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Conditions for the accumulation of organic sediments in the lower section of the Wełnianka river valley (Dubienka Depression) at transition from the Vistulian to the Holocene*

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ABSTRACT**.** The paper presents the conditions for the accumulation of organic sediments in the valley of the lower Wełnianka river during the transitional zone between the Late Glacial and the Holocene on the basis of palynological and geological data, as well as radiocarbon dating. The lithological features of the development of organic sediments depended on the climatic and local conditions. The spatial genetic and lithological differentiation of valley sediments suggests the development of characteristic fluvial subenvironments in the valley of the lower Wełnianka river. In the flood basins, organic sedimentation developed, while within the meandering belt there was a fluvial deposition of mineral sediments.

KEY WORDS: pollen analysis, organic sediments, Late Glacial, early Holocene, Dubienka Depression, Poland

INTRODUCTION

During the survey connected with the elaboration of the Detailed Geological Map of Poland 1:50 000 – Dubienka sheet, a special attention was paid to the geological structure of the flood plain in the valleys of the Bug river and its tributaries (the Udal, the Wełnianka) within the Dubienka Depression. The detailed geological works carried out at the Dubienka Depression allowed to establish the fact that practically the whole flood plain consists of bipartite alluvial muds with the total thickness of 5–6 m. These Holocene deposits are accompanied by peats, which fill only the oxbows of grandradial meanders. The situation is very much different in the valleys of the Bug river tributaries: Holocene deposits are mainly peats, the thickness of which reaches 6 m (Harasimiuk et al. 1989a, b, 1993, Szwajgier 1998a, b). Organic deposits in the valleys of the Dubienka Depression have not aroused up till now any greater interest of the Quaternary researchers (Szafer 1952, Nakonieczny 1967, Szwajgier 1998b, 2002, Superson & Szwajgier 2000).

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MATERIAL AND METHODS

The archival palynological materials (description of sediments, pollen values and pollen diagram drawn in pencil) analysed by Dr M. Sobolewska, from the W. Szafer Institute of Botany PAS in Kraków have been used for interpreting the environmental changes in the Wełnianka river valley. Other material was obtained from a series of borings during the geological charting for the Detailed Geological Map of Poland 1:50 000, Dubienka sheet (Harasimiuk et al. 1989a), and manual borings for peat samples assignated to radiocarbon datings performed in 2001.

The samples for palynological analyses were prepared by standard procedures: calcareous sediments were treated with 10% HCl and silica was removed with hydrofluoric acid. All samples were prepared by the Erdtman's acetolysis method (Erdtman 1943) and stained with basic fuchsin and silicon oil. An average of above 500 AP was counted in each sample. Sporadically, in the case of very low frequency smaller numbers were counted. Percentage values were calculated from the pollen aggregate including trees, shrubs and herbaceous plants. The total excluded spores and pollen of aquatic and swamp plants. The results are presented as percentage diagram obtained with the use the POLPAL programme (Walanus & Nalepka 1999). Because of high frequency of *Pinus* (over represented taxon) and Cyperaceae, which is a local species, a simplified diagram was prepared with *Pinus* and Cyperaceae excluded from the total pollen sum.

In order to supplement the archival pollen data, peat from the Wełnianka river valley was ^{14}C dated. Datings obtained in the Radiocarbon Laboratory of Archaeology and Ethnography Museum, Łódź.

MORPHOLOGICAL CHARACTERISTICS OF THE CATCHMENT AND THE FLOOR OF THE WEŁNIANKA RIVER VALLEY WITHIN THE DUBIENKA DEPRESSION

Dubienka Depression is situated within the East-European platform (Fig. 1). The crystalline basement occurs at a depth of about 1000 m. The overlying thick cover of the Palaeozoic rocks underwent tectonic movements, which formed many horsts and grabens during the Breton and Asturian phases of the Variscian megacycle. The Palaeozoic cover is overlain by the series of Mesozoic rocks (chalk, marls, and opokas), and Cainozoic rocks (glacial, fluvial, and lacustrine deposits).

The main element of the relief of the lower Wełnianka catchment is a denudation plain descending towards the Bug and the Wełnianka river valleys (Fig. 1). This plain became

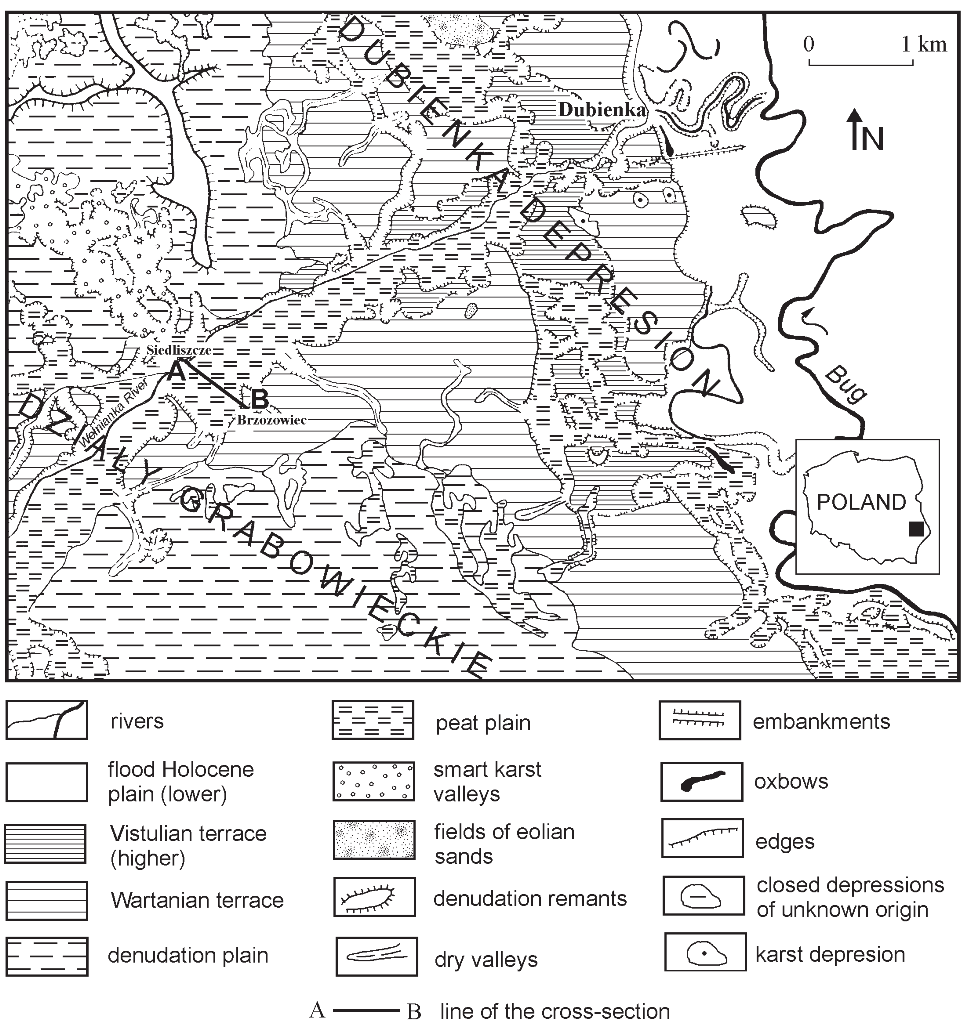

Fig. 1. Geomorphological scheme of the lower part of the Wełnianka catchment

more diverse due to the occurrence of shallow depressions of different size, where peats and mineral-organic muds accumulate presently. From the northern side, the denudation plain consists of a vast surface at the altitude of 177–185 m a.s.l. The plain is composed of the Cretaceous marls, covered in places by the Quaternary deposits. The relief of the plain abounds in numerous karst forms – dolines, uvalas, and small valleys, partially participating in surface drainage. Most of these forms are waterlogged and filled with organic deposits, which are not very thick. North of Siedliszcze there is quite a large sandy hill of denudation remnant character (Fig. 1). It might have been created as a result of relief inversion, with intensive karstification of Maastrichtian marls (Harasimiuk et al. 1995, 1997).

The Wełnianka river has its source in Rozkoszówka vicinity, south of Uchanie at the height of about 250 m a.s.l. In the upper part of its catchment the river and its tributaries gather the waters of the upland area, included by Maruszczak (1972) in Działy Grabowieckie (Grabowiec watershed). This fragment of the Wełnianka river is often called the Uchańka. The river is about 32 km long, and its average discharge is estimated at 0.7 m^3/s (Michalczyk & Wilgat 1998). The valley of the Wełnianka river cuts in the Cretaceous bedrock, which consists of resistant marls and opokas (siliceous limestones). Near Siedliszcze, where the Wełnianka river receives two left-side tributaries, it leaves the upland (Działy Grabowieckie) and enters the area of the Dubienka Depression.

Within the Dubienka Depression the width of the Wełnianka flat valley varies from about 1 km to 2 km, and the river flows in a regulated channel connected with a net of drainage ditches. Near Dubienka the valley narrows down to about 300 m. The river channel, crossing the Vistulian and Wartanian terraces of the Bug river, flows into it by one of oxbows. In the Dubienka Depression the river gradient equals 0.7 per mille (Szwajgier 1998b, 2002).

The surface of the valley floor is flat, though there are signs of little depressions, which evidence the exploitation of peat by the local population. It lasted till the 70's of the 20^{th} century. Some after-peat holes are waterlogged, and overgrown with osier. In the river channel, the peat layer covers the gyttja with shells, clayey gyttja, and gyttja with sand interbeds.

GEOLOGICAL STRUCTURE OF THE DEPOSITS FILLING THE VISTULIAN VALLEY

A geomorphological cross-section of the Wełnianka river valley (Fig. 2) was based on

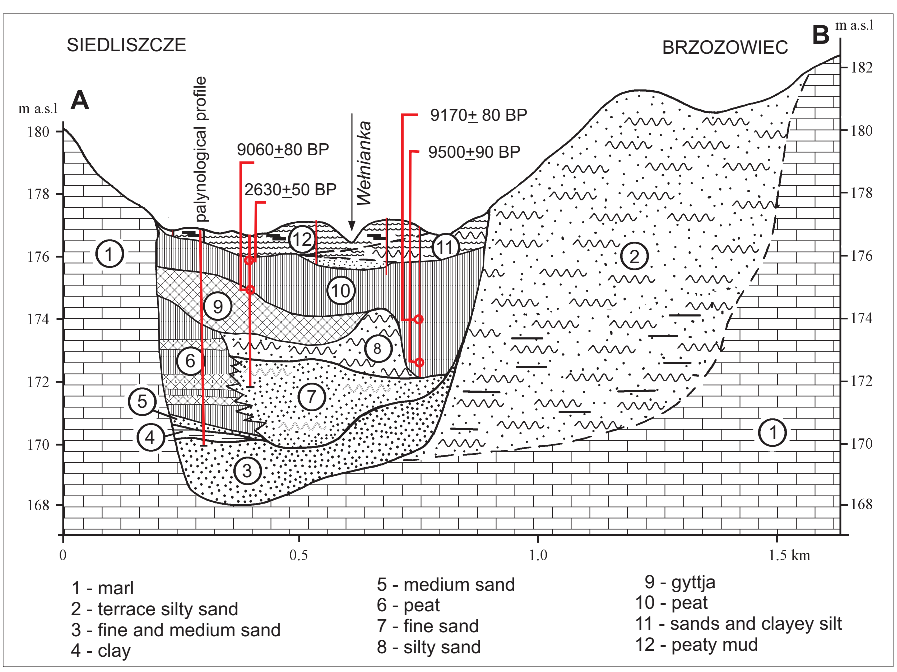

Fig. 2. A geological-morphological cross-section of the Wełnianka river valley near Siedliszcze

a series of borings made with a manual as well as a mechanical corer during the geological charting for the Detailed Geological Map of Poland 1:50 000, Dubienka sheet (791) (Harasimiuk et al. 1989a).

The line of the valley cross-section runs between two villages of Siedliszcze and Brzozowiec, about 10 km from the Wełnianka outlet to the Bug river. The floor of the valley is 700 m wide here. On the south-east side it is enclosed in a clear edge of the Wartanian terrace, several meters high, and on the opposite side the slope of the valley is rocky.

The Vistulian valley, about 9 m deep, has been eroded in the Wartanian deposits and Cretaceous marls filled with mineral and organic deposits (Fig. 2). On the rocky floor of the valley there is a series of medium- and fine-grained sands. At the north-west slope these sands are covered with thin layers of clays and sands, and in the remaining part of the valley – with a thick series of fine-grained channel sands, interfingering with peat. There are two more organic series: gyttja and peat above it. The top part of the filling consists of sands, silts and peaty muds.

LITHOLOGICAL FEATURES OF ORGANIC DEPOSITS

The lithological features of organic deposits, which occur in the north-west part of the Wełnianka river valley, were tested with three borings: Siedliszcze I, II and III. The description of the cores is given below.

Siedliszcze I	
25–30 cm	sedge peat, blackish-brown, slightly decomposed, with numerous rootlets
30–52 cm	sedge peat, dark brown but lighter than above, strongly decomposed, with irregular yellow laminae
52–160 cm	sedge peat, blackish, strongly decomposed, rather homogeneous, with light interbedding at 99–101 cm, downwards wetter and more plastic
160–232 cm	clayey gyttja, beige-brown with dark brown laminae, downwards lighter, with shells (very heterogeneous deposit, thin laminae of different colour and with different content of shells
232–325 cm	sedge peat, blackish, slightly decomposed, with numerous rootlets, homogeneous, laminae with shells at 280–282 and 292 cm
Siedliszcze II	
325–340 cm	sedge peat, blackish, strongly decomposed, with shells (as at 232–325 cm in profile I)
340–375 cm	clayey gyttja, grey-brown, with more numerous shells in the top part
375–425 cm	sedge peat, blackish, slightly decomposed, with numerous plant remains
425–469 cm	sedge peat, black-brown, strongly decomposed, downwards grey-brown, clayey. Heterogeneous, very hard deposit
469–513 cm	clayey gyttja with peat in the top part, black-brown, downwards lighter, grey-brown with beige laminae. Heterogeneous, hard deposit
513–533 cm	sedge peat, black-brown, downwards brown, with shells in the top part
533–545 cm	sedge peat, brown, strongly decomposed, with lighter laminae and sand
545–592 cm	clayey gyttja, light beige, hard deposit
592–625 cm	sedge peat, blackish-brown, strongly decomposed, downwards lighter, heterogeneous
625–630 cm	sedge peat, strongly decomposed, black-brown, water-logged
630–670 cm	sand, light beige
670–685 cm	clay, bluish, rather compact
685–725 cm	sand, yellowish-beige, with clay layers
Siedliszcze III	
575–585 cm	clayey gyttja, light brown with grey tint (it probably corresponds with the layer 545–592 cm in the profile II)
585–609 cm	sedge-moss peat, dark brown, downwards lighter, slightly decomposed, numerous plant remains (moss) (it corresponds with the layer 592–625 cm in the profile II)
609–629 cm	clayey gyttja, grey-brown
629–675 cm	sand, light grey with yellowish tint, water-logged

RADIOCARBON DATING

Peat samples for dating were collected from the borings made in the vicinity of the former research site. The results of the datings were presented below.

Sample	Depth in cm	Years ^{14}C BP/calibrated date	
Siedliszcze LOD 1150–1	40–50	2630±50	68.2% probability 2840BP (3.1%) 2830BP 2790BP (65.1%) 2710BP 95.4% probability 2860BP (87.3%) 2700BP 2640BP (2.8%) 2610BP 2590BP (3.7%) 2540BP 2530BP (1.6%) 2500BP
Siedliszcze LOD 1153–2	190–200	9060±80	68.2% probability 10400BP (12.6%) 10300BP 10290BP (53.2%) 10150BP 10290BP (53.2%) 10150BP 9990BP (2.4%) 9970BP 95.4% probability 10500BP (95.4%) 9900BP
Siedliszcze 3	300–330	9170±80	68.2% probability 10470BP (2.4%) 10460BP 10430BP (64.8%) 10230BP 95.4% probability 10560BP (2.9%) 10190BP 10510BP (93.5%) 10190BP
Siedliszcze 4	460–475	9500±90	68.2% probability 11070BP (27.0%) 10940BP 10870BP (6.6%) 10820BP 10810BP (32.1%) 10630BP 10620BP (2.6%) 10580BP 95.4% probability 11200BP (95.4%) 10500BP

RESULTS OF PALYNOLOGICAL ANALYSIS OF ORGANIC SEDIMENTS

The diagrams have been divided into biostratigraphic units which correspond to pollen assemblage zones PAZ (Birks & Berglund 1979, West 1970)

Description of pollen assemblage zones (Fig. 3)

***Salix*–Cyperaceae PAZ** (630–585 cm). The zone is distinguished by the high pollen frequency of *Salix* (14.4%). NAP values are also high, with Cyperaceae being dominant. Birch and pine reach 9.7–22.7% and 19.9–47.1% respectively. Sporadically, pollen of shrubs is found, i.e. *Betula nana*, *Hippophaë rhamnoides*, *Juniperus*, *Ephedra*. The pollen of thermophilous trees (*Ulmus*, *Quercus*, *Alnus*, *Fraxinus*, *Corylus*), which appears in small quantities, is probably redeposited from the upper layers or originates from the long-distance transport. Among the components of herbaceous vegetation Chenopodiaceae and *Artemisia* pollen, and spores of Polypodiaceae reach also higher frequency. The sporadically appearing pollen of *Typha latifolia*, *Myriophyllum spicatum* and *Potamogeton* represents aquatic plants.

The decrease in NAP values and the increase in *Pinus* and *Filipendula* percentages mark the upper boundary of this zone.

***Pinus–Filipendula* PAZ** (585–503 cm). The increasing values of *Pinus* and *Filipendula* pollen are characteristic for this zone. Birch pollen curve shows a clear depression in the middle part of the zone – pollen values decrease to 7.9%. The frequency of *Salix* pollen falls to 0.4%. Cyperaceae pollen also reaches the maximum values of 42.4% in the middle part of zone. Among swamp and aquatic plants, the pollen of *Typha latifolia* and *Nuphar* is worth noting. *Koenigia islandica*, *Linnea borealis*, *Bupleurum*, *Gypsophila fastigiata* pollen and one spore of *Selaginella selaginoides* have been found. Similarly to the previous zone, pollen of thermophilous trees and redeposited sporomorphs occur sporadically.

The rise in the *Artemisia*, Chenopodiaceae and *Salix* frequency and the fall in *Betula* and *Filipendula* values indicate the upper boundary of this zone.

***Artemisia*–Chenopodiaceae PAZ** (503–397 cm). The typical features of this zone are the higher percentages of *Artemisia* (4.8%) and Chenopodiaceae (1.4%). High values of *Pinus* pollen, usually above 60%, characterize the lower part of zone. Meanwhile, *Betula* shows low values – up to 3.7%. *Salix* curve forms two maxima. In NAP sum, Cyperaceae dominate, reaching the maximum values up to 39.9% in the upper part of zone. The falling frequency of *Typha latifolia* and *Filipendula* pollen should be mentioned. The high content of corroded sporomorphs suggests unfavourable conditions for pollen deposition.

The upper boundary of this zone is placed at the decrease in *Artemisia* and Chenopodiaceae values.

Betula–Ulmus **PAZ** (397–325 cm)**.** This zone is distinguished by the fall in the percentages of herbaceous plants (NAP) and the rise of AP values. *Pinus* and *Betula* pollen occurs in similar frequency. First *Ulmus*, then *Corylus* pollen appears and both form the continuous, slightly rising curves. *Quercus* pollen also occurs continuously but its values are very low. *Typha latifolia* and *Filipendula* pollen values rise again.

The decrease in *Betula* curve, and the increase in *Pinus*, NAP and Chenopodiaceae frequency mark the upper boundary of this zone.

Pinus–Ulmus–Corylus **PAZ** (325–265 cm). This zone is separated in Siedliszcze I profile. It is characterized by the rising pollen values of *Pinus* and the falling frequency of *Betula* pollen. The pollen values of thermophilous trees are still very low; they do not exceed 1.5%. *Corylus* pollen, not present yet in the sample at the depth of 315 cm, above that depth reaches values from 1.3 to 6.6%. The values of *Quercus*, *Fraxinus* and *Tilia* pollen are still low, and *Alnus* pollen occurs sporadically, not forming any continuous curve yet. This zone is characterized by higher values of Filicales monolete than in the previous zone.

THE ACCUMULATION CONDITIONS OF ORGANIC SEDIMENTS

In the erosional valley of the lower Wełnianka river, organic deposits began to form in the northern part of the valley floor, probably in the flood basin. This basin was formed because of cutting off a part of the valley floor by a vertically growing belt of sandy channel deposits (Fig. 2). Pollen spectra of the oldest organic layers analysed (*Salix*–Cyperaceae zone, 630–585 cm) illustrate the development of grass-sedge communities with the high proportion of willow shrubs on the floor of the valley (Fig. 3). The accumulation of organic deposits was probably related to the disappearance of permafrost. It began with the development of peat on a sandy basement, then clayey gyttja, and again peat accumulation, marked in pollen spectra by the considerable values of Cyperaceae pollen. This indicates changing conditions of water level at that time. The deposits of *Salix*-Cyperaceae zone should probably be correlated with the Older Dryas chronozone. This is supported by the high values of NAP and *Salix*, the presence of *Hippophaë rhamnoides*, *Juniperus*, *Ephedra*, and Chenopodiaceae, which suggests cold conditions at that time (Bałaga 1991, Bałaga et al. 1998). However, the sporadic presence of *Typha latifolia* pollen, a thermophilous species indicating the average temperature for July at about 14°C (Wasylikowa 1964), may evidence warmer climatic conditions, i.e. the early phase of the Alleröd. The beginning of the accumulation of organic deposits in upper sections of river valleys is dated at the Alleröd (Harasimiuk et al. in print, Zernitskaya 1996). To sum up the discussion, it should be assumed that the bottom part of organic deposits was probably formed at the transition from the Older Dryas to the Alleröd. The high pollen values of *Betula* and *Pinus* indicate that open pine-birch forests developed around the valley, which is further confirmed by high percentages of NAP pollen. The heliophilous plants probably grew on dry, sandy habitats.

The occurrence of taxa which indicate a considerable warming up (such as *Typha latifolia*, *Nuphar*, *Filipendula*) suggests amelioration of climatic conditions during the accumulation of deposits of the *Pinus–Filipendula* zone (585–503 cm), which should be correlated with a later phase of the Alleröd. The accumulation of gyttja with peat indicates a high groundwater level. The gradually melting permafrost, which made downward outflow impossible, favoured the development of waterlogged areas and the formation of small reservoirs, where the accumulation of clayey, sandy and peaty gyttja took place. The changes of organic accumulation indicate dynamic, unstable conditions in the Wełnianka river valley. In the pollen diagram the phase of the accumulation of peat over gyttja was marked with the temporarily rising values of Cyperaceae pollen.

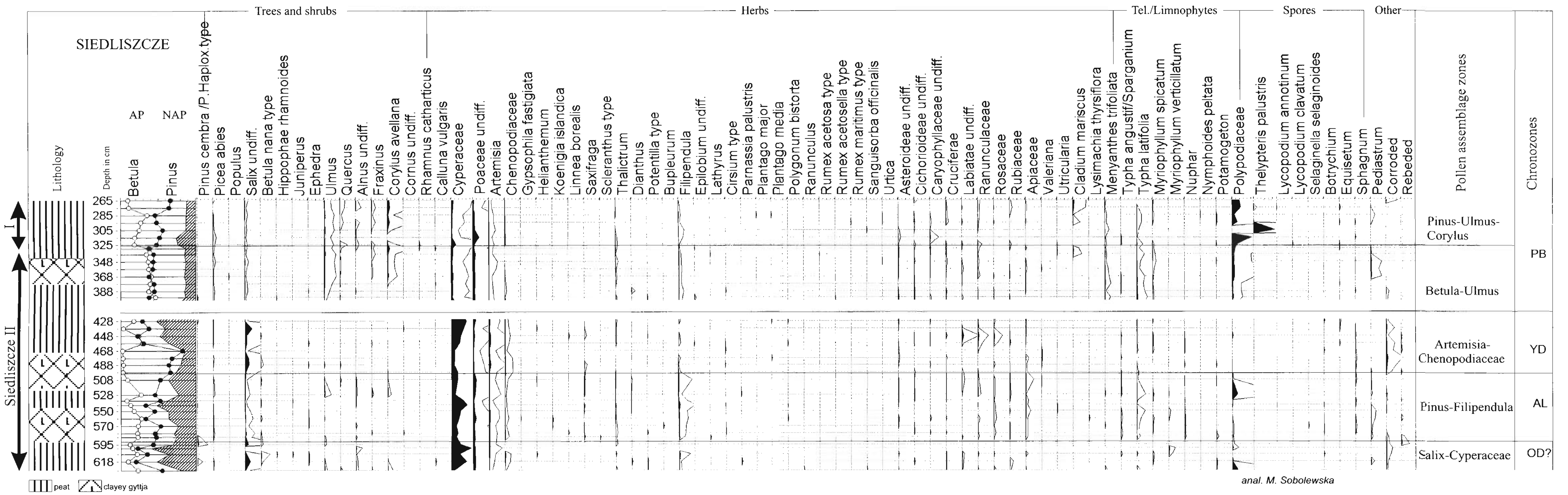

Fig. 3. A percentage pollen diagram of the Siedliszcze profile

In the Alleröd the valley of the lower Wełnianka river was surrounded by open pine-birch forests, and pine proportion was constantly growing during this period. *Koenigia islandica* and *Linnea borealis* probably occurred in the forests. The presence of *Selaginella selaginoides* or *Saxifraga* pollen, may indicate the occurrence of small patches of tundra vegetation, which could have been the remains from colder periods. In the valley itself the proportion of willow shrubs decreased, while communities of tall herbs, consisting of *Filipendula* cf. *ulmaria*, *Geranium* and Apiaceae have richly developed. In small reservoirs, which existed then, *Myriophyllum spicatum*, *M. verticillatum*, *Nuphar* and *Pediastrum* developed, and *Typha latifolia*, *T. angustifolia* and *Equisetum* occurred in the littoral zone.

The increase in the proportions of *Artemisia*, Chenopodiaceae, *Salix*, and the fall in the proportions of *Typha latifolia*, *Filipendula* indicate a clear cooling of the climate during the accumulation of the deposits of *Artemisia* – Chenopodiaceae zone (503–397 cm). The age of those deposits should be related to the Younger Dryas. During that period the thinning of forest cover occurred. Willow shrubs and sedge communities colonized the Wełnianka river valley. Dry, open grass communities with *Artemisia* and Chenopodiaceae expanded. The high content of corroded sporomorphs and the high *Pinus* pollen values in the older phase of this chronozone may suggest that unfavourable conditions for pollen deposition existed in that period. The diagram (Fig. 4) shows the selected pollen curves recalculated after excluding *Pinus* (over-represented taxon) and Cyperaceae (local taxon) from the total sum of pollen. The diagram evidences the alternating domination of willow or birch communities in the Wełnianka river valley. This may suggest a variable content of local pollen in the sediments of this zone. In the early phase of the Younger Dryas, the shallowing of reservoirs was followed by peat accumulation, recorded in the pollen diagram as a rise in the frequency of Cyperaceae and Poaceae pollen. A similar pollen spectrum was observed in the Younger Dryas deposits in the Krzywice profile which is 20 km far from the examined site (comp. Dobrowolski et al**.** 1999).

The rise in AP values, fall in NAP values and the continuous curve of *Ulmus* indicate the development of forests during the accumulation of sediments of the *Betula*–*Ulmus* zone (397–325 cm), and demonstrate that those deposits originate from the early Holocene (Preboreal chronozone). The forests consisted of pine, birch and elm. They were not dense, which is evidenced by high percentages of Filicales monolete spores. Hazel appeared on the forest margins. Fens were also developing. They included characteristic species, such as *Menyanthes trifoliata* and *Cladium mariscus* and, at places, communities with *Sphagnum*. The high percentages of *Thelypteris palustris* spores found in a sample from the depth of 305 cm may indicate a local development of communities with the swamp fern in the vicinity of the investigated site. The patches of Poaceae-*Artemisia* communities still survived in dry, open habitats. The curve of *Typha latifolia* pollen, as well as the development of forests, indicates a considerable amelioration of climatic conditions.

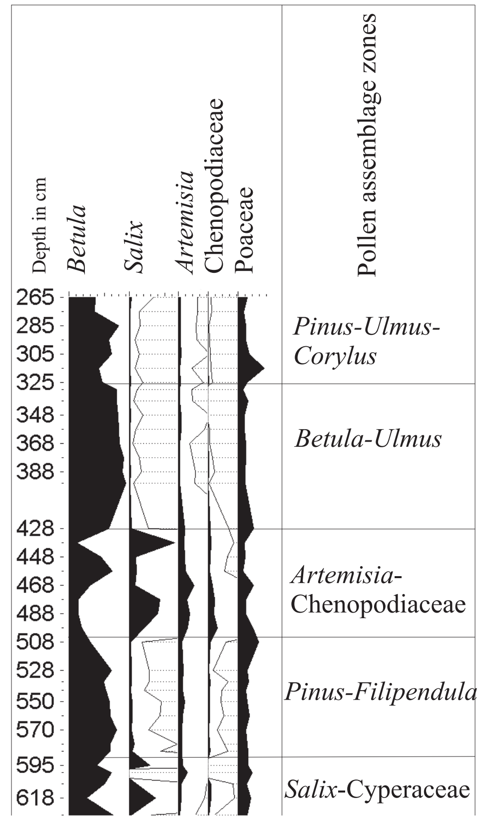

Fig. 4. A simplified pollen diagram of the selected curves after excluding *Pinus* and Cyperaceae from total sum

Pinus–*Ulmus*–*Corylus* zone (325–265 cm), occurring in Siedliszcze I profile, is characterized by very low pollen values of thermophilous trees, similarly to the *Betula*–*Ulmus* zone

(379–325 cm) described above in Siedliszcze II profile. However, it differs in the very low pollen frequency of *Betula* and high values of Polypodiaceae. Therefore, it is possible that this zone represents an older phase of the Preboreal chronozone (comp. Bałaga et al. 1998, 2002). The peat layers (situated on a mineral substratum about 300 m away from the palynological profile) were radiocarbon dated at 9500±90 BP (depth 460–475 cm) and at 9170±80 BP (depth 300–330cm) (Fig. 2). These results indicate that peat accumulation occurred in the younger phase of the Preboreal chronozone. Thus, it cannot be excluded that *Betula–Ulmus–Corylus* zone, recorded in peat deposits, corresponds to this phase (Figs 2, 3). However, a univocal determination of the age of the discussed zone is impossible because the radiocarbon dated peat series has not been palynologically analysed.

The alternating accumulation of gyttja and peat in the Wełnianka river valley indicates that the reservoirs in the valley were periodically drained. Limnic sedimentation prevailed in the Late Glacial, and in the early Holocene peat accumulation predominated there. However, the occurrence of gyttja at the depth of 160–232 cm, i.e. in the upper, not palynologically analysed part of Siedliszcze I profile, indicates the presence of a water reservoir also in the Holocene.

CONCLUSIONS

1. The accumulation of organic sediments in the Wełnianka river valley was conditioned by different processes (floods, accumulation of floodplain deposits) taking place in the Bug river valley.

2. The development of characteristic fluvial subenvironments in the bottom of the lower Wełnianka river valley during the Late Vistulian conditioned the spatial genetic and lithological differentiation of valley sediments. Organic accumulation developed in the flood basins, while the current deposition of mineral sediments occurred in the meandering belt.

3. The warm climate of the Alleröd chronozone caused the melting of permafrost, what contributed to a change of humidity conditions in the valley. As a result of these changes, organic sediments started to form in the valley floor.

4. Lithology sediments (peat and gyttja) dated for the Late Glacial indicate frequent changes in the hydrological conditions in the Wełnianka river valley at that time. Unlike in Holocene (from about 9500–9060BP), the stable conditions favoured continuous accumulation of peat.

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