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POLLEN AND MACROFOSSIL STRATIGRAPHY OF FOSSIL LAKE SEDIMENTS AT NIECHORZE I, W. BALTIC COAST

Wyniki analizy pyłkowej i makroskopowej kopalnych osadów jeziornych z Niechorza I na Wybrzeżu Bałtyckim

ABSTRACT. The paper describes the results of pollen and macrofossil analyses of the fossil lake sediments at Niechorze. Five macrofossil zones and eight local pollen zones are distinguished and the vegetational succession is described, starting with the shrub tundra dominated by *Betula nana*, *Salix* spp. and *Hippophaë*, through the different stages of birch woodland and birch-pine woodland development, to the revertence of partially open plant communities with *Betula nana* and *Empetrum*. The 4 radiocarbon dates from the base of organogenic sediment place its origin at the decline of Older Dryas chronozone. The upper part of sediments represent the shortened and discontinuous holocene sequence.

The pollen and macrofossil stratigraphy is compared with the results of diatom (Marciniak 1981) and cladocera (Szeroczyńska 1985) studies, and the lake development including water level changes is deduced.

The site stratigraphy is reinterpreted in relation to the previous pollen analytical results (Brykczyńska 1978). The time of the main woodland expansion in the S-peri-Baltic zone, in connection with Usinger's (1985 and earlier papers) studies at Bornholm and in Schlezwig-Holstein is discussed.

INTRODUCTION

The studies of fossil lake sediments at Niechorze, W. Baltic Coast, were initiated in 1974 by the late K. Kopczyńska-Lamparska, who investigated in detail the geology of the area (1976, and other quoted papers). The pollen analysis of lake sediments was performed by Brykczyńska (1978) and the diatom analysis by Marciniak (1979, and in: Cieśla & Marciniak 1982). The development of the cladoceran fauna (Szeroczyńska in Kopczyńska-Lamparska et al. 1983, Szeroczyńska 1985) and mollusc assemblages (Skompski in Kopczyńska-Lamparska et al. 1983) were also examined, and a detailed geochemical analysis of the sediments was made by A. Cieśla (Cieśla & Marciniak 1982, Cieśla in: Kopczyńska-Lamparska et al. 1983). Three sediment samples coming from the basal peat and from the bottom and top of the peat layer overlying lake sediments were radiocarbon dated (Kopczyńska-Lamparska 1976).

In connection with the IGCP-Project No 158 a new series of samples was collected from the cliff exposure in 1978, about 1 m away from Niechorze I profile (Niech. Ibis). The purpose was to perform new pollen analyses including pollen concentration counts, to make plant macrofossil, diatom and cladocera analyses, and some more radiocarbon datings, because both the exact age and stratigraphy of the Niechorze I site seemed unclear after the preliminary investigations, and the idea was to use it as a reference site for the Project.

However the site appeared to be unlucky. In 1980 K. Kopczyńska-Lamparska, the initiator of investigations, died, and E. Brykczyńska who started pollen analytical work and W. Podyma who started plant macrofossil analysis of Niech. I bis profile, both left their positions. To save the collected material, studies were taken up by A. Rzętkowska (plant macrofossil analysis) and M. Ralska-Jasiewiczowa (pollen analysis), but without any additional field work. The results are presented in this paper, without any discussion of the results obtained from other sites examined in the Niechorze area (Niechorze II — another site with fossil lake sediments exposed in the sea cliff ca. 0.5 km from Niechorze I site, Kopczyńska-Lamparska 1976, pollen analysis performed by Brykczyńska 1978; Niechorze III — fossil lake sediments covered with dune sand, found by coring in the sand-bar ca. 3.5 km eastwards from Niechorze I, and Niechorze IV — a living peat-bog ca. 2 km to the south from Niechorze I — pollen analyses made by Brykczyńska and Więcławek 1983). The pollen analytical data obtained from those sites seem too preliminary to contribute to a profitable discussion.

STUDY AREA AND METHODS

According to the regional subdivision of Poland, proposed for IGCP Project No 158 (Ralska-Jasiewiczowa 1982, and this volume), the study area is situated in the region of Baltic Coast (P-U). Fossil lake Niechorze I lies 1.7 km to the west of the village Niechorze (Fig. 1). The geological situation of the site (Fig. 2) has been described in detail by Kopczyńska-Lamparska (1976). The lithological description of its sediments exposed in the sea cliff was also made by Kopczyńska-Lamparska (unpubl.). In this paper her description is included using Troels-Smith (1955) system, in a simplified form (Table 1).

Three continuous profiles — a, b and c — were taken from the exposure close to each other. Samples for pollen analysis were taken from profile a at 5 cm, 2.5 cm or 1 cm intervals, following the changes of sediment, with a 1 cm^3 volumetric sampler. The samples were treated with hydrofluoric acid and Erdtman's acetolysis according to Faegri and Iversen (1964) with the modification introduced by Stockmarr (1971) for pollen concentration; two *Lycopodium* pellets were added to each sample ($x = 11300 \pm 400$). Samples were stained with

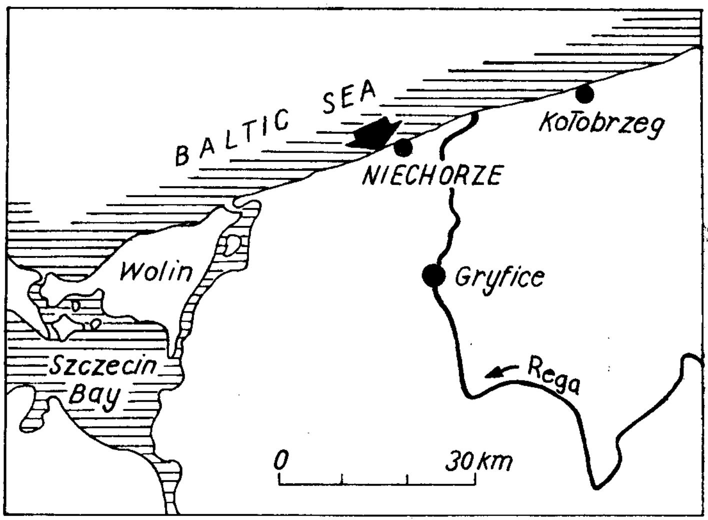

Fig. 1. Map showing the location of fossil lakes near Niechorze, western part of Baltic coast

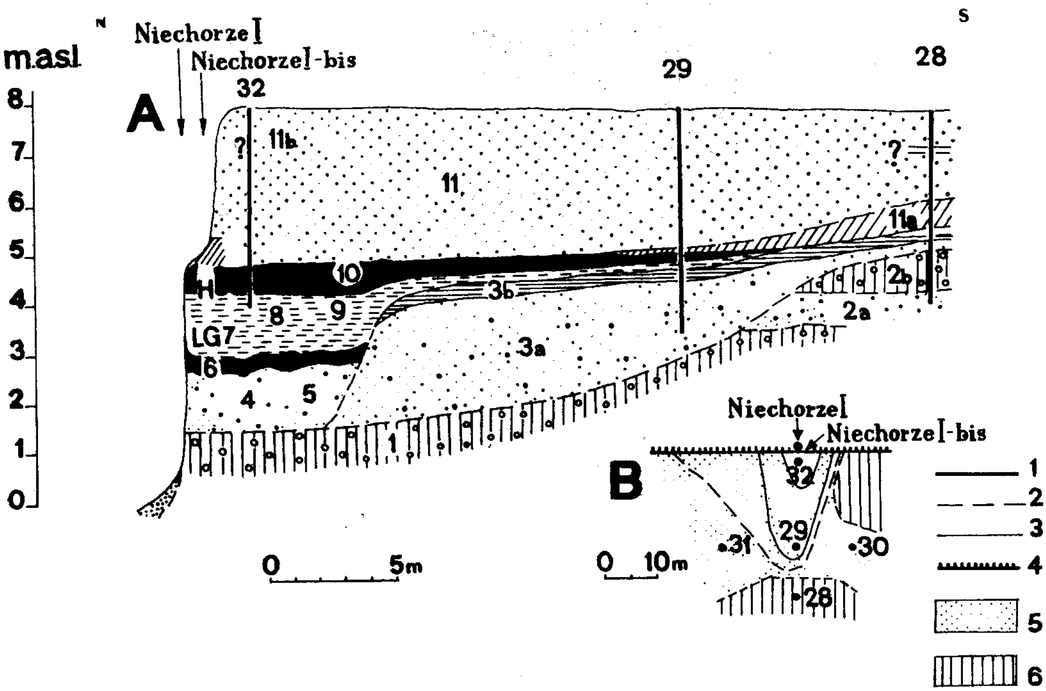

Fig. 2. Geology of Niechorze I site (after Kopczyńska-Lamparska 1976). A. Geological section. 1 — older till, 2 — varigrained subglacial sands, 2b — younger till, 3a-c — deposits of the fossil kame terrace: 3a — sands with gravel, 3b — silts, 3c — ablation till, 4—5 — fluvioglacial sands with gravel and silts, 6 — peat, 7—9 — fossil lake sediments: 7 — silty muds, 8 — clay gyttjas, 9 — peaty muds, 10 — peat, 11 — aeolian sands, 11a — with humus, 11b — with peat, 12 — beach sand; B. Geological structure of fossil lake surroundings. 1 — limits of the kettle, 2 — extent of lacustrine muds, 3 — extent of upper peat layer, 4 — sea-cliff, 5 — permeable deposits, 6 — impermeable deposits

Table 1

Sediment description according to Troels-Smith (1955) system, simplified (after Kopczyńska-Lamparska's unpubl. data, see Szeroczyńska 1985)

Layer no	Depth in cm	Sediment type	Sediment composition
17	0—317	sand, light grey	$Ga^{min+maj}$ 4
16	317—320	fossil soil with sand, grey brown	Sh 1, Ag+As 2.5, Ga 0.5
15	320—340	swamp peat with some sand, dark brown	$Th^{3}3$, Ag1, Ga+++
14	340—346	peaty mud with silt, dark brown, with plant fragments in upper part	$Th^{3}2$, Ag+As2, Dh++
13	346—362	silty mud with some humus, brown	Sh 1, Ld1, Ag+As 2
12	362—369	peaty mud, grey brown, with calcium carbonate, mollusc shells and plant fragments	$Th^{3}1$, Ld1, Ag+As 1.5, Lc0.5 (test. moll.+)
11	369—392	clayey calcareous gyttja, pale brown, with plant fragments and mollusc shells	Lc2, $Ld^{3}1$, Ag1, Dh++ (test. moll.++)
10	392—427 (423)	clayey calcareous gyttja, brown with light patches, with plant fragments and mollusc shells. Lower contact sloping	Lc2, $Ld^{2}1$, Ag1, Dh+++, (test. moll.++)
9	427 (423)—443	clay gyttja with calcium carbonate, pale green-brown, with plant fragments and small shell fragments	Lc1, $Ld^{2}1$, Ag+As 2, Dh++ (part. test. moll.+)
8	443—452	silty mud, black, with some calcium carbonate, plant fragments and mollusc shells	$Ld^{3}2$, Ag+As2, Lc++, Lf++ Dh++, (test. moll.+)
7	452—466	silt, grey, with some calcium carbonate and sand, with plant and shell fragments	$Ld^{2}1$, Ag+As3, Lc++, Dh++ (part. test. moll.+)
6	466—478	silty laminated mud, grey brown with dark/light bands, with calcium carbonate and fine fragments of plants and shells. Lower contact undulated	$Ld^{2}2$, Ag+As2, Lc+++, Dh+ (part. test. moll.+)
5	478—484	silty mud, grey brown, homogenous, undulated consistently with underlying sediments	$Ld^{2}2$, Ag+As2, Lc++
4	484—488	peat, brown black, strongly humified, undulated consistently with underlying sediments	$Th^{3}4$, Ag+++, Ga+
3	488—498	silty clay, brown, with humus and some sand. Upper contact undulated	Sh 1, Ag+As3, Lc+, Ga+++
2	498—502	sandy silt, grey, with some mollusc fragments	Ag+As3, Ga1, Sh+++, Lc++ (part. test. moll.+)
1	502—	sand, fine-grained, grey, with some gravel	$Ga^{min(+maj)}$ 4, Gs+

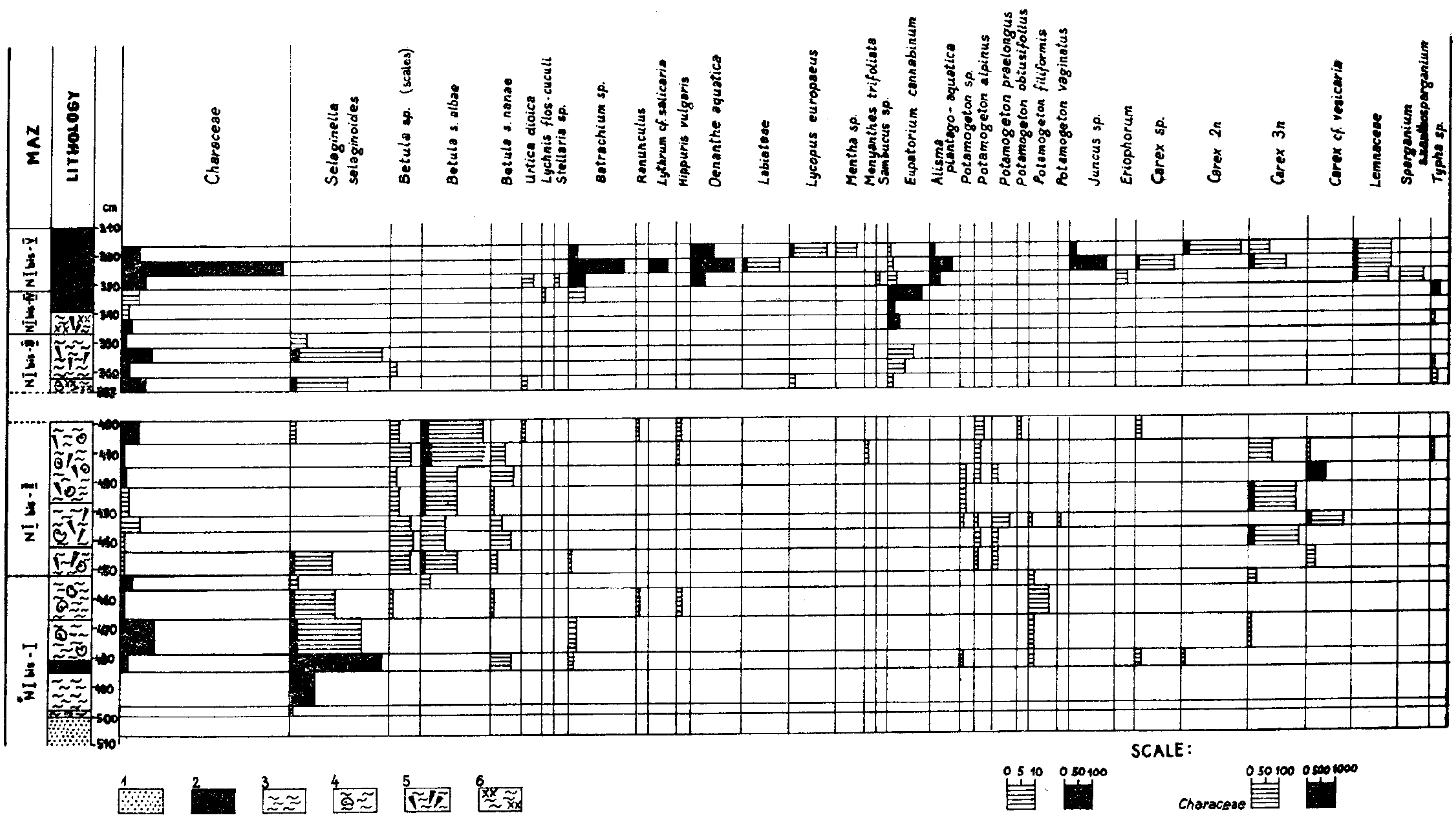

Fig. 3. Niechorze I bis profile. Plant macrofossil diagram, 1 — sand, 2 — peat, 3 — silty muds, 4 — clay gyttjas with mollusc shells, 5 — mud with humus, 6 — peaty mud

basic fuchsin and stored and counted in glycerine. Pollen spectra were counted using the Amplival-type Zeiss microscope. The conventions used for the names of pollen taxa follow Birks (1973) and Berglund & Ralska-Jasiewiczowa (1986).

Twenty four samples, 5—12 cm long, from profile b were used for the plant macrofossil analysis. The samples between 101 and 133 cm were lacking. To recover the macrofossil remains the samples were treated by the method described by Wasylikowa (1973). The initial volume of samples was 15—100 cm³. In order to obtain comparable results the number of macrofossils identified in each sample was recalculated for the volume of 100 cm³.

The analysis included fruits, seeds, megaspores and, in the case of the genus *Betula*, also fruit scales. The identification of macrofossils was based on the reference collections of recent fruits and seeds belonging to the Institute of Basic Geology and the Herbarium of the Department of Systematics and Phytogeography of Warsaw University. In addition, the following references were used for macrofossil identification: Mądalski (1949), Kowal (1958), Dombrovskaya et al. (1959), Białobrzeska and Truchanowiczówna (1960), Kac et al. (1965), Brzozy-*Betula* L. (1979), and Nilsson and Hjelmqvist (1967). The preparation and identification of part of the material was done by Mr W. Podyma. The results of macrofossil analysis are presented in the diagram as concentration values: number/100 cm³ (Fig. 3).

RADIOCARBON DATES

Eight samples from profile c Niech. I bis were radiocarbon dated at the Institute of Physics, Silesian Technical University in Gliwice, Poland, by dr M. F. Pazdur and collaborators (Pazdur et al. 1985).

The results are as follows (in uncorrected years based on Libby half-life of 5568 years):

Lab.	Depth	Sediment type	^{14}C years BP
Gd-1111	173—178	peat	3340±60
Gd-1099	163—168	peat/peaty silt transition	5910±80
Gd-1112	131—138	peaty silt	9330±120
Gd-782	48—53	peaty silt with mollusc shells	13430—150 NaOH-SOL
Gd-1245		“	12260±120 RES
Gd-1107	17—19	peat	11880±110
Gd-1108	15—17	peat	11980±130
Gd-1109	9—15	peaty silt	12150±100
Gd-673	2—0	peaty silt	12010±150

The results are discussed in the following chapters.

ANALYSIS OF PLANT MACROFOSSILS
(by A. Rzętkowska)

Description of macrofossil assemblage zones

The analysis of macroscopic plant remains provided rather scanty material as regards the number of taxa represented, especially in the Late-Glacial part of the profile. Nonetheless, it was possible to distinguish five macrofossil assemblage zones, indicative of the developmental stages of vegetation in lake Niechorze I and its direct neighbourhood.

MAZ N I bis — I — *Selaginella selaginoides* — *Potamogeton filiformis* (507—452 cm)

Regarding the number of subfossil plant remains identified, *Selaginella selaginoides* megaspores prevail here. This layer contained also the maximum number of *Potamogeton filiformis* fruits, and in its upper part the abundant oogonia of *Characeae*. In addition, two fruits of *Hippuris vulgaris*, few nuts of *Carex* sp., and also some macrofossils of *Betula* s. *nanae* and a single fruit-scale of *Betula* s. *albae* have been found.

MAZ N I bis — II — *Betula* sp. (452—399 cm)

The sediments of this part of the profile contain comparatively many plant remains, which show a greater specific differentiation than those from the underlying layers. Five species of the genus *Potamogeton* have been identified, namely *P. filiformis*, *P. obtusifolius*, *P. praelongus*, *P. alpinus* and *P. vaginatus*. The maximum number of *Carex* nuts has been found in this layer, a great many of them coming probably from *Carex vesicaria*. Also seeds of *Menyanthes trifoliata* are present. The frequencies of *Characeae* oogonia decrease. There is a constant rise in the number of *Betula* s. *albae* fruits throughout the zone, besides the consistently occurring macrofossils of *Betula nana*.

MAZ N I bis — III — *Selaginella selaginoides* (367—347 cm)

The megaspores of *Selaginella selaginoides* dominate in the sediments of this section of the profile, although they are not as abundant as in the N I bis — I layer. The other plant remains recorded are not numerous, and with few species. The oospores of *Characeae* are more aboundant again, the fruits of *Eupatorium cannabinum* appear, and single fruits of *Typha latifolia*, *Lycopus europaeus* and *Urtica dioica* have been found.

MAZ N I bis — IV — *Eupatorium cannabinum* (347—332 cm)

This zone has been distinguished on the basis of the maximum occurrence of *Eupatorium cannabinum* fruits. In addition only few oogonia of *Characeae*, *Stellaria* sp. and *Typha* sp. fruits have been identified.

MAZ N I bis — V — *Lemnaceae* (332—317 cm)

This zone is characterized by the greatest number of species in the profile. The most abundant are oogonia of *Characeae*, fruits of *Oenanthe aquatica*, *Batrachium* sp., *Alisma plantago-aquatica*, *Juncus* sp. and *Carex* sp. div. The fruits of *Lythrum salicaria*, *Lycopus europaeus*, *Mentha* sp. and *Sparganium* s. *xanthosparganium* are less numerous. The presence of *Lemnaceae* fruits is exclusive to the zone.

Stages of vegetational succession in and around the lake derived from the macrofossil data, including comments on some plant taxa

MAZ N I bis — I — *Selaginella selaginoides* — *Potamogeton filiformis*

Selaginella selaginoides dominant in this zone is a species of cool montane climates, including the whole of Scandinavia in its European range. It is particularly densely distributed in the Scandinavian mountains (Hulten 1950). In Poland and the remaining part of Europe it grows in the mountains, in the subalpine and alpine zones.

Potamogeton filiformis belongs to the group of ubiquitous species (Samuelsson 1934, after Wasylikowa 1964) and so does *Hippuris vulgaris*. The occurrence of the above-mentioned plant species, notably *Selaginella selaginoides*, may indicate that the climate in the region of the lake under study was rather cool.

The rise of water level causing the flooding of basal peat and accumulation of silty sediments on its surface is recorded in the macrofossil diagram by a rapid increase in the number of deposited oogonia of *Characeae* and then of *Potamogeton filiformis*. The presence of *Carex* nuts in this part of the profile suggests the occurrence of swamp communities around the lake. Sedges could also be a component of the tundra biocoenoses. The macrofossils of *Betula* s. *nanae*, indicate the presence of shrub tundra communities in the region of the lake. Their remains were commonly found in glacial and late-glacial fossil floras throughout Poland (Środoń 1972). By the end of zone groups of birchtrees belonging to *Betula* s. *albae* occurred locally in wetter places, which is evidenced by the presence of single fruits.

MAZ N I bis — II — *Betula* sp.

The macrofossils found in this zone evidence the further development of aquatic communities. *Potamogeton obtusifolius* and *P. praelongus*, are South-Scandinavian species, not going beyond the northern forest line (Wasylikowa 1964). *Potamogeton alpinus* is an ubiquitous plant, and *P. vaginatus* is a cold-resistant species. In Poland this last species was found in glacial floras (e.g. Tołpa 1952), and nowadays it only occurs in the northern part of the Baltic Basin. The association *Potametum filiformis* Koch 1926 can be deduced; it is composed of three of the pond-weed species present in this zone, namely *Potamogeton filiformis*, *P. praelongus* and *P. alpinus*. Stands of this association grow on mineral or humus-mineral substrata in cool mesotrophic waters (Matuszkiewicz 1981). A marked decrease in the number of *Potamogeton* fruits deposited in the sediments is visible at a depth of 415 cm. It may well be that at this moment the water level in the lake reached its minimum. The abundance of *Carex* nuts, mainly of *Carex vesicaria*, may indicate the development of the sedge-dominant swamp community round the lake, probably similar to *Caricetum vesicariae* Br. — Bl. et Denis 1926 (Matuszkiewicz 1981). This community chiefly colonizes organic-mineral substrata under about 30 cm of water. In stands of this association the water level is not higher than the ground surface in the season of full vegetation (Tomaszewicz 1979). It may be supposed that it was the time of intensive lake overgrowing, what is also evidenced by the presence of seeds of *Menyanthes trifoliata*. This is a very invasive aquatic perennial, whose occurrence is of great importance to the hydroseral processes (Podbielkowski & Tomaszewicz 1979).

The terrestrial environment is mainly represented by birch remains. The rise in the number of *Betula* s. *albae* fruits indicates the growing importance of birch-trees in the communities surrounding the lake and is probably connected with the improvement of climatic conditions.

MAZ N I bis — III — *Selaginella selaginoides*

The presence of *Selaginella selaginoides* megaspores in the sediments of this zone may indicate a cool spell. The amounts of molluscan shells, which were fairly abundant in the underlying layers, decline and calcium carbonate is no longer present in the sediment.

MAZ N U bis — IV — *Eupatorium cannabinum*

Eupatorium cannabinum, the main component of macrofossil flora of this zone, is not an indicator species of climatic changes. Nevertheless, its present-day distribution, including West Europe and Southern Siberia, does not extend beyond latitude 63° N, and covers only the southern part of the Scandinavian Peninsula (Hulten 1950). The July isotherm of this region is +14°C. This indicates relatively high thermic requirements of this species. In the deposits of this part of the profile there are no molluscan shells and the number of deposited plant macrofossils is slight. It may be supposed that the water level underwent strong fluctuations. The traces of similar processes, unfavourable from the viewpoint of the development of the lacustrine ecosystem, were found also in the pre-boreal and boreal deposits of Lake Mikołajskie (Ralska-Jasiewiczowa 1966), Lake Wielkie Gacno (Hjelmroos-Ericsson 1981) and Lake Żarnowieckie (Latałowa 1982).

MAZ N I bis — V — *Lemnaceae*

Plant taxa found in this zone are mostly components of the communities which form the successive zones of vegetation around the natural water body. Patches of submerged weeds were composed of *Characeae* species which reach their quantitative maximum in this zone. In shallower places, not deeper than 3 m, there were stands of floating-leaved plants, with *Batrachium* sp. being dominant. As the depth decreased, swamp plant communities developed, including *Oenanthe aquatica*, *Alisma plantago-aquatica*, *Sparganium* s. *xanthosparganium*, accompanied by *Lemnaeae* species, *Lythrum salicaria* and *Lycopus europaeus*. Many of these species occur nowadays in the swamp community *Oenanthe-Rorippetum* Lohm 1950, growing on organic-mineral substrata in shallow (to 50 cm) eutrophic water, which may dry up during the summer (Tomaszewicz 1979). Patches of sedge-dominant swamp vegetation with *Juncus* sp., *Eriophorum* sp. and *Carex* sp. may have occurred in places round the lake. The species recorded from this layer are for the most part characteristic components of eutrophic lakes with water of pH 7.0—8.5.

The presence of *Lemnaceae* fruits in these sediments is a significant fact. Today the species belonging to this family are widely distributed in Poland but they reproduce mainly vegetatively. Flowering occurs sporadically. Several conditions must be satisfied for the flowers to be produced, namely, the water must contain large amounts of organic substances and calcium, and the lighting and temperature must be suitable. According to the studies carried out by Czopek (1960), the mass flowering of most species of the *Lemnaceae* is conditioned by a persistent temperature above 25°C in warm summer periods. For this reason the occurrence of *Lemnaceae* fruits in the zone N I bis — V may evidence the relatively high temperatures prevailing during the accumulation of the uppermost peat. This is a kind of swamp peat consisting mostly of rootlets, rhizomes and epiderms of herbs and sedges. Such peat was probably deposited under favourable water and nutrient conditions (Tjuremnov 1957). This macrofossil assemblage should be referred to a period in which the lake was very shallow, permitting the development of some aquatic vegetation, being however subject to the intensive overgrowing.

POLLEN ANALYSIS
(by M. Ralska-Jasiewiczowa)

Description of pollen zones

The pollen diagram of Niechorze I bis profile (Fig. 4) has been divided into 8 local pollen zones corresponding to 3 regional pollen assemblage zones (disregarding the upper 25 cm of profile with discontinuous stratigraphy). The zonation follows the division of percentage pollen stratigraphical data indicated by numerical methods. Three methods (CONSLINK, SPLITINF and SPLITSQ), developed by Gordon and Birks (1972, and Birks & Gordon 1986) as computer program "ZONATION" written in FORTRAN IV, were applied using computer "SPECTRUM". The program was adapted, and the zonation performed by Dr. A. Walanus, Polytechnic University Gliwice. The local pollen zones are briefly characterized below:

N-Ibis-4 *(Pinus) — Hippophaë — Salix* local and regional pollen assemblage zone (499—486 cm)

The very low pollen concentration (Fig. 5) is the statistical reason for *Pinus sylvestris* type pollen being the dominant element of AP in the percentage pollen diagram. The most abundant local pollen types are *Hippophaë* (max. 5%), *Betula nana* type (max. 9%), different morphological *Salix* pollen types, *Cyperaceae* and *Gramineae*. Percentages of *Artemisia*, *Chenopodiaceae*, *Parnassia palustris*, and *Tofieldia palustris*, are relatively high, and a variety of other NAP pollen types occurs, including *Dryas octopetala*, *Linnea borealis* and *Helianthemum nummularium* type. Frequencies of *Equisetum* and *Selaginella* spores are high, and form maxima by the end of zone. Rebedded pollen is present, up to 3%. Upper boundary: rise of *Betula* undiff., *Betula nana* type and *Gramineae* pollen values, and fall of *Pinus sylvestris* pollen curve.

Betula regional pollen assemblage zone (486—368 cm)

The common feature of local pollen zones N-Ibis-2 to N-Ibis-6 is the dominance of *Betula* undiff. pollen in both percentage (21—50%) and concentration AP values.

N-Ibis-2 — *Betula nana* type — *Gramineae* l.p.z. (486—469 cm)

AP pollen is less than 30% throughout the zone, with *Betula* undiff. pollen at ca. 20%, *Pinus sylvestris* type less than 10%, and *Betula nana* type at 12—14%. Pollen curves of *Salix* sp. div., *Hippophaë* and *Juniperus* are significant. Within NAP *Gramineae* is the dominant pollen type (21—36%); *Cyperaceae* and *Artemisia* pollen are subdominant; *Chenopodiaceae*, *Helianthemum nummularium* type, *Rumex acetosella* type, *Ranunculus* undiff., *Tofieldia*, *Parnassia*, *Selaginella*, and *Sphagnum* occur consistently in low amounts, and *Helianthemum canum* type, *Saxifraga oppositifolia* type, *Lotus*, *Hedysarum*, cf. *Oxyria*, *Plantago maritima* s.l., *Pimpinella* type, *Chrysanthemum* type, and *Botrychium*, appear sporadically. Pollen of various aquatic plants is consistently present. Frequencies of *Pediastrum* colonies are very high (up to 137%). Rebedded pollen is present at the end of zone.
Upper boundary: rise of *Betula* undiff., *Artemisia* and *Chenopodiaceae*, fall of *Gramineae* pollen values.

N-Ibis-3 — *Artemisia-Chenopodiaceae* l.p.z. (469—458 cm)

Betula undiff. pollen values rise throughout the zone to 32%, and the *Juniperus* curve to 3%, *B. nana* type is ca. 7%, occasionally more. *Gramineae* pollen values decline to 15%, frequencies of *Artemisia* rise to ca. 5—7% and of *Chenopodiaceae* pollen to ca. 1.5%, the variety of herb pollen types decrease, and frequencies of *Sphagnum* spores rise. Rebedded pollen is up to 2%.
Upper. boundary: rise of *Betula* undiff., *Juniperus* and *Cyperaceae*, fall of *Artemisia*, and *Chenopodiaceae* pollen curves.

N-Ibis-4 — *Juniperus* l.p.z. (458—432 cm)

The *Betula* undiff. pollen curve reaches 50% *Betula nana* type, and *Salix* sp. div. pollen frequencies attain maxima. The *Juniperus* curve rises throughout the zone to 15%. *Cyperaceae* pollen frequencies are high (23—32%), and *Gramineae*, *Artemisia*, *Chenopodiaceae* and *Thalictrum* values are reduced. The variety of sporadically appearing herb pollen taxa is still high. Pollen of aquatic plants is well represented, with *Myriophyllum spicatum* and *Ranunculus trichophyllus* type pollen being especially abundant at the beginning of zone. *Typha latifolia*, *Lemna* and cf. *Comarum* appear as new pollen taxa. The occurence of *Selaginella* is reduced to single spores.
Upper boundary: decrease of *Juniperus* and *Cyperaceae* and rise of *Thalictrum*, *Filipendula* and *Umbelliferae* pollen frequencies.

N-Ibis-5 — *Filipendula-Umbelliferae* l.p.z. (432—412 cm)

There is a maximum of *Betula* undiff., and a significant rise of *Pinus sylvestris* type pollen concentration. *Juniperus* pollen values fall, and the continuous *Hippophaë* pollen curve ends in the middle of the zone. *Umbelliferae* frequencies rise to 2.5%, those of *Filipendula* and *Thalictrum* to 1%. Pollen frequencies of aquatics decline, and the variety of their taxa is reduced.
Upper boundary: rise of *Pinus* pollen and *Equisetum* and *Sphagnum* spores frequencies, fall in *Juniperus*, and beginning of continuous *Typha latifolia* pollen curve.

N-Ibis-6 — *Pinus-Filipendula* l.p.z. (412—368 cm)

Betula undiff. pollen concentration declines, its pollen percentage values being more or less constant (35—45%). The *Pinus sylvestris* pollen curve rises throughout the zone to 36%, and *Betula nana* pollen values to 5%. The *Juniperus* pollen curve decreases gradually to 1—0.5%, *Gramineae* to 4%, and *Cyperaceae* to 11%. In the upper part of zone *Empetrum* pollen and *Polypodiaceae* spores appear continuously. There is a further reduction in variety and amounts

of aquatic pollen taxa. *Typha latifolia* and *Menyanthes* form continuous curves. *Equisetum* spore frequencies are 3—6.5% and *Sphagnum* up to 3.5%.
Upper boundary: decrease in *Betula* undiff. pollen curve, and less significant decline in *Pinus sylvestris* type pollen. Rise in frequencies of *Betula nana, Juniperus, Empetrum, Gramineae* and *Artemisia* pollen and *Sphagnum* spores.

Betula nana type — *Empetrum* regional pollen assemblage zone (368—340 cm)

The common features of N-Ibis-7 and N-Ibis-8 local pollen zones are reduced *Betula* undiff. pollen concentration and percentage values (12—23%), rising *Pinus sylvestris* type pollen values, and significant frequencies of *Betula nana* (5—12%), *Empetrum* (ca. 4%), and *Artemisia* pollen (2—6%).

N-Ibis-7 — *Gramineae-Artemisia* l.p.z. (368—348 cm)

The NAP curve rises to 47%, and together with shrub pollen forms 50—67% of the total pollen sum. *Juniperus* pollen values decrease throughout the zone from 5% to 0.3%. *Salix glauca* is the dominant *Salix* pollen type with values up to 2%. *Cyperaceae* pollen frequencies rise to 21%, *Gramineae* to 12%, and *Artemisia* to 6%. *Helianthemum nummularium* type and *H. canum* type, *Plantago maritima* s.l. and *Gypsophila fastigiata* pollen and *Botrychium* spores are consistently present, and many other pollen types representing open habitats appear sporadically. *Caltha* type pollen values are up to 1.6%, pollen of limno- and telmatophytes, occasional at the beginning of zone, reappear consistently by its end. Frequencies of *Sphagnum* spores and of *Pediastrum* colonies rise.
Upper boundary: rising *Pinus* pollen, *Typha latifolia* pollen and *Polypodiaceae* spore values, and decrease of *Betula nana* type, *Salix glauca* type, *Cyperaceae, Gramineae* and *Artemisia* pollen frequencies.

N-Ibis-8 — *Pinus-Polypodiaceae* l.p.z. (348—340 cm)

NAP values decrease to ca. 25%, *Pinus sylvestris* type frequencies are ca. 50%, *B. nana, Salix glauca* type and *Juniperus* pollen values decrease. *Cyperaceae, Gramineae* and *Artemisia* pollen curves decline. The variety of herb pollen types decrease significantly. *Helianthemum canum* type, *Gypsophila fastigiata, Dianthus* and *Saussurea* appear occasionally. *Filipendula, Myriophyllum spicatum* and *Ranunculus trichophyllus* type pollen curves are continuous again. Frequencies of *Typha latifolia* pollen, *Polypodiaceae* spores and *Pediastrum* colonies (60%) rise.

The upper 20 cm of profile do not reflect any continuous sequence of vegetational development:

Sample at 335 cm is characterized by dominance of *Pinus* pollen (80%), and very low amounts of other tree pollen (*Betula* undiff., *Salix glauca* type). NAP is only 4%, and the variety of herb pollen taxa is very poor (*Cyperaceae,* *Gramineae*, *Filipendula* and *Vaccinium* type). Pollen of aquatics is practically absent, but *Typha latifolia* and spores of *Polypodiaceae* attain high values.

Sample at 330 cm is characterized by low frequencies of *Pinus* (22%) and *Betula* (4%), high frequencies of thermophilous tree pollen (*Alnus*, *Corylus*, *Tilia*, *Ulmus*, *Quercus* — 36% altogether), presence of *Hedera* and *Viscum* pollen and a higher variety of NAP pollen types with dominant *Gramineae*, *Cyperaceae*, *Umbelliferae* and *Compositae Liguliflorae*. *Artemisia*, *Chenopodiaceae* *Rumex acetosella*, *Plantago lanceolata* and other culture indicators are present.

In the uppermost 2 samples (at 325 and 320 cm) no significant changes in pollen composition occur, but *Carpinus*, *Fagus* and *Cerealia* pollen appear in low amounts.

VEGETATIONAL HISTORY

N-Ibis-1 *Hippophaë* — *Salix* PAZ

The sediment of this zone is composed mainly of silt with a low content of organic matter, and reveals distinct, sharply undulated structures in its upper part. These resemble cryoturbation structures and may have been formed during melting of permafrost or dead ice. The silt is overlain by a thin layer of highly humified peat at the end of zone, recording the establishment of a small mire in the shallow depression made by melting of the frozen ground. The peat layer runs consistently with the undulation of underlying sediments, showing that the melting processes were still active during and after its accumulation.

Two radiocarbon dates, 12010±150 and 12150±100 B. P. were obtained from the two neighbouring samples of silt with humus covering nearly the whole thickness of the zone. They indicate the last part of Older Dryas chronozone as the probable time of sediment accumulation.

Because of very low pollen concentration, this pollen assemblage reflects poorly the vegetational development around the site. The low values of AP evidence the open treeless landscape around the site. The dominant plant communities were sedge- and grasslands with species of *Artemisia*, *Chenopodiaceae*, *Ranunculus*, *Chrysanthemum*, *Geum*, *Thalictrum*, *Helianthemum* (*H. nummularium* type), *Botrychium*, and elements of pioneer arctic tundra — *Dryas octopetala* and (cf.) *Oxyria*. The places with more advanced vegetational succession supported shrub communities composed of *Hippophaë rhamnoides*, *Juniperus*, and on moister habitats of different *Salix* species, *Betula nana*, and dwarf shrubs with dominant *Ericaceae* species (*Arctostaphylos*, *Empetrum*, *Vaccinium* type). A high representation of eutrophic mire plants — *Parnassia palustris*, *Tofieldia calyculata*, *Selaginella selaginoides*, as well as *Equisetum* and *Cyperaceae* indicates the first colonization stage of the damp depression by a mire, with some open water where species of *Sparganium* and *Potamogeton* sect. *Eupotamogeton* were growing. The high content of silt in the sediment and significant frequencies of rebedded pollen testify to the unstable soils. The formation of a mire by the end of zone is shown by the accumulation of a peat layer with high frequencies of *Cyperaceae* pollen (27%), *Equisetum* spores (33%) and an abundance of *Selaginella selaginoides* micro- and megaspores.

A 4 cm thick sample of this peat has been radiocarbon dated. The lower and upper parts were dated separately revealing ages of 11980±130 and 11880±110 respectively. The age confirms the reliability of the basal dates, pointing to the transition from Older Dryas to Allerød chronozones.

Betula — regional PAZ

N-Ibis-2 *Betula nana* — *Gramineae* l.p.z.

This zone probably records the beginning of woodland development in the Niechorze area. Scattered trees of *Betula*, possibly *B. pubescens*, *Populus tremula* and *Sorbus aucuparia* appeared near the site, but the landscape still remained rather open, as shown by the tree:shrub:herb pollen ratio. The shrub and dwarf shrub vegetation with *Hippophaë*, *Juniperus*, and *Ephedra distachya* in drier places, and *Betula nana* (pollen and macrofossils), and *Salix* sp. div. on moister habitats formed a mosaic with open communities dominated by grasses, sedges and *Artemisia*. The floristic composition of the open communities was basically similar to that of the preceding zone, but it was much richer, especially in its younger part (the lower section is inadequately sampled). A wide variety of new taxa appeared, represented by pollen of *Helianthemum canum* type, *Saxifraga oppositifolia* type, *Hedysarum*, *Polygonum bistorta*/*P. viviparum*, *Rumex* cf. *acetosella*, *R. acetosa*, *Lotus*, *Plantago maritima*, *P. coronopus*, *Trollius*, *Pulsatilla*, *Armeria* and representatives of *Rubiaceae*, *Compositae Liguliflorae* and *Umbelliferae*. The development of tall herb communities is recorded by the appearance of *Urtica dioica* and *Filipendula*. The communities of eutrophic mire plants — *Parnassia*, *Tofieldia*, *Selaginella* have been reduced. Because of progressive melting out, the existence of the mire came to an end, the depression got waterlogged and the aquatic flora developed in the newly-formed lakelet, including *Myriophyllum spicatum*, species of *Batrachium* (*Ranunculus trichophyllus* type pollen and seeds of *Batrachium* sp.), *Hippuris vulgaris*, *Hottonia palustris*, *Potamogeton filiformis* (fruits, and *P.* sect. *Coleogeton* pollen), *Callitriche* and *Characeae* (oospores) and an abundance of algae, genus *Pediastrum*.

The change of sediment into silty mud still showing undulated structures conformable to the underlying layers, and then into laminated muds infilling and levelling the irregularities of the bed, is evidence of two subsequent stages of stabilization of the landscape:1:less silt being washed in from more stable shores but melting processes still active, 2: the subsidence of the bed and the beginning of more or less undisturbed sediment accumulation, together with the stabilization of vegetation surrounding the site.

N-Ibis-3 *Artemisia* — *Chenopodiaceae* l.p.z.

This is a local zone of dubious significance and difficult ecological interpretation. The rising *Betula* percentage and concentration pollen curves, as well as declining NAP values (*Gramineae* mostly contributing to the change of AP : NAP ratio), suggest progressing woodland development. The first fruit scales of *Betula* tree-type have been found by the end of zone. At the same time the change of sediment into more silty and not laminated mud and a new rise in frequencies of rebedded pollen point to some renewed soil erosion. The rise of *Artemisia* and *Chenopodiaceae* pollen frequencies are the main characteristics of zone. Together with small rises in *Hippophaë* and *Juniperus* pollen values and the appearance of *Gysophila fastigiata* type pollen they suggest some minor oscillation towards a drier, more continental climate (?). Also characteristic of this zone are the regular occurrence of *Anemone* type and *Helianthemum canum* type pollen, occasional grains of *Viola*, *Papaver* and *Epilobium*, and small rises in *Thalictrum* pollen and *Sphagnum* spore frequencies.

N-Ibis-4 *Juniperus* l.p.z.

This pollen zone reflects a distinct phase of birch woodland spread. The rise in the *Betula* pollen curve is accompanied by numerous macrofossils — fruits and fruit scales of *B.* s. *alba* type. The NAP values fall to 23 %, the lowest of the whole *Betula* regional PAZ. This is especially distinct in pollen curves of components of open, rather xeric grassland communities — *Gramineae*, *Artemisia* and *Chenopodiaceae*, and *Thalictrum*. Some rise in *Ranunculus*, *Umbelliferae*, *Filipendula* and *Urtica* frequencies, especially in the upper part of zone, together with the appearance of *Saussurea alpina* pollen suggest some development of tall herb communities, though most of grassland species are still present. *Hippophaë* shrubs suffered a heavy reduction, but *Juniperus* communities spread, its pollen reaching maximum values of 15 % by the end of zone, in the way which is typical of Allerød vegetation in maritime climates of Scandinavian countries (Iversen 1973). The mire with *Tofieldia* and *Parnassia* dissappeared, and aquatic vegetation developed rapidly, as shown especially by maxima of *Myriophyllum spicatum* and *Ranunculus trichophyllus* type pollen and the maximum variety and amounts of *Potamogeton* macrofossils (*P. alpinus*, *P. praelongus*, *P. vaginatus* and *P. filiformis*), accompanied by pollen of *P.* sect. *Eupotamogeton* and *P.* sect. *Coleogeton*, and the presence of *Myriophyllum verticillatum*, *Hottonia palustris*, *Hippuris vulgaris*, *Lemna*, and *Rumex aquaticus*. At the same time the reduction of *Characeae* submerged swards (decrease of oospores frequencies) and of *Pediastrum* abundance occurred. The marginal zone of the lake was colonised by telmatic vegetation with *Typha latifolia* and *Comarum palustre*. The rise of *Cyperaceae* frequencies might also be associated with these communities.

The presence of *Typha latifolia* is assumed to indicate a July temperature around +14° C, and the appearance of *Lemna* in the lake is also a sign of climatic improvement.

The black silty mud deposited in the older part of zone was radiocarbon dated — the soluble fraction and residuum being dated separately. Probably due to the hard water effect the age obtained appeared too old, and differed between the fractions by more than 1000 yrs (13430±150 SOL and 12260±120 RES). In the younger part of the zone a pale-green-brown clayey gyttja was deposited in the lake.

N-Ibis-5 *Filipendula* — *Umbelliferae* l.p.z.

The stable AP values at ca. 60% are indicative of the stabilization of a woodland-shrub landscape, with treebirches still being dominant (a maximum of *Betula* sect. *alba* macrofossils at the transition to N-Ibis-6 l.p.z.). The contribution of pine slightly increased, and *Populus tremula* and *Sorbus aucuparia* were present in small amounts. *Betula nana* shrubs underwent some reduction, and juniper communities were past their maximum development. The rise of *Filipendula*, *Umbelliferae*, *Urtica dioica* and *Thalictrum* pollen frequencies reflects further development of tall herbs associated probably with the woodland establishment. Otherwise there is no significant change in the herb communities still existing in open habitats. The flowering of aquatic vegetation was reduced and some pollen taxa *(Hottonia*, *Potamogeton* sect. *Coleogeton)* disappeared. The increasing frequencies of *Equisetum* and *Sphagnum* spores and the maximum numbers of *Carex vesicaria* fruits may evidence the progressive overgrowing of the lake shore.

N-Ibis-6 *Pinus* — *Filipendula* — *Equisetum* l.p.z.

The successional changes lead to the maximum woodland development during this zone, with increasing *Pinus* and decreasing *Betula* contributions. The *Juniperus* communities underwent further reduction. *Empetrum* and *Calluna* possibly grew in the understory of open woods, as well as the tall herbs with *Filipendula* predominant, *Urtica dioica* (fruits) and *Melandrium*, associated with moister habitats. However the open grasslands were not only present all the time, but seemed to show some temporal spread in the middle of the zone (slight increase of *Artemisia*, *Chenopodiaceae*, *Gramineae* and *Cyperaceae* frequencies). The variety of herb pollen taxa represented in the pollen flora did not show any essential change, and even some new taxa were recorded *(Bupleurum*, *Scleranthus annuus)*.

The vegetation in the lake underwent a marked change. Nearly all aquatics decreased strongly in frequency or disappeared, and the overgrowing by telmatophytes progressed rapidly, as shown by *Typha latifolia*, *Menyanthes trifoliata* (both pollen and macrofossils), *Scheuchzeria palustris*, *Caltha palustris* pollen and *Equisetum* and *Sphagnum* spores. These changes reflect the lowering of water level and lake infilling processes. Possibly a temperary increase of climatic dryness happened during this zone.

By the end of zone the maximum of aforestation is reached, correlated with the strongest reduction of herb and shrub communities.

N-Ibis-7 *Betula nana* — *Empetrum* PAZ.

A rapid change in pollen assemblages undoubtedly reflects significant changes of vegetation around the site. The fall of the total tree pollen curve to 34%, and rise of shrub, dwarf shrub and herb pollen frequencies suggest the correlation of this zone with the Younger Dryas chronozone. However the radiocarbon date obtained for the peaty mud layer corresponding to the zone onset is in conflict with such an age estimation. It is 9330±120 BP, more than 1500 years younger than expected. The reason is unknown to the author, who did not take part in any field work at the site, or in laboratory preparation of samples.

The drastic fall in *Betula* pollen values is well seen in the pollen concentration diagram in spite of very high total pollen concentration. The latter opens the question whether the temporal fall in the *Pinus* percentage pollen curve reflects a real reduction of pine, for the concentration diagram shows a rise in pine values at the same time. However the data are incomplete, as the pollen concentration counts are lacking in two crucial samples in this zone.

After a small development phase at the very beginning of the zone, there occurred a gradual reduction of juniper shrubs, in what is another "Scandinavian" feature of this diagram. In the pollen diagrams from Polish lake districts juniper most often reveals a considerable spread throughout the whole Younger Dryas time (Hjelmroos-Ericsson 1981, Pawlikowski et al. 1982), which certainly has climatic reasons.

The high frequencies of *Betula nana*, *Salix glauca* type (*Salix pentandra* type pollen ceases to be represented), and *Empetrum*, together with the rise of *Cyperaceae*, *Gramineae*, *Artemisia* and *Chenopodiaceae* pollen values reflects a considerable thinning of woodland and the revertence to partially open vegetation. Pollen of such heliophytes as *Helianthemum nummularium* type and *H. canum* type, *Gypsophila fastigiata*, *Botrychium lunaria* type, *Plantago maritima* s.l. occur more consistently again, and are accompanied sporadically by pollen of *Dianthus*, *Lathyrus*, and *Scleranthus annuus*. This is further evidence for the spread of xeric grasslands rich in plant taxa. However *Selaginella* megaspores are abundant.

The reduction of *Filipendula* and *Umbelliferae* pollen frequencies to single pollen may indicate the disappearance of tall herb communities because of the reduction of humid habitats. The rising frequencies of *Typha latifolia* pollen and macrofossils together with those of *Menyanthes trifoliata*, *Caltha*, *Sphagnum* (up to 18%), and the presence of *Lycopus europaeus* (macrofossils), *Polygonum bistorta*, and *Eupatorium cannabinum* (macrofossils) are indicators of the widening lakeshore zone and progressive overgrowing. They indicate the lowering of the water level, which is also confirmed by the close-to-telmatic character of sediment. However, by the end of zone the open-water habitats unabling the good flowering of *Myriophyllum spicatum*, *Ranunculus trichophyllus* type, *Sparganium*, *Hippuris*, *Lemna* and abundant *Pediastrum* were regained. This suggests a small, temporary rise of water level around the transition to the next zone.

The above picture of Younger Dryas vegetation differs in many aspects from that obtained by Latałowa (1982) in the eastern part of Baltic coastal zone. In the Żarnowiec area the characteristic features of plant communities at that time were the abundance of juniper shrubs, like in lake district areas, the presence of such tundra plants as *Dryas octopetala* (macrofossils), and *Saxifraga nivalis* type, and high frequencies of tall heıbs — *Filipendula* and *Urtica*, interpreted by the author as the sign of rising water level in the lake because of dead-ice melting.

Pinus-Polypodiaceae l.p.z.

Though the upper part of the profile reveals hiatuses in pollen sequence, this pollen zone still shows consistency with the pollen picture obtained from the underlying sediments. It reflects the increasing importance of pine woodland with a rather stable amount of birch, a distinct reduction of open grasslands, and the beginning of the restriction of shrub communities of *Betula nana*, and *Salix* sp. div. The *Empetrum* heaths were still well developed. The progressive degradation of grasslands is expressed by the diminishing number of taxa represented. Still present are *Helianthemum canum* type, *Gypsophila fastigiata* type, *Dianthus*, *Botrychium* and *Selaginella*, together with *Chrysanthemum* type and *Anemone* type. *Filipendula* grew in abundance again, and so did *Eupatorium cannabinum* (seeds), *Typha latifolia*, and also aquatics — *Myriophyllum spicatum* and *Ranunculus trichophyllus*. Their abundance was probably a response to both the ameliorating climatic conditions and a temporary rise od water level. The frequencies of *Pediastrum* are also high at that time. A few pollen grains of *Alnus* and *Corylus* found in the upper sample of the zone may originate from the overlying peat.

The upper 20 cm of the profile covering swamp peat deposits show no continuity with the part of the profile below. Two radiocarbon dates from the lower and upper parts of this peat layer are 5910$\pm$80 B. P. and 3340$\pm$60 B. P.

The 5900 yrs sample represents the time of dominant pine woodland, with small amounts of *Betula*, *Corylus*, *Salix glauca* type, and the presence of *Tilia* and *Viscum*. There was very sparse and poor herb vegetation, reflecting the woodland herb layer, mostly grasses, ferns, and *Vaccinium*. Aquatics are virtually absent, as the lake has been overgrown with reed-swamp (15% of *Typha latifolia* pollen).

Small amounts of *Alnus* and *Filipendula* represent woods of moist habitats.

The other 3 samples record the Late-Holocene vegetation, with less pine woodland and more mixed deciduous forest, with *Ulmus*, *Tilia*, *Corylus*, *Quercus*, *Carpinus*, *Fagus*, *Hedera* and *Viscum* on more fertile soils, and alderwoods on damp soils. Herb pollen (up to 38%) originates partly from the areas deforested by man, as shown by the presence of weeds *(Centaurea cyanus)* and cereals. The local pollen flora reflects a minor oscillation of water level at the site expressed by fairly large amounts of *Sparganium* type pollen (up to 11%) together with consistently occurring *Potamogeton* sect. *Eupotamogeton*, and *Lemna*, and also by the abundance of macrofossils of limno- and telmatophytes: *Characeae*, *Batrachium* sp., *Oenanthe aquatica*, *Lythrum salicaria*, *Alisma plantago aquatica*, *Lemna*, *Sparganium* sp. The high peak of *Cyperaceae* pollen (56%) in the uppermost sample is indicative of site overgrowing by sedge communities (*Lycopus europaeus*, *Mentha* sp. and *Carex* sp. div. macrofossils).

The mechanisms causing the break in peat accumulation from the early Holocene till the late Atlantic, and its renewal, but with reduced accumulation rates, between 6000 and 3400 B. P., are not clearly understood. They might have originated from the oscillations of ground water level. Judging from both ^{14}C dates and pollen spectra, the mire ceased to grow some time after 3000 B. P. (the ^{14}C date for the top layer of peat in profile Niechorze I is 2700 ± 130, Brykczyńska 1978). The lowering of ground water is shown by the thin layer of fossil soil on the top of the peat which was later covered by dune sands (Kopczyńska-Lamparska 1976).

COMPARISON OF POLLEN, MACROFOSSIL, DIATOM AND CLADOCERA ASSEMBLAGE ZONES FROM NIECHORZE I bis PROFILE

In table 2 the sequencies of assemblage zones distinguished in pollen, macrofossil, diatom and cladocera profiles are compared, together with the deduced conclusions concerning climatic and lake-developmental changes. The table speaks for itself and needs only few comments.

The macrofossil zones show a good correspondence with the pollen zones though the macrofossil subdivision is rougher. The most consistent are the pollen and cladocera stratigraphies.

The improvement of climate and synchronous formation of the lake is recorded in all stratigraphical sequencies around 480 cm. Interestingly, a short phase N-Ibis-3 distinguished in the pollen diagram by a rise in some herb and shrub pollen taxa and in rebedded pollen frequencies (the latter possibly in connection with the renewed soil erosion), and interpreted as an oscillation towards a drier, more continental climate, is also reflected in diatom and cladocera analyses (diatom zone Ibis-N-3 and cladocera zone 3). However, the corresponding changes in diatom assemblage assumed to express the cooling of climate and shallowing of lake begin slightly later, while the phase of rather poor cold-resistant cladoceran fauna starts and ends slightly earlier than the pollen zone N-Ibis-3. Another reduction in number of cladoceran taxa recorded, corresponds with the pollen zone N-Ibis-5 reflecting the lake shallowing processes. The "climatic optimum" of the late glacial section studied, occurring between 418 and 370 cm is reflected in the pollen assemblage (N-Ibis-6) by the increasing pine pollen values and minimum of NAP, accompanied by the changes in aquatic and telmatic plant pollen taxa, indicating the progressive lake overgrowing by a reedswamp, and in cladoceran assemblage by the richest in the profile, mainly littoral fauna, including newly appeared species. The following cool phase is indicated in the macrofossil diagram by the reappearance of *Sela-*

Depth (cm)	Regional pollen assemblage zones	Local pollen zones	c/l	Macrofossil assemblage zones	c/l	Diatom assemblage zones (after Marciniak 1981)		c/l	*Cladocera* assemblage zones (after Szeroczyńska 1985)	c/l
320—	no pollen zones distinguishable		water level oscillations; later lake disappearance	N-Ibis-V *Lemnaceae*	warm; very shallow overgrowing lake	no analyses performed			9	sporadic *Chydorus*
340—	*Betula nana-Empetrum*	N-Ibis-8 *Pinus-Polypodiaceae*	warming; higher water level	N-Ibis-IV *Eupatorium cannabinum*	warming; water level fluctuations				8	no *Cladocera*
360—		N-Ibis-7 *Gramineae-Artemisia*	cooling; low water level rising by end	N-Ibis-III *Selaginella selaginoides*	cool				7	sporadic *Chydorus*; cooling?
380— 400—	*Betula*	N-Ibis-6 *Pinus-Filipendula*	warmest and possibly temporarily drier climate; water level lowering/progressive lake overgrowing	not examined					6	warm; richest fauna; *Camptocercus rectirostris*, *Sida crystallina*
420—		N-Ibis-5 *Filipendula-Umbelliferae*	stable climate; lake overgrowing	N-Ibis-II *Betula* sp.	climatic improvement; lake deepening followed by extension of telmatic lake shore zone	IbisN5 b, a	species — rich	progressing shallowing; some rise of water level by end	5	slight cooling?
440—		N-Ibis-4 *Juniperus*	warming; lake development			IbisN4 c, b, a		gradual extension of littoral, alkaliphil. bentic/epiphyt. taxa develop	4	warming; temporal deepening in older part; pelagial taxa 25%
460—		N-Ibis-3 *Artemisia-Chenopodiaceae*	more continental? renewed soil erosion	N-Ibis-I *Selaginella selaginoides* *Potamogeton filiformis*	cool; lake formation on a mire	IbisN3		shallowing, cooling	3	cooling; cold-resistant fauna
480—		N-Ibis-2 *Betula nana-Gramineae*	warming; lake formation			IbisN2	species — poor	slight warming/deepening; *Cyclotella comta*	2	rapid warming, rich fauna; dev. of littoral; *Camptocercus rectirostris*
500—	N-Ibis-1 *(Pinus)-Hippophaë-Salix*		cool; melting processes; mire formation			IbisN1		cold, shallow; *Frag. pinnata* 50% *Cyclotella antiqua*	1	cold? sporadic *Chydorus sphericus*

c/l = inferred climate/lake changes.

ginella selaginoides megaspores (MAZ Ibis-III), and in the pollen diagram by the increase in herb, shrub and dwarf shrub pollen values, and nearly total elimination of aquatic taxa with only reed swamp pollen present (N-Ibis-7). The corresponding cladoceran assemblage (7) shows the reduction of fauna to the sporadically occurring *Chydorus* specimens. All that speaks for the cool climate, and lowered water level. The following temporary rise of water level, corresponding with the transition between pollen zones N-Ibis-7 and 8, did not make it possible for the clacoceran fauna to regenerate. It did not happen even later in the Holocene, when the macrofossil and pollen record (MAZ-Ibis V, in pollen diagram assemblage zones not distinguished) reveal the existence of a small lakelet within a reed-swamp with exuberant shallow-water and telmatic vegetation. In this profile — section only *Chydorus* species that can live even in stagnant water puddles reappear sporadically (Szeroczyńska 1985).

DISCUSSION

The history of vegetation recorded in the Niechorze cliff I profile was originally interpreted as a full Late-glacial sequence starting at the decline of Oldest Dryas chronozone, covering Bølling, Older Dryas, Allerød and Younger Dryas chronozones, and including also early Holocene — Pre-Boreal and Boreal chronozones, with the first hiatus occurring during the Atlantic period (Brykczyńska 1978).

The starting point for such inference was the ^{14}C date of 12920$\pm$330 B. P. (Kopczyńska-Lamparska 1976) made from the 7 cm peat layer at the base of profile corresponding to layer 4 in Niech. Ibis profile. The pollen diagram published by Brykczyńska (l.c.) gave a rather unclear picture of vegetational succession. A phase of rather high (ca. 40%) NAP values, with the curve of *Selaginella* spores up to 35%, coincident with the basal peat formation, was assumed to cover Oldest Dryas and part of Bølling zones, the following phase of dominant *Betula* pollen was attributed to Older Dryas and Allerød a, and a long phase of nearly co-dominant *Betula* and *Pinus*, with a slight prevalence of *Betula*, and rather stable NAP (at ca. 20%) was thought to cover Allerød b, Younger Dryas, Pre-Boreal, and part of Boreal zones in Brykczyńska (1978) stratigraphy. The new set of four ^{14}C dates obtained from the basal part of Niech. Ibis profile with the age between 12150$\pm$100 and 11880$\pm$110 B. P. is younger by several hundreds of years than the bottom date from Niechorze I, even if we keep in mind the high statistical uncertainty of that date, being $\pm$330. These four dates point to the Older Dryas/Allerød chronozones transition as the probable age for the origin of Niechorze I sediments what corroborates the suggestion made by Tobolski (1983) based on pollen sequence published by Brykczyńska (1978)). Unfortunately, the other dates from Niechorze Ibis did not help to set up the stratigraphy of the site as discussed earlier. The Late-glacial sequence obtained from Niech. Ibis profile by Ralska-Jasiewiczowa, records a successional cycle from treeless vegetation of shrub tundra type, through several phases of woodland establishment, to a phase of partial woodland recession and a new spread of open vegetation. The *Artemisia-Chenopodiaceae* local pollen zone N-Ibis-3 together with corresponding diatom and cladocera zones might represent a minor oscillation towards a drier and more continental (cooler?) climate within this cycle, close to its beginning.

Such sequencies are known not only from central, Western and North-Western Europe, but also from S Sweden (Berglund 1976, 1979), and may represent the interstadial complex of Bølling and Allerød with the poorly distinguishable Older Dryas oscillation inbetween. The age of woodland expansion is of crucial importance here, but unfortunately there are not so many full Late-glacial sequences with a reliable series of ^{14}C dates. The newest data from Hakull's Mosse in the Skane area place the beginning of afforestation processes between the dates 12660±125 and 13020±135 (uncorr. yrs. BP, Berglund in: Berglund & Ralska-Jasiewiczowa 1986). On the other hand, according to Usinger's investigations at Bornholm (1977) and in Schlezwig-Holstein (1978), the main invasion of tree-birches took place in both areas during Allerød time only, following the expansion of shrub communities with *Betula nana* and *Hippophaë* during Bølling time. The extensive studies of Late-glacial sites in Schlezwig-Holstein allowed Usinger (1985) to reconstruct a very detailed generalised picture of vegetational development in these areas. He assumes the plant communities of shrub tundra with dominant *Hippophaë* and *Betula nana* and very scarce tree-birches are typical of Bølling, and proposes a complicated sequence of vegetational succession during Allerød, with at least two cooler phases. He also extends his conclusions to larger areas of Northern Europe. According to his new interpretations the shrub phases distinguished prior to Allerød in the diagrams from continental N Europe (the Netherlands, Lower Saxony) would correspond to Bølling chronozone, but the woodland phases included in Bølling chronozone in S Sweden and Great Britain would belong to the early Allerød chronozone. His considerations are not, however, based on a strong chronostratigraphical basis of radiocarbon datings.

The data at our disposal are too poor to entitle us to take a serious part in this discussion. There are very few sites with well represented Late-glacial sediments known from the Baltic coastal zone of Poland (e.g. Ustka — Tobolski, unpubl.). Most of the investigated N Polish sites with Late-glacial/Holocene sequences came into being not earlier than between 12000 and 11000 BP, and contain at best the Allerød sediments at their bases, often of much reduced thickness. If we accept for Niechorze I site the stratigraphy proposed in this paper, placing the beginning of sediment accumulation at the decline of Older Dryas, as being most probable and in agreement with the basal ^{14}C dates from Niechorze Ibis profile, then, as a consequence, we join Usinger's viewpoint that the main woodland expansion in the S peri-Baltic zone of the European continent occurred at the beginning of Allerød chronozone, i.e. after 12000 yrs BP (uncalibr.). This approach is in conflict with the Scandinavian interpretations mentioned above. The scarce Polish data, coming mainly from the central part of Poland, record the development of birch woodland (Witów, Wasylikowa 1964, Lake Łukcze, Bałaga 1982), or birch-pine woodland (Węglewice, Tobolski 1966, undated; Rośle Nowe, Krajewski & Balwierz 1985; Żabinko, Tobolski, in print) during the Bølling chronozone. However, the conflict concerns first the interpretations, and is not so serious regarding the age differences. To explain these discrepances, many more sites with complete Late-glacial sediment sequences carefully investigated and dated, are certainly needed. The construction of palaeovegetation maps would be the best way to deal with the problem, but due to the scantiness of suitable data it is still far from being possible.

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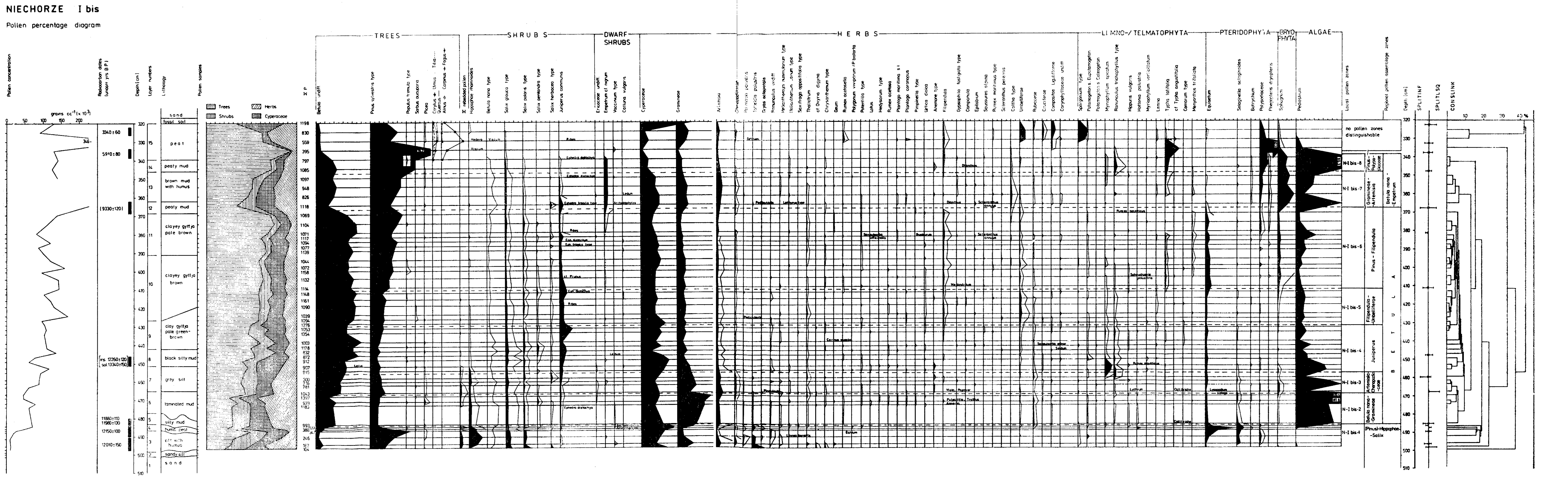

Fig. 4. Niechorze I bis profile. Pollen percentage diagram. The layer numbers follow the sediment description on page 156

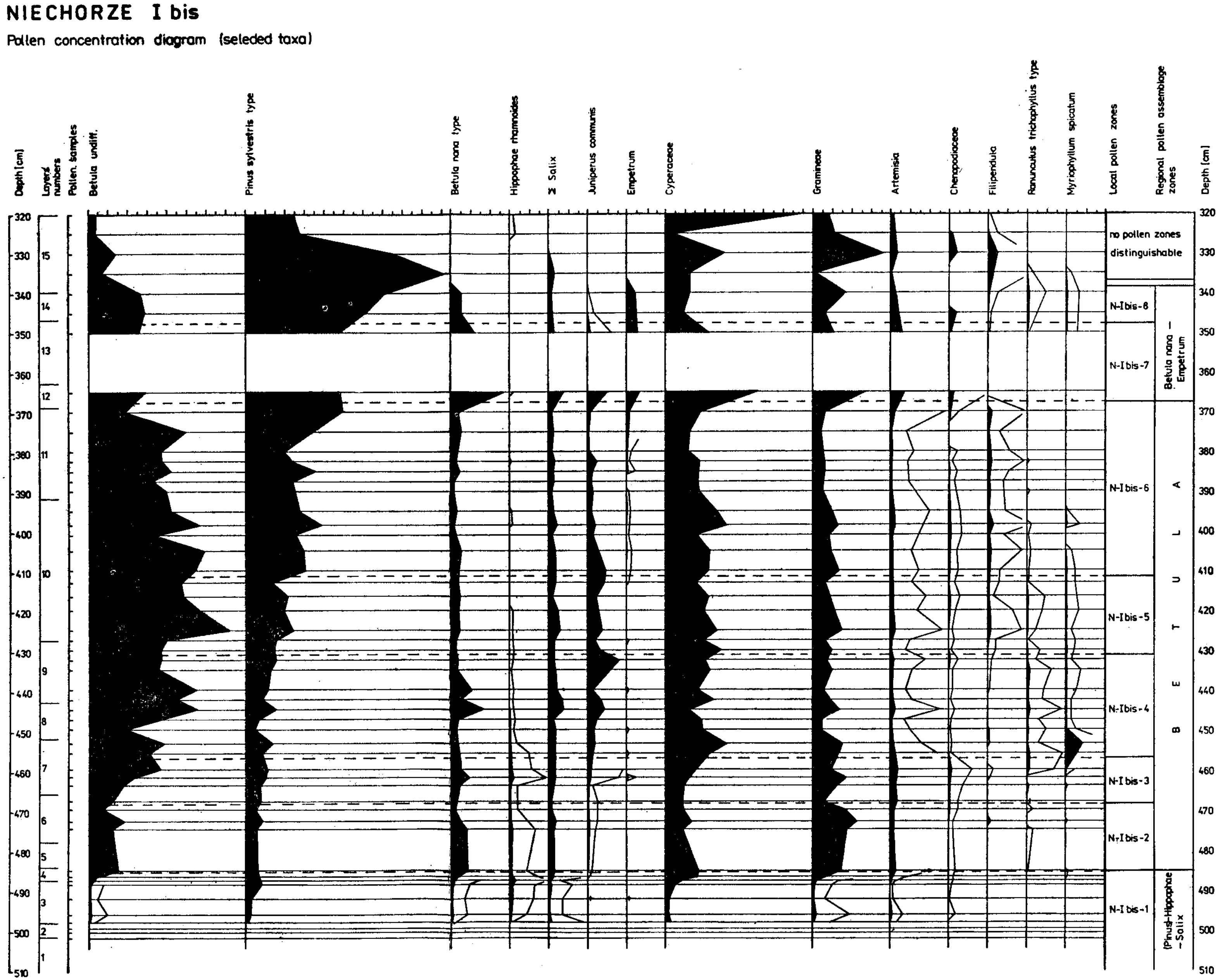

Fig. 5. Niechorze I bis profile. Pollen concentration diagram, selected taxa