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Łódź

VEGETATION OF UPPER VISTULIAN COLD PHASES IN CENTRAL POLAND

Abstract

The paper shows the results of palynological analyses refering to organic horizons, in most cases dated by ^{14}C, from the Middle and Upper Plenivistulian in the area of Central Poland. The period being comparable with the Denekamp Interstadial was characterized by the shrub tundra conditions. The grass tundra with not entirely compact cover is dated at about 21,000 years BP. The optimum of last glaciation (about 17,100 BP) was followed by very poor, pioneer communities with grasses and sedges prevailing. Afterwards, i.e. about 16,200 years BP, yet poorer communities of cryptogams could have dominated.

INTRODUCTION

The Eemian Interglacial and the beginning of Early Vistulian are recorded in the continuous pollen diagrams at many sites of Poland (JANCZYK-KOPIKOWA, 1965, 1966; DYLIK, 1968; KLATKOWA, 1972; JASTRZĘBSKA-MAMEŁKA, 1984; KUPRYJANOWICZ, 1991). Whereas the sites reflecting the Eemian period and complete or almost complete early Vistulian are not so common (BITNER, 1954; ŚRODOŃ, GOŁĄBOWA, 1954; BORÓWKO-DŁUŻAKOWA, 1960; JASTRZĘBSKA-MAMEŁKA, 1985; TOBOLSKI, 19991).

Approaching the optimum of last glaciation the organic horizons, and consequently the ^{14}C datings, become less frequent (GOŹDZIK, PAZDUR, 1987). The record of Middle Plenivistulian is preserved at few dated sites in the shape of isolated mineral or mineral-organic layers (ROTNICKI, TOBOLSKI, 1965, 1969; PAZDUR, STANKOWSKI, TOBOLSKI, 1980; MANIKOWSKA, BALWIERZ, 1987; ŚRODOŃ, 1987a, b; MANIKOWSKA, 1992, 1993; KRZYSZKOWSKI, BALWIERZ, PYSZYŃSKI, 1993). The palynological data on dated Upper Plenivistulian horizons are still scarcer, nevertheless available (PAZDUR, STANKOWSKI, TOBOLSKI, 1980).

Presented paper concerns the results of palynological analyses of the Middle and Upper Plenivistulian organic horizons from Central Poland.

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METHODOLOGICAL APPROACH

All samples were boiled with 10% KOH, afterwards treated with hydrofluoric acid (FAEGRI, IVERSEN 1975) and finally determined by means of the acetolysis method (ERDTMAN, 1943).

The percentage of individual taxa was calculated in relation to the pollen sum of trees and shrubs (AP) and herbaceous plants (NAP). *Pediastrum* and *Botryococcus*, spores of mosses and ferns, unidentified grains i.e. the unknown ones, the corroded ones and the others, such as crumpled grains, thus the ones that are non-determined for the other than corrossion reasons, did not enter into the calculations.

Due to low and very low frequency of the pollen grains and majority of the NAP grains, not the AP sum but the counted area (no less than 4 cm^2 was studied) was the criterion of the sample count. The results of analysis are shown in the pollen diagrams. The "rebedded sum" refers to the sum of pollen grains of the thermophilous trees, which in general occur singly (*Ulmus, Corylus, Carpinus, Quercus, Tilia), Abies* and *Picea*. The "pollen sum" column is placed separately from the curves of taxa that are involved in the AP + NAP sum. The Bełchatów II, III, IV diagrams were drawn at a scale of 1 : 1, whereas the Bełchatów 1985 Ib diagram at a scale of 1 : 10.

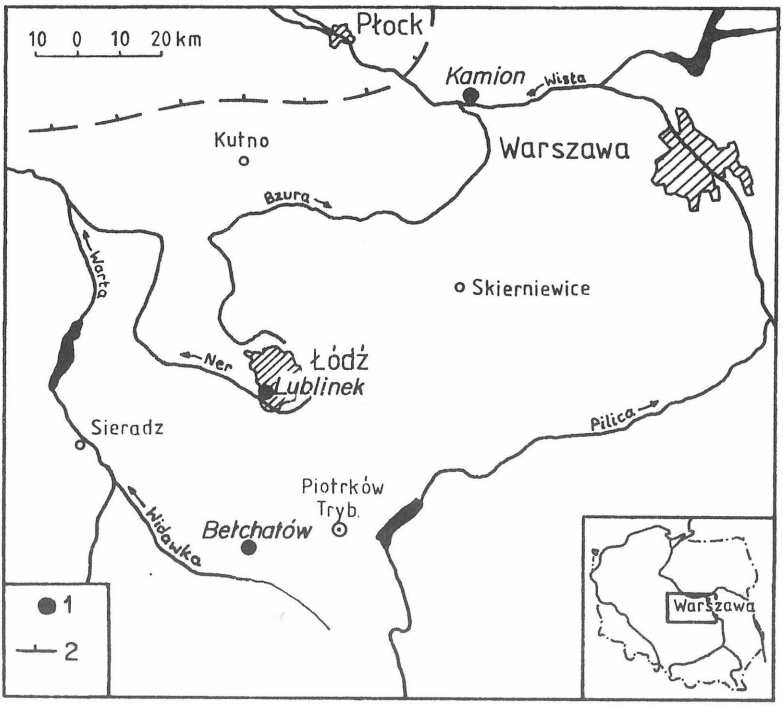

Fig. 1. Location of studied sites
1 – studied site; 2 – southern limit of the Vistulian ice sheet

Only the Bełchatów 1985 Ib diagram offered an opportunity to identify the local assemblage zones (PAZ). With the other diagrams, due to the slight variation of curves, there is no such division.

Palynological analysis was carried out for the deposits from the "Bełchatów" opencast mine (Bełchatów 1985 Ib, II, III, IV, Wola Grzymalina 35, Kleszczów 2), from the Lublinek site and the Kamion site (Fig. 1). The results of palynological analysis at the Wola Grzymalina 35 and Kleszczów 2 sites were published earlier (KRZYSZKOWSKI, BALWIERZ, PYSZYŃSKI, 1993). With the exception of Bełchatów 1985 Ib, each site was dated by means of the radiocarbon method.

All deposits called here "Bełchatów" are derived from the aggradational series, which is a member of the dry valleys' infilling; these forms join the Świętojańka valley – a tributary of the Widawka river (MANIKOWSKA, 1993). Bełchatów 1985 Ib and Bełchatów II deposits come from the same valley but their position differs, Bełchatów III and IV – from different valleys. Further data on the geological setting as well as lithology are available in the MANIKOWSKA (1992) article.

RESULTS OF PALYNOLOGICAL ANALYSIS

Bełchatów 1985 Ib – undated layer which lies between erosional series – at the bottom and peat series dated at 32,700 ± 900 BP – at the top (MANIKOWSKA, 1993). It is the silt layer, about 1 m thick, with varying content of organic matter. 20 samples were taken, and 7 of them, i.e. these richest in organic remains, from the bottom part, were palynologically examined. The results are depicted in Fig. 2.

All samples are characterized by very low frequency, the great quantity of corroded grains and the high content of NAP pollen grains. The *Picea* curve reaches up to 14.2%, *Betula* up to 9.1%, but generally the values are lower.

Cyperaceae–Selaginella–Botrychium PAZ (samples no 14–18). The curves of *Cyperaceae* pollen grains (60.3%), *Selaginella* (10.3%) and *Botrychium* (13.6%) achieve the maximum values. The *Artemisia* curve, except for the sample no 18, comes to a few percentage. The values of *Helianthemum* are the highest within this zone.

Salix–Cruciferae PAZ (samples no 10–12). The AP curve rises due to the increase of *Salix* pollen up to 35.0%. The *Artemisia* curve maintains, more or less, at the same level as in the previous horizon. The *Cruciferae* pollen grains in considerable numbers occur. This curve appears and achieves the maximum point in the sample no 14 (12.1%).

Accumulation of the studied deposit took place under the treeless tundra conditions. At first the herbs and cryptogams dominated, afterwards

the considerable share of *Salix* shrubs appeared. Such alternation could have resulted from the warming and the transition from the Middle Arctic climate (*Cyperaceae–Selaginella–Botrychium PAZ*) to the Low Arctic one (*Salix–Cruciferae PAZ*).

Bełchatów II – organic layer dated at 32,700 ± 900 BP. This layer belongs to the older aggradational series (MANIKOWSKA, 1992) and rests in the same valley as the layer described above, but in the other cross-section. The preliminary results of the palynological analysis were published earlier (MANIKOWSKA, BALWIERZ, 1987). Samples were collected from an 11 cm thick layer containing peat, peaty silt and organic silt. Six out of the 16 taken and prepared samples entered into the calculation. The results are shown in Fig. 3. Examined samples are characterized by fairly high frequency of pollen grains, which are well preserved, the content of warm-demanding species is insignificant (rebedded sum in the diagram). The pollen diagram reveals the very small quantity of tree and shrub pollen (2.4–12.9%). They are mainly the *Pinus* pollen grains (from 1.0 up to 7.4%) and *Betula* (from 1.0 up to 4.8%). Shrubs are represented by the *Salix* and *Juniperus*, their curves reach up to over 2.0%. Individual grains of *Betula cf. nana, Hippophaë, Ephedra fragilis* and *Ephedra distachya* occur.

The pollen grains of herbaceous plants are widely represented. The *Cyperaceae* (38.5–81.4%) and *Gramineae* (12.2–37.9%) grains dominate. The *Artemisia* curve achieves 4.0%, the values of *Cruciferae* range from 1.3 to 5.7%. The *Rubiaceae* and *Thalictrum* curve is constant, whereas the *Caryophyllaceae* and *Chenopodiaceae* one is almost constant. In the highest sample, where the *Helianthemum, Armeria, Polygonum viviparum, Saxifraga t. oppositifolia* pollen grains occur, the variety of herbaceous plants is striking.

Therefore the conclusion can be drawn that the fairly compact treeless tundra, which was not restricted only to the wet habitats, dominated. The pollen flora composition indicates that also the dry and slightly wetter grounds, the sandy and poor in humus areas were covered with the vegetation. *Artemisia, Armeria, Saxifraga oppositifolia, Papaver, Gentiana, Juniperus* and very likely a lot of species of the *Cruciferae, Rubiaceae, Caryophyllaceae* families grew. Richer and wetter habitats favoured the *Thalictrum* development. The bog was abundantly overgrown with sedges and mosses, as well as *Betula* nana was present in this environment. Willows, *Salix* shrubs here, could have occupied the places in which the humus content was differential, however they were rather wet habitats. The wetter and most differentiated in humus soils were covered with grasses.

Continuous though decreasing upwards the *Artemisia* share and the *Ephedra distachya* and *E. fragilis* grains in the middle part of diagram indicate cool, Low Arctic climate[1] conditions, initially under the continental-

[1] Terminology after TOBOLSKI (1991).

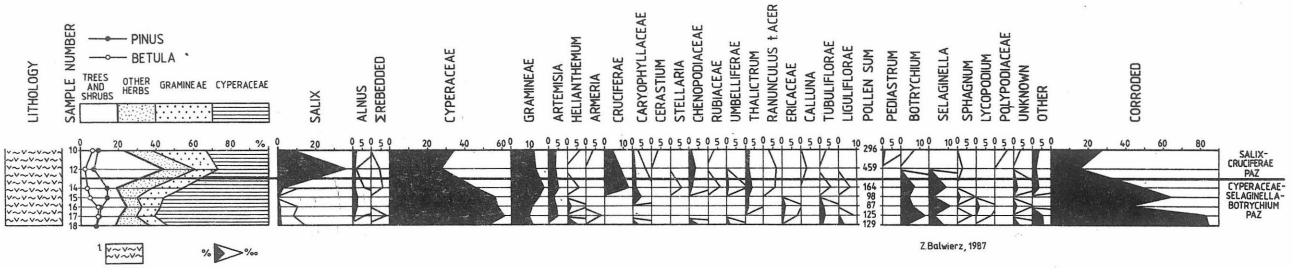

Fig. 2. Bełchatów 1985 Ib. Pollen diagram

1 – organic silt

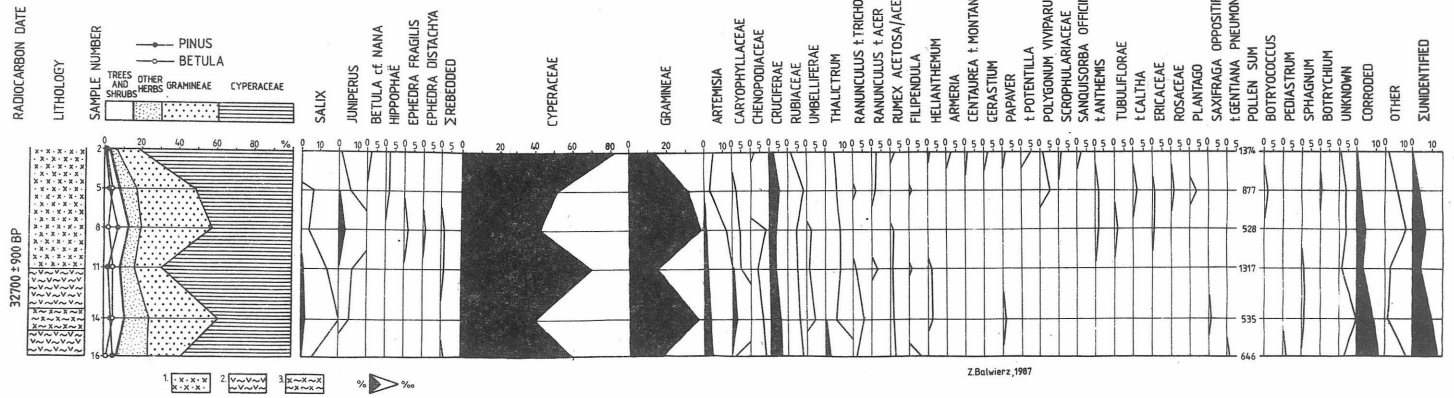

Fig. 3. Bełchatów II. Pollen diagram

1 – sandy peat; 2 – organic silt; 3 – peaty silt

ity control. It is conceivable that the greater quantity of the *Juniperus* pollen grains (sample no 8) resulted from slight warming, nevertheless the highest sample, in which taxa of herbaceous plants increase and the *Polygonum viviparum* appears, would indicate re-cooling. In the KOLSTRUP (1980) opinion 3.0–5.0% *Juniperus* pollen grains point to the presence of large forms (not the dwarf ones) since they yield more pollen which are scattered over a wider area. At the Bełchatów II site the values approximate 3.0%. Assuming that the *Juniperus* pollen grains were produced by the shrub forms, the discussed horizon would be a more definite proof of warming, thus such climatic conditions, in which the mean temperature of July exceeds 10°C (IVERSEN, see: KOLSTRUP, 1980).

Bełchatów III – organic layer dated at 32,600 ± 1,300 BP (humin acid) and 33,900 ± 2,600 years BP (insoluble fraction) (MANIKOWSKA, 1992). This layer, likely as in the previous two cases, is a member of aggradational series. During the field procedure 10 samples from about 20 cm thick organic layer were collected. Six samples from very slight sandy peat and organic silt were prepared in the laboratory and counted.

The frequency of pollen grains is considerable, the content of corroded grains ranges from 5.3% to 11.5%. The palynological pattern (Fig. 4) approximates to Bełchatów II. The pollen grains of herbaceous plants dominate (from 82.2 up to 92.0%), especially *Cyperaceae* and *Gramineae*. The AP curve shows mainly *Betula* and *Pinus*, both *Pinus haploxylon* and *P. cembra*. At the top part of diagram the AP curve comprises also the *Salix* and *Betula t. nana* pollen grains.

Except for *Cyperaceae* and *Gramineae*, the composition of herbaceous pollen grains nearly repeats the Bełchatów II pattern, thus *Artemisia, Polygonum bistorta/viviparum, Polygonum viviparum, Armeria, Helianthemum, Cruciferae, Rubiaceae, Caryophyllaceae, Thalictrum, Sanquisorba officinalis*. Therefore it seems reasonable to assume similar plant communities and similar climatic conditions.

Wola Grzymalina 35 – organic layer dated at 31,800 ± 700 BP and 3,800 ± 2,000 BP. Its geological position and ^{14}C dates were provided by KRZYSZKOWSKI (1990), whereas the results of pollen analysis and studies on macrofossils were published in the article by KRZYSZKOWSKI, BALWIERZ, PYSZYŃSKI (1993).

The palynological pattern displays similarities to the Bełchatów II and III. The 4 examined samples reveal distinctive domination of the NAP pollen grains. The AP curve keeps within a 10% limit and consists of the small quantity of arboreal pollen (*Pinus* and *Betula*) and of the small, though constant amount of shrubs *Betula t. nana* and *Salix*. Besides the *Cyperaceae* and *Gramineae* prevailing, the herbaceous plants are represented by the continuous curves of *Artemisia* and *Cruciferae*. The pollen grains of *Helianthemum, Polygonum bistorta/viviparum, Saxifraga t. oppositifolia, Sanquisorba officinalis* are present.

According to the analysis of macrofossils by PYSZYŃSKI (KRZYSZKOWSKI, BALWIERZ, PYSZYŃSKI, 1993) the plant remains numerously occur, although the material is not varied at all. The bottom sample contains mainly the fragments of *Drepanocladus sp.* and *Calliergon sp.* mosses (about 70%), the rest belongs to *Cyperaceae* and *Gramineae*. In the top sample such fragments of *Cyperaceae* as roots and seeds prevail. Besides, the remains of mosses and grasses have been found. The analysis shows that the studied deposit, namely sedge-moss peat, originated under continously wet conditions, nevertheless the constituents of its bottom part point to a drier environment. The remains of trees are absent. Therefore the arctic climate, and consequently the treeless tundra with the small share of dwarf shrubs dominated.

Kleszczów 2 – two layers dated at 26,900 ± 500 BP (upper) and 29,200 ± 1,100 BP (lower) (KRZYSZKOWSKI, 1990; KRZYSZKOWSKI, BALWIERZ, PYSZYŃSKI, 1993).

Due to very low frequency of pollen grains and considerable quantities of corroded grains the material is practically worthless for palynological purposes. Some identified grains indicate predominance of the herb pollen, including *Cyperaceae* and *Gramineae*. The occurrence of individual *Artemisia* pollen and *Selaginella* spores implies that the deposit might have originated in cool climate conditions with the discontinuous limited vegetation.

Bełchatów IV – organic layer dated at 21,200 ± 220 BP (MANIKOWSKA, 1992). Three samples were taken from about 6 cm thick peat with considerable sand admixture. The results of analysis are shown in Fig. 5.

The pollen grains are fairly frequent, whereas the amount of corroded grains is relatively low (below 4%). The AP pollen have here the lowest values among all diagrams presented so far – 1.1–5.1%. Herbaceous plants are represented mainly by the *Gramineae* pollen grains (71.0–95.2%). *Cyperaceae* amounts only from 3.4 to 23.3%. Variety of taxa of the other herbaceous plants is slight as well as their percentage is minimal. Following indicator plants have been recognized: *Artemisia, Helianthemum, Polygonum bistorta/viviparum.*

Both the slight variety of species and the appreciable admixture of mineral material in the peat point to poor vegetation. The vegetation was loose and restricted to the wet habitats. As opposed to the above presented sites, sand hence drier grounds were probably free of plants. Mineral material was easily winnowed and carried, among others, to the area covered with plants, where was accumulated. That is why the appreciable admixture of sand in the discussed deposit occurs.

Lublinek – purification plant – the layer dated at 21,720 ± 200 BP (TURKOWSKA, 1992). Two samples from the silty sand with organic admixture were examined; the results are shown in Fig. 6. The samples

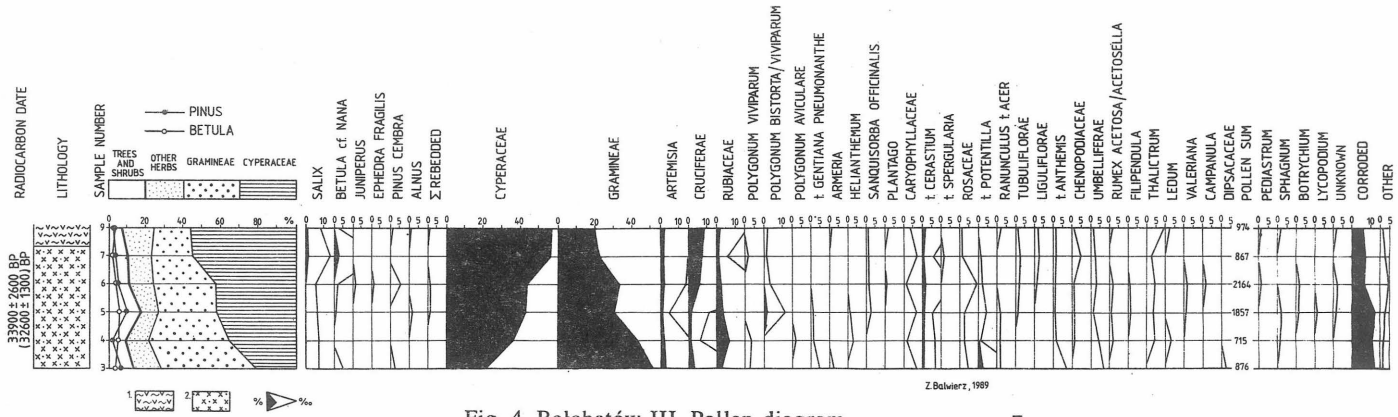

Fig. 4. Bełchatów III. Pollen diagram

1 – organic silt; 2 – sandy peat

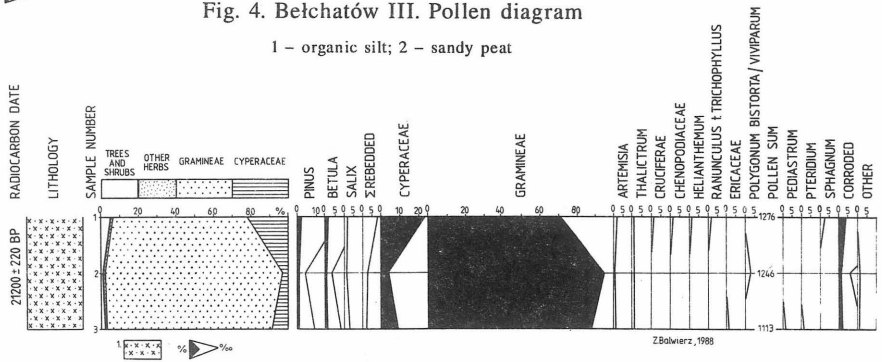

Fig. 5. Bełchatów IV. Pollen diagram

1 – sandy peat

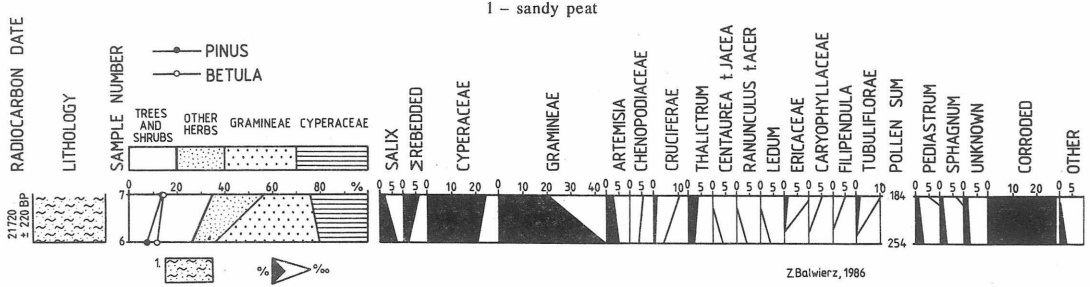

Fig. 6. Lublinek–purification plant. Pollen diagram

1 – sandy silt

are characterized by very low frequency (sample no. 7 – 184 identified pollen grains and 54 unidentified grains in 8 cm^2) and great quantities of corroded grains. The pollen grains of warm-demanding trees (rebedded sum in the diagram) are here more common (*Ulmus, Carpinus, Quercus, Corylus, Tilia*), which along with the mentioned low frequency result in their high percentage.

The pollen grains of herbaceous plants, mainly *Cyperaceae* and *Gramineae* constitue most identified grains. There occurs also a few percentage of the *Artemisia* and *Thalictrum* grains, whereas the *Tubuliflorae, Ericaceae, Cruciferae, Caryophyllaceae, Filipendula, Chenopodiaceae, Ledum, Ranunculus t. acer, Centaurea t. jacea* values equal 1% or less.

The ground was covered with plants only occasionally. Willows, some species of grasses and sedges inhabited the wetter places only. The absence of the pollen grains of indicator plants makes more detailed conclusions difficult. The occurrence of *Centaurea t. jacea* supports the common appearance of grass communities because most current *Centaurea* species grows in such complexes.

Lublinek – station – the tributary fossil valley – the layer dated at 17,100 ± 200 BP (TURKOWSKA, 1992). The slightly organic silty sand was sampled. Four out of 5 taken samples were prepared in the laboratory. The samples no 1 and 4 were counted whereas the samples no. 2 and 3 were only scanned. The results are set out in Table I.

Since pollen grains are infrequent and generally poorly preserved, the samples are not suitable for the palynological analysis. In the sample no. 1 the pollen grains of shrubs and trees prevail (73.1%). There are the same quantities of the *Pinus* and *Betula* pollen grains (23.4%) and the *Alnus* pollen grains (18.6%). The *Juniperus* and *Salix* pollen grains are present as well. Herbaceous plants are represented, first of all, by the *Cyperaceae* pollen grains (8.9%). Relatively great quantities of the *Helianthemum* pollen is noteworthy.

The content of AP pollen grains in the sample no 4 equals only 23.0%. They are almost exclusively the *Pinus* and *Betula* pollen. The *Cyperaceae* (43.6%) and *Gramineae* (23.0%) pollen grains are most numerous among herbaceous plants. The grains of *Artemisia, Armeria, Helianthemum* and *Gentiana t. pneumonanthe* have been recorded too.

Dealing with the interpretation of results among others the ratio between AP and NAP pollen grains is essential. Thus, it seems that the two last samples are worth considering in details. In both samples a great quantity of corroded grains have been registered. Such grains are not involved in the AP + NAP sum, in relation to which the percentage of identified grains is calculated. In the vast majority of cases the pollen grains of herbaceous plants, which are varied and more difficult to identify, are corroded. Even slight corrosion resulting in destruction of the sculpturing

Lublinek–station. Absolute quantities of pollen grains

Table I

TAXON	Sample no. 1		Sample no. 4	
	Quantity of pollen grains	%	Quantity of pollen grains	%
Pinus	34	23.4	18	6.4
Betula	34	23.4	45	16.0
Juniperus	4	2.8	–	–
Salix	2	1.4	1	0.3
Alnus	27	18.6	1	0.3
Abies	1	0.7	–	–
Corylus	1	0.7	–	–
Ulmus	3	2.0	–	–
ΣAP	106	73.0	65	23.0
Cyperaceae	4	2.8	123	43.6
Gramineae	13	8.9	65	23.0
Helianthemum	9	6.2	1	0.4
Artemisia	3	2.1	13	4.6
Filipendula	3	2.1	–	–
Calluna	2	1.4	–	–
Ericaceae	2	1.4	–	–
Rosaceae	1	0.7	2	0.7
Ranunculus t. trichophyllus	1	0.7	–	–
Papilionaceae	1	0.7	–	–
Armeria	–	–	1	0.4
Gentiana t. pneumonanthe	–	–	1	0.4
Caryophyllaceae	–	–	3	1.1
t. Anthemis	–	–	3	1.1
Liguliflorae	–	–	1	0.3
Cruciferae	–	–	1	0.4
Umbeliferae	–	–	1	0.3
Rubiacae	–	–	2	0.7
ΣNAP	39	27.0	217	77.0
Botrychium	2	1.4	2	0.7
Polypodiacae	3	2.1	–	–
Sphagnum	–	–	1	0.3
Corroded	145	99.9	192	68.1
Others	2	1.4	5	1.8

of the pollen grain makes the identification very difficult and uncertain or impossible. The arboreal pollen are more distinctive, thus the identification is easier. That is why, as mentioned earlier, most corroded grains belongs to the herbaceous pollen. Supposing the corroded grains were included into the AP + NAP sum as the NAP, and afterwards the percentage of AP and NAP was calculated, it would appear that this percentage is appreciably higher than the values in Table I. Thus, the communities of herbaceous plants, particularly sedges and grasses dominated, which certainly occupied no entire area but only the wettest habitats.

Lublinek - station – the tributary fossil valley – the layer dated at 16,200 ± 200 BP (TURKOWSKA, 1992). The most organic horizons of about 60 cm thick layer were sampled; only 1 out of 6 taken samples was palynologically examined. The sample is derived from the dated C horizon.

On the slide 2 cm^2 in area 70 sporomorphs were found, but as many as 53 grains were useless due to destruction. The rest (21) of sporomorphs has been as follows: 7 – *Betula*, 1 – *Pinus*, 1 – *Carpinus*, 1 – *Cyperaceae*, 1 – *Cruciferae*, 1 – *Gentianaceae*, 1 – *Sphagnum*, 4 – *Botrychium*. Such spectrum does not provide with sufficient information from which to draw conclusions on the vegetation, however relatively great amount of the *Botrychium* spores is worth pointing out.

Kamion – the top of terrace, dated at 14,500 ± 270 BP (MANIKOWSKA, 1985). From the soil accumulation horizon 3 samples were taken and prepared, while only 1 was counted. On the slides (12 cm^2) following sporomorphs have been recognized: *Betula* – 116, *Pinus* – 2, *Corylus* – 1, *cf Centaurea* – 1, *Polypodiaceae* – 4, corroded – 10. Interestingly, despite very low frequency there is not a lot of corroded grains (8.0%). The great quantity of the *Betula* pollen is noteworthy as well. The slide contains much of amorphous material, most probably of plants, in addition to pollen grains, charcoal and the fragments of tracheae. In the other sample from the same layer WASYLIKOWA (MANIKOWSKA, 1985) found the small quantity of corroded grains and the appreciable admixture of Tertiary sporomorphs, thus obviously such material has no value.

STRATIGRAPHIC SETTING OF THE STUDIED DEPOSITS THE PATTERN OF VEGETATION

MIDDLE PLENIVISTULIAN

The undated layer of the Bełchatów 1985 Ib site is the oldest among studied horizons. Accumulation of the underlying older aggradational series took place between 45,000 years BP and 20,000 years BP (MANIKOWSKA, 1992). The age of the Bełchatów peat horizon lying above is estab-

lished at 32,700 ± 900 years BP. Thus, the 1 m thick organic silt Bełchatów 1985 Ib could have been deposited between 45,000 years BP and 32,000 years BP, i.e. in the period corresponding to the Moershoofd Interstadial complex and the Hengelo Interstadial (VAN DER HAMMEN, WIJMSTRA, 1971).

The Bełchatów 1985 Ib diagram exhibits the vegetation type cooler than the Piaski Formation dated at 43,700 + 3,700, −2,400 BP (BARANIECKA, 1980) and the flora dated at more than 42,000 years BP at Maliniec (PAZDUR, STANKOWSKI, TOBOLSKI, 1981; TOBOLSKI, 1991). Both dates correlate with the Moershoofd Interstadial complex. According to the preliminary analyses by JANCZYK-KOPIKOWA (1980) the lacustrine deposits at Piaski reveal glacial flora features, nevertheless the forest tundra record in the series above and beneath is conceivable. Basing on the JANCZYK-KOPIKOWA (1980, 1985) publications KRZYSZKOWSKI (1990) confirms it. The flora of Maliniec shows the complete interstadial cycle of vegetation development. In the optimum of this interstadial, under the subarctic conditions, the tundra with loose groups of *Betula* trees began to expand (PAZDUR, STANKOWSKI, TOBOLSKI, 1981; TOBOLSKI, 1991). Whereas in the warmer part of this period registered in deposits of the Bełchatów 1985 Ib site only the shrub tundra in the Low Arctic conditions was developed. Therefore it seems that the flora from Piaski and Maliniec and the flora from Bełchatów 1985 Ib are incomparable in age.

The vegetation from Bełchatów 1985 Ib site displays closer similarities to the vegetation of the Moershoofd Interstadial complex of the Netherlands (ZAGWIJN, 1974; KOLSTRUP, WIJMSTRA, 1977), where the forestless tundra also occurred.

Due to the lack of recognized flora of the Hengelo Interstadial in Poland its comparison with the Bełchatów 1985 Ib vegetation is difficult. Hence, there is nothing for it but to remain the formation of discussed horizon in the wide time-span – 45,000–32,700 years BP.

The dates obtained for the Bełchatów II, III and Wola Grzymalina 35 sites correlate their flora with the Denekamp Interstadial, i.e. with the last warm fluctuation of Middle Plenivistulian (VAN DER HAMMEN, WIJMSTRA, 1971; KOLSTRUP, WIJMSTRA, 1977). Despite some individual features, these sites reveal essential similarities. All of them are characterized by very small content of the AP grains, which are regarded either as the long-distance pollen (*Pinus, Betula*) or as redeposited (rebedded sum). Trees were absent, whereas shrubs dominated. Throughout accumulation of the deposit, or for a spell at least, the area remained under the shrub tundra conditions and the Low Arctic climate control. At each site abundant and recurrent taxa of the herbaceous plants of open cool communities have been found. Examples of the comparable vegetation, dated back to the Denekamp Interstadial, have been reported from the Kępno site (ROTNICKI, TOBOLSKI, 1965, 1969) as well as from the Netherlands (KOLSTRUP, WIJM-

stra, 1977; Kolstrup, 1980; Ran, 1990). The record in peat dated at 29,650 ± 650 years BP of the Sowliny site (the Western Carpathians) indicates the glacial flora (Środoń, 1987a). The vegetation dated at 30,500 ± 700 years BP at the Sadowie site (the Miechów Upland) was developed under warmer conditions. Basing on the pollen spectrum obtained by Mamakowa, A.Środoń (1987b) assumes the occurrence of the park tundra with shrubs and trees growing individually or in groups (*Pinus cembra, Pinus sylvestris, Betula sp.*) in rather wet boreal climate. Very likely the trees of southern Poland must have been a source of grains which in the diagrams of Bełchatów vicinity are regarded as the long-distance pollen.

UPPER PLENIVISTULIAN

The ice sheet in the Upper Vistulian period expanded to the largest extent. Deteriorating climatic conditions, between the Denekamp Interstadial and 20,000 years i.e. the maximum ice advance, resulted in poor vegetation. Consequently, the organic horizons are absent, thus the ^{14}C dates are less frequent (Goździk, Pazdur, 1987). Such unfavourable conditions persisted until 13,000 years BP. Nevertheless the palynological investigations of deposits in the Netherlands (Kolstrup, 1980) evidence the Upper Plenivistulian plants. Also, at the sites of middle Poland the organic horizons with pollen flora have been preserved. The organic layers from Bełchatów IV and Lublinek-purification plant reveal nearly identical dates as well as the similar pattern of vegetation. There dominated the grass tundra, with the prostrate willows perhaps. However the ground was not densely carpeted with plants but only the wettest habitats were occupied. Due to the lack of continuous vegetation the other processes giving rise to the displacement of mineral deposits operated. The transitional climate, between Middle- and High Arctic, could have dominated. At the Maliniec II site the vegetation recorded in the layer dated at 22,050 ± 450 and 22,230 ± 480 BP indicates the moss tundra that was developed in the Middle Arctic climate (Pazdur, Stankowski, Tobolski, 1980; Tobolski, 1991). The inferences drown from the Maliniec site do not differ essentially from the ones from the Bełchatów IV and Lublinek-purification plant sites.

The samples from the Lublinek-station site (17,100 ± 200 BP) and from the Kleszczów 2 site (26,900 ± 500 and 29,200 ± 1,100 BP) are characterized by similar spectra (frequency, quality of pollen as well as identified taxa). Obviously these spectra suggest no similarity in age but the comparable environment and climate of deposition at the most. Very poor vegetation inhabited the wettest and quiet places.

Yet severer conditions must have controlled the formation of the layer dated at 16,200 ± 200 BP at the Lublinek-station site. The presence of

Botrychium is noteworthy. Besides the preparations described in details in the preceding paragraph some more samples deriving from the undated, though being at the same stratigraphic position layer, have been worked out. Significantly, the great quantity of spores, including *Botrychium*, occurs among few and mostly corroded grains. Hence, domination of the lower plants might be assumed.

No reliable information can be gathered from the spectrum of the Kamion site (14,590 ± 270 BP), nevertheless the case is interesting. The results obtained by WASYLIKOWA (MANIKOWSKA, 1985) and by the author of this article differ though the samples deriving from the same not uniform organic horizon were subjected to analysis. Although the author has registered the exceptionally high proportion of the *Betula* pollen grains, it does not mean that the birch forest dominated. Such kinds of spectra should be treated with extreme caution. On the other hand it seems that the analyses of such deposits should be continued and results compared. Nearly the same in age (14,000 ± 150 BP) organic horizon in Epe contains the pollen flora, therefore the vegetation existed (KOLSTRUP, 1980). Perhaps its remains will be found in Poland too.

CONCLUSIONS

Discussed organic horizons were deposited in the older part of Middle Plenivistulian, in Denekamp Interstadial and Upper Plenivistulian. None of presented diagrams include total closed cycle of vegetation development. All profiles from the mine dated back to Denekamp reveal remarkable similarities, namely each of them registered the stage of vegetation's development which was marked by the occurrence of shrubs. Also, the vegetation dated at 28,300 ± 900 BP at the Kalinko site (MANIKOWSKA, 1993) was characteristic for the shrub tundra (BALWIERZ – not published). The differences have been found in the order of stages in vegetational development as well as in the quantitative composition of particular taxa. All AP has been counted as belonging to the grains due to long-distance transport. Probably the trees of southern Poland (ŚRODOŃ, 1987b) supplied with this pollen. The middle Poland area in the Denekamp optimum was covered with forestless communities with shrubs developed under arctic conditions.

All horizons that are correlated with the Denekamp Interstadial are dated at about 30,000 years. However, neither two identical profiles nor two identical dates exist. The question raises the point whether the profiles reflect the vegetation of warmer fluctuations of perhaps not uniform in terms of temperature period, or they express the changes in the other elements of climate (e.g. humidity, presence or absence of snow, occurrence and force of wind) or the changes in habitat conditions (moisture of

substratum). Most tundra species has a wide distribution and wide variety of habitats (BESCHEL, 1970)(see: RAN, 1990). A temperature does not have to be the factor determining the occurrence of given species. For example, not only temperature but also existence and thickness of snow affect the presence of shrubs in tundra. Therefore, their absence may indicate the snowless winters, not the fall in temperature. In the light of obtained results it seems that differences registered in the Denekamp spectra illustrate no changes in temperature but the other ones. In general, there was the Low Arctic and, essentially, humid climate with the mean temperature of July about 10°C.

The organic horizons of the Bełchatów IV and Lublinek-purification plant sites (both dated at about 21,000 BP) are characterized by the discontinuous vegetation of grass tundra. Differences in the pollen spectra (frequency, amount of corroded grains, rebedded sum) can result from the habitat conditions and the manner of deposition. The appreciable admixture of mineral particles evidences greater intensity of mineral accumulation than during the Denekamp. Likely the Middle Arctic climate dominated.

The organic horizons at the Lublinek-station sites (17,100 ± 200 and 16,200 ± 200 BP) reflect very poor, pioneer vegetation. At first the communities were a little richer, with grasses and sedges prevailing. Afterwards cryptogams played a more important role. The vegetation occurred in mosaic pattern, namely it was restricted to the wettest and quiet places. At the Smerek site (the Western Bieszczady) dated at 16,925 ± 325 BP RALSKA-JASIEWICZOWA (1992) has found the remains of cool park vegetation with the groups of *Pinus cembra*, *Larix* and the subalpine brushwood of *Pinus mughus*, *Alnus viridis* and *Betula carpatica*. According to the authors of the recent publication (KRZYSZKOWSKI, CHOMA-MORYL, KUSZELL, MALKIEWICZ, PAZDUR, 1995) the open forest with heliophilous plants presumably occupied the Sudetic Foreland during the Upper Plenivistulian. It is possible that the trees existed in southern Poland throughout the Plenivistulian.

Certainly the lack of richer vegetation over a period of 7,000 years, i.e. between the maximum ice advance and the first palaeobotanically documented sites (TOBOLSKI, 1984; TOMCZAK, 1987), was a consequence of not only the temperature but also of the dryness of climate and the wind strength.

The palynological analysis of Plenivistulian deposits is difficult indeed. Considering the variety of factors involved, namely the property of deposit, the content of mineral particles, the amount of corroded grains and the frequency of pollen grains, the results require careful thought. Nevertheless, the results obtained so far encourage further studies on the vegetational history of this time. With a view of achieving a comprehensive

description of the environment it would be well to combine the palaeobotanical analyses with the studies on animals' remains and with the mineralogic analyses.

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