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GEOLOGIC-FLORISTIC SETTING OF THE MAZOVIAN INTERGLACIAL SEDIMENTS AT BIAŁA PODLASKA (E. POLAND) *

Sytuacja geologiczno-florystyczna osadów interglacjału mazowieckiego w Białej Podlaskiej (wschodnia Polska)

ABSTRACT. In the western part of Biała Podlaska there is an easternmost Polish site of interglacial sediments with a floristic succession of the Krępiec (Mazovian) type. It presents a climatic optimum with maxima of *Taxus, Carpinus* and *Abies*. Interglacial sediments are composed of bituminous shales, several metre thick. They are underlain by a glacigenic series of the youngest South Polish (= Mogielanka, Elstera II, Oka II) Glaciation or by lake sands from the initial part of the interglacial. They are mantled with thin till of the older Middle Polish (= Odra, Saale I, Dnieper) Glaciation, its residuum and younger valley deposits.

INTRODUCTION

The paper presents a detailed geologic and palynologic description of a new site with interglacial organic sediments in eastern Poland. This site is located just at a western boundary of Biała Podlaska. Interglacial sediments occur at both sides of the road to Warsaw (Fig. 1) and were discovered in 1983 due to pitt for a gas pipe. Information on these organic sediments were passed to the authors by Professor E. Falkowski.

In the site 3 boreholes were done (1/83, 2/83. 3/83 on Figs. 1, 6) and proved that the series is composed of bituminous shales, several metres thick. Preliminary investigations of palynologic and diatomologic composition indicated a floristic succession which was typical for the Mazovian Interglacial (Krupiński 1986), and diatoms (Marciniak 1986). These facts as well as a thin mineral cover of interglacial sediments made the authors (Krupiński et al. 1986) study this site with greater care, especially as there had been previous suggestions of Nowak (1973, 1974, 1977) and Baraniecka (1984) on a possible further extent of the Warta Glaciation (Stadial) in this part of Poland than

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commonly accepted (cf. Mojski 1982, 1985, Lindner 1984). In this paper a geologic setting of mentioned sediments is presented, accompanied by a full floristic succession of this interglacial, prepared on the basis of full-cored sections 1/84 and 2/84 of 1984, collected with a use of the K. Więckowski's core sampler (Więckowski 1961).

GEOLOGIC SETTING

The analyzed bituminous shales are 0.5—5.0 m thick and occur on a morainic plateau, cut by a seasonal stream running southwards to the Krzna River valley (Fig. 1). They are covered by 0.5—1.0 m thick bed of gray-blue clays with poorly preserved sporomorphs or floristicly barren, with a sand insert in the bottom. Above there is 0.5—2.0 m thick till and sands with boulders

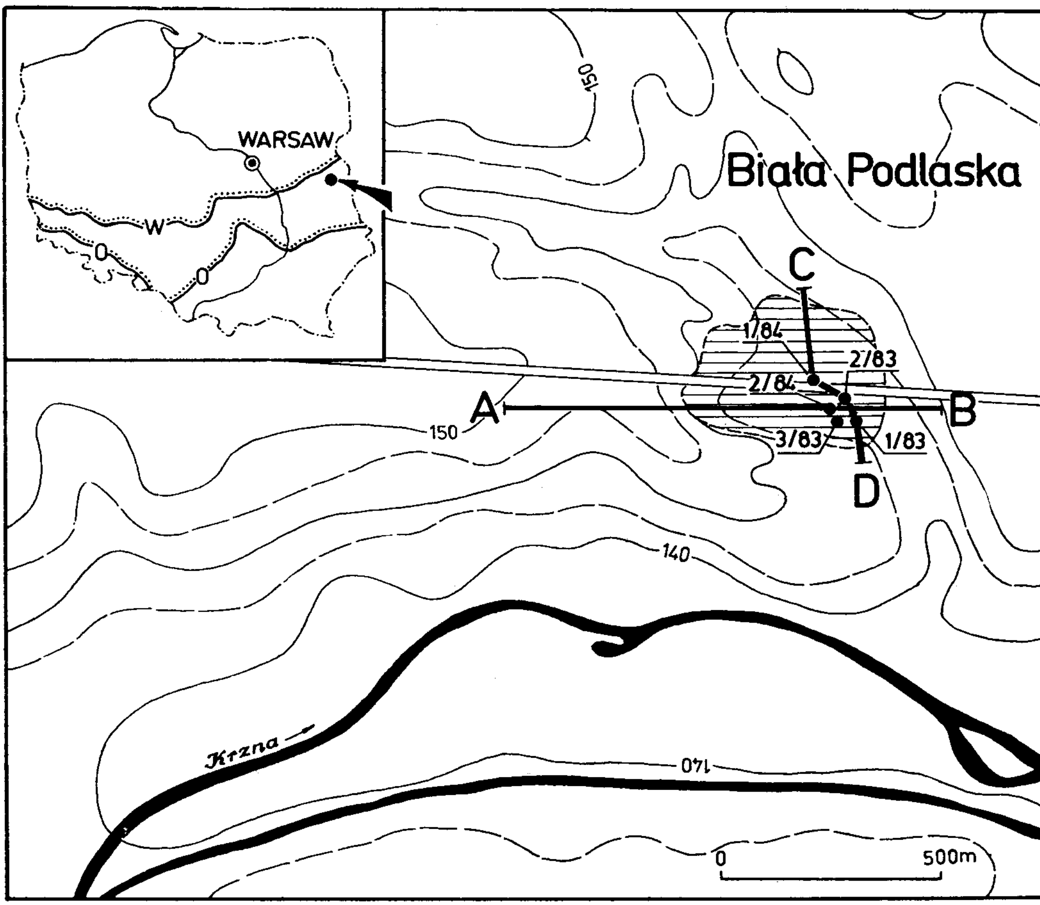

Fig. 1. Location of described interglacial sediments with borehole sections (which were palynologicaly analyzed) and geologic sections (A—B and C—D). O — maximum extent of the Odra Glaciation, W — maximum extent of the Warta Glaciation

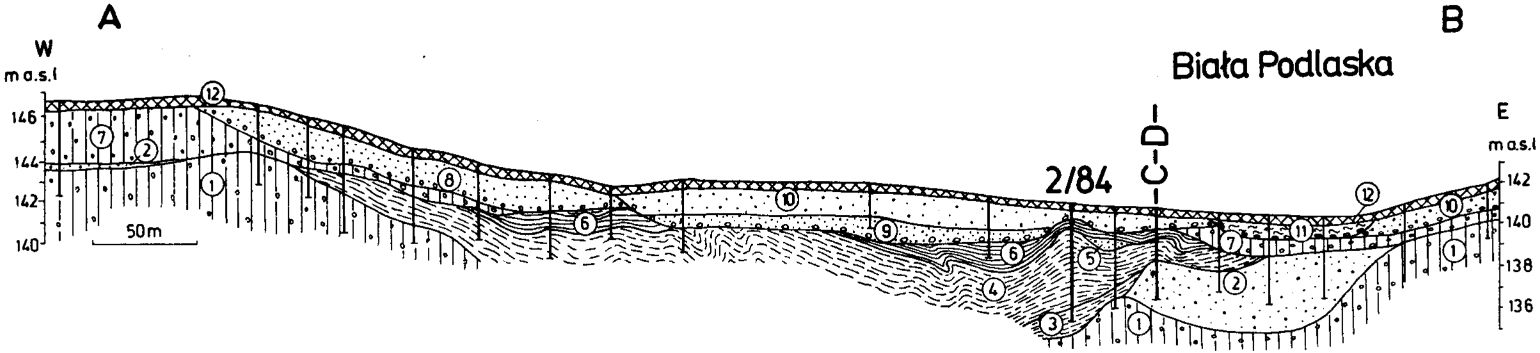

Fig. 2. Geologic section A—B of organogenic sediments of the Mazovian Interglacial in Biała Podlaska area. Mogielanka Glaciation: 1 — till; Mazovian Interglacial: 2 — varigrained sands with gravels of fluvial and lake deposition, 3 — silts, 4 — bituminous shales, 5 — lake sand, 6 — clay; Odra Glaciation: 7 — till; Warta Glaciation: 8 — glaciofluvial sands; Eemian Interglacial: 9 — fluvial sands and gravels with boulders (lag concentrate) in the bottom, 10 — fluvial sands with boulders (lag concentrate) in the bottom; Holocene: 11 — organic muds 12 — present soil

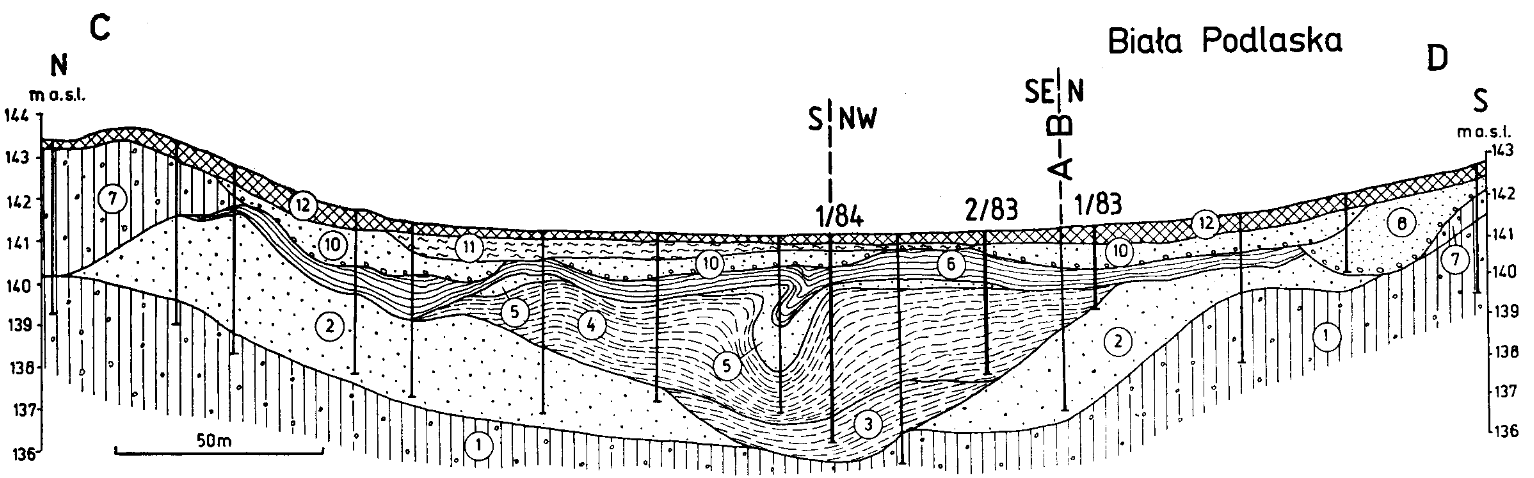

Fig. 3. Geologic section C—D. Explanations as in Fig. 2

(coming from a washed till). In the axis of this cutting they are also mantled with recent organic muds and peats. The shales fill a buried depression within the underlying till and locally they are separated from the latter by sands with gravel (Figs 2, 3).

Due to last boreholes (1/84 and 2/84) that supplied with undisturbed cores, an intensive folding of the upper part of analyzed shales and overlying deposits was noted. It was expressed by inclination of laminae at about 40°. This folding, noted also in pits that cut these sediments, has probably resulted from deformations of analyzed series by a non-uniform loading by ice sheet during deglaciation of the Biała Podlaska area (Falkowski 1986).

The ice sheet deposited a till, now locally preserved in residuum above the analyzed organic sediments, and a corresponding till bed on the land surface to the north and west of Biała Podlaska (Turowski 1986). A till overlies there lacustrine sandy silts and underlying fluvial sands and gravels, composed of several erosive-accumulative cycles that are typical for valleys of the early and middle parts of the so-called Great Interglacial (cf. Różycki 1964, Lindner 1981). The older cycle represents erosion and then, fluvial deposition during the Ferdynandów Interglacial and Wilga Glaciation, whereas the younger cycle proves fluvial erosion and deposition during the Barkowice Mokre (Mazovian) Interglacial and initial part of the Odra Glaciation (Krupiński et al. 1986).

To the west of Biała Podlaska the sediments of these cycles fill a buried meridional river valley. This valley cuts two tills, the upper one of which forms in the same time a substrate of organogenic deposits at Biała Podlaska (Figs. 2, 3) and represents the Mogielanka Glaciation whereas the lower one corresponds with the San Glaciation (cf. Lindner 1984). These tills cover an older, buried valley, a development of which should be referred to the Kozi Grzbiet Interglacial. This valley was formed due to cutting of two oldest tills. The latter are directly overlain by Tertiary sands and silts. The younger of these tills is to be referred to the Nida Glaciation and the older one to the Narew Glaciation. These tills are separated by the alluvial series of the Przasnysz Interglacial (Turowski 1986, Krupiński et al. 1986).

PALYNOLOGIC ANALYSIS

Most samples from the sections 1/84 and 2/84 were prepared for the pollen analysis by the Erdtman's acetolysis. Only the samples from the upper part of the section 2/84 and from bottoms of both sections were treated with hydrofluoric acid before the acetolysis. The sections were usually sampled at 5 cm intervals. Over 500 pollen grains of trees (AP) and all noted sporomorphs of bushes and herbs (NAP), marsh, rush, water and spore plants were counted. They were supplemented by counting of *Pediastrum*, *Botryococcus*, varia, destructed and indeterminate sporomorphs and of Tertiary plants. A total of AP+NAP was accepted for the basic sum, used for defining the percentage contents of individual taxa or groups of plants. Macroscopic remnants could not be separated from these sediments as independently on soaking time and conditions, the shales do not absorb water and cannot be submitted to peptization.

Pollen diagrams of the sections 1/84 (Fig. 4) * and 2/84 (Fig. 5) * were subdivided into periods I—V and within them, local pollen assemblage zones were distinguished.

I. Period of woodless assemblages and of rare boreal forests, represented by two pollen zones:
B. P. — A — *Betula*, NAP, *Salix*, *Juniperus*
B. P. — B — *Betula*, *Pinus*, *Larix*

II. Period of dense forest assemblages of a boreal type, represented by two pollen zones:
B.P.—C — *Picea*, *Alnus* *(Betula)*
B.P.—D — *Picea*, *Alnus* *(Taxus)*

III. Period of forests of the interglacial climatic optimum, represented by four pollen zones:
B.P.—E — *Taxus*, *Picea*, *Alnus*
B.P.—F — *Pinus*, *Picea*, *Alnus*
B.P.—G — *Carpinus*, *Abies*, *Quercus*, *Corylus*
B.P.—H — *Carpinus*, *Quercus*, *Abies*, *Corylus*

IV. Period of gradual disappearance of forest assemblages at the end of interglacial, represented by two pollen zones:
B.P.—J — *Pinus*, *Betula*, *Sphagnum*
B.P.—K — *Pinus*, *Betula*, *Picea*, NAP

V. Period of woodless or park forest-bush assemblages, noted only in a single sample of the section 2/83 (Fig. 6), defined by a pollen zone:
B.P.—L — *Betula*, *Salix*, NAP.

These periods were preceded by a redeposition of Tertiary material, containing over 50% of sporomorphs which are exotic for the Quaternary of Poland.

Deposits of the zone "secondary bed" (Table 1, Fig. 6) are preserved in the section 1/84 (Fig. 4). They are composed of silts and sandy silts with admixture of organic matter. They contain a considerable amount of redeposited sporomorphs of Tertiary plants (to 40%), numerous *Hystrichosphaeridae* and sporomorphs of Quaternary plants of higher thermic demands. A poor frequency of pollen within these sediments and a considerable participation of redeposited elements (about 60%) can indicate the absence of a compact vegetation cover in this time.

Period I. Sediments of this period are well preserved in both sections (Figs. 4, 5) as silts with a high admixture of organic matter (pollen zone B.P.—A) and thick-laminated bituminous shales (pollen zone B.P.—B). This period had woodless assemblages (pollen zone B.P.—A) and rare boreal forests (pollen zone B.P.—B).

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* Fig. 4 and Fig. 5 under the cover.

Table 1

General characteristics of sediments from pollen zones of analyzed sections from Biała Podlaska

Local pollen zones	section no. 1/83	2/83	3/83	2/84	1/84	symbol: local pollen zones B.P.	symbol: plant development period
Betula, Salix, NAP	—	—	1 /1/ 1,04 - 1,15 > 0,11	—	—	L	V
Pinus, Betula, Picea, NAP	—	—	non-distinguished	1-3 /3/ 1,20 - 1,35 0,15	—	K	IV
Pinus, Betula, Sphagnum	—	—	2 - 7 /6/ 1,15 - 1,50 0,35	4 - 10 /7/ 1,35 - 1,70 0,35	—	J	
Carpinus, Quercus, Corylus, Abies	—	—	8 - 9 /2/ 1,50 - 1,60 0,10	11 - 14 /4/ 1,70 - 1,90 0,20	1 - 2 /2/ 1,30 - 1,40 0,10	H	III
Carpinus, Abies, Quercus, Corylus	—	1 - 3 /3/ 1,20 - 1,35 0,15	10 - 18 /9/ 1,60 - 2,05 0,45	15 - 24 /10/ 1,90 - 2,40 0,50	3 - 19 /17/ 1,40 - 2,25 0,85	G	
Pinus, Picea, Alnus	—	4 - 13 /10/ 1,35 - 1,85 0,50	19 - 25 /7/ 2,05 - 2,40 0,35	25 - 36 /12/ 2,40 - 3,00 0,60	20 - 31 /12/ 2,25 - 2,85 0,60	F	
Taxus, Picea, Alnus	—	14 - 22 /9/ 1,85 - 2,30 0,45	26 - 34 /9/ 2,40 - 2,80 0,40	37 - 41 /5/ 3,00 - 3,25 0,25	32 - 41 /10/ 2,85 - 3,35 0,50	E	
Picea, Alnus	? 1 /1/ 1,15 - 1,20 0,05	23 - 30 /8/ 2,30 - 2,70 0,40	35 - 40 /6/ 2,80 - 3,20 0,40	42 - 45 /4/ 3,25 - 3,45 0,20	42 - 46 /5/ 3,35 - 3,60 0,25	D	II
Picea, Alnus (Betula)	2 - 8 /7/ 1,20 - 1,55 0,35	31 - 40 /10/ 2,70 - 3,20 0,50	41 - 44 /4/ 3,20 - 3,40 > 0,20	46 - 56 /11/ 3,45 - 4,05 0,60	47 - 56 /10/ 3,60 - 4,10 0,50	C	
Betula, Pinus, Larix	9 - 15 /7/ 1,55 - 2,00 0,45	41 - 48 /8/ 3,20 - 3,60 > 0,40	•	57 - 68 /12/ 4,05 - 4,65 0,60	57 - 64 /8/ 4,10 - 4,50 0,40	B	I
Betula, NAP, Salix, Juniperus	•	•	•	69 - 77 /9/ 4,65 - 5,05 > 0,40	65 - 70 /6/ 4,50 - 4,80 0,30	A	
„Secondary bed"	•	•	•	•	71 - 74 /4/ 4,80 - 5,00 > 0,20	„Secondary bed"	
Total: Sample nos. (number of analyzed samples) depth in m thickness of sediments in m	1 - 15 /15/ 1,15 - 2,00 0,85	1 - 48 /48/ 1,20 - 3,60 > 2,40	1 - 44 /44/ 1,04 - 3,40 > 2,36	1 - 77 /77/ 1,20 - 5,05 > 3,85	1 - 74 /74/ 1,30 - 5,00 > 3,70		

• no data

— absent

During this time when a climate got gradually warmer, the area of Biała Podlaska was gradually covered by more and more dense bushes and plant assemblages with predominant *Betula* and *Salix*, abundant shrubs of open areas inclusive *(Hippophaë, Juniperus)* and herbs. With time a gradually increased significance of *Pinus* and *Larix* was marked, accompanied by a drop in NAP, *Betula*, *Salix* and disappearance of *Hippophaë*, *Juniperus*, *Empetrum*, *Heliant-*

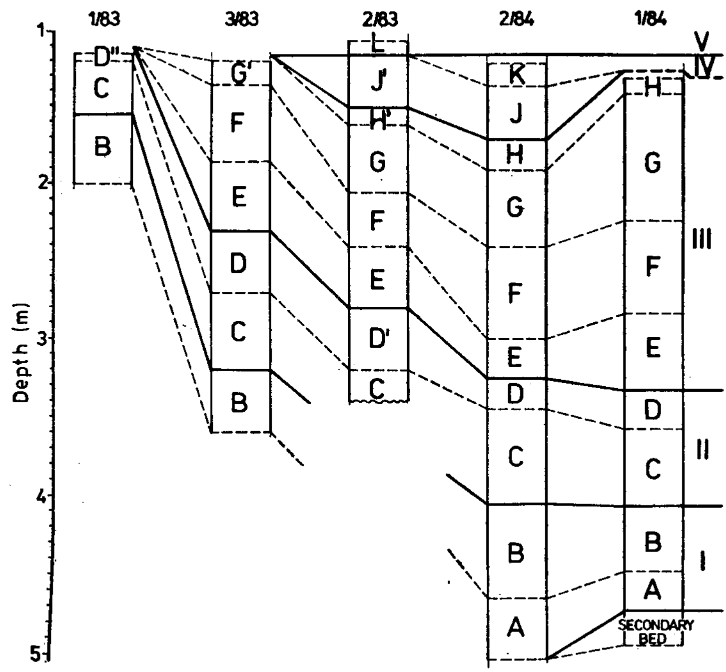

Fig. 6. Depths and thicknesses of interglacial sediments in five analyzed sections (1/83, 2/83, 3/83, 1/84, 2/84) with their subdivision into pollen zones: B. P. — A — *Betula*, NAP, *Salix, Juniperus* B.P.-B — *Betula, Pinus, Larix*, B.P.-C — *Picea, Alnus (Betula)*, B.P.-D — *Picea, Alnus (Taxus)*, B.P.-D' — *Picea, Alnus (Pinus, Taxus)*, B.P.-D" — *Alnus, Picea (Taxus, Carpinus)*, B.P.-E — *Taxus, Picea, Alnus*, B.P.-F — *Pinus, Picea, Alnus*, B.P.-G — *Carpinus, Abies, Quercus, Corylus*, B.P.-G' — *Carpinus, Abies, Corylus, Quercus*, B.P.-H — *Carpinus, Quercus, Abies, Corylus*, B.P.-H' — *Carpinus, Quercus, Corylus, Abies*, B.P.-J — *Pinus, Betula, Sphagnum*, B.P.-J' — *Pinus, Betula*, NAP, *Sphagnum*, B.P.-K — *Pinus, Betula, Picea*, NAP, B.P.-L — *Betula, Salix*, NAP

hemum. At the end of this period the almost completely developed forests were inhabited by quickly rising contents of *Ulmus, Alnus* and *Picea*. The area around the reservoir got marshy *(Equisetum)*. In its littoral part, well insolated and without muds at the bottom, there were favorable conditions for *Typha angustifolia*. In the reservoir itself, with stagnant water or with a limited overflow, there were numerous algae of the genus *Pediastrum*.

Thermic demands of plants of this period indicate a cool and wet climate. Wetness of the climate and existing hydrologic conditions resulted from a small surface evaporation due to thermic conditions as well as decreased soil permeability, resulting from a presence of permafrost in a substrate.

Pollen zone B.P.—A — *Betula*, NAP, *Salix, Juniperus* is distinct in both sections (Figs 4, 5). Its sediments are about 30—40 cm thick (Fig. 6). This zone was not identified in previous boreholes (Krupiński 1986). A pollen assemblage is predominated by *Betula* (60—75%), *Salix* (2—3%) and NAP (about 20%). The remaining 10—15% was used by the increasing contents of

Pinus and *Larix* and sporadic *Populus*. Noted sporomorphs of plants of slightly higher thermic demands (mainly of dendroflora) are to be considered for a secondary deposit.

Initial plant assemblages contained *Hippophaë*, *Juniperus*, *Pleurospermum*, *Empetrum*, *Plantago*, *Ephedra distachya* type, *Campanula*, *Polygonum bistorta-viviparum* type, *Gentiana*, *Saxifraga*, *Selaginella selaginoides*, and others. This pollen zone is to be considered for a pioneer stade of developing assemblages, at first of bushes and herbs, and then of forest-tundra. A climate was quite mild as there was a constant presence of *Typha latifolia* that demands minimum +14°C as a mean temperature of the warmest month (Hulten 1950, Iversen 1954). Absence of well developed forests in such thermic conditions should be explained by a delay in a forest development if compared with a quick climatic warming. Herbs and particularly water ones, record a rate and dynamics of climatic transformations at interglacial beginnings considerably quicker (cf. Iversen 1954, Mamakowa 1962).

Pollen zone B.P.—B — *Betula*, *Pinus*, *Larix*. Sediments of this zone are distinctly thicker in the section 2/84 (Figs 5, 6). Their bottom and top occur here at lowest altitudes if compared with other sections (Fig. 6). The section 2/84 seems to be located in the deepest part of the reservoir. A participation of the more important taxa in pollen spectra of this zone is equal: *Betula* 35—50% (with a distinct drop), *Pinus* 30—35% (rising trend), *Larix* about 5%, NAP about 10—15%. But an appearance and quick rise of *Picea* about 5%, *Alnus* about 10%, as well as considerable participation of *Ulmus*, *Fraxinus*, *Quercus* and in the zone top also of *Tilia cordata* type and *Corylus*, are the most significant elements of a floristic succession. Numerous heliophytes present in the initial part of the previous pollen zone (B.P.—A) have retreated here completely. It indicates a development of relatively dense boreal forests of pine-birch type, with spruce and larch, in which a gradual rise of deciduous trees of temperate zone is noted (among others *Ulmus*, *Fraxinus*, *Quercus*).

Period II was the main development stage of boreal forests (Figs 4, 5). Two distinct phases of their development are distinguished here. The first one (pollen zone C) was predominated by *Picea*, *Alnus*, retreating *Betula* and rising *Pinus*. Besides there were: *Larix*, *Ulmus*, *Fraxinus*, *Quercus*, *Corylus*, *Tilia*. During the second phase (pollen zone D) trees of slightly higher thermic demands got more significant whereas *Taxus* and *Carpinus* appeared for the first time. A distinct climatic warming was indicated in the younger phase of this period by *Salvinia* which occupied waters of a reservoir and by *Typha latifolia* in a littoral zone. A distinct drop in NAP content, accompanied by absence of typical heliophytes, proved a presence of compact forest assemblages.

Pollen zone B.P.-C — *Picea*, *Alnus*, *(Betula)* was noted in all analyzed sections (Fig. 6). *Betula* is still abundant here but its content is slightly lower than the one of *Pinus*. Amidst important components of forests there are: *Picea* (about 17%) and *Alnus* (about 25%), as well as *Ulmus*, *Fraxinus* and *Quercus*, and *Taxus* and *Caprinus* at the end. A constant presence of *Humulus*, sporadicly of *Hedera* and *Viscum*, at a contemporaneous low content of NAP and absence of heliophytes, can indicate a complete occupation of the area by compact boreal forests (of pine-birch, spruce-birch and alder swamp types). Sites, rich from edaphic point of view, started to be overgrown by *Quercus*, *Fraxinus* and *Tilia*. Sites of wetter dry forests and marshy meadows were occupied by *Ulmus*, *Fraxinus*, with admixture of *Quercus*, *Alnus* and nitrophilous *Humulus* in the undergrowth. Numerous algae of the genus *Pediastrum* in sediments of this pollen zone prove a stagnant water in the reservoir or a limited flow.

Pollen zone B.P.-D — *Picea*, *Alnus*, *(Taxus)* is preserved in sediments of all sections (Fig. 6). It indicates a distinct variability in mutual quantitative relations amongst the main floristic elements (Krupiński 1986; Figs 4, 5). It continues the evolutionary trends of dendroflora of the previous pollen zone (C). *Picea* reached its development maximum. A distinct break in high content of *Betula* is noted at a considerable stability of *Pinus*. Main and most significant floristic transformations are marked in the final part of the described zone. At first constant but rare *Taxus* started to be more important, considerably earlier than *Corylus*. In all sections a transitional but distinct drop of *Fraxinus* and *Alnus* is noted. Further drop of *Larix* and rise of *Quercus* occur. There were also thermophilous bushes as *Hedera* and *Viscum*, herbs of *Humulus*, rushes of *Typha latifolia* and water plants of *Salvinia*.

The area of Biała Podlaska was occupied in this time by well developed boreal forests with some atlantic features. Dry sites and edaphicly poor were occupied by *Pinus* with admixture of *Betula* (probably *B. verrucosa*). Wet areas were covered by *Picea*, *Alnus*, with admixture of *Betula* (probably *B. pubescens*). Edaphicly rich habitats were occupied by *Quercus*, *Ulmus*, *Fraxinus*, *Tilia* and quickly rising *Taxus*, with *Corylus* and admixture of *Picea* and *Pinus*. *Humulus* found favorable conditions in the undergrowth of wet deciduous forests, particularly of marshy meadows.

This pollen zone can be distinguished from the previous one by appearance of *Corylus* and *Taxus* in the final part at well as by a quick and distinct rise of the latter.

Period III should be considered for the climatic optimum (sensu lato) of an interglacial. It indicates three distinct climatic-floristic members (Figs 4, 5). The older one (zone B.P.-E) and the younger one (zones B.P.-G, H) of warm and wet climate, separated by a middle one (zone B.P.-F) with a warm but distinctly drier climate (rise of *Pinus*).

The first part (zone B.P.-E) was predominated by *Taxus*, *Picea*, *Pinus*, *Alnus*, accompanied by *Quercus*, *Corylus*, *Fraxinus*, *Ulmus*, *Tilia*, *Carpinus*. There were also plants of higher thermic demands as *Hedera*, *Viscum*, *Ligustrum*, *Buxus*, *Vitis*. A slight climatic drying in the middle part of this period (zone B.P.-F) resulted in a limited development of *Taxus* (sensitive to climatic changes) and created favorable conditions for expansion of *Pinus*. In the final part of this period (zones B.P.-G, H) a maritime climate favored an expansion of rich *Carpinus-Abies* forests with a high content of *Quercus* and *Corylus* (zone B.P.-G), and of *Carpinus-Quercus* forests with *Abies* and *Corylus* (zone B.P.-H). In the same time a development of wet and excessively wet forests with predominant *Alnus* was distinctly limited. A maximum occurrence of plants of higher thermic and moisture demands (among others *Hedera*, *Buxus*, *Vitis* and *Ligustrum*) is also noted in this period.

Sediments of this period are preserved only in the sections 2/83, 1/84 and 2/84 (Fig. 6, Table 1). They are absent in a peripheral section 1/83 and are incomplete in 3/83 and 1/84. Such a varying content of paleoflora in the top of unconsolidated (in that time) lake sediments of sapropel-type seems to result from destruction and deformation during ice sheet advance and during deglaciation.

Glaciotectonic deformations of these sediments are visible in a core from the section 1/84. In the top, layers of fine-laminated shales ran vertically and were parallel to a root inside them (which was of about 3 cm in diameter). Basing on similar observations from the interglacial site in Komarno area (Krupiński — MS), root systems are found to have taken advantage of fissures within glacigenicly deformed shales.

Pollen zone B.P.-E — *Taxus*, *Picea*, *Alnus* is well developed and preserved in sediments of most sections (Fig. 6). It is only absent in the section 1/83. It is characteristic for a very high content of *Taxus* (to 25%), known only from Krępiec near Łęczna (Janczyk-Kopikowa 1981). In the site Biała Podlaska a content of *Picea* and *Alnus* was quite high (about 15% and 20% respectively) and did not indicate greater changes. On the other hand a further drop of *Betula* and insignificant but distinct one of *Pinus* is noted. A considerable rise of *Quercus*, *Corylus* and *Carpinus* occurs too. *Taxus* becomes the predominant element in local assemblages.

A southeastern part of Podlasie was in that time occupied by boreal forests with certain atlantic features. Dry areas and edaphicly poor were still inhabited by *Pinus* with admixture of *Betula*, wet environment and edaphicly mid-rich by *Picea* and *Taxus* mainly whereas the one which was periodicly excessively wet by *Alnus* and a possible admixture of *Fraxinus*. *Taxus* occurred mainly in considerably wet areas. An occurrence of *Quercus*, *Corylus*, *Fraxinus*, *Tilia* and then also of *Carpinus* and sporadic *Abies* should be connected with habitats of most fertile dry forests and dry meadows. Plants with higher thermic demands as *Hedera*, *Viscum*, *Ligustrum*, *Stellaria* nemorum appeared there too. *Salvinia* reached its maximum development.

Numerous plants of slightly greater thermic demands allow to consider the pollen zone *Taxus*, *Picea*, *Alnus* for the first phase of a climatic optimum of described interglacial.

A comparison of climatic demands of *Taxus*, predominant in the pollen zone B.P.-E, and of *Carpinus* and *Abies* in the second phase of a climatic optimum (zones B.P.-G, H) suggests that a climate during deposition of sediments with numerous *Taxus* could be similar to the conditions present during a development of hornbeam-fir assemblages. *Taxus baccata* which occurs in Poland now, belongs to the European boreal-mountain plants that do not pass the isotherm of July of +16°C whereas *Carpinus betulus* of +17°C (Hulten 1950). According to K. Rubner (Goetz 1932) the most favorable conditions for *Carpinus betulus* (expressed by its most abundant occurrence) exist at the eastern limit of its extent. The present climate of Central Poland is not certainly suitable for it (Szymanowski 1960).

Pollen zone B.P.-F — *Pinus*, *Picea*, *Alnus* is well developed and preserved in sediments of the sections 1/84 and 2/84 (Figs. 4, 5). These sediments have a similar thickness (about 60 cm), close to the one as in the previosuly analyzed sections (Fig. 6). They are similarly developed in all sections (Krupiński 1986). *Taxus* which predominated in the previous zone, is here an accompanying element only. It occurs permanently although in small quantities (more in 1/84). Its place in phytocoenoses is decidedly taken by the rising *Pinus*, a curve of which reached about 40%, indicating a distinct bipartity in most sections. It is not present in the section 2/84, possibly due to a much too rare sampling. Other main floristic elements (*Picea*, *Alnus*, *Quercus*, *Corylus*) occurred in similar quantities as previously, only a distinct rising trend of *Carpinus* is noted. *Abies* appeared in quantities that prove its presence in situ, reaching a significance together with *Carpinus* in the final phase.

Carpinus appeared early in the flora of Biała Podlaska (almost or in the same time as *Taxus*). It gained its development maximum after *Abies*. On the other hand *Abies* appeared at the end of the maximum of *Taxus*, and very quickly reached its maximum. A participation of primary numerous *Picea* was high (about 10—15%) and very stabile and indicated a distinct drop in the second part of this zone. *Picea* became only accompanying tree.

Southeastern Podlasie was occupied by boreal forest assemblages with predominant of *Pinus* and by *Picea*, lossing its significance. Different habitats of pine forests (on dry and edaphicly poor soils), pine-spruce forests (on temperature wet and wet, mid-edaphicly rich soils and previously occupied by assemblages with predominant *Taxus*) were developed. Habitats which were occasionally too wet were still overgrown by alder forests. Most fertile habitats with most favorable water relations were covered by more and more significant assemblages of deciduous forests with *Quercus*, *Corylus*, *Carpinus*, *Fraxinus*, *Ulmus*, *Abies*, rare *Tilia* and *Acer*. These sites could be occasionally occupied by *Pinus* that replaced *Taxus*.

Warm and mild climate resulted in appearance of *Vitis*, *Buxus* and further presence of *Ligustrum*, *Hedera* and *Viscum*. Surface waters of the lake were occupied by *Salvinia* whereas *Typha latifolia* occurred in a littoral zone. *Osmunda* appeared and gained its development maximum, being a significant floristic element of fertile and wet assemblages of deciduous forests.

Pollen zone B.P.-G — *Carpinus*, *Abies*, *Quercus*, *Corylus* is developed and preserved only in sediments of sections 1/84, 2/84 and 2/83 (Fig. 6). It has a considerably varying thickness. Due to a location in the top, it is least thick and incomplete in the section 3/83 (Krupiński 1986).

Dendroflora is predominated by *Carpinus* (to 30%), and *Abies* (to 20%), *Quercus* (to 15%), *Corylus* (to 12%), *Alnus* (to 20%). A content of *Pinus* is considerably lower and equals 10—15%. Compact assemblages of atlantic or atlantic-boreal mixed forests were formed. Favorable climatic conditions principally decided about a floristic succession. The edaphic factor could only exceptionally limit a development of hornbeam-fir assemblages with hazel, occasionally with ash, linden, maple, elm (*Osmunda* in undergrowth) what enabled a survival of previously developed assemblages with abundant pine or alder (only in climax habitats). A thermophilous vegetation indicates also very favorable climatic conditions, suitable for development of thermophilous plants whereas on tree crowns *Viscum* occurred. In warm and well insolated waters there was abundant (although less than previously) *Salvinia*, occasionally *Stratiotes*, rich *Nymphaea*, *Nuphar* while *Typha latifolia* in a littoral zone.

Numerous floristic elements of high thermic demands, present in this pollen zone, allow to consider it for the second phase of climatic optimum of the interglacial or for its optimum s. s., with a mean temperature of about 20°C during the warmest month.

Pollen zone B.P.-H — *Carpinus*, *Quercus*, *Corylus*, *Abies* is preserved only in sediments of the sections 2/83 (Krupiński 1986), 2/84 and 1/84 (Figs 4, 5) and has a small thickness (Fig. 6). It indicates the second phase of development of hornbeam-fir assemblages in which a further rise of *Carpinus* and *Quercus* is noted. They reached here their interglacial maximum (*Carpinus* over 40%, *Quercus* over 15%) and a distinct retreat of *Abies* occurred. A content of its pollen is temporarily below 10%.

A separation of this zone may be somewhat controversial as it is not distinct in all sections of this site. In sections 1/84 and 2/84 its occurrence is beyond doubts.

A trend of climatic changes in the final part of this zone towards a continentalization and particularly, a start of more severe and frosty winters,resulted in a quick retreat of *Quercus*, *Alnus*, *Fraxinus*, *Ulmus*, *Tilia*, complete disappearance of *Taxus* and other plants of higher thermic demands. On the other hand a rise of *Pinus* and *Picea* as well as of bush and herbaceous plants of greater luminuous demands is noted.

A water reservoir started to be overgrown by a peat-bog with numerous *Sphagnum*. Favorable conditions existed again in a reservoir for a development of algae of the genus *Pediastrum*. This factor constituted the beginning of boreal assemblages in a final part of the interglacial. It delimited the end of predominating deciduous and mixed forests of atlantic type.

Period IV presents a replacement of warm assemblages of deciduous and mixed forests by less climaticly and edaphicly exacting assemblages of pine forests with birch and disappearing elements of deciduous forests of the previous period (Figs. 4, 5). *Picea* appeared again and started to develop. A further reduction of development of *Alnus* is noted. An expansion of bush and herbaceous plants resulted in a quick occupation of the areas that were previously covered by forest assemblages. The area with warmer dendroflora must have been dislodged further to the south.

The area of the almost completely shallow and filled (with bottom sediments) water reservoir was invaded by peats with abundant *Sphagnum*. Algae of the genus *Pediastrum* occured in still preserved and well insolated ponds.

Sediments of this period are preserved only in fragments in sections 2/83 (Krupiński 1986) and 2/84 (Figs 5, 6).

Pollen zone B.P.-J — *Pinus*, *Betula*, *Sphagnum* is preserved in sediments of both sections (Fig. 6), indicating a slight floristic differentiation. In the first part of it, at a stabile content of *Alnus* and *Abies* (about 5% each), a rapid rise (slightly before the one of *Betula*) of *Pinus* (to about 60%) is noted, accompanied by a distinct rise of *Betula* (to about 15%) and slightly lower of NAP (10—12%) and *Picea* (5%). Trees with slightly higher thermic demands (*Quercus*, *Corylus*, *Fraxinus*, *Tilia*, *Ulmus*, *Carpinus*) lost much in their significance. Rare *Pterocarya* appeared in forests. No bushes and herbs of slightly greater thermic demands occurred. Peat-bogs with *Sphagnum* were formed and developed. In the second part of this pollen zone the rising trees were supplemented with bush and tree forms of *Salix* (Kurpiński 1986). Favorable conditions for representatives of the family *Ericaceae* existed on well developed peat-bogs.

Area of Biała Podlaska was occupied by predominant loose assemblages of pine forests with birch and admixture of other, rare or single trees. More favorable habitats could be covered by patches of survived spruce-fir assemblages whereas scarce *Alnus* occupied excessively wet areas of mineral substrate.

Pollen zone B.P.-K — *Pinus*, *Betula*, *Picea*, NAP was distinguished only in sediments of the section 2/84 (Fig. 5). It is thin and represented by three samples only (Table 1). This zone is much similar to the previous one. It is characteristic for a rapid rise and participation of algae of the genus *Pediastrum* as well as distinct increase of spore plants, mainly *Polypodiaceae*. This zone forms a final phase of development of forest assemblages.

Period V is preserved only in sediments of the section 2/83 (Fig. 6, Table 1). It indicates a succession dependent on climatic changes. Boreal forest communities were replaced by abundant bush and herbaceous plants, of open areas inclusive. In this time a northern forest boundary was here considerably moved southwards. In Biała Podlaska area the climatic-floristic conditions started to be close to the present ones in southern part of forest-tundra zone with abundant bushes and herbs, represented mainly by *Artemisia*, *Gramineae*, *Cyperaceae*, bushy-like species and forms of *Betula*, *Pinus* and *Salix*. *Alnus incana* could still occasionally occur along streams.

Pollen zone B.P.-L — *Betula*, *Salix*, NAP (*Alnus*, *Pinus*, *Polypodiaceae*) is represented by a single sample of clay from the section 2/83 (Krupiński

1986). Many similar floristic features are indicated by palynologic investigations of a clay sample (Table 1) which was collected by Prof. E. Falkowski (Falkowski 1986). These samples contain abundant spores of *Polypodiaceae* and algae colonies of the genus *Pediastrum*. They differ from each other by a considerably greater content of pollen of *Betula* and *Salix* in a sample from the section 2/83 as well as of *Pinus* and NAP in the sample of Prof. E. Falkowski. The latter sample seems to be slightly younger and represents a complete disappearance of patchy assemblages of park forest. Declining vegetation is predominated by busches and herbs with common *Artemisia* (over 18%). The clay sample from the section 2/83 can represent the phase with highly thinned forest and forest-bushy assemblages, with more and more significant bushes and herbs, of open areas inclusive. *Betula* became the predominant in these assemblages, reaching almost 50% whereas *Pinus*, *Salix* and *Picea* could form and admixture. A total of their pollen is not over 15%. Other elements of dendroflora (about 8%) should be considered for redeposited ones or, what seems more probable, for coming from a far transport.

There is also a possibility of quite different floristic and particularly, biostratigraphic interpretation of sediments in this part of the section. One cannot exclude a presence of hiatus between bituminous shales and overlying clays. If this is the case, then the flora from clays that contact with shales in the section 2/83 (Krupiński 1986) cannot form a further continuation of a floristic succession which is marked in the top of shales, and its origin remains unclear.

FOSSIL FLORA FROM BIAŁA PODLASKA AGAINST OTHER INTERGLACIAL SITES OF POLAND

The fossil flora from Biała Podlaska is undoubtedly of interglacial origin. Determined sporomorphs enable to study its evolution, starting from subarctic assemblages (zone "secondary bed" and pollen zones B.P.-A and B) through boreal forests (B.P.-C, D), temperate climate forests — climatic optimum of an interglacial s. l. (B.P.-E, F, H), again boreal forests (B.P.-J, K), till bush-forest assemblages of the interglacial decline (B.P.-L). Amidst interglacial sites of Poland, this flora is specific for its well developed phase of forest assemblages with a high content of *Taxus*, then of *Abies* and *Carpinus* as well as elements of greater thermic demands among others *Vitis*, *Ligustrum*, *Buxus*, *Hedera*, *Viscum*, *Ilex*, *Salvinia*, *Azolla foliculoides*. The presence of the latter is connected with a flora of the Mazovian Interglacial.

A lack of synantropic floristic elements excludes the Late Holocene age of analyzed sediments. An early occurrence of *Picea* that quickly reached its development maximum (decidedly before *Abies*), later *Abies* and particularly *Carpinus* (after *Picea*) and absence of phase with an absolute predominance of deciduous forests with *Quercus*, *Corylus*, exclude the Eemian origin.

A paleogeographic location of these sediments and succession of described flora clearly correspond with a fossil flora from Krępiec (Janczyk-Kopikowa 1981), Nowiny Żukowskie (Dyakowska 1952), Ciechanki Krzesimowskie (Brem 1953), Syrniki (Sobolewska 1956) and Gościęcin (Środoń 1957). A fossil flora from these sites is ascribed to the Mazovian Interglacial.

An explanation of development trends, identified in the pollen zone B.P.-F — *Pinus*, *Picea*, *Alnus*, is an extremely important case in succession of interglacial flora from Biała Podlaska. A noted rise of *Pinus* (present in all diagrams) after a maximum of *Taxus* (yew phase) and before a phase of *Carpinus-Abies* assemblages, is difficult to be explained. Its reasons are to be found in climatic as well as edaphic factors.

A succession of fossil flora of this age from other sites of Poland presents a similar phenomenon (Janczyk-Kopikowa 1981, Środoń 1957). But it should be underlined that in the flora from Krępiec after a yew phase and before a hornbeam-fir phase, there is also (but a rise of *Pinus*) a very distinct rise of *Picea* which is sensitive of atmospheric and soil droughts (see Tomanek 1966), and a distinct expansion of *Carpinus*. A climatic drying could be very insignificant, felt by *Taxus* but still stood by *Picea*. The latter seems, however, improbable as *Picea* in a fossil flora from Krępiec indicated in that time a distinct trend of rise in local phytocoenoses.

These reasons seem to have been of edaphic origin. The only tree that could replace the predominant (in forest assemblage) *Taxus* during unfavorable climatic conditions, is supposed to be represented by *Pinus*. It could suffer its occasional shadow and root secretions. Such a suggestion is based on observations of present *Taxus* assemblages which is not accompanied by other plants in the vicinity. In such a situation there would be no sufficient evidence to accept a bipartity of this interglacial and only an idea of its two phases or stages is possible. A role played by climatic, edaphic and other factors in trends of floristic transformations remains still uncertain. A wider analysis and more complete evidence are difficult as, independently on age, there are only few sites in Poland with the Quaternary fossil flora in which a high content of *Taxus* is noted. Amongst these sites with the Eemian flora there is only the one at Imbramowice (Mamakowa 1976), and with the Mazovian flora: Krępiec Janczyk-Kopikowa 1981), Gościęcin (Środoń 1957) and Komarno (Krupiński — MS). At Krępiec, Gościęcin, Komarno and Biała Podlaska a transitional post-yew and pre-hornbeam-fir rise of pine is very distinct and can be distinguished without any doubts. Similar succession trends can be expected in a suitable part of a pollen diagram of the Mazovian fossil flora from Ciechanki Krzesimowskie (phase II/III, Brem 1953) in which no yew was noted but its presence is proved by macrofossils. A similar rise of pine is distinct at the turn of phase II/III in pollen diagrams from Olszewice, Syrniki (Sobolewska 1956) and to a smaller degree at Wylezin (Dyakowska 1956), Maków Mazowiecki (Gołąbowa 1957), Barkowice Mokre (Sobolewska 1952) and Nowiny Żukowskie (Dyakowska 1952, phase B/C) in which any yew was found. In the Eemian flora from Imbramowice (Mamakowa 1976) a similar yew-pine dependency cannot be noticed.

Taxus baccata which occurs in Poland now, belongs to trees with small edaphic demands. Only dry and barren soils are not suitable for a yew but it grows well on marshy and peaty ones. It bears shadow and in unfavorable conditions even needs it. The northern extent of yew includes the western part of the Scandinavian Peninsula and part of Alaska whereas in the south, passes equator in Indonesia (Seneta 1981).

Pollen grains of yew are very hardly determinable and many a time their identification is doubtful, even with a use of the present light microscopes. Separating capacities of microscopes that were used in Poland 30—40 years ago, were considerably lower. For this reason there is no doubt that they could be omitted or considered for indeterminate in spite of good intentions and high competence of scientists. Besides these pollen grains are folded, twisted and do not possess distinct identificatory features. So a presence of yew in the flora of Poland seems to be partly proved for the Mazovian succession but it calls for further supplements and investigations.

FINAL REMARKS

In the site Krępiec, Lublin Upland, the Mazovian Interglacial is TL dated for 460—330 ka (Wojtanowicz 1984) and in a faunistic site Draby near Częstochowa for 440—320 ka by FCl/P method (Głazek et al. 1976).

In the European part of the Soviet Union it corresponds to the Likhvin Interglacial, among others analyzed in the Chekalin section (Ushko 1959). It was dated there by TL method for 459 ± 56 ka to 318 ± 33 ka (Sudakova & Aleshinskaya 1974). In the Krukienicze section to the west of Lvov, it was TL dated by Shelkoplyas for 387.09 ± 52.444 ka to 322.58 ± 58 ka (Bogutskiy et al. 1980).

In German Democratic Republic this period corresponds with the Holstein Interglacial, among others represented by Wuthenow and Pritzwalk sections (Cepek & Erd 1975, Erd 1978).

A floristic succession of the Krępiec type recorded from sediments of the site Biała Podlaska, enabled to considered it for the equivalent of the Mazovian Interglacial, expressed here by 5 periods of vegetation development. This interglacial corresponded to a worldwide climatic warming, recorded from deep-sea sediments as the horizon ^{18}O dated for 440—367 ka (Shackleton & Opdyke 1973). A duration of its optimum is evaluated for 15—16 ka (Müller 1974).

Sediments of this interglacial in the Biała Podlaska area are covered by a single till or its residuum and by younger valley deposits. This till is connected by the authors with occupation of this area by the ice sheet of the Odra Glaciation, responsible probably also for erosion and deformation of the top part of interglacial series. No evidence for the younger advance of the Scandinavian ice in this area seems to speak for a smaller extent of the Warta Glaciation (Stadial) than suggested by Nowak (1973, 1974, 1977) and Baraniecka (1984).

Due to a diagenesis at high pressure and low temperature the primary (before ice sheet advance) interglacial lake sediments of a sapropel type have been transformed into intensively pressed and deformed well-bedded bituminous shales with a very good frequency of pollen material.

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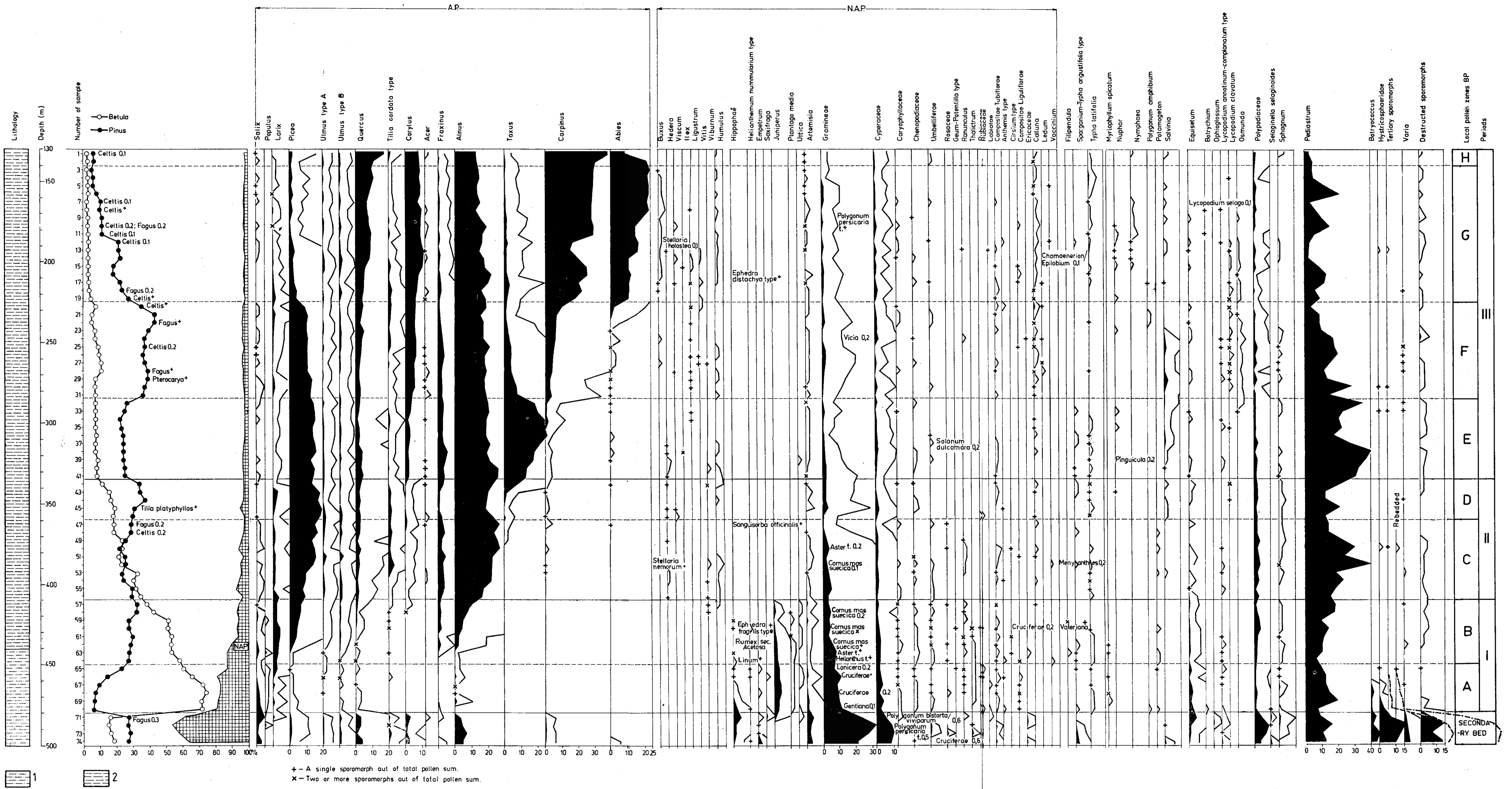
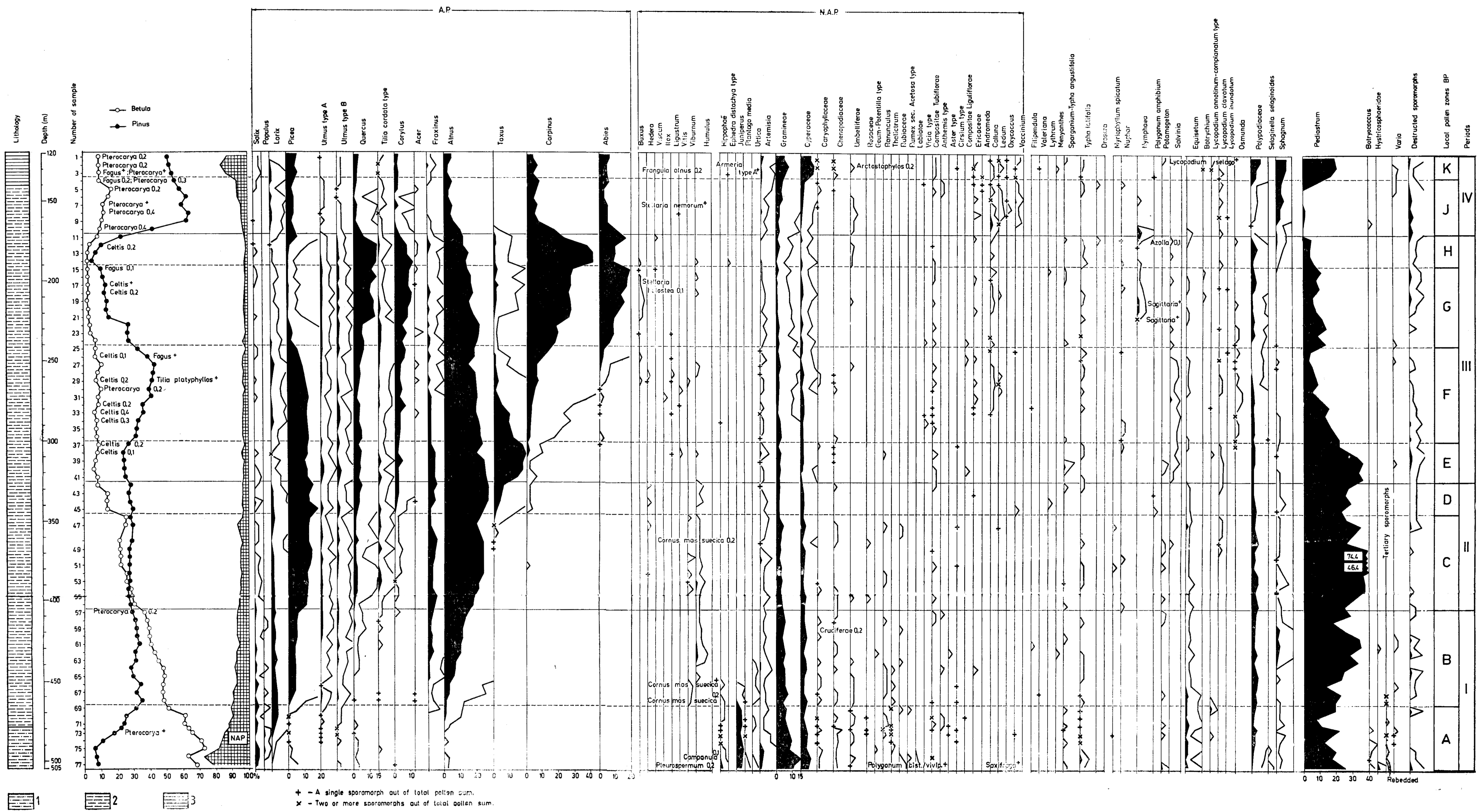


Fig. 4. Biała Podlaska. Palynologic diagram of the section 1/84. 1 — silts, 2 — bituminous shales



+ — A single sporomorph out of total pollen sum.
× — Two or more sporomorphs out of total pollen sum.

Fig. 5. Biała Podlaska. Palynologic diagram of the section 2/84. 1 — silts, 2 — bituminous shales, 3 — blue clay