITHOLOGY
NUMBER OF SAMPLE
BETULA
PINUS
NAP
Larix 0,6
Populus 0,2
Larix 0,1
Larix 0,2
SALIX
ULMUS TYPE A
ULMUS TYPE B
FRAXINUS
QUERCUS
CORYLUS
TILIA CORDATA TYPE
TILIA PLATYPHYLLOS
ACER
TAXUS
CARPINUS
FAGUS
ABIES
PICEA
ALNUS
A.P.
ILEX
BUXUS
HEDERA
LIGUSTRUM
VISCUM
HUMULUS
STELLARIA HOLOSTEA
STELLARIA NEMORUM
FRANGULA ALNUS
HIPPOPHAË
JUNIPERUS
EPHEDRA FRAGILIS TYPE
ARMERIA TYPE A+B
HELIANTHEMUM NUMMULARIUM TYPE
HELIANTHEMUM OELANDICUM TYPE
EMPETRUM
SAXIFRAGA
POLYGONUM BISTORTA-VIVIPARUM
URTICA
ARTEMISIA
GRAMINEAE
CYPERACEAE
CARYOPHYLLACEAE
CHENOPODIACEAE
UMBELLIFERAE
ROSACEAE
RANUNCULACEAE
THALICTRUM
RUBIACEAE
COMPOSITAE LIGULIFLORAE
COMPOSITAE TUBIFLORAE
ERICACEAE
CALLUNA
LEDUM
VACCINIUM
NAP
Valeriana 0,1
Chamaenerion/Epilobium t. 0,2
Menyanthes 0,2
Alisma 0,2
TYPHA LATIFOLIA
SPARGANIUM-TYPHA ANGUST. TYPE
MYRIOPHYLLUM SPICATUM
NUPHAR
NYMPHAEA
POTAMOGETON
SALVINIA (mikrospory)
m-mikrosporangium
Stratiotes 0,2
EQUISETUM
BOTRYCHIUM
LYCOPODIUM ANN.
OSMUNDA
POLYPODIACEAE
SPHAGNUM
PEDIASTRUM
BOTRYOCOCCUS
VARIA
DESTRUCTED SPOROMORPHS
OTHERS
HYSTRICHOSPHAERIDIUM
REBEDDED (Σ)
TERTIARY SPOROMORPHS
REBEDDED
PHASES
LOCAL POLLEN ZONES WW
STAGE
L.G. M.P.G.
E E M I A N
EARLY VISTULIAN

in the profile WW I into individual pollen zones may support this supposition although the sediments show no perceptible lithological variation.

The pollen zone WW 7a — *Corylus-Quercus-(Tilia)* – occurs in 4 profiles and has been separated as an individual biostratigraphic unit in 2 profiles: WW IX (no 40, 4.45–4.50 m) and WW XV (no 68, 4.92–4.97 m). In profiles WW I and WW VI it is treated together with the zone WW 7b. In all the profiles it is composed of similar bituminous shales and its thickness is very small 0.05 m (Fig. 11).

This zone is characterized by high *Corylus* (50–55%) and *Quercus* (10–20%) and slightly lower percentages of *Fraxinus* (1.1–2.5%) and *Ulmus* (2.0–3.5%). The role of *Alnus* (5–10%) and *Tilia cordata* type (2–5%) grows in significance. Sporadic *T. platyphyllos* pollen grains are noted while *Taxus* (0. 2–0.4%) and *Carpinus* pollen appears more and more frequently. *Pinus* and *Betula* pollen are very low and those of NAP are low. Pollen of *Gramineae* and *Cyperaceae* as well as plants with greater climatic demands such as *Humulus, Hedera, Viscum, Ligustrum* and, out of the aquatics *Nuphar* and *Nymphaea* predominates.

At the boundary between WW 6c and WW 7a in the profile WW I there seems to be a stratigraphic hiatus because the curves of *Carpinus, Corylus, Alnus*, and *Tilia* rise too rapidly, while those of *Pinus* and *Quercus* drop. Moreover this part of the profile has been poorly sampled.

The pollen zone WW 7b — *Corylus-Tilia-Taxus* – is distinguished as a separate biostratigraphic unit, in two profiles: WW XV (nos. 66–67, 4.82–4.92 m) and WW IX (No 39, 4.40–4.45 m) whereas in the profiles WW VI and WW I it is treated in combination with WW 7a. It consists of bituminous shales. In the profile WW IX its upper boundary is placed at the beginning of a gyttja layer which, as result of diagenesis is changed into shaly gyttja.

This zone is marked by exceptionally high *Corylus* (51–62%) values and lower values of *Quercus* (7–10%). The frequencies of *Alnus, Tilia cordata* type (sporadic *Tilia platyphyllos*), *Fraxinus* and *Ulmus* are similar to those in the previous zone. At the end of the zone *Taxus* and *Carpinus* (0.3–5.0%) values are considerably higher. *Taxus* values are visibly differentiated in particular profiles: WW XV – 0.7–5.4%, WW IX – 0.9%, WW VI – about 3% and WW I – about 1.4%. The *Acer* pollen is almost constantly present.

The pollen of *Pinus* and *Betula* and NAP are of no major significance. The occurrence of *Humulus, Hedera, Viscum* and, out of the aquatic plants *Nuphar* and *Nymphaea* pollen is greatly stabilized. A single *Ilex aquifolium* pollen has been found.

The pollen zone WW 7c — *Corylus-Tilia-(Carpinus)* – has been distinguished in 4 profiles: WW I (no 55, 4.95–5.00 m), WW VI (no 2, 4.85–5.05 m), WW IX (nos. 36–38, 4.25–4.40 m) and WW XV (nos. 63–65, 4.67–4.82 m). Its thickness varies from 0.05 to 0.20 m. In the profile WW IX there is a shaly gyttja, in the other ones – bituminous shales. At the upper boundary of this zone in profiles WW XV and WW I a sapropel passes into calcareous sediments. In the profile WW VI this zone constitutes the upper part of sampled and palynologically examined lacustrine series.

The pollen zone WW 7c is characterized by high *Corylus* values (40–48%), and the frequency of *Tilia cordata* type, *Quercus* and *Alnus* similar to this in the preceding zone.

Tilia platyphyllos is sporadic. In the upper part of the zone the *Carpinus* value rises (up to 23%), while *Taxus* values are slightly lower (0.8–3.0%). The low values of *Ulmus, Fraxinus, Pinus, Betula* and NAP persist. There are sporadic *Acer* pollen grains the first pollen grains of *Abies* (WW VI) appear and the continuous *Picea* curve attains 0.2–0.3%. As regards NAP, *Ericaceae* (mainly *Calluna*), *Humulus, Hedera* and *Viscum*, are constantly present, *Cornus sanguinea* being sporadic (WW IX). *Typha latifolia, Salvinia* (WW IX – entire microsporangium), *Nuphar, Nymphaea* are present.

The pollen zone WW 7d — *Corylus-Carpinus-Tilia* – has been found in 3 profiles: WW I (nos. 59–62, 4.47–4.67 m), WW IX (no 35, 4.20–4.25 m), and WW XV (nos. 50–54, 4.70–4.95 m). Its thickness varies from 0.5 to 0.25 m (Fig. 11). In all the profiles this zone is made up of shaly gyttja and only in the profile WW I its upper part is of bituminous shales. This zone has not been sampled in the profiles WW V and WW VI (Fig. 11).

It is characterized by high *Corylus* (30–46%) values and relatively high percentages of *Carpinus* (15–32%), *Alnus* (14–17 %) and *Tilia cordata* type (3–5%). Values of *Quercus* (3–7%), *Fraxinus* (1–3%), *Ulmus* (1–2%), *Taxus* (0.3–3. 1%), *Pinus* (3–6 %) and *Betula* (1–2%) are decreasing. The continuous *Picea* and *Acer* curves attain 0.2–0.4%. A single *Fagus* pollen has been identified from profile WW IX. The NAP share does not exceed 3 %. *Humulus, Hedera, Viscum, Salvinia* pollen occurs regularly and that of *Nuphar, Nymphaea, Typha latifolia* and *Stratiotes aloides* decidedly less regularly (WW I). Noteworthy are sporadic pollen grains of *Stellaria holostea, Stellaria nemorum, Viburnum* and one spore of *Botrychium* (WW I).

The pollen zone WW 8a — *Carpinus-Corylus-Tilia* – is distinguished in 3 profiles: WW I (nos. 39–49, 4.15–4.70 m), WW IX (nos. 26–34, 3.75–4.20 m) and WW XV (nos. 50–58, 4.02–4.47 m). Its thickness is similar (0.40–0.55 m) in all the profiles. This zone corresponds with the layers of shaly gyttja in the profile WW XV, shaly gyttja in bottom part and grey gyttja in the upper of the profile WW IX, and bituminous shales (only 1 sample) and grey calcareous gyttja (10 samples) in the profile WW I. Lithological differentiation of sediments in individual profiles reflects the differences in depth between particular zones of the lake and may indicate the diversity of biochemical, hydrological and hydrochemical processes.

The pollen zone WW 8a is characterized by high and distinctly rising *Carpinus* values (26–47%), high but decreasing *Corylus* (33–18%) and *Alnus* (21–13%) values and lower proportions of *Tilia cordata* type and *Quercus* (2–6%). There are *Tilia platyphyllos* in significant amounts, *Fraxinus, Ulmus, Taxus, Pinus, Betula* and *Picea* are very low, *Acer* shows a low interglacial maximum (0.1–0. 6%). In the final part of this

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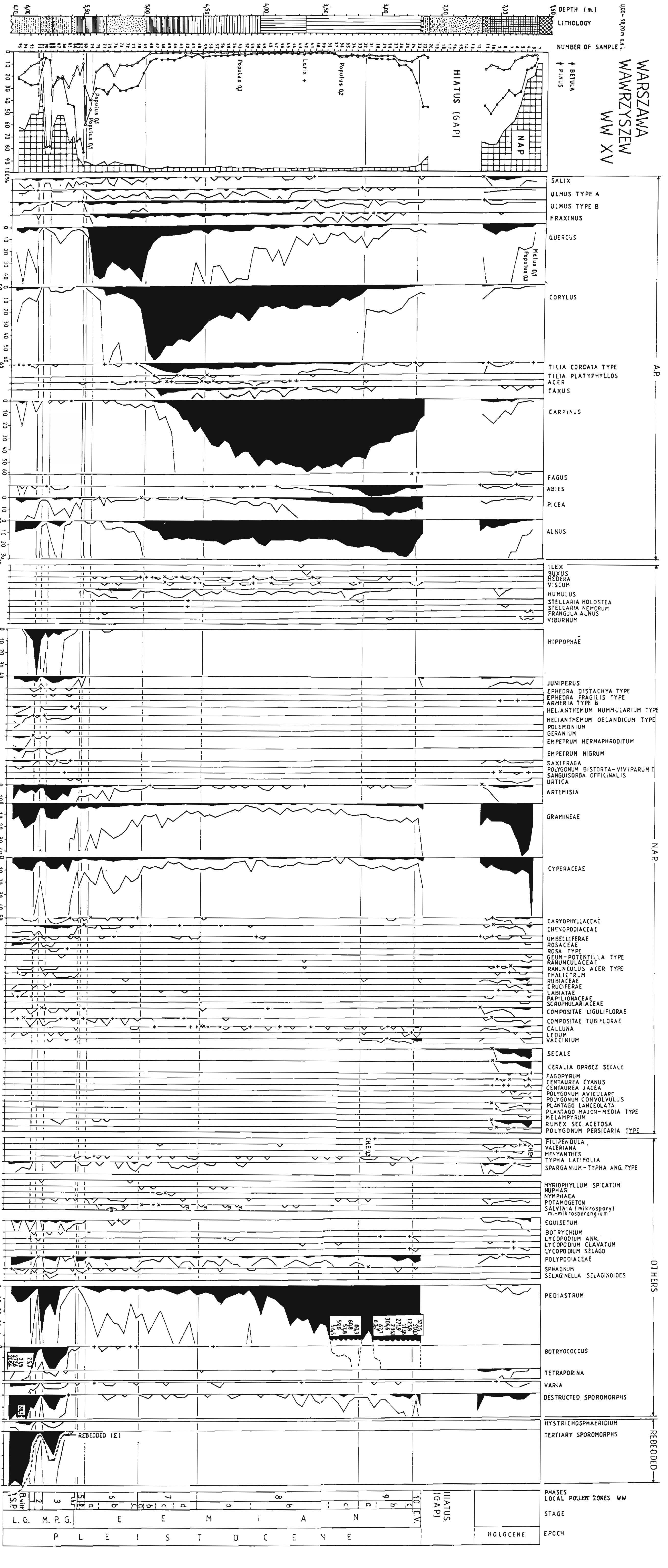
Fig. 10. Warszawa Wawrzyszew. Pollen diagram of the profile WW XV. Taxa which not marked in the diagram: sample No(%): *Malus* 2(0.1): *Boraginaceae* 93(0.2): 7(0.1): *Calystegia* 1(0.1): *Centaurea montana* type 88(+): *Cornus mas-suecica* type 72(0.2): 70(+): *Dipsacaceae* 1(+): *Euphorbia* 84(0.1): *Ligustrum* 69(+): *Linum* 5(+): *Papaveraceae* 8(+): *Rhamnus cathartica* 2 (0.1): 1(0.1): *Ribes* 74(0.2): 4(0.1): 3(0.1): 2(0.1): *Trifolium* 94(+): *Viola* 30(0.2): 1(x): *Hydrocharis* 85(0.1): 72(0.2): *Myriophyllum alterniflorum* 88(0.2): *Ophioglossum* 22(0.2): 21(0.6): *Osmunda* 1(0.1): *Pteridium* 78(0.1): 77(0.3); Denotations as in Fig. 11


WARSZAWA
WAWRZYSZEW
WW XV
DEPTH (m.)
LITHOLOGY
NUMBER OF SAMPLE
BETULA
PINUS
HIATUS (GAP)
NAP
Populus
Larix
SALIX
ULMUS TYPE A
ULMUS TYPE B
FRAXINUS
QUERCUS
Malus
CORYLUS
TILIA CORDATA TYPE
TILIA PLATYPHYLLOS
ACER
TAXUS
CARPINUS
FAGUS
ABIES
PICEA
ALNUS
A.P.
ILEX
BUXUS
HEDERA
VISCUM
HUMULUS
STELLARIA HOLOSTEA
STELLARIA NEMORUM
FRANGULA ALNUS
VIBURNUM
HIPPOPHAË
JUNIPERUS
EPHEDRA DISTACHYA TYPE
EPHEDRA FRAGILIS TYPE
ARMERIA TYPE B
HELIANTHEMUM NUMMULARIUM TYPE
HELIANTHEMUM OELANDICUM TYPE
POLEMONIUM
GERANIUM
EMPETRUM HERMAPHRODITUM
EMPETRUM NIGRUM
SAXIFRAGA
POLYGONUM BISTORTA-VIVIPARUM T.
SANGUISORBA OFFICINALIS
URTICA
ARTEMISIA
GRAMINEAE
CYPERACEAE
CARYOPHYLLACEAE
CHENOPODIACEAE
UMBELLIFERAE
ROSACEAE
ROSA TYPE
GEUM-POTENTILLA TYPE
RANUNCULACEAE
RANUNCULUS ACER TYPE
THALICTRUM
RUBIACEAE
CRUCIFERAE
LABIATAE
PAPILIONACEAE
SCROPHULARIACEAE
COMPOSITAE LIGULIFLORAE
COMPOSITAE TUBIFLORAE
CALLUNA
LEDUM
VACCINIUM
SECALE
CERALIA OPRÓCZ SECALE
FAGOPYRUM
CENTAUREA CYANUS
CENTAUREA JACEA
POLYGONUM AVICULARE
POLYGONUM CONVOLVULUS
PLANTAGO LANCEOLATA
PLANTAGO MAJOR-MEDIA TYPE
MELAMPYRUM
RUMEX SEC. ACETOSA
POLYGONUM PERSICARIA TYPE
N.A.P.
FILIPENDULA
VALERIANA
MENYANTHES
TYPHA LATIFOLIA
SPARGANIUM-TYPHA ANG. TYPE
MYRIOPHYLLUM SPICATUM
NUPHAR
NYMPHAEA
POTAMOGETON
SALVINIA (mikrospory)
m.-mikrosporangium
EQUISETUM
BOTRYCHIUM
LYCOPODIUM ANN.
LYCOPODIUM CLAVATUM
LYCOPODIUM SELAGO
POLYPODIACEAE
SPHAGNUM
SELAGINELLA SELAGINOIDES
PEDIASTRUM
BOTRYOCOCCUS
TETRAPORINA
VARIA
DESTRUCTED SPOROMORPHS
OTHERS
HYSTRICHOSPHAERIDIUM
TERTIARY SPOROMORPHS
REBEDDED (Σ)
REBEDDED
PHASES
LOCAL POLLEN ZONES WW
STAGE
EPOCH
L.G.
M.P.G.
E E M I A N
E.V.
HIATUS (GAP)
HOLOCENE
P L E I S T O C E N E

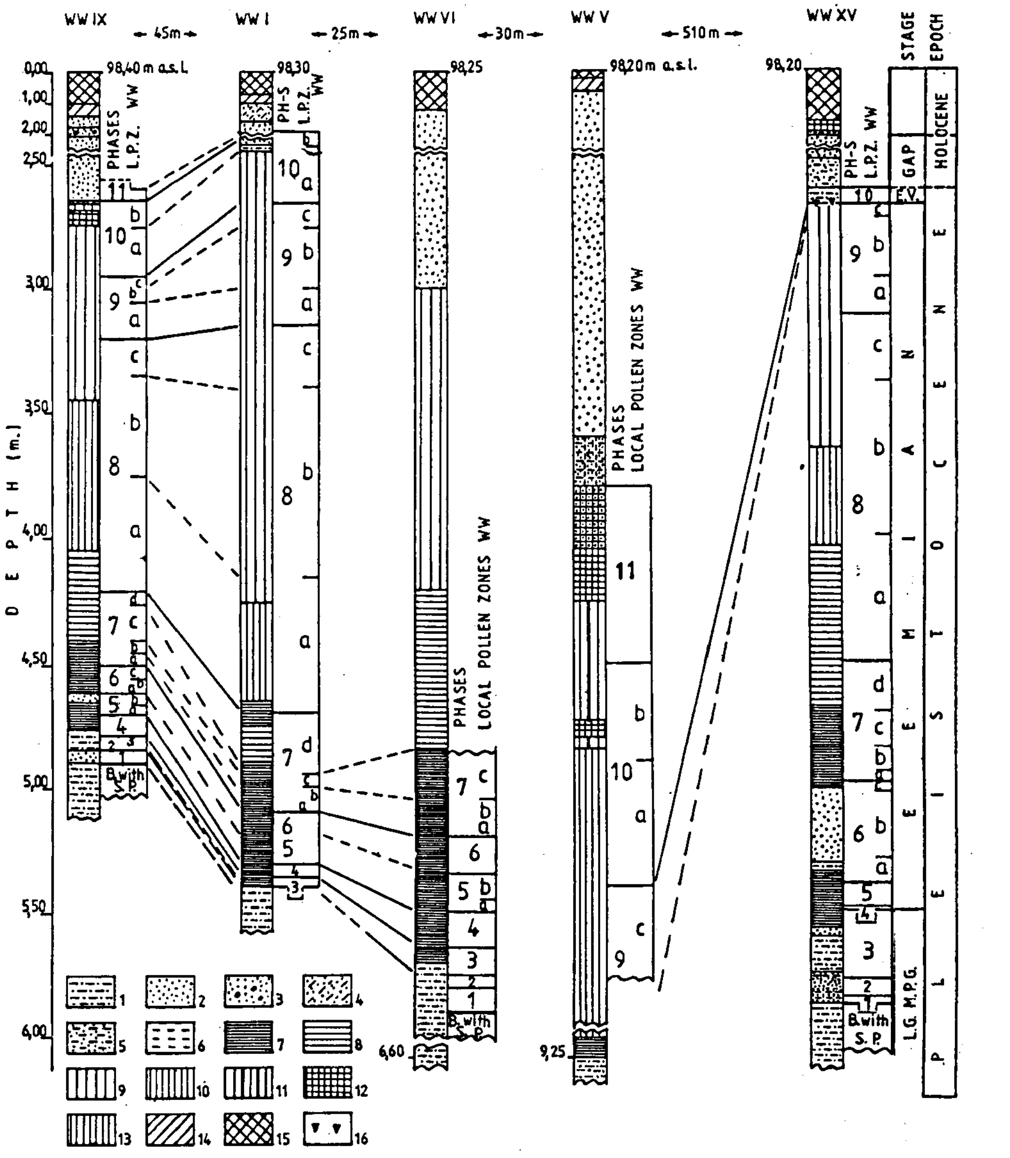


Fig. 11. Depths and thicknesses of interglacial sediments in five analysed profiles (WW I, WW V, WW VI, WW IX, WW XV) with their subdivision in to pollen zones: Bed with secondary pollen (NAP + secondary pollen), WW 1 – *Hippophaë*-Salix-NAP, WW 2 – *Betula-Hippophaë*-Artemisia, WW 3 – *Pinus-Juniperus* (*Artemisia-Hippophaë*), WW 4 – *Betula-Pinus*-NAP-(*Ulmus*), WW 5a – *Pinus-Betula-Ulmus-(Quercus)*, WW 5b – *Pinus-Quercus- Ulmus-(Fraxinus)*, WW 6a – *Quercus-Pinus-Fraxinus*, WW 6b – *Quercus-Fraxinus-(Corylus)*, WW 6c – *Quercus-Corylus-(Alnus)*, WW 7a – *Corylus-Quercus-(Tilia)*, WW 7b – *Corylus-Tilia-Taxus*, WW 7c – *Corylus-Tilia-(Carpinus)*, WW 7d – *Corylus-Carpinus- Tilia*, WW 8a – *Carpinus-Corylus-Tilia*, WW 8b – *Carpinus- Corylus-(Picea)*, WW 8c – *Carpinus-Picea-(Abies)*, WW 9a – *Abies-Picea-Carpinus*, WW 9b – *Picea-Abies-Carpinus*, WW 9c – *Picea-Pinus-Carpinus*, WW 10a *Pinus-Picea-(Carpinus)*, WW 10b – *Pinus-Betula*-(NAP), WW 11 – *Pinus*-NAP-*Betula*. B. with S. P. – Bed with secondary pollen, L. G. M. P. G. – Late Glacial Middle Polish Glaciation, E. V. – Early Vistulian. Lithology: 1 – silts and clays, 2 – sands, 3 – sands with gravel, 4 – sands changed by soil processes, 5 – silty sand or sandy silt, 6 – sands with peat or with humus, 7 – bituminous shales, 8 – shales gyttja, 9 – light gray gyttja calcareous, 10 – gray gyttja calcareous, 11 – peaty gyttja, 12 – peat, 13 – peat with sand, 14 – soil, 15 – mound, 16 – concentration Fe, Mn

zone *Abies* increases in quantity. The NAP proportion is 1.4–3.5%. The fairly abundant and constant presence of *Humulus* (up to 0.7%) ends in the zone WW 8a. The pollen of such plants with greater climatic demands as *Hedera* and *Viscum* is still noted. In addition to the above taxa the following numbers of pollen grains of other plants have been identified: *Stellaria holostea* – 1 grain, *S. nemorum* – 4 grains, *Ilex* – 2 grains, *Ligustrum* – 4 grains, *Frangula alnus* – 1 grain, *Buxus* – 1 grain, *Vitis* – 1 grain, *Evonymus* – 3 grains and *Fagus* – 2 grains. Several *Osmunda* and *Lycopodium annotinum* spores have also been identified. The presence of a *Hippophaë* pollen grain in profile WW I (sample no 47) may result from contamination or rebedding. The occurrence of *Ericaceae* (mainly *Calluna*) and *Nuphar* and *Nymphaea* is constant. There is a visible rise of the *Pediastrum* curve (10–23%).

The pollen zone WW 8b — *Carpinus-Corylus-(Picea)* – is distinguished in 3 profiles: WW I (nos. 24–38, 3.40–4.15 m), WW IX (nos. 18–25, 3.35–3.75 m) and WW XV (nos. 37–49, 3.37–4.02 m). The biggest (0.75 m) and the smallest (0.40 m) thickness have been encountered in the profiles WW I and WW IX respectively (Fig. 11). In the profiles WW XV and WW IX a lower part of the zone is composed of grey gytja and the upper one oof light grey gyttja. A light grey gyttja occurs in the profile WW I.

The zone WW 8b is characterized by the highest *Carpinus* values in these profiles (41–57%) and high *Corylus* (16–26%) and *Alnus* (13–21%) values, the rational *Picea* boundary (0.4–5.8%) and increasingly frequent occurrence of *Abies* pollen grains (up to 0.8%). As compared with the zone WW 8a, no significant changes have been found in pollen percentages of other trees, excepting the evidently lower values of *Tilia cordata* type (0.2–3.6%) and the more regular occurrence of *Acer*. Frequency of other trees remaind low or very low: *Quercus* (0.7–4.0%), *Fraxinus* (0.4–2.9%), *Ulmus* (0.2–3.5%), *Taxus* (0.5–1.8%), *Pinus* (1.4%), *Betula* (0.5–2.3%). Amidst the scanty NAP (1–2%), *Gramineae* and *Cyperaceae* pollen prevails, *Hedera* (0.1–0.4%) and *Viscum* (0.1–0.2%) being continuously present. Other taxa of similar climatic demands but lower frequency *Ilex* (WW XV – 2 grains, WW I – 2 grains), *Ligustrum* and *Vitis* (WW I – 1 grain each), *Buxus* (0.2–0.4%) and *Evonymus, Osmunda* and *Stellaria holostea* are noteworthy. The *Humulus* curve declines steeply and so do, to a certain degree the *Salvinia, Nuphar* and *Nymphaea* curves. The taxa, presence of which in this part of the profile might seem surprising are *Hippophaë* (WW IX – 1 grain) and *Ephedra distachya* type (WW I – 1 grain) and, to a smaller extent, *Larix* (WW XV) and *Fagus* (WW I – 4 grains). *Pediastrum* shows no substantial changes in relation to the previous zone.

The pollen zone WW 8c — *Carpinus-Picea-(Abies)* – is distinguished in 3 profiles: WW I (nos. 19–23, 3.15–3.40 m), WW IX (nos. 15–17, 3.20–3.35 m) and WW XV (nos. 32,36, 3.12–3.37 m). It is marked by light grey calcareous gyttja, a thickness of which is similar in all the profiles (0.15–0.25 m).

This zone is characterized by high *Carpinus* pollen values (40–55 %), distintcly lower frequency of *Corylus* (17–7%) and *Alnus* (23–15%) rising *Picea* (up to 9%), appearance and subsequent rapid rise of *Abies* (0.5–2.1%). The pollen of the remaining trees is insignificant. Their values are close to those of the previous zone or slightly lower. In this zone the abundant *Corylus* comes to its end, *Acer* decreases and *Pedias-*

trum begins to grow (16–80%). The NAP does not exceed 3.1%. The taxa of great climatic demands, very regularly occurring so far, are present in visibly smaller quantities, particularly: *Hedera, Humulus*, and *Viscum*. Single pollen grains of *Ilex, Ligustrum, Buxus, Stellaria holostea, Nymphaea* and *Typha latifolia* still appear. In addition, the zone contains 2 *Fagus* grains(WW IX and WW I), *Populus* (WW XV), rare *Lycopodium* spores, among others, *L. selago* (WW XV) and *L. clavatum* (WW XV) as well as *Osmunda*. The family *Ericaceae* is represented by at least three taxa: *Calluna* (the most frequent), *Ledum* and *Vaccinium*. From among the water plants, *Salvinia* rises, in particular in the WW XV and WW I, where whole microsporangia of this plant have been found.

The pollen zone WW 9a — *Abies-Picea-Carpinus* – is distinguished in 3 profiles: WW I (nos. 16–18, 3.00–3.15 m), WW IX (nos. 12–14, 3.05–3.02 m) and WW XV (nos. 29–31, 2.97–3.12 m). In all the profiles its thickness is similar (0.15 m) and it is made up of light grey calcareous gyttja. A similar thickness of analogous sediments indicates similar rate and conditions of sedimentation.

The zone WW 9a is characterized by high *Abies* (6.7–10.5%), *Picea* (8–15%), *Carpinus* (48–31%) and *Alnus* (18–23%) values, a distinctive decrease of *Corylus* (1.7–4.7%), a slight rise of *Pinus* (6–10%) and high *Pediastrum* (16–61%). The pollen of thermophilous and moderately thermophilous trees – *Quercus, Fraxinus, Ulmus, Tilia*, and *Taxus* – continue to decrease. Only single *Acer* and scarce *Betula* grains are noted and *Fagus* pollen has been identified from the WW I. NAP values are low (2–3%). There is a distinst fall in occurrence of *Hedera, Viscum, Ligustrum, Ilex* (WW I – 1 grain), *Buxus* and *Vitis* (WW I – 1 grain each), *Stellaria nemorum, Humulus* (up to 0.3%) and, on the other hand, the appearance of swamp and aquatic plants of greater climatic demands – *Nuphar*; particularly *Salvinia* (0.2–0.3%) clearly increases its regularity as well as *Sphagnum* spores.

The pollen zone WW 9b — *Picea-Abies-Carpinus* – is distinguished as a separate biostratigraphic unit in two profiles: WW I (nos. 11–15, 2.75–3.00 m) and WW XV (nos. 24–28, 2.72–2.97 m) and in conjunctions with the WW 9c in profiles WW IX and WW V which results mainly from too sparse sampling. A thickness of grey calcareous gyttja in this zone in the compared profiles is similar (Fig. 11).

The pollen zone WW 9b is characterized by high *Pinus* (12–18%) values *Abies* (8.4–1.8%), *Alnus* (21–30%), *Carpinus* (35–22%), *Corylus* (1.0–2.3%) and *Quercus* (0.3–2.3%) proportions are lower than in the preceding zone. The upper boundary of the zone WW 9b is placed at the end of the regular occurrence of *Taxus* (only in the profile WW I its occurrence is regular at below 1%) and *Fraxinus* (0.2–1.1%) at the beginning of a pronounced rise of the *Pinus* (6–20%), less distinct of *Betula* (3–9%) and NAP (2.6–3.5%). *Pediastrum* attains high values (36–305%).

A declining significance of plants with higher climatic demands is expressed chiefly by their irregular occurrence, but presence of single or scarce pollen grains should be noted: *Ilex* (WW I – 3 grains), *Vitis* (WW I – 1 grain), *Buxus* (WW I – 2 grains), *Stellaria holostea* (WW I), *Typha latifolia* and *Nymphaea*. Distinct rise of *Salvinia* (WW I up to 2%) and regular presence of *Lycopodium annotinum* (WW I), *Osmunda* (WW I) and *Sphagnum* (WW I – 0.2–0.7%) spores are noteworhy.

The pollen zone WW 9c — *Picea-Pinus-Carpinus* – has been distinguished as a separate biostratigraphic unit in 2 profiles: WW I (nos. 9–10, 2.65–2.75 m) and WW XV (no 23, 2.67–2.72 m) and in conjunction with the previous zone in WW V and WW IX. A thickness of light grey calcareous gyttja is variable and does not exceed 0.1 m.

As compared with the previous zone, the zone WW 9c is characterized by slightly lower *Picea* (10–23%), *Alnus* (14–26%), *Abies* (up to 5%) and *Carpinus* (20–26%) values, higher *Pinus* (24–31%) proportions and similar *Betula* (5–9%) and NAP (2.4–3.6%) values. The proportion of thermophilous tree pollen is low: *Corylus* (up to 1.6%), *Quercus* (up to 1.5%), *Tilia* (up to 0.5%), *Fraxinus* (up to 0.6%), *Ulmus* (up to 0.5%). *Taxus* values do not exceed 0.8%. A single *Fagus* grain from the WW XV has been identified.

There is a distinct fall in pollen percentages of shrubs and herbs with greater climatic demands expressed by their irregular occurrence (*Viscum, Hedera, Ligustrum* and *Humulus*). The presence of *Buxus, Vitis, Ilex* and *Frangula alnus* has been noted. The percentages of *Ericaceae, Typha latifolia, Nuphar, Salvinia* (1.1–1.9%) and *Sphagnum* are practically unchanged.

The pollen zone WW 10a — *Pinus-Picea-(Carpinus)* – occurs in 3 profiles: WW I (nos. 2–8, 2.35–2.65 m), WW V (no 32, 4.90–5.40 m) and WW IX (nos. 5–9, 2.73–2.95 m). It is market by grey calcareous gyttja, the top of which corresponds to the upper boundary of the zone WW 10a. In the profile WW XV the sediments of this zone are only partly preserved and it is difficult to set the boundary with the following zone. In this profile a total thickness of the two zones is very small and does not exceed 0.07 m. The fact that a sediment thickness in the three profiles in which these pollen zones are preserved appears variable is due to the too sparse sampling, preventing precise demarcation of the zones.

The pollen spectra of this zone show high *Pinus* values (51–73%) and a marked decrease in proportions of *Picea* (13.3–4.1%), *Carpinus* (7.5–0.2%), *Abies* (2.0–0.2%) and *Alnus* (1.4–0.2%). *Betula* (3.0–7.5%) and NAP (2.2–4.6%) values resemble those from the previous zone. Pollen of other trees is of no major significance (*Corylus* up to 0.6%, *Quercus* up to 2.9%) or appears only sporadically (*Taxus, Tilia, Acer, Fraxinus, Ulmus*). Several *Fagus* grains have been identified (WW I – 3 grains, WW V and WW IX 1 grain each). Few *Hedera, Viscum, Ligustrum* and *Buxus* pollen grains are still present. In the lower part of this zone *Nuphar* and *Salvinia* maintain continuous curves, and so do *Ericaceae* (mainly *Calluna*), *Sphagnum* and *Lycopodium* – mainly *L. annotinum*. Throughout the zone one *Pteridium* spore from the WW I has been identified. The high *Pediastrum* values (up to 51%) persit.

The bottom of this zone may be regarded as the upper boundary of this interglacial. This zone marks the beginning of the Early Vistulian vegetational history. The boundary, however is disputable as neihter two zones – WW 10a or WW 10b – contains a significant pollen amount of shrubs and herbs (below 15%), from which heliopythes are still absent with the exception of a slight number of grains: *Juniperus* (WW I – grain) and *Helianthemum* (WW I – 1 grain, WW IX – 1 grain).

The pollen zone 10b — *Pinus-Betula* (NAP). Its sediments (grey gyttja, peat and peaty gyttja) are best preserved in the profile WW V (nos. 17–29, 4.51–4.90 m). In a residual form it can be discerned also in WW I (no 1, 2.30–2.35 m – sand) and in the WW IX (nos. 2–4, 2.63–2.73 m – peat, light grey gyttja and sand, sand with peat interbeddings). In the profile WW XV this zone is clearly destroyed. In particular profiles its thickness is extremely variable and ranges from 0.39 to 0.05 m.

The pollen spectra of the zone WW 10b are characterized by high and clearly differentiated *Pinus* (53–80%) values and visibly lower and also differentiated values of *Betula* (3–17%), *Alnus* (13.0–0.2%), *Carpinus* (10.0–0.5%), *Corylus* (4.0–0.2%), *Quercus* (up to 0.7%) and NAP (4.1–13.7%). The evident distinctness of the pollen spectrum of the profile WW I could imply that it has been correctly classified in the preceding zone (WW 10a). The considerably higher pollen values of thermophilous and moderately thermophilous trees as well as the amount of demaged material (1. 8%) in this spectrum may have been caused also by shifting of sediments from older pollen zones. The above sample has been collected from the top of organic sediments preserved in this profile.

No pollen of shrubs and herbs of great climatic demands has been found in this zone whereas new taxa appear in small numbers in the profile WW IX: *Juniperus, Larix, Chamaenerion-Epilobium, Myriophyllum spicatum* and *Botrychium*. Frequency curves of *Ericaceae* (mainly *Calluna*), sporadically *Ledum* and *Vaccinium, Equisetum, Sphagnum* as well as *Nuphar* and *Lycopodium annotinum* remain at their previous level or rise slightly. There is a visible drop in *Pediastrum*.

The pollen zone WW 11 — *Pinus*-NAP-*Betula* – is fully preserved in one profile only – WW V (nos. 1–16a, 3.80–4.51 m – peaty gyttja, peat and sandy peat). In fragmentary form it has been found in sands that overlie the organogenic series in the profile WW IX.

This zone is characterized by high *Pinus* (50–75%) and NAP (12–36%) and decidely lower *Betula* (7–12%) values, *Picea* (1.2–6. 6%), *Alnus* (0.2–2.7%), *Salix* (0.2–1.4%) and *Juniperus* (0.1–0.7%) pollen occurs in small variable values. pollen grains of *Ulmus, Quercus, Corylus, Carpinus, Tilia, Abies* and *Fagus* are sporadically and irregularly present. *Pediastrum* values are differentiated (the first maximum 67% in lower part, the second 124% in the upper. As regards NAP, *Gramineae* (4–15%) and *Cyperaceae* (6–22%) pollen predominantes and *Artemisia* (0.2–1.8%), *Calluna, Caryophyllaceae, Chenopodiaceae* etc. are relatively frequent. Heliophilous plants appearing irregularly are as follows: *Armeria* type B, *Helianthemum, Polemonium, Saxifraga, Polygonum bistorta-viviparum, Sanguisorba officinalis, Rumex sec., Acetosa* and *Hippophaë* (1 grain), *Selaginella selaginoides* (2 spores) and *Chamaenerion-Epilobium* (1 pollen grain). Moreover *Menyanthes trifoliata, Lycopodium annotinum* and slightly higher pollen values of *Polypodiaceae* (up to 4%), *Sphagnum* (up to 8%) and *Equisetum* (up to 1%) have also been found.

The pollen spectrum of a sample from the top of the profile WW IX has been correlated with the beginning of this pollen zone. In addition to numerous floristic elements, the high *Artemisia* (3%) and *Sphagnum* (5.4%) values as well as the presence of *Polygonum bistorta-viviparum* support its inclusion in the WW 11 zone but its classification in the preceding zone could hardly be regarded as erroneous either.

HIATUS

Only a few pollen grains have been found in the 9 sand samples from the profile WW XV (nos. 12–20, 2.20–2.60 m) subjected to palynological examination. Their number does not permit us to compile their percentage pollen spectra. The most frequent is *Pinus* decidedly less frequent *Betula* while *Alnus, Carpinus, Quercus, Tilia, Caryophyllaceae, Ericaceae, Gramineae, Botrychium* and *Polypodiaceae* occur sporadically. One unquestionable Tertiary sporomorph and single colonies of *Pediastrum* have been identified. Sporomorphs are heavily demaged.

These sediments should be treated as floristically barren, which allows the conclusion that a very big depositional and time gap occurs between the underlying organogenic sediments, the top part of which has been referred to the Early Vistulian and the Late Holocene sediments occurring higher up in the sequence. It is difficult to relate these sands to any part of this period.

HOLOCENE POLLEN ZONES
(profile WW XV, Fig. 10)

In the peats regarded as the Late Holocene (as evidenced by numerous pollen of synanthropic plants) at least two pollen assemblage zones can be distinguished: a) the older (nos. 9–11, 2.0–2.15 m) characterized by high *Pinus* (44–52%) values, lower proportions of *Betula* (11–15%), *Alnus* (5–10%), *Quercus* (3–8%), *Salix* (up to 2.8%) and considerable values of NAP (22–24%) with traces of synanthropic plant pollen in its upper part, and b) the younger one (nos. 1–8, 1.68–2.0 m) distinguishable by considerably lower *Pinus* (6–39%), similar to those in previous zone *Betula* (3–14%) and distinctly higher NAP (32–90%) values. The proportion of pollen synanthropic plant is 3.7–21.0% and it consists chiefly of *Cerealia* (1.9–13.8%) and *Rumex* sec. *Acetosa* (1.4–5.9%); *Fagopyrum, Centaurea cyanus, Centaurea jacea* type, *Polygonum aviculare, Melampyrum, Plantago lanceolata* etc. are also present. Besides the trees mentioned above, the presence of pollen of *Fagus, Abies, Carpinus, Picea, Alnus, Tilia, Quercus, Corylus, Ulmus, Taxus* and *Salix* in also noteworthy. There is no need to list other floristic elements here since vegetation and evolution of the natural environment of this period in the Warsaw area is not the subject of the present paper and the data reported above permit us to ascribe these sediments to the Late Holocene.

LOCAL AND REGIONAL VEGETATIONAL SUCCESION

PRE-INTERGLACIAL (LATE GLACIAL)

Very good and detailed sampling of sandy and silty sediments that underlie the lacustrine series of the interglacial organogenic sediments in Warsaw-Wawrzyszew permits to record the initial developmental phases of pioneer vegetation in this area. With other sampling methods these sections of the profiles are usually lost as a result of inadequate techniques and unfavorable hydrogeological conditions (Krupiński 1993).

An analysis of the floristic elements from the sediments regarded as a bed with secondary pollen (NAP + secondary pollen) suggest that some sporomorphs may have been redeposited, some came from long-distance transport but other may be of local origin, derived from the first plants appearing here. It is very difficult and sometimes even impossible to establish their quantitative relations. Main constituents of the first flora, quantitatively very modest but diversified, were shrubs, dwarf shrubs and herbaceous plants, represented mainly by *Gramineae, Cyperaceae, Artemisia, Juniperus, Salix, Rosaceae* and typical heliophytes such as *Ephedra distachya* type, *Empetrum nigrum, Empetrum hermaphroditum, Helianthemum, Polemonium, Armeria, Pleurospermum austriacum, Polygonum bistorta-viviparum* type, *Saxifraga* and *Selaginella selaginoides*. These plants formed first stands of open communities. *Pinus* and *Betula* may have appeared sporadically as shrub species or few specimens as trees.

A considerable proportion of floral remains varying in age, being clearly at variance with prevailing climatic conditions, is responsible for difficulties encountered in discrimination of the above-mentioned pollen groups.

Scarce tundra-type communities, occurring only in patches, were poor pollen producers and as a result, even small numbers of sporomorphs transported from distant southern regions of fairly abundant vegetation and the material derived from washing of older sediments attained such marked proportions in pollen spectra (37–58%). This opinion is supported by observations of the present-day pollen rain in the Petsamontunturit Massif (Aario 1943), the Bernese Alps (Welten 1950, 1957) and Arctic tundra moss communities varying with altitude in Spitsbergen (Środoń 1960), Iversen (1954), Dyakowska (1959), Tauber (1967) and Krupiński (1975).

The vegetational history of the Warsaw-Wawrzyszew region in the Late Glacial of the Middle Polish Glaciation is represented by three main phases corresponding to three local pollen zones (WW 1, WW 2 and WW 3). Observation of lower part of pollen diagrams (Figs 6, 8–10) referred to this period may produce on impression that changes in natural environment very quickly caused very distinct differences in composition between the pollen spectra of neighboring samples. These differences may however be only apparent, caused by very low sedimentation rate, great compaction, shortness of particular phases and too great distances between samples in relation to the rate and duration of sedimentation.

The phase WW 1 – pollen zone WWb 1 – *Hippophaë*-Salix-NAP – started the process of expansion of shrubs and herbs (to 88% of AP+NAP sum) and first trees. The substratum rich in basic compounds and exposure to insolation caused that *Hippophaë* became the main constituent of local shrub and herbs communities (to 73% of total pollen sum), with a slight admixture of *Juniperus, Artemisia, Gramineae* and *Cyperaceae*. No such high *Hippophaë* pollen values have hitherto been found in the best-known sites either of the Late Glacial of the Last Glaciation (see Środoń 1970, Krupiński 1991, 1992b) or of the late glacial of earlier glaciations (Jastrzębska-Mamełka 1985, Janczyk-Kopikowa 1966, 1981, Krupiński 1984–85, 1988a, c, Krupiński et al. 1986, 1988, 1991). Apart from the plants mentioned above, the following taxa were abundant in these communities: *Empetrum nigrum, E. hermaphroditum, Ephedra distachya type, Helianthemum, Pleurospermum austriacum, Polygonum bistorta-viviparum*, etc. *Pinus* and *Betula* (shrubby species or degenerated tree forms) began to appear. Rich willow communities must have developed in wet, swampy or periodically flooded places, which is suggested by high *Salix* pollen percentages (ca 5%). According to Welten (1950), such pollen values may be indicative of the abundant occurrence of willow thickets.

The coverage of the area by thicket-, thicket-grass- and thicket-sedge-type communities brought about an increase in the local pollen production, a distinct fall in the effectiveness of erosional processes and an increase in resistance of the surface formations to denudation, reflected by a fall in the proportion of redeposited sporomorphs.

The phase WW 2 – pollen zone WW 2 – *Betula-Hippophaë -Artemisia* – shows distinct differences in *Betula* pollen proportion between particular profiles. The lack of the full birch phase in the profile WW VI can be explained by too sparse sampling or the incompleteness of its sediments (Fig. 8).

Betula became the main constituent of the plant communities of this area, *Salix, Juniperus* and *Hippophaë* are also abundant. The initially marked share of shrubs and herbs (to 70%) decreased considerably (ca 21%) towards the end of this phase, which was chiefly due to withdrawal of *Hippophaë* (*Hippophaë* has been included in NAP because of the nature of the communities and conditions in which it occurs). *Gramineae, Cyperaceae* and *Artemisia* predominated decidedly in herb communities. The occurrence of heliophytes, e. g. *Ephedra distachya* type, *Armeria, Helianthemum, Empetrum, Saxifraga* and *Polygonum bistorta-viviparum* became more stable. The expansion of shrub and herb communities contributed to the rise of local pollen production and a reduction in the effectiveness of erosional and denudation processes and, in consequence, also in the amount of redeposited material.

High values of NAP in pollen spectra of the phase WW 2 suggest predomination of woodless type assemblages during this time. To slightly different conclusion led morphological analysis of pollen of the genus *Betula*. In opinion of dr hab. K. Mamakowa who examined investigated material within paleotaxon *Betula* morphotype *B. alba* dominates, that is represented by forest genus of birch. This fact allows to expect that during this phase were only few patchy of distributed forests formed, composed mostly of forest genus of birch. Open space between patchy birchy forest were covered by bush and herbs, among which plants with higher light requirements survived. This type assemblages should be defined as bushy-herbs with patches of birchy forest assemblages.

The phase WW 3 – the pollen zone WW 3 – *Pinus-Juniperus- (Artemisia-Hippophaë)* – is marked by the increasing significance of *Pinus* and to a decidedly smaller degree, *Hippophaë, Artemisia* and *Juniperus*. The share of *Betula* in communities in which it was absolutely predominant previously, decreased. Shrubs and herbs grew in significance. *Empetrum* reaches considerable values in the pollen spectra (ca 1%). The *Hippophaë* curve indicates this plant to lose competition for light with a forest vegetation. A substratum, impoverished as regards basic compounds, by soil processes, may have substantially influenced its quick retreat. This phase finished abundant or continuous occurrence of *Hippopha* and other light-demanding plants: *Empetrum, Juniperus, Helianthemum, Ephedra distachya* type, *Armeria, Geranium, Linum, Polygonum bistorta-viviparum* type. First forest communities of the following phytophase WW 4 appear, initially only in patches or in poorly closed stands. The phase WW 3 terminates the floristic history of the late glacial of the Saalian Glaciation.

INITIAL PART OF THE INTERGLACIAL

The phase WW 4 – the pollen zone WW 4 – *Betula-Pinus*-NAP – *(Ulmus)* – constitutes the first stage of development of dense or relatively dense forest communities. In the areas less favourable in respect of edaphic conditions these forests abundant in *Betula* and *Pinus* may have been of a parkland nature, permitting survival of some light-demanding plants as *Hippophaë, Juniperus, Artemisia, Helianthemum, Empetrum, Ephedra distachya* type, *Saxifraga, Geranium, Selaginella selaginoides* and *Polygonum bistorta-viviparum*. The frequency of the communities of open habitats, at first still fairly high (to 15% of the total AP+NAP), underwent distinct reduction in a final part of the phase (5%). *Ulmus* and sporadic *Quercus* became constant components of a boreal-type forest communities. The pollen spectra are of pure Quaternary origin. This phase corresponds to the phytophase *d* of Jessen and Milthers' (1928) scheme.

The phase WW 5 includes two pollen zones: WW 5a – *Pinus- Betula-Ulmus-(Quercus)* and WW 5b – *Pinus-Quercus-Ulmus- (Fraxinus)*. It reflects several development stages of dense boreal-type forest communities with noticeable admixture of deciduous trees, mainly *Ulmus, Quercus* and *Fraxinus*. These forests constituted an introductory stage in the development of rich multi-species closed deciduous forests of the climatic optimum of the Eemian Interglacial.

Closed mixed pine-birch forests with elm and still sporadic oak and ash prevailed during older part of the phase (WW 5a). The shrub and herb vegetation was no longer of major significance and was represented mainly by *Gramineae, Cyperaceae, Artemisia* and not many specimens of *Juniperus*.

In this younger part (WW 5b) the pine-brich communities have been reduced and distinct expansion of *Ulmus, Quercus* and *Fraxinus* occurred. *Corylus* and *Alnus* appeared sporadically. Dense mixed pine-birch and pine-oak forests and in wet places elm-ash forests with hop in undergrowth were present.

First plants of higher climatic demands (*Hedera, Typha latifolia* and *Salvinia*) appeared at that time.

The upper boundary of the phase WW 5 is placed at the sharp downward turn of the *Pinus* curve and the distinct rise of the *Quercus* curve. The phase WW 5 corresponds to the phytophase *Ed* of Środoń's scheme (Środoń 1967a).

CLIMATIC OPTIMUM OF THE INTERGLACIAL

The phase WW 6 includes three pollen zones: WW 6a – *Quercus- Pinus-Fraxinus*, WW 6b – *Quercus-Fraxinus-(Corylus)* and WW 6c – *Quercus-Corylus-(Alnus)*. This phase represents the first dominance of closed mixed forests and a beginning of expansion of rich deciduous forests. Shrubs and plants of greater climatic demands (*Hedera, Viscum, Ligustrum, Frangula alnus* and *Humulus*) as well as swamp and water plants (*Typha latifolia, Salvinia*) appeared.

Dense mixed multi-species forests with *Quercus* and *Pinus* as main components and admixture of *Betula, Ulmus* and *Fraxinus*, predominated in the older part of the phase (WW 6a). There was also a distinct rise of *Corylus*.

In the middle part of the phase (WW 6b) mixed coniferous-deciduous forests were transformed into deciduous-coniferous and then deciduous forests. *Corylus* entered the common oak forests, with *Pinus, Betula, Ulmus* and *Fraxinus* to gain there quickly in importance. *Tilia cordata* and *Acer* appeared at that time. *Picea* occurred sporadically. Elm-ash communities with *Alnus*, whose role was increasing, and *Humulus* in undergrowth occurred in somewhat damper areas. In these communities *Fraxinus* reached its interglacial maximum.

In the youngest part (WW 6c) abundant *Corylus* expanded in the predominant mixed oak forests, leading to a slight thinning of a tree cover or even reduction of other trees. A distinct humidification of the climate have brought about a slight increase in wet areas and formation of favourable conditions for alder communities or communities with admixture of alder.

The upper boundary of this phase was placed at the beginning of a distinct rise in the *Corylus* curve and the decline in the *Quercus* and *Fraxinus* curves and the start of rational curves of *Tilia* and *Alnus* (cf. Krupiński 1988c).

The phase WW 6 may be correlated with the phytophase *Ee* of Środoń's scheme (1967 a) and with the older part of the phytophase *f* of Jessen and Milthers' scheme (1928).

The phase WW 7 covers four pollen zones: WW 7a – *Corylus- Quercus-(Tilia)*, WW 7b – *Corylus-Tilia-Taxus*, WW 7c – *Corylus-Tilia-(Carpinus)* and WW 7d – *Corylus-Carpinus-Tilia*. It reflects floristic changes in the climatic optimum sensu stricte of the Eemian Interglacial. It is characterized by exceptionally abundant occurrence of *Corylus*. In most profiles examined so far its proportions in pollen spectra of the Eemian Interglacial decidedly exceed 50% of the total AP+NAP, and many a time reach 60–70% (Bitner 1954, Borówko-Dłużakowa 1960, Janczyk-Kopikowa 1966, 1971, 1973, 1985, Jastrzębska-Mamełka 1985, Krupiński 1978, 1988c, 1992a, 1993, Krupiński et al. 1982, Mamakowa 1976, Niklewski 1968, Niklewski & Krupiński 1992, Niklewski et al. 1964, Noryśkiewicz 1978, Raniecka-Bobrowska 1954, Sobolewska 1961, 1966, Tołpa 1961, Środoń & Gołąbowa 1956).

This phase is important to pollen stratigraphy as an indicator and a distinctive phase. It is characteristic of this only section of the Pleistocene throughout Europe.

The oldest part of this phase (WW 7a) is a period of the already abundant occurrence and fairly rapid expansion of *Corylus*, accompanied by *Quercus*, while *Ulmus* and *Fraxinus* occurred in rather wet places. The percentage of *Tilia* in forests was already fairly high and *Taxus* also appeared. Shrubs of higher climatic demands were always present. Abundant occurrence of *Salvinia* came to an end in the lake. *Nuphar* and *Nymphaea* appeared.

The next part of this phase (WW 7b) was the main stage of the expansion of *Corylus* (60–65%) in the Eemian Interglacial. Besides it was the period of abundant occurrence of *Tilia cordata* type and *Taxus* (to 5.4% of the total AP+NAP) and of a rise of *Carpinus* and *Alnus*. Furthermore occurrence of Picea become constant at that time and *Ilex aquifolium* appeared among the shrubs of greater climatic demands (WW I). Small amount of *Pediastrum* indicate a marked depth and movement of water in a lake.

In a subsequent part of this phase (WW 7c) expansion of *Corylus* and *Quercus* underwent a slight restriction and the abundant occurrence of *Tilia* and *Alnus*. Expansion of *Carpinus* took place in this part of the interglacial. Closed hazel communities with admixture of board-leaved trees or oak, linden, linden-hornbeam or else elm-ash forests with abundant hazel in undergrowth prevailed at that time. *Taxus* was a frequent component of these communities and *Alnus* occurred in swampy habitats.

The youngest part of this phase (WW 7d) coincided with the last stage of a climatic optimum of the interglacial. The flora showed first signs of a climatic optimum of the interglacial and a slight cooling of a climate. Hornbeam linden forest with numerous *Corylus* and *Quercus* began to develop, while hazel-oak or oak communities with hazel and, in damp areas, of forest communities with elm, ash, yew and alder may still have survived locally. Apart from the above-mentioned plants of higher climatic demands, *Stellaria holostea* appeared among herbs and *Stratiotes aloides*, in addition to *Nuphar* and *Nymphaea* in shallow waters of a lake (cf. Krupiński 1988c).

The phase WW 7 could be correlated with the phytophase *Ef* of Środoń's scheme (1967a) or with the younger part of the phytophase *f* of Jessen and Milthers' scheme (1928).

The upper boundary of this phase is placed at a steep decline in the *Corylus* and *Ulmus* curves and the rise of the already high *Carpinus* pollen values as well as the beginning of a continuous *Picea* curve.

YOUNGER PART OF THE INTERGLACIAL

The phase WW 8 includes three pollen zones: WW 8a – *Carpinus- Corylus-Tilia*, WW 8b – *Carpinus-Corylus-(Picea)* and WW 8c – *Carpinus-Picea-(Abies)*.

This phase constitutes the first stage of the expansion of moderately thermophilous trees. The advancing process of slight cooling and humidification of the climate manifested itself in expansion of *Carpinus*, which was then predominant in forest communities, at first with abundant *Corylus* and *Tilia* and, in the final part of the phase also with abundant *Picea* and rare *Abies*.

The oldest part of this phase (WW 8a) makes the first stage in development of hornbeam-linden forests with much *Corylus* and admixture of *Quercus*. At the time *Picea* appeared presumably, reaching 0.2–0.8% in the pollen spectra (see Środoń 1967b). Abies turned up towards the end of this phase. Alder communities prevailed in wet places. *Taxus* still persisted rather abundant. Shrubs and herbs of great climatic demands were represented by *Hedera, Viscum, Ilex* and *Ligustrum; Buxus* and *Vitis* appeared for the first time while *Osmunda* was present amongst herbs layer of the rich multi-species deciduous forest.

The middle part of this phase (WW 8b) reflects maximum development of hornbeam forests (*Carpinus* pollen above 55%), with an admixture of *Corylus* and in small numbers of *Tilia, Quercus, Ulmus, Fraxinus* and *Taxus*. At the time the role of *Picea* and to a smaller extent, of *Abies* increased.

Slight shallowing of a lake and restriction in movement of its waters caused distinct rise in the importance of *Salvinia* and algae from the genus *Pediastrum*.

The last stage of predominance of the moderately thermophilous deciduous forest communities with *Carpinus* occurred in the youngest part of this phase (WW 8c). The process of ousting of these communities and replacing them by coniferous trees (*Picea and Abies*) was initiated. Alder communities still persisted in wet places. Other deciduous trees (*Tilia, Quercus, Acer, Ulmus* and *Fraxinus*) were of no major significance, except *Corylus*, which was fairly abundant. *Hedera, Viscum, Ilex, Ligustrum, Buxus, Humulus, Stellaria holostea, Nuphar, Nymphaea* and *Salvinia* were still present.

Pediastrum expanded in waters of a lake, suggesting their limited movement and good insolation.

The phase WW 8 can be correlated with the phytophase *Eg* in Środoń's scheme (1967a) and the phytophase *g* in Jessen and Milthers' scheme (1928).

The phase WW 9 covers three pollen zones WW 9a – *Abies-Picea- Carpinus*, WW 9b – *Picea-Abies-Carpinus* and WW 9c – *Picea-Pinus-Carpinus*. Its lower boundary is placed at downward slope of the curves of deciduous trees, mainly *Carpinus*, and the rising significance of moderately thermophilous coniferous trees (*Picea and Abies*).

Maximum occurrence of coniferous trees – *Picea* and *Abies* – fell in this phase, at first with still numerous *Carpinus* and towards the end of the phase with quickly rising *Pinus*, and to a considerably smaller extent, with *Betula* and *Alnus*. *Buxus* which had appeared in the preceding phase, attained the greatest constant occurrence. In this phase (WW 9) all shrubs and herbs of higher climatic demands – *Hedera, Ilex, Ligustrum, Viscum, Humulus* and *Vitis* – and the aquatics of similar demands – *Nuphar*, *Nymphaea* and *Salvinia* – reached the end of their occurrence.

In the oldest part of this phase (WW 9a) *Abies* had the interglatial maximum of occurrence, its pollen values attaining 7–10%, a contribution of *Picea* was already marked and the role of *Carpinus, Corylus* and *Tilia* decreased rapidly. Closed communities of fir-spruce forests developed at the time, initially with still abundant *Carpinus* and small admixture of *Corylus, Tilia, Quercus, Taxus* and *Pinus*. Riverside and alderwood communities with admixture of elm, ash and possibly pubescent birch grew slightly in significance in wet and swampy areas.

In the middle part (WW 9b) *Picea* attained its interglacial maximum (11–20% of total AP+NAP). A pollen productivity of *Picea* and abundant *Alnus* suggest that actual share of *Picea* in the then existing stands was decidedly larger. Spruce formed about 40% and fir about 15–20% of trees in stands.

Coniferous trees prevailed in closed forest communities. *Picea* was their main component, the share of *Abies* being smaller while *Pinus*, gaining in importance, was an admixture. *Taxus* was occasional and reached here its very end. Out of the deciduous trees *Alnus* survived in largest numbers, occupying the lowest-lying positions and forming autonomous stands or those with a possible admixture of *Fraxinus* (reaching the end of its occurrence here), *Ulmus* and perhaps also pubescent birch. In areas providing favourable water and edaphic conditions *Carpinus* may have survived as an admixture. *Corylus* and *Quercus* occurred in small numbers while *Tilia* and *Acer* sporadically. Towards the end of this phase the occurrence of most shrubs with somewhat greather climatic demands, e.g. *Hedera, Viscum* and *Ligustrum* but not *Buxus*, came to the end.

The youngest part of this phase (WW 9c) closed a developmental cycle of dense boreal-type forest communities of the Eemian Interglacial in the Warsaw region. A change of climatic conditions towards continentality and further shortening of the vegetation season brought about a gradual withdrawal of moderately thermophilous trees, which were replaced mainly by *Pinus* and partly also by *Betula.* Spruce forest communities, with, *Abies, Carpinus*, scarce *Corylus* and sporadical *Ulmus, Fraxinus, Tilia* and *Taxus* still prevailed. The role of *Pinus* was increasing and so was, to a smaller degree, that of *Betula. Larix* and *Salix* appeared and *Artemisia* became more frequent. Decreasing *Alnus* pollen is due to reduction of the damp and seasonally flooded areas previously occupied by alder. Thermophilous shrubs withdrew completely, shifting their main occurrence zone further to the south of Europe, except for *Buxus*, which persisted sporadically. Slight thinning of forest communities is shown by a small rise in the NAP curve. In the lake, *Salvinia* reached end of its occurrence and *Pediastrum* expanded.

POST-INTERGLACIAL (EARLY VISTULIAN)

The phase WW 10 covers two pollen zones: WW 10a – *Pinus-Picea-(Carpinus)* and WW 10b – *Pinus-Betula*-(NAP). It represents the first stage of a distinct thinning of still closed communities of coniferous forests with admixture of deciduous trees. The older part of this phase coincides with decline of the interglacial or else regarded as the first post-interglacial section. Forest nature of plant communities occurring at that time indicates rather the first alternative. In the present paper that part is considered to be the beginning of the development of the post-interglacial vegetation.

The older part of the phase (WW 10a) reflects distinct climatic changes manifested by slight thinning of still closed or relatively closed forest cover. A rapid rise in the *Pinus* curve may result from radical and rather rapid change in climatic conditions or from decrease in sedimentation rate. The first alternative seems more probable. Expanding quicly, *Pinus* occupied most of both dry and moist areas and formed boreal-type communities. Pine become predominant (to 70% of total AP+NAP), with admixture of *Picea, Abies, Betula, Alnus, Carpinus, Quercus*, small numbers of *Corylus* and sporadic *Tilia* and *Ulmus*. Slight increase in herbs was mainly due to rise of *Gramineae, Cyperaceae* and *Artemisia.*

The sligtly more open or thinned (NAP – 5–14% of total AP+NAP) communities of pine and pine-birch forests with an admixture of *Picea*, scarce *Abies, Carpinus* and *Salix* and sporadically persisting deciduous trees of higher climatic demands (*Quercus, Corylus, Ulmus, Fraxinus* and *Tilia*), originated and next predominated in the younger part of this phase (WW 10b). The more light-demanding shrubs and herbs (*Juniperus* and *Artemisia*) began to appear and grow in importance.

The phase WW 11 – the pollen zone WW 11 – *Pinus*-NAP-*Betula* provides evidence of the progressing process of decline of closed forest communites (NAP ranges from 12 to 36%). Heliophilous plants gained in importance; among them *Helianthemum, Polemonium, Saxifraga* and *Polygonum bistorta-viviparum* were relatively frequent, *Hippophaë, Armeria, Sanguisorba officinalis* and *Chamaenerion-Epilobium* and at the end of the phase also subarctic *Selaginella selaginoides*. *Artemisia* and *Juniperus* played an essential role in the plant cover.

Forest communities thinned or formed patches (parkland), with decidedly prevailing *Pinus*, abundant *Betula* and admixture of *Picea, Alnus, Carpinus* and *Salix*, became dominant. It may be supposed on the basis of the materials examined that sporadically appearing pollen of other trees (*Quercus. Corylus, Tilia, Abies, Ulmus* and *Fraxinus*) may result from contamination of sediments, long-distance transport or redeposition.

In the profiles the sediments of this phase are preserved fragmentarily (Figs 7, 9 and 10), which makes a full characterization of vegetation development impossible. Interruption of bottom sedimentation or failure in preservation of some sediments may have been caused either by agents of a climatic nature (a cooling of the climate) or by elements of local environment connected with distinct shallowing of the reservoir (filling up with sediments) and deterioration of plant cover in the area.

Greater exposure of surface formations to increasing erosion and denudation was suggested by the sanding-up of sediments or change into sandy sedimentation. Completed deposition of bottom sediments have given rise to formation of *Sphagnum* peatbog (*Sphagnum* reached ca 8% in pollen spectra) or plant communitieis of swampy areas with numerous *Polypodiaceae* and *Equisetum*. In an insolated depression filled with stagnant water it came to expansion of algae of the genus *Pediastrum*. A similar picture of changes (with the expansion of *Pediastrum*) is provided from many other sites of that age in the territory of Poland (Janczyk-Kopikowa 1973, 1985, Krupiński 1973, 1978, 1986, 1993, Krupiński et al. 1982, Niklewski 1968, Noryśkiewicz 1978) and in the west of Europe (Środoń 1967a) as well as in the phases in which the plant successions of the earlier interglacials, the Mazovian (Krupiński 1984–1985, 1988a, b, 1993, Krupiński et al. 1986, 1988) and the Ferdynandów (Janczyk-Kopikowa 1975), ended.

SUMMARY

Six profiles of lacustrine sediments (Raniecka-Bobrowska 1954, Borówko-Dłużakowa 1960) and one peatbog profile (Krupiński 1988c) with the Eemian flora from Warsaw have been studied palynologically. All these profiles come from the large buried Żoliborz channel, its branch or a valley opening into it. Apart from the published materials, a profile of lacustrine sediments of the same age from Warsaw-Odolany has been studied on the basis of random samples (Krupiński 1990). It comes from a separate channel subparallel and tributary to the Żoliborz channel (cf. Morawski 1979, 1980).

Unfortunately, most of those palynological studies were carried out rather a long time ago. A detailed comparison of palynological results concerning deposits from a separate Wawrzyszew lake with those materials is very difficult both quantitatively and in respect of some identified taxa.

Results obtained from palynological studies of the five profiles of lake sediments from Warsaw-Wawrzyszew have provided some new information concerning, among other things, occurrence of certain taxa not found or not identified in earlier studies of sediments of a similar age. This is especially true for *Taxus*. It was neither found or it was represented only by rare pollen neighbouring sites: Główczyn (Niklewski 1968, to 0.4%, Niklewski et al. 1964), Gołków, carchment basin of Widawka, Grodzisk Mazowiecki, Błonie (Janczyk-Kopikowa 1966, 1971, 1973, 1974), Góra Kalwaria, Józefów (Sobolewska 1961, 1966) Sławno (Tołpa 1961), Żyrardów (Krupiński 1973, 1978 – to 0.5%), Bedlno (Środoń & Gołąbowa 1956) and Bobrówka Valley near Łowicz (Klajnert & Piechocki 1972).

In the older studies of the Mazovian Interglacial floras in Poland a pollen representation of this taxon was not mentioned, although its macrofossils were found in sediments (1 seed at Ciechanki Krzesimowskie – Brem 1953). Only in the profile from Gościęcin-Koźle Środoń (1957) found considerable amounts of *Taxus* pollen.

Recent studies show that *Taxus* was a very important element of the flora of the Mazovian age. Amounts of its pollen in pollen spectra of the yew phase reach 25% (Janczyk-Kopikowa 1981, Borówko-Dłużakowa 1981, Krupiński 1984–1985, 1988a, 1993, Krupiński & Lindner 1991, Krupiński et al. 1986, 1988).

There are also similar differences between older and more recent studies of the Eemian floras from the territory of Poland. In the recent studies *Taxus* is identified and amounts of its pollen above beyond doubt its presence in situ (see: Nakło – Noryśkiewicz 1978 – to 10%, Rogow – Janczyk-Kopikowa 1985 – to 5%, Zgierz-Rudunki – Jastrzębska-Mamełka 1985 – to 5%, Komorów – Krupiński 1986, 1993 – to 5%, Warsaw, ul. Kasprzaka – Krupiński 1988c – to 3%, Karczunek – Krupiński et al. 1982 – to 2.7%, Łomża – Krupiński 1992a – to 3%, Piła – Dąbrowski et al. 1987 – to 3.5%). Mamakowa (1976) found its still higher values (to 12%) in the sediments from Imbramowice near Wrocław. In the profile from Kittlitz in Lusatia (Eastern Germany) *Taxus* pollen reaches 20% (Erd 1973).

Therefore, it may be concluded that *Taxus* was an important component of the Eemian vegetation in the territory of Poland. The main period of its occurrence fell in the younger part of the hazel phytophase, including also the hornbeam and fir-spruce phase and the older part of the spruce-fir phase. Its amounts forest communities of the Eemian Interglacial in Poland increased from east-north to south-west. The values of *Taxus* pollen, reaching 5% in the profiles from Warsaw-Wawrzyszew and 3% in those from Warsaw-Wola (Krupiński 1988c), permit the conclusion that yew was an important and essential element of the forest communities of this interglacial and verify the interferences concerning its geographical distribution in Poland.

The results obtained in this palynological study of the five profiles from a rather small fossil lake basin made it possible to investigate the differentiation of the pollen rain over a small area. This question has been partly presented in the analysis of the local pollen zones. Great differentiation of the pollen spectra in the sediment referred to the same pollen zones in particular profiles suggest that the applied 5-cm spacing of sampling places is unsatisfactory in some cases. This may have been caused by the low sedimentation rate and the great compaction of the sediments or the high rate of the climatic-floristic changes. In consequence, not all the stages of these changes in particular profiles are recorded in the samples analysed palynologically. The time intervals comprising the time of accumulation of individual samples may have been longer than the duration of the quickly changing particular plant communities.

Making of good use of the conditions of sampling (in excavations) made it possible to observe the formations time of accumulation of which was referred to the Late Glacial of the Saalian Glaciation (Fig. 11) in three out the five profiles examined (WW XV, WW IX and WW VI). They differ distinctly from other sites of this age in the territory of Poland. This problem makes the subject of another paper (Krupiński 1993).

The main phases of vegetational history distinguished in the profiles from Warsaw-Wawrzyszew permitted the author to trace a development of plant communities, starting from the first inconspicuous by the glacier (Late Glacial: phases WW 1, WW 2 and WW 3).

The sediments which are well preserved in these profiles come from the periods of: – formation and predominance of the first boreal-type communities (phases WW 4 and WW 5), – predominance of the deciduous-forest communities of the Interglacial climatic optimum (phases WW 6 and WW 7) and – predominance of deciduous, deciduous-coniferous and coniferous forest communities with moderately prevailing thermophilous ones (phases WW 8 and WW 9).

Vistulian sediments are very poorly preserved in these profiles. Plant succession referred to the first phases of the post-interglacial cooling (Early Vistulian: phases WW 10 and WW 11) was found only in the profiles WW V and, partly, WW IX.

Vegetational history of the Late Glacial is characterized by the exceptionally high pollen values of *Hippophaë* (to 70%), unknown from any other studies, next those of *Betula* (to 70%) and *Pinus* (to 80%) and by the presence of numerous elements of the heliophilous flora, e.g. *Ephedra distachya* type, *Pleurospermum austriacum, Helianthemum, Empetrum, Armeria, Polemonium, Geranium, Linum, Centaurea montana* type, *Selaginella selaginoides, Artemisia, Juniperus* and the like.

Vegetational history of the initial part of the interglacial is distinguishable by a successive dominance of birch-pine, pine-birch and pine communities with elm, oak, ash, and sporadically surviving light-demanding plants (in the older part) and with appearing shrubs, herbs, swamp plants and aquatics of climatic demands: *Hedera, Humulus, Typha latifolia* and *Salvinia*.

Two main phases can be distinguished in the vegetational history of the climatic optimum of the interglacial: the older during a formation and have dominance of oak forests with pin and some deciduous trees of greater climatic demands (*Ulmus, Fraxinus and Corylus*) were characteristic, and the younger – when oak forest with abundant hazel or hazel communities with the above-mentioned thermophilous trees were are dominant. *Tilia, Alnus, Taxus, Acer* and towards the end, also *Carpinus* began to appear and grained quickly in significance. Of the plants with greather climatic demands *Hedera, Viscum, Ligustrum, Ilex, Frangula alnus, Humulus, Typha latifolia, Salvinia, Nuphar, Nymphaea* and sporadically *Stratiotes aloides* showed the greatest constance in their occurrence.

Vegetational history of the younger part of the interglacial can be divided into two phases: the older in which the a hornbeam forest with initially abundant *Corylus* and *Tilia* prevailed, and the younger characterized by predominant communities of fir-hornbeam and other deciduous trees. In addition to the earlier occurring floristic elements of greater climatic demands, there were also *Buxus* and *Vitis*.

Vegetational history of the post-interglacial (Early Vistulian) is marked by appearance of the closed and subsequently becoming more open communities of pine-spruce forests and pine forests with spruce, and next pine-birch forests with admixture of surviving trees of somewhat greater climatic demands. In the thinned communities of a forest-tundra nature (or in spaces between their patches) the first light-demanding plants began to appear; these were *Helianthemum, Selaginella selaginoides, Artemisia, Juniperus, Polemonium, Armeria, Sanguisorba officinalis, Chamaenerion-Epilobium* and *Polygonum bistorta-viviparum*.

The above-mentioned characteristics of the plant succession, reconstructed on the basis of results of the pollen analysis including the sediments in the profiles from Warsaw-Wawrzyszew suggest represent a full development cycle of an interglacial and its Eemian age cannot be called in question.

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