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THE HISTORY OF THE VEGETATION OF BORY TUCHOLSKIE AND THE ROLE OF MAN IN THE LIGHT OF PALYNOLOGICAL INVESTIGATIONS

Historia roślinności Borów Tucholskich i rola człowieka w świetle badań palinologicznych

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ABSTRACT. The paper describes the results of pollen analysis of the fossil lake sediments in three lakes in Bory Tucholskie (Lakes Mały Suszek, Suszek and Kęsowo). The investigations continued and expanded on the palaeoecological investigations of Lake Wielkie Gacno, (Hjelmroos-Ericsson 1981a, 1982). On the basis of distinguished local pollen assemblage zones, 11 regional pollen assemblage zones are described which cover the period from about 11810 years B.P. to the present day.

The 10 radiocarbon dates of organogenic sediment of Lake Mały Suszek and comparisons with the absolute age of certain events for Wielkie Gacno (23 radiocarbon dates – Hjelmroos 1981b) permit the use of a time scale.

Special attention was paid to the role of man and his interference with the natural vegetation. 7 periods of human impact was distinguished and all of them are compatible with archaeological data on the development of particular cultures in Bory Tucholskie.

KEY WORDS: Bory Tucholskie, IGCP, Holocene, palynological analysis, palaeoecology, forest successions, human impact, radiocarbon datings, numerical analyses

CONTENTS

INTRODUCTION

The investigations whose results are discussed in the present paper were begun in 1982 as part of interdepartmental programme R-III-15 "Ecological processes within selected landscape units and their energy balance" and since 1986 have been continued as central programme 04.10.01 entitled "Natural foundations of the protection and forma-

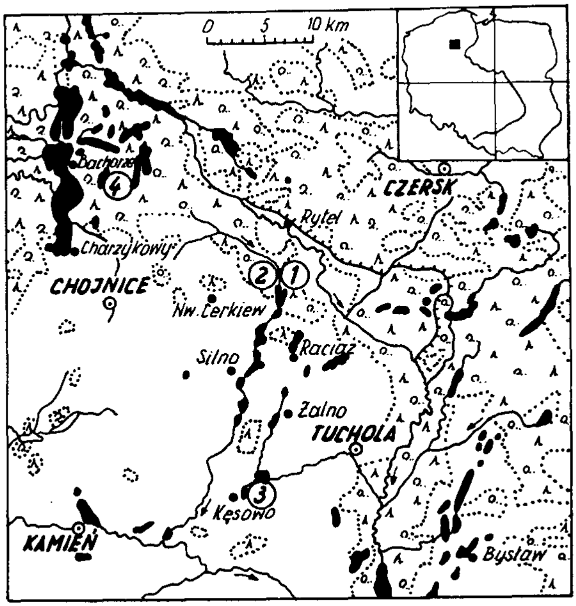

Fig. 1. Maps of the Bory Tucholskie region with reference lakes indicated (1 – Mały Suszek, 2 – Suszek, 3 – Kęsowo, 4 – Wielkie Gacno)

tion of the natural environment".

The investigations continued and expanded on the palaeoecological investigations of Lake Wielkie Gacno, which also formed part of the above-mentioned departmental programme (Hjelmroos-Ericsson 1981a, b, 1982). This lake was a "reference site" in the International Geological Correlation Programme (IGCP) 158 B "Palaeohydrological changes in the temperate zone in the last 15000 years". The investigations reported in this paper became part of that programme in 1987.

The aim of thus expanded palaeoecological investigations was to deepen knowledge about the history of vegetation in this area. Special attention was paid to the role of man and his interference with the natural vegetation. Learning about the development of the lakes under study and the influence of human activity on trophic changes, comparing the results obtained with archaeological data and finally attempting to apply these changes to the entire area of Bory Tucholskie (cf. Berglund et. al. 1984) were secondary aims of the investigations. The sampling of deposits in the three selected lakes: Suszek, Kęsowo and Mały Suszek (Fig. 1) was facilitated by the personnel of the Department of Quaternary Geology, University of Lund, headed by Professor Bjorn E. Berglund. They were twice in Poland in the area of Bory Tucholskie in 1982 and 1983, each time bringing their own coring equipment.

The description of the regional history of vegetation and the interpretation of the economic activity of man comprises, in addition to the three mentioned sites (Lakes Suszek, Mały Suszek and Kęsowo), the results of the investigations of Lake Wielkie Gacno (Hjelmroos-Ericsson 1981a, 1982).

DESCRIPTION OF BORY TUCHOLSKIE AREA

PHYSIOGRAPHY

Bory Tucholskie with an area of 2106 km^2 (Kondracki 1978) is the greatest woodland region in Western Pomerania and one of the greatest in Poland. It lies between two tributaries of the Vistula river, the Wda (Czarna Woda) and the Brda. According to the physiographic division of Poland (Kondracki 1978), Bory Tucholskie is a mesoregion in the South-Pomeranian Lakeland macroregion. The macroregion is part of the South-Baltic Lakeland sub-province of the Central European Lowland province.

GEOLOGY AND GEOMORPHOLOGY

The entire area of Bory Tucholskie lies within the border synclinorium (Galon 1972, Augustowski 1977). A sedimentary complex composed of Cambrian, Ordovician and Silurian formations rests on the cristallic pre-Cambrian base built mostly of gneiss. These are basically sandy, clayey and silty deposits. A reduced structural Permian-Mesosoic layer lies on Silurian deposits (Augustowski 1977). The Tertiary series is represented by sea deposits of the Oligocene, mainly fine-grained glauconite sands of very small thickness and mineroganic or lake formations of the Miocene such as quartz sands, clays and silts. The land period of the Pliocene was marked by an intensive reliefs of the pre-Quaternary surface in which an erosion cut of several dozen meters was found (Atlas Geologiczny Polski 1986). Quaternary deposits have thickness of 50 m to over 200 m (Wilczyński 1973, Augustowski 1977, Mojski 1984). Pleistocene deposits are represented by boulder clays, sands, gravels, silts and erratic blocks (Augustowski 1977). Holocene deposits are present only locally.

Bory Tucholskie lies in the foreland of end moraines in the area of an outwash plain known as the Brda Outwash, formed at the Pommeranian stage of the Baltic Glaciation (Galon 1953, 1972, Kondracki 1978, Augustowski 1977). The outwash plain is bent towards the southbound outlet of melt waters and is drained off mainly by the Brda and its numerous tributaries. Within the outwash plain a number of moraine islands and peninsulas have remained (Galon 1953, Augustowski 1977). These are islands: Brusy, Radunia, Wiele, Czersk and Gutowiec and peninsulas: Konarzyny and Jarcewo (Fig. 2).

RELIEF

Bory Tucholskie lies within the area characterized by young glacial relief in the morphogenetic zone of lake uplands (Galon 1972, Roszko 1973). The outwash plain of Bory Tucholskie is diversified by erosion steps and intersected by numerous channel lakes (e.g. Lake Charzykowskie, Lake Śpierewnik, Lake Ostrowite and others) and tunnel valeys partially or completely transformed into river valleys, e.g. the upper Brda (Roszko 1973). The plain character changes at places into a diversified, even hummocky one, owing to the accumulation of greater number of deep kettle-holes. The relative altitudes range from 20 m to 30 m (Galon 1953). Small dunes located at the height of 140 m to

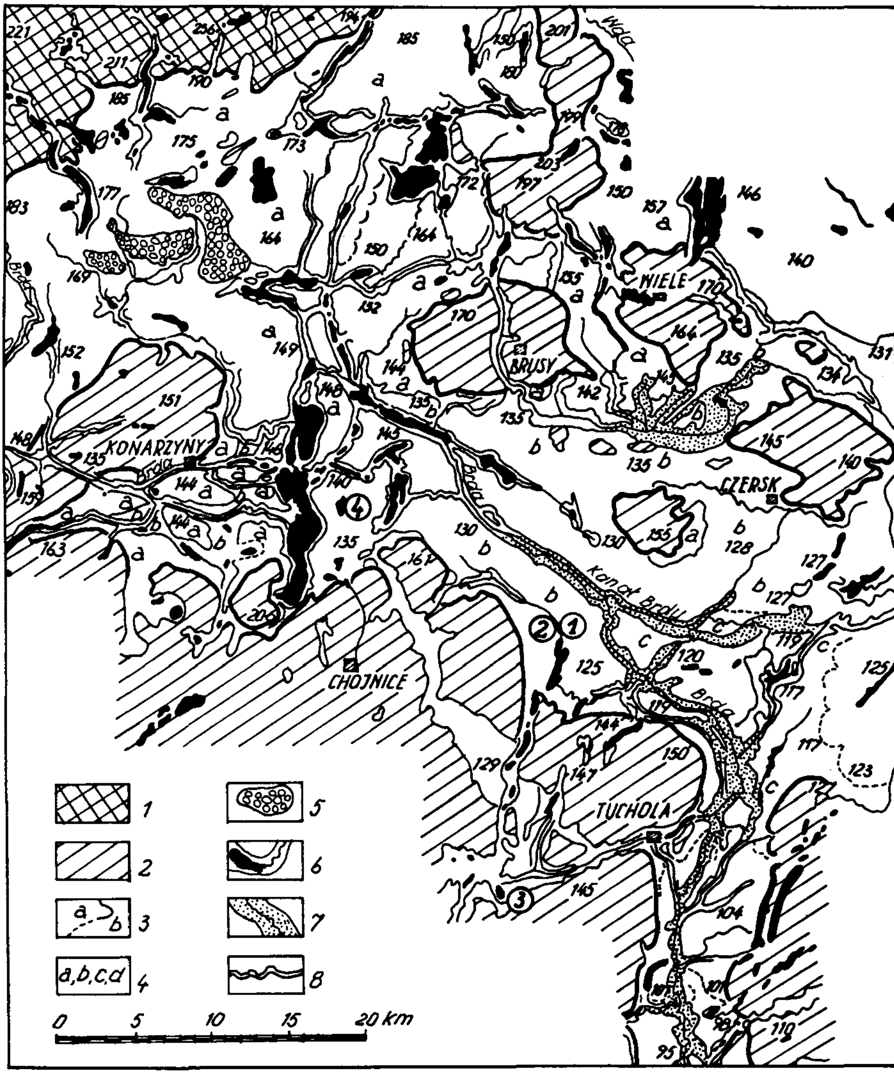

Fig. 2. Geomorphological map of Bory Tucholskie (acc. Galon 1953) 1 – head moraines of the Pomerania stage, 2 – moraine uplands, 3 – outwash, 4 – successively younger outwash areas, 5 – accumulation of kettle holes, 6 – river and lakes valleys, 7 – valley of the Brda and its tributaries

145 m a.s.l. are another diversification of the relief. The dunes were formed in the Late Glacial period and partly during the Holocene (Galon 1961, Wasylikowa 1964). Holocene dunes were probably connected with human activity (Tobolski 1966, Kozarski & Tobolski 1968, Kozarski et al. 1969).

WATERS

Underground waters play the most fundamental role in the water balance of each region. Due to the water conditions the area of Bory Tucholskie belongs mainly to type A according to Celmer (Celmer & Churski 1973). This type is characterized by the greatest retention capabilities in the form of underground water. This is due to the great permeability of surface deposits: rainfall water almost entirely infiltrates the ground. Its flow to water courses is non-existent or is of local insignificance. The depth of underground water level is only occasionally found at about 2 meters below the surface; normally it is found at the depth of 4 m or more. A rather dense network of ephemeral ditches, numerous small swamps and water reservoirs, so called field ponds and pools is found over small areas of flat and wave ground moraines, mainly in the southern part of Bory Tucholskie (Celmer & Churski 1973).

CLIMATE

The greater part of the Bory Tucholskie area belongs to the Tuchola-Złotów Land of the Lakeland Climate Region (Romer 1949). The main climatic features of Bory Tucholskie are shown in the climatic diagram (Fig. 3) for the meteorological station in Chojnice (after Fałtynowicz 1981) and on Fig. 4.

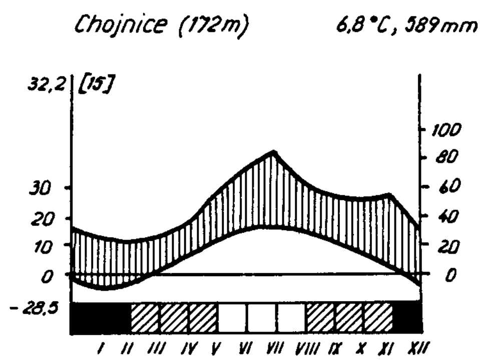

Fig. 3. Climatic diagram (Walter 1955 after Fałtynowicz 1981)

The area surrounding Chojnice lies in the zone of the smallest rainfall in Poland (Hohendorf 1973) but in particular years deviations from the average are rather considerable. For example in 1964 the rainfall was 418 mm while in 1970 it was 820 mm (Chomicz 1977). Snow covers the ground for 73 days a year on average. The arrival of spring is delated and summers are cold due to the great number of lakes. The length of the growing season is from 190 to 200 days. There are on average about 30 sunny and 166 cloudy days (Chomicz 1977) a year. Westerly winds are dominant (according to Piasecki after Augustowski 1977, Chomicz 1977). A small annual amplitude of rainfall and a greater amount of autumn than spring rainfalls indicates that this area lies within the reach of the sea-continental type of atmospheric rainfalls (Kwiecień 1979).

Fig. 4. Selected climatic data: A – July isotherms, B – January isotherms, C – annual isotherms, D – annual rainfall (after Augustowski 1977)

SOILS

The extensive outwash plain of Bory Tucholskie create favourable conditions for the development of semipodsols and podsols (Prusinkiewicz 1973). Semipodsols with a generally poor degree of podsolization are present in the northern part of the Tuchola Plain which borders on end moraines of the Pomeranian stage of the Baltic glaciation. Further to the south, the podsol features are more evident. In addition to podsol soils, pseudopodsol soils and brown soils are also found (the latter are infrequent) (Fig. 5). Pseudopodsols have most frequently formed on the deposits of the flat ground moraine while brown soils developed from more or less sandy and decalcified marl clays of the wave ground moraine (Prusinkiewicz 1973).

PRESENT-DAY VEGETATION

According to Szafer's (1972) geobotanic division the area of Bory Tucholskie is a region in the Pomeranian Transitional Belt in the Maritime Plains and Pomeranian Uplands which is a part of the Baltic division of the Central European Lowland-Highland Province.

About 45% of the area of Bory Tucholskie is covered by forests (Boiński 1985). Forests have survived in habitats which were not suitable for farming because the soil was poor and sandy with ground waters at great depths.

Pinus sylvestris is the dominant tree in Bory Tucholskie. Pine associations have been

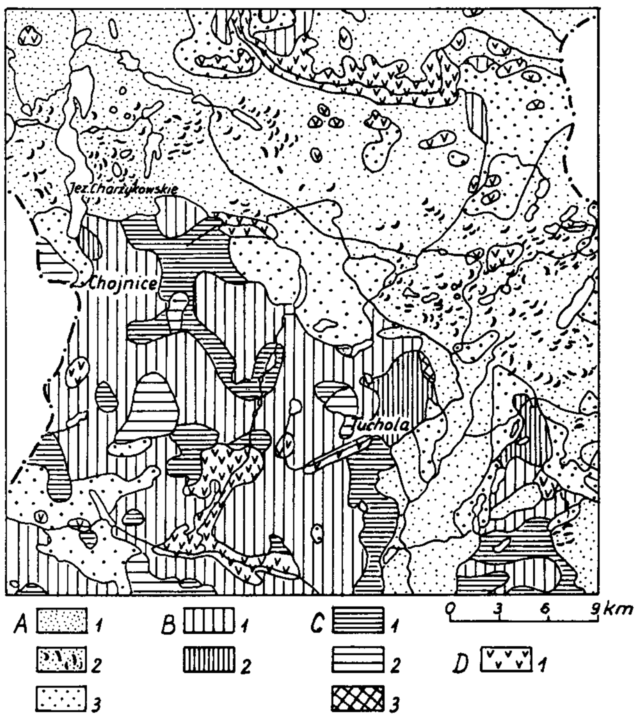

Fig. 5. A fragment of the soil map of the Bydgoszcz province (acc. Prusinkiewicz and Regel – Toruń 1967). A. a compex of podzol ground soils formed from: 1 – loose unduned sands, 2 – loose duned sands, 3 – poorly clayey sands, B. fallow soils formed from: 1 – clayey light sands, 2 – clayey strong sands, C. brown soils formed from: 1 – clayey strong sands, 2 – light clays, 3 – medium and heavy clays, D. peat soils

divided into four complexes: *Cladonio-Pinetum, Vaccinio myrtilli-Pinetum, Vaccinio uliginosi-Pinetum* and *Deschampsio-Pinetum* (Boiński 1985). Associations of deciduous forests are presently found only on banks of lakes, riverside terraces and on the slopes of lake channels. They are often formed fragmentarily. *Fagus sylvatica* forms insular complexes at places building phytocenoses *Luzulo-Fagetum* and more often entering the fresh forest as a canopy (Fałtynowicz 1981). *Alnus glutinosa* is present alongside the water courses and on the banks of peatbogs. *Salix*, mainly *Salix alba* and *S. fragilis* are found in similar habitats. Other trees (*Acer platanoides* and *A. pseudoplatanus, Alnus incana, Fraxinus excelsior, Picea abies, Quercus robur, Q. sessilis, Sorbus aucuparia* and *Tilia cordata*) are very sporadic in the area under study.

Taxus baccata, which as a complex has been preserved only in one natural site in Wierzchlas, is a dendrological peculiarity of Bory Tucholskie. *Sorbus torminalis* finds its north-eastern border here (Boiński 1985). The distribution of more important trees, shrubs and dwarf shrubs in the area of Bory Tucholskie and adjacent areas is shown in Fig. 6.

The introduction of pine monocultures to many habitats increased the susceptibility of trees to diseases and pests. Due to large gradations of insects (pine-bud moths – in 1924, pine-bud moths and Tussock-moths in 1981) thousands of hectares of forests were

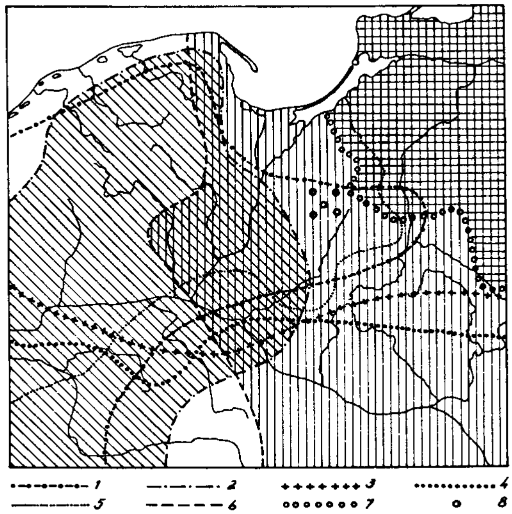

Fig. 6. The distribution of major trees, shrubs and dwarf shrubs in north-eastern Poland (acc. Walas 1973). 1 – *Acer pseudoplatanus*, 2 – *Sorbus torminalis*, 3 – *Linnaea borealis*, 4 – *Betula humilis*, 5 – *Fagus sylvatica*, 6 – *Evonymus verrucosa*, 7 – *Picea excelsa*, 8 – insular sites of this species

destroyed (Kochler 1971, Fudała 1980 after Fałtynowicz 1981). This phenomenon and frequent felling of trees are the cause of a relatively young age of the trees. Trees over one hundred years old are very rare.

The vascular flora of Bory Tucholskie, despite an apparent monotony of the landscape and poverty of habitats is relatively abundant. On the basis of a number of floristic data (Lisowski, Szafrański & Tobolski 1965, 1966a, 1967a, 1969, 1970, Ceynowa & Rejewski 1969, Boiński & Gugnacka-Fiedor 1977, Fałtynowicz 1978, Fałtynowicz & Szmeja 1978, Rejewski 1981, Boiński 1985) the occurence of many vascular plants, rare and very rare on the national and regional scale, have been found. This is the site of the greatest number of glacial and post-glacial relicts in Poland (Czubiński 1950, Walas 1973). They include: *Betula humilis, Oxycoccus microcarpus, Nuphar pumilum, Carex chordorrhiza, Arnica montana, Tofieldia calyculata, Linnaea borealis, Saxifraga hirculus, Salix livida, S. myrtilloides.* A few rare Atlantic species such as: *Elisma natans, Lobelia dortmanna, Isoetes lacustris*, characteristic of oligotrophic lobelia lakes which are found in the north-western part of Bory Tucholskie are also worth stressing (Ławrynowicz 1964, 1965, Rejewski 1981, Boiński 1985). The floristic composition of these lakes is diversified by some interesting and rare taxa of algae (Luścińska 1979, Luścińska & Oleksowicz 1984).

THE HISTORY OF SETTLEMENT

Older and middle Stone Age

The findings from the end of the older Palaeolithic and middle Palaeolithic are exceptional rarity. The end of late Palaeolithic is characterized by a considerable increase in population in Poland (Gąssowski 1985). First traces of settlement in Pomerania are from that time. A rich complex of findings from late Palaeolithic has been found in Leśno (Walenta, in print) and Chocimski Młyn (Bagniewski 1987). These findings are connected most probably with the Lyngby culture.

During early Mesolithic the entire area of river valleys of Polish Lowland was under the influence of the Komornice culture (Gąssowski 1985). At the turn of the 7th and 6th centuries B.C. the Chojnice-Pieńki culture developed. Compact settlement complexes from the end of the Mesolithic are present in the lower (near Bydgoszcz) and upper (from Tuchola to Swornigacie) Brda.

Neolithic

The oldest phase of the Neolithic settlement associated with the spread of the Linnear Pottery culture was connected with fertile lands, mainly in river valleys. The northern circle of Neolithic cultures was formed as late as in the 4th c. B.C. The areas of Polish Lowland were under the influence of the eastern group of Funnel Beaker culture. This group developed until the middle of the 3rd century B.C. It was characterized by the dominance of breeding economy and a considerable role played by hunting and fishing. Cattle and pigs were bred, sheep and goats were marginal (Gąssowski 1985). Ard ploughing made the introduction of farming to uplands possible. From the half of the 3rd century B.C. the Globular Amphorae culture developed and gradually replaced the Funnel Beaker culture. The peoples of this culture engaged themselves mainly in breeding which is evidenced by a great number of animal bones found at archaeological sites. At the same time representatives of the Corded Ware cultures appeared.

In the area of Bory Tucholskie the Neolithic sites are mainly connected with the Funnel Beaker culture.

Bronze Age

In Poland the Bronze Age is divided into five periods (according to Godłowski & Kozłowski 1985): early I (1800–1400 years B.C.), older II (1400–1200 years B.C.), middle III (1200–1000 years B.C.), younger IV (1000–800 years B.C.), late V (800–700, 650 years B.C.).

The development of the Bronze Age cultures was based on the Corded Ware cultures. This feature is typical of the Iwno culture, which appeared at the beginning of the Bronze Age. During this culture a special role was played by cattle breeding, which has been confirmed by the excavations of great cattle corralls.

At the turn of the I and II periods of the Bronze Age pre-Lusatian culture developed. It was characterized by increased significance of shepherdy what was manifested by the appearance of settlements on light soils, often on dunes. This culture developed until the 13th c. B.C. and gave rise to the western branch of the Lusatian culture. At this time farming and breeding developed although collecting, fishing and hunting were still very important (Okulicz 1973). Among the grains, millet, wheat and barley were most common. Rye was sporadic (Godłowski & Kozłowski 1985). Cattle was bred most frequently, pigs, sheep, goats and horses were rarer. Traces of the Lusatian settlements were well preserved in, for example, Brusy, Leśno, Główczewice, Zalesie and Czarnów (Walenta, in print).

Iron Age

Hallstatt C and D

The peak development of the Lusatian culture took place in the Hallstatt C period followed by its rapid decline. At the beginning of the Hallstatt D period (first half of the 6th c. B.C.) the Kashubian group of the Lusatian culture transformed into a separate culture called Pomeranian or East Pomeranian (Kostrzewski 1966). At the end of this period the culture spread to the area of almost entire Pomerania.

La Tene Period

A further spread of the Pomeranian culture took place. The sites of this culture are grouped in rather dry and fairly high areas (Grzelakowska 1984). The preserved plants remains are evidence for the growing of barley, wheat, millet, rye and peas (Godłowski & Kozłowski 1985).

After the disapearance of the Pomeranian culture the settlement in Bory Tucholskie was clearly weakened (Walenta, in print)

Roman Period

At the beginning of the modern era the Wielbark culture developed and spread over the area of almost entire Pomerania. The economy was based on farming and breeding. Rye, millet, barley, different varieties of wheat, oats, peas, large beans, flax, hemp and most probably vetch, gold-of-pleasure and Tartarian buckwheat were grown. On the basis of an analysis of bone material found in settlements it was concluded that cattle was primarily bred. Pigs were less imporant. In addition to intense agricultural production various crafts developed (Godłowski & Kozłowski 1985).

Migration Period

In the entire area of Pomerania, apart from the costal zone, there are only very few traces of late Roman and Migration period settlements. In Bory Tucholskie this is the time of the so called settlement emptiness (Walenta, in print).

Early Middle Ages

The dating of the earliest materials of the Slavonic culture is difficult. Most probably they come from the 6th and the beginning of the 7th centuries.

The economy was based on agriculture, which decided about the concentration of settlement groups in agricultural lands. The proportion of rye and oats in cultivations was higher (Gąssowski 1985). Pigs and cattle were most important in breeding (Godłowski & Kozłowski 1985).

From the 9th till the 12th centuries, due to the political partitioning of the country, the numbers of strongholds increased and open settlements entered the forests (Łuka 1973). Only in medieval Raciąż castellany there were three strongholds: Raciąż, Obrowo and Gostycyn (Kowalczyk 1986).

Beginning in the 12th c. in Bory Tucholskie and the entire Pomerania there was a frequent forest clearings in order to gain new areas which could be used for agriculture and breeding. The population of Bory Tucholskie occupied themselves also with bee-keeping, hunting and fishing (Boiński 1985, Kowalczyk 1986).

In the 15th c. the settlement activity was weakened, which was mainly caused by the war between Poland and the Teutonic Order. An increase in the number of settlements in Bory Tucholskie is again observed in the first half of the 16th c. However, this was the beginning of a rapid reduction of forest areas as well as degeneration of forest phytocoenoses consisting in the change of the composition of tree species (Boiński 1985).

The distribution of archaeological sites in the area of Bory Tucholskie (Fig. 7) was based on information taken from the catalogue of archaeological sites of the Chair of Archaeology at Łódź University supplemented by data contained in publications by Bagniewski (1987), Kowalczyk (1986) and Grzelakowska (1984).

METHODS

SAMPLING TECHNIQUES

Sampling of sediments from Lakes Suszek and Kęsowo was begun in autumn of 1982. Cores were taken with a piston corer (described by Livingstone (1955), modified corer described by Wright (1967)) and loose surface sediments (0–100 cm) – with a corer described by Digerfeldt and Lettevall (1969). Since the bottom parts of the sediments appeared young, in autumn of 1983 new cores were taken. A series of deeper sediments from Lakes Suszek and Kęsowo were obtained and a complete core from Lake Mały Suszek was taken. Bottom parts of the sediments were taken with a peat sampler. The cores were then transported in plastic tubes to the Institute of Biology, Nicolaus Copernicus University in Toruń and stored in a coolroom at the temperature of 0–5°C.

Samples for the detailed analyses were taken and stored according to the suggestions recommended for project IGCP 158B (Berglund 1979). Samples for dating by the radiocarbon method were taken from carbonate-free parts of the sediments of Lake Mały Suszek. These samples (300–350 cm^3) were taken every 100 cm.

DESCRIPTION OF SEDIMENTS

The sediments have been classified on the basis of a system developed by Troels-Smith (1955). Also symbols used in stratigraphic collumns of the diagrams follow Troels-Smith (1955). A detailed description of the sediments can be found in the separate chapter.

POLLEN ANALYSIS

Preparation of the material

Due to large sedimentation rate, samples for pollen analysis were taken every 10 cm. Only in the bottom, late-Glacial and early Holocene, parts of core from Lake Mały Suszek samples were taken every 5 cm. This density of sampling was sufficient and satisfied the requirements that time resolution of about 100 years between samples be maintained (Digerfeldt 1979).

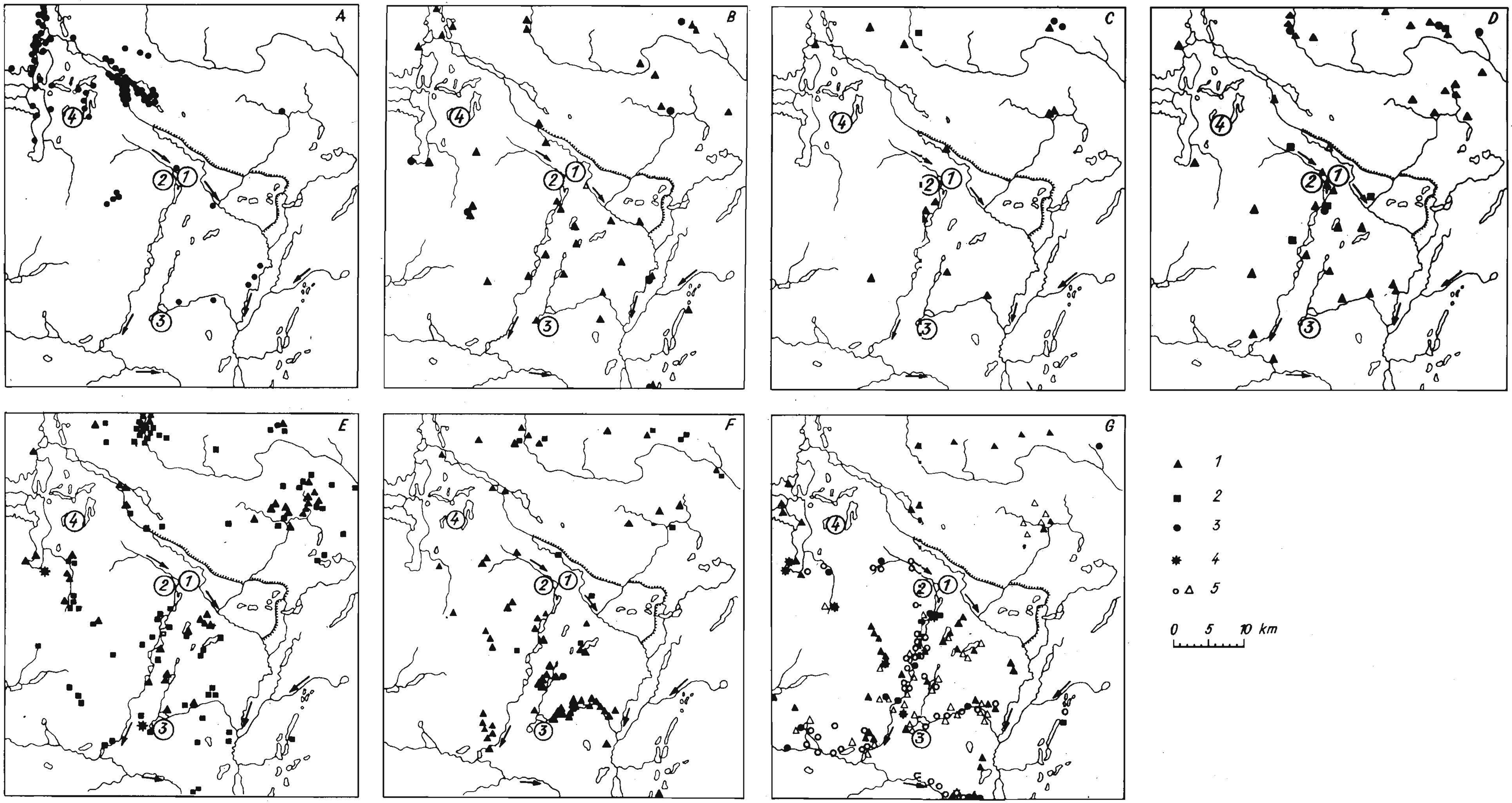

Fig. 7. Settlement in Bory Tucholskie: A. Mesolithic, 8000 B.C-? (the Komornice culture and the Chojnice-Pieńki culture), B. Neolithic, 4200–1700 B.C. (the Funnel Beaker culture), C. Early Bronze Age 1600–1500 B.C. (the Iwno culture), D. IV Bronze Age – Hallstatt C, 1000–600 B.C. (the Lusatian culture), E. Hallstatt – Middle La Tene, 600 B.C. –0 (the Pomeranian culture), F. Rome, 50–300 A. D. (the Wielbark culture), G. Early Middle Ages, 570–1250 A. D. 1 – loose finds, tresures, 2 – graves, burian places, 3 – camps, settlement, 4 – castles, 5 – 13th c. settlement

Samples were prepared according to a method required by IGCP project 158B (Berglund 1979). The concentration of pollen grains in 1 cm^3 of the sediment was calculated by the method described by Stockmarr (1971, 1973). Two Lycopodium tablets were usually added to each sample: one tablet was added to samples from late-Glacial sediments with low frequency of pollen grains.

At least 1000 pollen grains of trees were counted. In the case of two bottom samples from Lake Mały Suszek, due to low frequency, only about 500 pollen grains were counted.

Presentation of material

The results of the pollen analysis have been presented as pollen diagrams, constructed in accordance with recommendations made by Berglund and Ralska-Jasiewiczowa (1986).

Sum of AP + NAP = 100% was the basis of percentage calculations. Pollen grains of shrubs were included in the AP sum and pollen grains and spores of local plants were excluded from the NAP sum. The influx value (pollen x cm^{-2}x $year^{-1}$) was obtained by the multiplication of pollen concentration (grains x cm^{-3}) x the sediment deposition rate (cm x $year^{-1}$). The main pollen diagrams were drawn on the depth scale. Diagram A in these diagrams consists of total diagram A1 in which also a common curve for the components of *Quercetum mixtum (Quercus, Ulmus, Tilia, Fraxinus)* is placed and diagram A2 which contains curves indicating the percentages and %. values for particular taxa. Herbs are arranged according to the principle recommended by Berglund and Ralska-Jasiewiczowa (1986). In diagrams B through F the basis for the calculation of the percentage of taxa was the sum of pollen grains of terrestrial plants (AP+NAP) + the sum of pollen grains or spores of taxa of a given diagram.

Diagrams whose aim was to show the economic activity of man were drawn on a time scale, determined on the basis of uncorrected ^{14}C dates (Lake Mały Suszek) or by the interpolation method. Depth-time curves (Fig. 27, 28, 29) were used to determine the scale of radiocarbon years. Curves of herbs related to the economic activity of man have been grouped according to Behre (1981) in modification made by Berglund and Ralska-Jasiewiczowa (1986). The diagrams are completed with a column in which periods of more intensive economic activity of man have been marked. In order to make the comparison of the human activity in the vicinity of particular lakes easier, synthetic diagrams have been drawn following those drawn by Ralska-Jasiewiczowa for Lake Woryty (Berglund & Ralska-Jasiewiczowa 1986).

Pollen zones

The diagrams have been divided into biostratigraphic units, characterized by similar pollen spectra. These units have been called after Jańczyk-Kopikowa (1987) "poziomy zespołów pyłkowych" and correspond to English "pollen assemblage zones" (PAZ). In the opinion of Jańczyk-Kopikowa the name of a pollen assemblage zone should be derived from no more than three dominant taxa. In the present paper the names of pollen zones are much longer because they have been adopted after Mervi Hjelmroos (1981a).

Local pollen assemblage zones distinquished for Lake Mały Suszek and regional pollen assemblage zones distinquished for Bory Tucholskie have been designated as MS and BT, respectively and with numbers indicating the position of a given zone, beginning with the bottom of the profile. Pollen assemblage zones distinguished for Lakes Suszek and Kęsowo have been given numbers of corresponding regional zones. Pollen assemblage zones have been divided into pollen assemblage sub-zones.

CHARCOALS

The content of microscopic charcoal fragments in the sediment has been determined in each sample by means of five-degree scale, taking into account the degree to which the surface of microscopic preparations has been covered. Layers with the greatest number of charcoal fragments have been marked on synthetic diagrams which depict the economic activity of man.

DETERMINATION OF THE RATE OF SEDIMENT ACCUMULATION

The rate of sediment accumulation is calculated for particular segments of the core; their length is divided by the number of years in which they were formed (Fredskild 1973, Birks & Mathews 1978).

^{14}C dates were the basis for the calculation of the rate of sediment accumulation in Lake Mały Suszek. For the remaining two lakes (Suszek and Kęsowo), whose sediments could not be determined by means of the radiocarbon method, the absolute age of certain event has been determined through comparisons. When analysing the curves of trees in the diagrams for Lakes Mały Suszek, Suszek, Kęsowo and Wielkie Gacno (Hjelmroos-Ericsson 1981a, b) it was found that certain events are represented in the diagrams in the same way and probably occurred at the same time. It was assumed that the following events meet the above criteria: the first drop of *Ulmus* curve – 5100 years B.P. and changes in the *Carpinus* curve: 3700, 2850, 2000, 1300, 750 years B.P. (cf. Tab. 6). tHE age of this events, determined by the interpolation method became the basis of the calculation of the rate of sediment accumulation.

NUMERICAL ANALYSES

Numerical analyses have been done only for palynological data from the Lake Mały Suszek, which was accepted as reference site for programme IGCP 158B.

The analyses were done at the Institute of Physics of Silesian Polytechnic in Gliwice by Dr Adam Walanus. The programs were written on the basis of algorithms described by Birks & Gordon (1985). The analysis comprised taxons which constitute at least 2% of the pollen spectrum in each sample. Taxons which are significant only locally, such as *Sphagnum, Polypodiaceae*, have been excluded from the analysis. The analysis were done by ZONATION programme which consisted with three subroutines: CONSLINK, SPLITSQ and SPLITINF. The CONSLINK subroutine is based on the numerical measure of probability between two samples. Its work consists in successive connecting neighbouring zones or neighbouring groups of zones connected earlier. The results of the calculations are presented as a dendrogram. The zones are joined by a brace: the more dissimilar they are, the higher the brace. The work of SPLITSQ and SPLITNF subroutines consists in successive dividing of the profile into smaller segments. It was assumed to perform a number of divisions equal to one fourth of the number of samples. This gives series of the division of a sequence of samples marked with lines of different lengths. The length of the lines is proportional to the scatter expressed in percentage values. The greater the number defining the scatter (in %) and the longer the line along the vertical line on the left side of the dendrogram, the greater the significance of the division. In order to determine mutual correlations and anticorrelations, a PCA (principal components analysis) program has been used in which taxons are not arranged one with the other into so called main components, not correlated among themselves. The greatest amount of information is contained in the first component (usually about 80% of the information contained in the entire diagram). Numbers defining the percentage of particular taxons in the main components provide information on the role each taxon performs in defining a given component and on the mutual correlation between taxons.

DIATOM ANALYSIS

Samples for the diatom analysis were taken on average every 20 cm and only in the late-Glacial and early Holocene parts of the core from Lake Mały Suszek every 5 and 10 cm. All diatom analyses were performed by Dr Bożena Bogaczewicz-Adamczak. The results are the subject of a separate publication on the development of the lakes under investigation (Bogaczewicz-Adamczak 1990). The present contains only the curve of water level changes in the lakes (Fig. 17).

CLADOCERA ANALYSIS

This analysis comprised only samples taken from the sediments of Lake Suszek. The *Cladocera* analysis was performed by Dr Krystyna Szeroczyńska. In the present paper the results are presented only as the information about water level changes and the eutrophication of the lake (Fig. 17). Detailed results of Cladocera analysis are described separately (Szeroczyńska 1991).

PHYSICO-CHEMICAL ANALYSES

Samples of the deposit (volume 10 cm^3) taken every 10 cm were used in the analyses. The analyses were performed mostly by Urszula Kępińska M.Sc. in accordance with the recommendations of IGCP – project 158 (Bengstsson 1979). They comprised the determination of the bulk density (g/cm^3), the humidity of the deposit, the contents of organic matter and the contents of carbonates. The content of the organic matter and carbonates has been given as the percentage of dry mass of the deposit. The results have been presented as diagrams (Figs. 30, 31, 32). Detailed results of these investigations will be discussed separately.

DESCRIPTION OF THE LAKES

In accordance with the assumptions made earlier lakes situated in the central, forested part of Bory Tucholskie (Lakes Suszek and Mały Suszek) and that lying beyond the present forest border (Lake Kęsowo) (Fig. 1) have been selected for detailed palaeoecological investigations.

Lake Mały Suszek (53°43'32"N, 17°46'22"E) fills small kettle hole lying at the altitude of 115 m a.s.l. (Fig. 8). It represents a typical dystrophic lake, surrounded by a peatbog with a clear structure of hummocks and hollows and a well formed lagg. The bestdeveloped part of the peatbog is on north-eastern part of the lake where it borders on a swamp pine forest (*Vaccinio uliginosi-Pinetum*), which then changes into fresh pine forest (*Vaccinio myrtilli-Pinetum*). On the southern and south-eastern side behind the peatbog lagg there are meadows and arable lands. Floating mat enters the surface, leaving empty space of about 40 m in diameter.

The core was taken in the north-eastern part of the lake, right at the border of floating mat and the water surface. The thickness of the *Sphagnum* peat layer was 45 cm and the

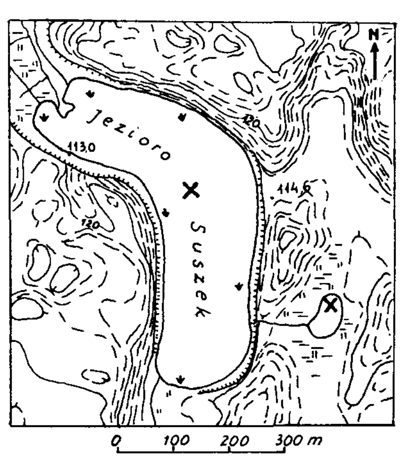

Fig. 8. Lake Suszek and Lake Mały Suszek. x – coring points for the sediment sampling

depth of the water – 65 cm. The attempt to collect about 40 cm of loose surface sediments was not successful. Sediments were taken from 105 to 1323 cm.

Core description:

Layer no	Depth (cm)	Description of sediment
8	105–180	coarse detritus gyttja with remains of plants, strongly hydrated, dark brown: Dh 2, Dg 1, Ld 1, nig 2, strf 0, elas 1, sicc 1, lim 0, humo 1
7	180–240	coarse detritus gyttja with remains of plants, dark brown; Dl 1, Dh 1, Dg 1, $Ld^1$1, nig 2, strf 0, elas 1, sicc 2, lim 0, humo 1
6	240–525	medium detritus gyttja with remains of plants, light brown: $Ld^2$3, Dh 1, Dg +, nig 2, strf 0, elas 2, sicc 1–2, lim 0, humo 2
5	525–1088	fine detritus gyttja with remains of plants, light brown turning to dark brown downwards; Upper part: $Ld^2$3, Dh 1, bottom part: $Ld^3$3, Dh 1, nig 2–3, strf 0, elas 2, sicc 1–2, lim 0, humo 3
4	1088–1135	fine detritus gyttja with carbonates single sand grains, dark brown-gray; $Ld^3$2, Lc 1, Dh 1, Ga +, nig 2, strf 0, elas 1, sicc 2, lim 0, humo 3
3	1135–1273	calcareous gyttja with remains of plants and some sands, light gray with a few dark zones; Lc 3, $Ld^3$1, Dh +, Ga +, nig 1–2, strf 0, elas 1, sicc 2, lim 0, humo 3
2	1273–1286	moss peat, dark brown: $Tb^3$4, nig 3–4 strf 0, elas 1, sicc 3, lim 0, humo 2
1	1286–1323	sand light gray: Ga +, Gs 4, nig 2, strf 0, elas 0, sicc 3, lim 1

Lake Suszek (53°43'1"N, 17°46'2"E) lies at the altitude of 114 m a.s.l.. This is a channel lake with a flow located in pradolina (melt water channel) running from NE to SW and belongs to the catchment area of Raciąska Struga-Brda-Vistula (Materials of the Institute of Inland Fishing – Materiały Instytutu Rybactwa Śródlądowego 1957). The area of the water surface is 11 hactares (Katalog Jezior Polski 1954), its maximum length is 650 m and maximum width – 200 m. The depth of the lake in its central part is 4–6 m. The lake is mostly surrounded by fresh pine forest (*Vaccinio myrtilli-Pinetum*) and adjoined by meadows on the northern and southern sides and arable lands on the south-western part. Remaines of deserted village of Śpierewnik are found south-east of the lake. The shores of the lake are overgrown mainly by *Alnus glutinosa* with *Quercus sessilis, Frangula alnus, Fraxinus excelsior, Betula pubescens, Sorbus aucuparia* and *Viburnum opulus*. Shores on the eastern and western sides are rather steep and have terrace levels. The littoral is formed by a belt of rushes with *Phragmites communis* and *Typha latifolia* which are adjoined, mainly in the northern and southern parts, by patches of *Myriophyllo-Nupharetum* (cf. *Nuphareto-Nymphaetum albae* Rejewski 1981).

At the coring site (Fig. 8) the water depth was 4.45 m. The core was taken in two parts: from the depth of 445 cm to 1270 cm and from 1200 cm to 1700 cm.

Core description:

Layer no	Depth (cm)	Description of sediment
4	445–493	fine detritus gyttja, rich in sulphides, black with a few levels of detritus gyttja: $Ld^3$3, Dg 1, Lc +, nig 3–4, strf 0, elas 2, sicc 1, lim 0, humo 3
3	493–732	fine detritus gyttja with carbonate concretions and remains of plants, greenish-brown; $Ld^2$3, Lc 1, Dg +, nig 2, strf 0, elas 1, sicc 2, lim 0, humo 4
2	732–931	algal gyttja with carbonate concre tions, dark greenish-black; $Ld^3$2, Ld (Algae) 2, Lc +, nig 3, strf 0, elas 2, sicc 2, lim 0, humo 4
1	931–1700	algal gyttja with carbonate concretions, slightly clayey, dark greenish-brown; $Ld^2$1, Ld(Algae) 2, Lc 1, (Ac + Ag) +, nig 2–3, strf 0, elas 2, sicc 2, lim 0, humo 4

Lake Kęsowo (53°33'6"N, 17°43'4"E) at the altitude of 111.6 m a.s.l. (Katalog Jezior Polski 1954) is also a channel lake located in a pradolina facing the same direction as Lake Suszek and belonging to the catchment of Kicz-Brda-Vistula. It is surrounded by arable lands and meadows with the village of Kęsowo adjoining its NE bank. The area of the water surface is 23.7 ha, the shoreline is 2075 m, the maximum length of the lake is 750 m, maximum width - 430 m and maximum depth -7.5 m (IRS Materials 1957). The bathymetry of the lake is shown in Fig. 9.

Small fragments of alluvial forest with dominant *Alnus glutinosa*, abundant zone of shrubs (*Sambucus nigra*, *Viburnum opulus*, *Frangula alnus*, *Corylus avellana*) and diversified undergrowth (among others; *Humulus lupulus*, *Myosotis palustris*, *Scrophularia nodosa*, *Equisetum sylvaticum*, *Eupatorium cannabinum*, *Carlina vulgaris*) are found on the eastern bank of the lake. A belt of rushes built mainly of *Phragmites communis*, *Schoenoplectus lacustris*, *Acorus calamus* and *Typha angustifolia* is well developed. It occupies 1.6 ha, which constitutes 6.7% of the water surface area (IRS materials 1957). *Myriophyllo-Nupharetum* association neighbours the rushes which is an indication of great fertility of water and advanced stage of the lake ageing (Rejewski 1981).

The sediment core was not taken in the deepest part of the lake but in the northern bay (Fig. 9), where the depth was 3.7 m. The first part of the core was taken at the depth of 372 cm to 900 cm and the other from 800 cm to 1500 cm.

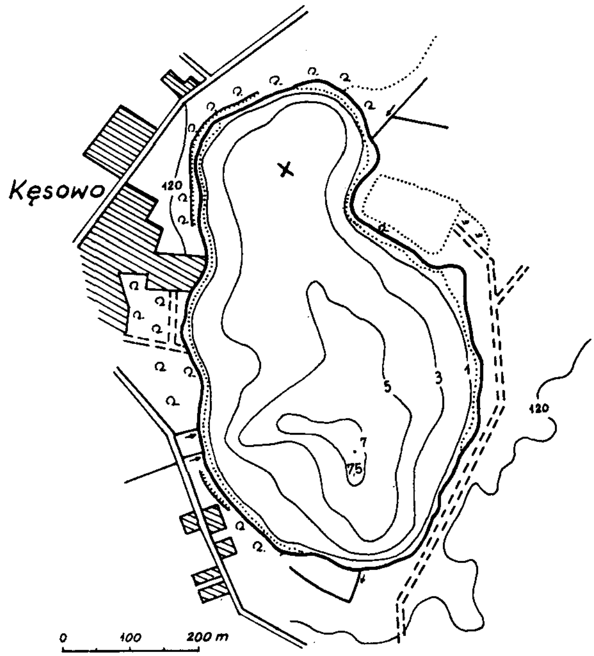

Fig. 9. Bathymetric sketch of Lake Kęsowo. X – coring point for the sediment sampling

Core description:

Layer no	Depth (cm)	Description of sediment
7	372–410	clayey gyttja, strongly hydrated with remains of plants, black gray; Ld^{3}2, Lc 1, Dh 1, (As + Ag) +, nig 3–4, strf 0, elas 2, sicc 1, lim 0 humo 2
6	410–445	clayey gyttja with carbonates, black gray; Ld^{3}2, Lc 1, (As + Ag) 1, Dh +, nig 3, strf 0, elas 1, sicc 2. lim 0, humo 3
5	445–537	clayey gyttja with plant remains, dark grayish-green with some darker zones; Ld^{2}3, Lc 1, (As + Ag) +, Dg +, nig 2–3, strf 0, elas 1, sicc 2, lim 0, humo 4
4	537–895	clayey gyttja with plant remains and pieces of shells, grayish - green turning to brown-gray down- wards, 720 cm – charcoal, 750–810 cm fewer shells: Ld^{2}2, Lc 2, (As+Ag) +, Dg +, [part. test(moll)], nig 2–3, strf 0, elas 1, sicc 2, lim 0, humo 4
3	895–1140	clayey gyttja with carbonate concretions, gray; Ld^{2}2, Lc 2, Dg +, (As + Ag) +, nig 2, strf 0, elas 1, sicc 2, lim 0, humo 4

2	1140–1290	clayey gyttja with ferric concretions, brown-gray; $Ld^2 2$, Lc 2, (As + Ag) +, nig 3, strf 0, elas 1, sicc 2, lim 0, humo 4
1	1290–1500	clayey gyttja black gray; $Ld^2 3$ Lc 1, (As + Ag) +, nig 3, strf 0, elas 1, sicc 2, lim 0, humo 4

^{14}C DATING

Sediments of Lakes Suszek and Kęsowo did not lend themselves to datings by the ^{14}C method. Only the carbonate-free part of the sediment of Lake Mały Suszek was proper material for radiocarbon dating.

The datings were done in ^{14}C Laboratory of the Institute of Physics, Silesian Polytechnic in Gliwice (9 samples) and at the Laboratory of Radiological Datings of the Department of Quaternary Geology in Lund (1 sample). The age of the samples is given in the conventional radiocarbon scale B.P. "Oxalic Acid NBS" was used as a standard of ^{14}C activity. Sample ages were calculated assuming half-life of the ^{14}C isotope to be 5568 years. The results are given in Tab. 1.

Table 1. Radiocarbon dates

Sample	Description	Depth (cm)	No of measurement	Age B.P.
Dystrof 8	medium detritus gyttja almost at the boundary MS9/MS10, at the decre ase of *Corylus*	240–250	Gd–2673	2230 ± 100
Dystrof 7	medium detritus gyttja, bottom part of MS9, slightly above the beginning of *Carpinus*, beginning of decrease in *Corylus*, slightly below the definite decrease in *Ulmus* and beginning of *Fagus*	350–360	Gd–4147	3570 ± 120
Dystrof 6	medium detritus gyttja, upper part of MS8, below MS8:1/MS8:2, slightly above the decrease in *Fraxinus*	450–460	Gd–4146	4210 ± 80
Dystrof 5	fine detritus gyttja, bottom part of MS8, decrease in *Tilia*, slightly before the decrease in *Ulmus*, beginning of the increase in *Corylus*	545–555	Gd–2688	5310 ± 120
Dystrof 4	fine detritus gyttja, upper part of MS7, below the boundary MS 8:1/MS8:2, insignificant decrease in *Alnus* and increase in *Quercus*	645–655	Gd–2690	5740 ± 120
Dystrof 3	fine detritus gyttja, bottom part of MS7, slightly above the beginning of *Tilia* and *Fraxinus*, an increase in *Ulmus* and *Quercus*	745–755	Gd–2687	7180 ± 130
Dystrof 2	fine detritus gyttja, upper part of MS6, minimum *Pinus*, a decrease in *Alnus*	845–855	Gd–2681	7850 ± 140

Table 1. Continued

Sample	Description	Depth (cm)	No of measurement	Age B.P.
Dystrof 9	fine detritus gyttja, beginning of MS6, a clear increase in *Alnus* and *Quercus*, a decrease in *Corylus*, slightly before the beginning of *Fraxinus*	945–955	Gd–2678	8900 ± 170
Dystrof 1	fine detritus gyttja, middle of MS5, beginning of *Alnus* and *Ulmus*, slightly above *Quercus*, a clear increase in *Corylus*	1045–1055	Gd–2686	9320 ± 180
Suszek bog	moss peat MS1, maximum *Cyperaceae*, upper part of MS1, maximum *Cyperaceae*	1273–1275	Lu–2296	11810 ± 140

Samples of sediments sent to ^{14}C Laboratory in Gliwice for analysis were called Dystrof, as this was the working name given to this small unnamed lake. The name was later changed to Mały Suszek because of the vicinity of Lake Suszek in about 200 m distance.

VEGETATION HISTORY

LOCAL POLLEN ASSEMBLAGE ZONES

A complete sequence of the local pollen assemblage zones, beginning in pre-Allerød, was distinguished on the basis of the diagram of Lake Mały Suszek (Fig. 10). The cores of sediments from Lakes Suszek (Fig. 11) and Kęsowo (Fig. 12) comprise a much shorter period of time and contain only younger zones (cf. Tab. 5). The maximum and mean pollen percentages of selected taxons in pollen assemblage zones from particular sites have been shown in Tab. 2).

Lake Mały Suszek (Fig. 10)*

MS 1 *Pinus-Cyperaceae* l paz (1285–1280 cm)

Description: A clear decrease in *Pinus* pollen, the percentage of *Cyperaceae* increases to 51%. About 2% of *Salix* and 9% of *Betula*, *Gramineae* ranges between 4 and 9%. Few *Artemisia* pollen grains.

Top boundary: A rapid decrease in *Cyperaceae* and an increase in *Pinus*.

Age: Pre-Allerød. The zone has been dated at ^{14}C 11810±140 years B.P.(Lu 2296)

Sediment: Moss peat containing *Camptothecium nitens*, *Brachythecium* sp. and one leaf of *Sphagnum* sp. (anal. Dr U. Boińska).

* Fig. 10 under the cover

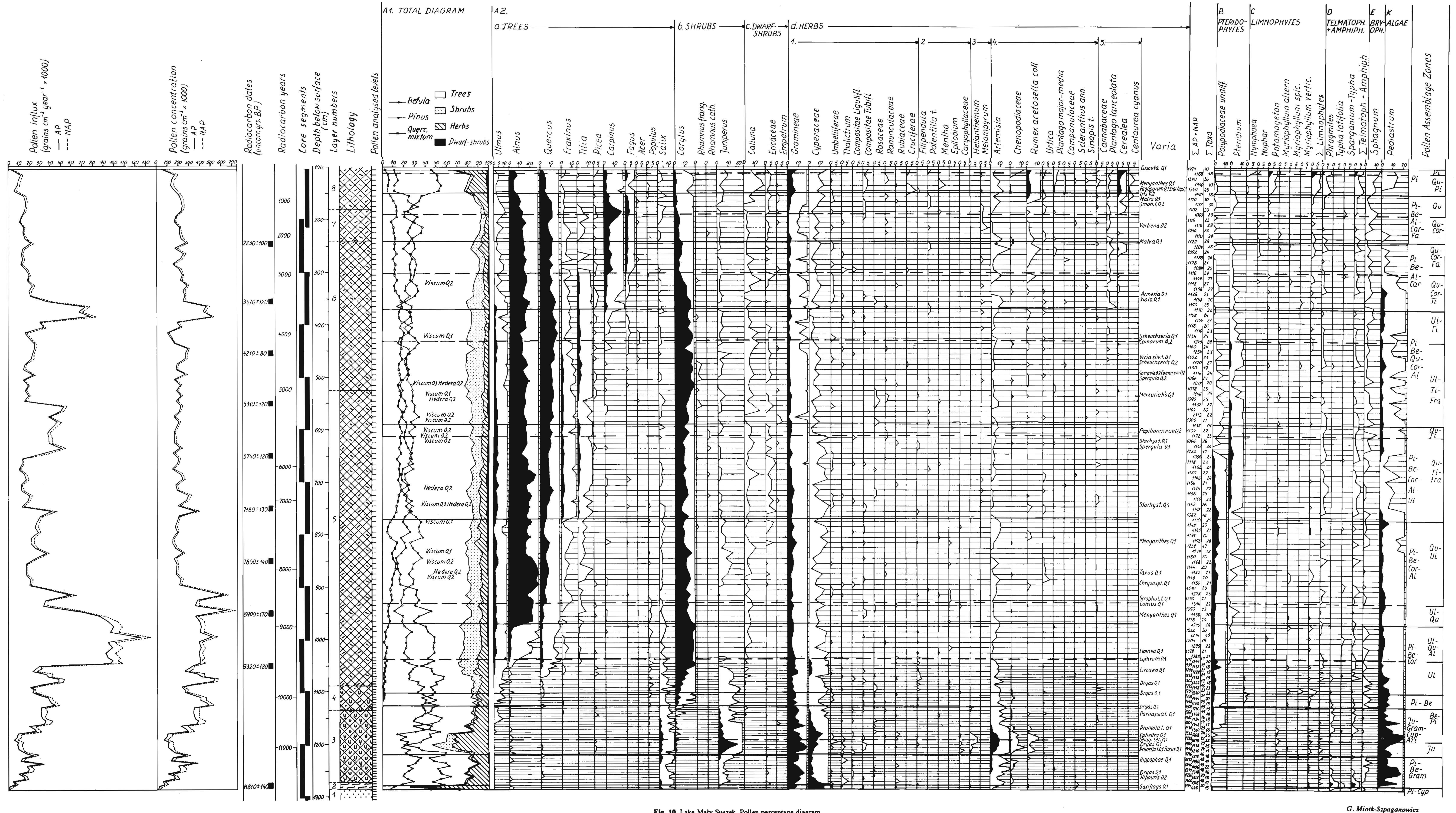

Fig. 10. Lake Mały Suszek. Pollen percentage diagram

Table 2. Maximum and mean percentage values of selected taxa in distinguished pollen assemblage zones

Pollen assemblage zones	Taxons	Mały Suszek max %	Mały Suszek mean %	Suszek max %	Suszek mean %	Kęsowo max %	Kęsowo mean %
1. Pinus-Cyperaceae		-11800 B.P.					
	Pinus	71.8	48.9				
	Cyperaceae	51.3	31.0				
	Betula	10.1	9.1				
2. Pinus-Betula-Gramineae		11800-11200 B.P.					
	Pinus	63.7	54.2				
	Betula	36.1	26.2				
	Gramineae	15.9	10.1				
3. Juniperus-Gramineae Cyperaceae-Artemisia		11200-10150 B.P.					
	Juniperus	18.6	4.8				
	Gramineae	17.8	10.6				
	Cyperaceae	12.7	4.7				
	Artemisia	9.6	3.6				
	Pinus	59.2	33.0				
	Betula	55.3	39.6				
4. Pinus-Betula		10150- 9700 B.P.					
	Pinus	46.9	39.9				
	Betula	52.7	45.7				
5. Pinus-Betula-Corylus		9700- 8950 B.P.					
	Pinus	57.0	46.8				
	Betula	38.1	27.1				
	Corylus	19.7	11.8				
	Quercus	2.4	0.9				
	Ulmus	3.1	1.3				
	Alnus	5.2	0.9				
6. Pinus-Betula-Corylus Alnus		8950- 7300 B.P.					
	Pinus	45.9	23.7				
	Betula	38.0	26.7				
	Corylus	13.9	10.4				
	Alnus	28.0	22.0				
	Quercus	8.8	4.9				
	Ulmus	4.4	2.6				
7. Pinus-Betula-Corylus-Alnus-Ulmus		7300- 5500 B.P.				- 5500 B.P.	
	Pinus	28.6	23.0			28.7	26.2
	Betula	31.4	26.4			29.8	26.5
	Corylus	12.3	8.6			7.9	6.1
	Alnus	25.9	18.8			21.7	19.4
	Ulmus	5.0	3.4			4.4	3.3
	Quercus	12.1	8.7			10.7	9.1
	Tilia	2.8	1.5			2.0	1.1
	Fraxinus	2.8	1.6			2.5	1.5
8. Pinus-Betula-Quercus-Corylus-Alnus		5500- 3700 B.P.		- 3650 B.P.		5500- 3650 B.P.	
	Pinus	33.7	23.2	30.6	23.9	36.3	22.4
	Betula	34.2	25.2	20.0	15.5	32.5	24.5
	Quercus	16.3	12.3	16.8	13.7	18.2	12.3
	Corylus	19.1	13.6	13.4	8.9	14.2	9.1
	Alnus	19.2	15.1	33.9	27.1	23.5	19.3
	Ulmus	3.6	1.7	1.8	0.8	3.9	1.9
	Tilia	4.1	1.9	4.9	2.5	2.8	1.8
	Fraxinus	2.0	1.0	2.3	1.4	2.6	1.6
9. Pinus-Betula-Alnus-Carpinus		3700- 2150 B.P.		3650- 2150 B.P.		3650- 2150 B.P.	
	Pinus	33.3	25.4	45.6	33.3	46.8	28.5
	Betula	31.4	27.0	24.7	17.6	25.5	19.5
	Alnus	19.2	15.7	31.7	26.3	29.5	20.2
	Carpinus	7.7	3.7	5.2	2.0	5.2	2.3
	Quercus	14.2	10.8	16.7	7.9	15.9	9.1
	Tilia	1.7	0.9	3.8	1.2	3.6	1.0
	Fraxinus	1.0	0.6	2.4	0.9	2.7	1.0
	Corylus	15.0	8.1	7.9	4.3	20.7	6.4
	Ulmus	2.2	0.7	1.9	0.6	2.2	0.7
10. Pinus-Betula-Alnus Carpinus-Fagus		2150- 750 B.P.		2150- 750 B.P.		2150- 750 B.P.	
	Pinus	36.5	28.7	46.9	34.1	40.6	27.5
	Betula	37.1	28.2	27.6	17.1	34.9	18.1
	Alnus	16.1	12.3	28.9	20.6	26.4	17.4
	Carpinus	16.3	7.3	18.3	5.5	12.6	5.0
	Fagus	3.6	2.0	1.8	0.9	2.0	1.1
	Quercus	11.9	9.6	13.6	8.5	19.9	10.1
	Corylus	4.6	3.4	5.5	2.5	6.2	3.5
11. Pinus		750 B.P. -		750 B.P. -		750 B.P. -	
	Pinus	54.6	51.1	60.3	50.0	39.4	31.2
	Quercus	5.9	4.5	4.8	2.5	5.8	2.9
	Gramineae	8.9	5.7	16.5	9.3	15.0	12.4
	Betula	14.9	12.3	8.7	6.7	9.1	6.1
	Alnus	8.2	5.5	12.8	9.3	16.4	9.3

MS 2 *Pinus-Betula-Gramineae* l paz (1280–1220 cm)

Description: High values of *Pinus* and *Betula* pollen. A small decrease of *Juniperus* and *Salix* in the middle part of the zone and an increase at its end. A decrease in *Cyperaceae* from about 18% to below 5%. *Gramineae* have maximum values in the middle part of zone when the percentage curve of *Artemisia* appears.

Top boundary: A clear increase in the values of *Juniperus, Gramineae, Artemisia* and *Cyperaceae.*

Age: Allerød

Sediment: Calcareous gyttja with remains of plants, slightly sandy

MS 3 *Juniperus-Gramineae-Cyperaceae-Artemisia* l paz (1220- 1125 cm)

Description: In the initial phase of the zone a decrease in *Pinus* pollen. The growing percentage of *Betula*; in the middle part its rapid decrease. High percentage of NAP, mainly *Artemisia, Cyperaceae, Gramineae, Chenopodiaceae, Rumex* and of shrubs - *Salix* and *Juniperus.*

Top boundary: A clear decrease in the taxa dominant in the zone and at the beginning of a continuous *Ulmus* pollen curve and percentage *Corylus* curve.

Division: Two subzones have been distinguished in this zone:

MS 3:1 *Juniperus* l pa subz (1220–1190 cm)

The subzone is characterized by the highest content of *Juniperus* pollen in the entire profile. A decrease in *Pinus* and increase in *Betula.* A high curve of NAP (about 35%). The top boundary is in the place of a decrease in *Juniperus* pollen.

MS 3:2 *Pinus-Betula* l pa subz (1190–1125 cm)

A gradual decrease in the values of taxa characteristic of the first subzone. A temporary decrease in *Betula* and an increase in *Pinus* pollen. Slight increase of *Ulmus* and *Corylus* pollen curves. The top boundary is at the same time the boundary of the zone.

Age: The end of Allerød and Younger Dryas.

Sediment: Calcareous gyttja, sandy, with plant remains. The top part of the zone corresponds almost to the boundary between lithological layers.

MS 4 *Pinus-Betula* l paz (1125–1100 cm)

Description: Almost equal values of *Pinus* and *Betula* pollen. *Corylus* percentages below 5%. Continuous curve of *Ulmus,* single *Quercus* and *Alnus* pollen, 1–2% of *Juniperus.*

Top boundary: Changes in pollen curves of *Pinus* and *Betula* and a clear increase in *Corylus.*

Age: The end of Younger Dryas and beginning of the early Pre-Boreal period.

Sediment: Fine detritus gyttja with carbonates and single sand grains.

MS 5 *Pinus-Betula-Corylus* l paz (1100–970 cm)

Description: *Pinus* pollen is dominant (35–55%), while values of *Betula* gradually decrease from about 40% to about 20%. *Corylus* increases to about 20%. Continuous curve of *Juniperus* and *Cyperaceae* disappear.

Top boundary: An increase in *Alnus* and decrease in *Corylus* pollen curves.

Division: The zone has been divided into two subzones:

MS 5:1 *Ulmus* l pa subz (1100–1040 cm)

An increase in the amount of *Ulmus* pollen to percentage values. The highest percentage of *Pinus* and a decline of *Betula* pollen curves. Top boundary – the disappearance of the continuous curve of *Juniperus*, beginning of the percentage *Alnus* curve.

MS 5:2 *Ulmus-Quercus-Alnus* l pa subz (1040–970 cm)

Pinus and *Betula* have more or less constant values. An increase in *Ulmus* and *Quercus* pollen (to 2.4%). *Alnus* appears and reaches values of about 10% at the end of the subzone. The top boundary overlaps the zone boundary.

Age: The middle part of the zone has been ^{14}C dated at 9320 ± 180 years B.P. (Gd 2686). The entire zone comprises the end of the early and late Pre-Boreal period.

Sediment: Fine detritus gyttja with carbonates and some sand changing upwards into fine detritus gyttja without carbonates.

MS 6 *Pinus-Betula-Corylus-Alnus* l paz (970–770 cm)

Description: Values of *Pinus* decreases from 45% at the beginning of the zone to 10% at its end. *Betula* increases to 38%. In the middle part of this l paz *Alnus* reaches its absolute maximum (28%). Continuous curves of *Fraxinus* and *Tilia* appear.

Top boundary: The increase of *Quercus* values, beginning of percentage pollen curves of *Fraxinus* and *Tilia*.

Division: The zone is divided into the following subzones:

MS 6:1 *Ulmus-Quercus* l pa subz (970–930 cm)

Similar values of *Ulmus* and *Quercus*. Top boundary – an increase in the *Quercus* value.

MS 6:2 *Quercus-Ulmus* l pa subz (930–770 cm)

Quercus is clearly dominant over *Ulmus*. The significance of *Betula* and *Juniperus* increases. The top boundary of the subzone corresponds with the zone boundary.

Age: The bottom part of the zone has been ^{14}C dated at 8900±170 years B.P. (Gd 2678). The entire zone corresponds to the Boreal period and the early Atlantic period.

Sediment: Fine detritus gyttja with plant remains.

MS 7 *Pinus-Betula-Corylus-Alnus-Ulmus* l paz (770–590 cm)

Description: More or less constant values of *Pinus and Betula. Fraxinus and Tilia* have continuous percentage curves although with a slightly changing values.

Top boundary: An increase in values of *Quercus* and *Pinus*, and a clear decrease in *Betula*.

Division: Two subzones have been distinguished within this zone:

MS 7:1 *Quercus-Tilia-Fraxinus* l pa subz (770–610 cm)

Constant large amounts of *Quercus* with the maximum in the middle part of the subzone. A simultaneous increase in the pollen values of *Corylus, Gramineae* and *Fraxinus*. The top boundary is determined by an decrease in the values of *Pinus* pollen and an increase of *Tilia, Corylus* and *Quercus* pollen curves.

MS 7:2 *Quercus-Tilia* l pa subz (610–590 cm)

Pinus curve has lower values than *Betula*. Pollen curves of *Corylus, Quercus* and *Tilia* increase insignificantly, the amounts of *Fraxinus* pollen clearly decrease.

Age: The bottom part of the zone has been dated at 7180±130 years B.P. (Gd 2687) and the top part at 5740±120 years B.P. (Gd 2690), i.e. the entire zone is within the time interval from the early to the middle of the late Atlantic period.

Sediment: Fine detritus gyttja.

MS 8 *Pinus-Betula-Quercus-Corylus-Alnus* l paz (590–370 cm)

Description: Values of *Pinus* pollen range between 27% and 35%. A considerable percentage values of *Quercus, Corylus* and *Alnus*. At the end of the zone a decrease in the amount of *Fraxinus* and *Ulmus* pollen. Small amounts of *Carpinus* and *Fagus* pollen appear. Low NAP values.

Top boundary: The beginning of the percentage curve of *Carpinus*.

Division: The zone is divided into two subzones:

MS 8:1 *Ulmus-Tilia-Fraxinus* l pa subz (590–430 cm)

In the middle part – an increase in *Corylus* pollen and depression of *Ulmus* curve. The top boundary has been placed at the decrease of *Fraxinus* curve.

MS 8:2 *Ulmus-Tilia* l pa subz (430–370 cm)

Small amounts of *Tilia* pollen (1–3%) and large – of *Corylus* and *Quercus* (19%). In the middle part of the subzone the *Ulmus* pollen curve is broken and the percentage values of *Alnus* increase to about 5%. The top boundary overlaps the boundary of the zone.

Age: The zone has two ^{14}C dates: in the bottom part – 5300±120 years B.P. (Gd 2688) and in the top part – 4210±80 years B.P. (Gd 4146). The entire zone corresponds to the end of the Atlantic period and the early and partly the middle Sub-Boreal period.

Sediments: Fine detritus gyttja changing to medium detritus gyttja.

MS 9 *Pinus-Betula-Alnus-Carpinus* l paz (370–240 cm)

Desription: A gradual decrease in *Corylus* and *Ulmus* pollen values. Almost a complete regress of *Fraxinus* and *Tilia* pollen in the middle part of the zone. An increase in *Carpinus* and *Fagus*. At the end of the zone especially, pollen grains of plants connected with the economic activity of man appear in greater amounts.

Top boundary: Equal values of *Pinus* and *Betula* (30%) and an decrease in *Quercus* and *Corylus* curves and an increase in *Carpinus* pollen.

Division: Two subzones have been distinguished within this zone:

MS 9:1 *Quercus-Tilia-Corylus* l pa subz (370–300 cm)

Large amounts of *Quercus* and *Alnus* pollen. An increase in *Carpinus* pollen curve. The top boundary is connected with the disappearance of continuous pollen curves of *Tilia* and *Fraxinus*, maximum of *Carpinus* pollen and the beginning of the percentage curve of *Fagus*.

MS 9:2 *Quercus-Corylus-Fagus* l pa subz (300–240 cm)

High constant pollen values of *Alnus* (about 15%), *Quercus* (about 10%) and *Carpinus* (6%). A percentage curve of *Fagus*. The top boundary overlaps the zone boudary.

Age: The bottom part of the zone has been dated at 3570±120 years B.P. (Gd 4147) and the top part at 2230±100 years B.P. (Gd 2673). The entire extends between the middle Sub-Boreal period and the early Sub-Atlantic period.

Sediment: Medium detritus gyttja. The top boundary overlaps that between medium and coarse detritus gyttja.

MS 10 *Pinus-Betula-Alnus-Carpinus-Fraxinus* l paz (240–150 cm)

Description: Changing values of *Pinus* and *Betula* with a clear dominance of *Pinus* at the end of the zone. A large amounts of *Quercus* and *Alnus* pollen. An absolute maximum of *Carpinus* pollen values in the middle part of the zone together with an increease in *Fagus* curve. Sporadic occurrence of *Ulmus*, *Tilia* and *Fraxinus* pollen.

Top boundary: The clear decrease in *Carpinus*, *Fagus*, *Quercus* and *Alnus* pollen curves and an increase in *Pinus*.

Division: The zone is divided into two pollen assemblage subzones:

MS 10:1 *Quercus-Corylus* l pa subz (240–190 cm)

High values of *Quercus* and in the middle part – of *Betula* pollen. The top boundary has been drawn at the absolute maximum of *Carpinus*.

MS 10:2 *Quercus* l pa subz (190–150 cm)

A decrease in the values of *Betula* pollen and other deciduous trees. An increase in NAP values, especially *Gramineae*, *Cerealia* and *Rumex*. The top boundary of the subzone is at the same time the boundary of the entire zone.

Age: The zone corresponds to the end of the early, middle and the beginning of the

late Sub-Atlantic period.
Sediment: Coarse detritus gyttja.

MS 11 *Pinus* l paz (150–105 cm)

Description: The absolute dominance of *Pinus* pollen. The amounts of *Quercus* pollen decrease from 7% to 1%, *Betula* from 25% to 10%, *Carpinus* from 3% to 1%. Simultaneously values of NAP increase, especially those of *Gramineae*, *Cerealia*, weeds of arable lands and meadows.
Top boundary: The surface sediment sample.
Division: Two subzones have been distinguished in the zone:

MS 11:1 *Quercus-Pinus* l pa subz (150–110 cm)

High values of *Pinus* pollen (50–60%). The top boundary has been drawn at a decrease in *Quercus* and *Pinus* pollen curves and an increase of the amount of NAP

MS 11:2 *Pinus* l pa subz (110–105 cm)

Absolute dominance of *Pinus* pollen (45–50%). Age: The end of the Sub-Atlantic period
Sediment: Coarse detritus gyttja, strongly hydrated.

Lake Suszek (Fig. 11)*

8 *Pinus-Betula-Quercus-Corylus-Alnus* l paz (1680–1465 cm)

Description: *Pinus* pollen in the amount from 18% to 31% and *Betula* from 9% to 21%. *Quercus* has absolute maximum (15–17%) in the middle part of the zone. *Corylus* curve ranges from 9% to 14%.
Top boundary: Percentage curve of *Carpinus* and an decrease in *Corylus* pollen.
Division: Two subzones have been distinguished in this zone:

8:1 *Ulmus-Tilia-Fraxinus* l pa subz (1680–1545 cm)

Changing values of *Pinus* (18–28%) and *Betula* (13–21%) curves. Large amounts of *Alnus*, *Corylus* and *Quercus* pollen. Small, values of *Tilia*, *Fraxinus* and *Ulmus* pollen curves. The top boundary is determined by the decrease of the *Quercus* and *Ulmus* values.

8:2 *Tilia-Fraxinus* l pa subz (1545–1465 cm)

Constant amounts of *Pinus* pollen (26–30%). Low but constant values of *Fraxinus* (1–2%) and more variable amounts of *Tilia* (1.3–4.0%) pollen curves.. The top boundary is the zone boundary.
Age: The zone, or more precisely, the younger its part corresponds to the early and

* Fig. 11 under the cover

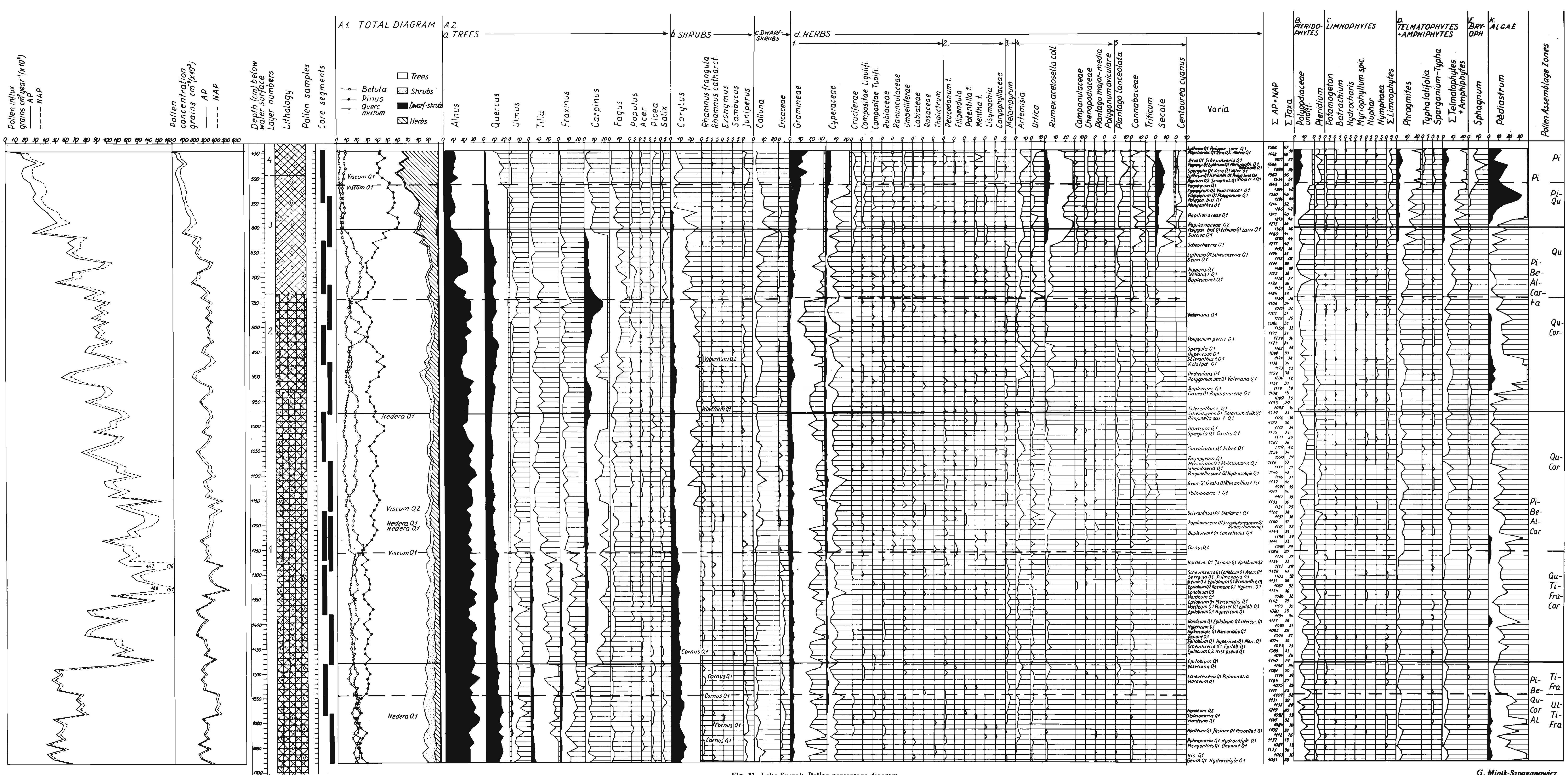

Fig. 11. Lake Suszek. Pollen percentage diagram

the beginning of the middle Sub-Boreal period.
Sediment: Algal gyttja with carbonates, slightly clayey.

9 *Pinus-Betula-Alnus-Carpinus* l paz (1465–975 cm)

Description: *Pinus* pollen is dominant (25–45%). The values of *Betula* curve are varied (12–26%). A gradual decrease in *Quercus* and *Corylus* and an increase in *Carpinus* pollen curve. *Ulmus*, *Tilia* and *Fraxinus* pollen disappear almost completely. Small but constant (to 0,8%) values of *Fagus*.
Top boundary: The clear increase in *Carpinus* and *Fagus* pollen.
Division: Two pollen assemblage subzones have been distinguished within this zone:

9:1 *Quercus-Tilia-Fraxinus-Corylus* l pa subz (1465–1255 cm)

Pinus pollen in 25–35% and *Betula* in 14–20%. In the middle part – a small increase in *Quercus*, *Tilia* and *Fraxinus* pollen curves and a decrease in *Carpinus*. The top boundary – at the disappearance of percentage values of *Tilia* and *Fraxinus*.

9:2 *Quercus-Corylus* l pa subz (1255–975 cm)

A growing tendency of *Pinus* curve. *Quercus* and *Corylus* pollen decrease. The top boundary designates also the subzone boundary.
Age: The zone comprises part of the middle and late Sub-Boreal period and almost the entire early Sub-Atlantic period.
Sediment: Algal gyttja with carbonates, slightly clayey.

10 *Pinus-Betula-Alnus-Carpinus-Fagus* l paz (975–605 cm)

Description: *Pinus* pollen curve dominates but in the middle part of the zone – slightly decrease. High values of *Betula* pollen (20–28%). An decrease in amounts of *Alnus* and *Corylus* pollen. In the middle part – an absolute maximum of *Carpinus* pollen (18%) and an increase in *Fagus*, *Ulmus*, *Tilia* and *Fraxinus* pollen curves. An increase in NAP values, especially at the end of thezone.
Top boundary: The disappearance of the percentage curve of *Carpinus* and a clear increase in *Pinus* pollen.
Division: The zone has been divided into two subzones:

10:1 *Quercus-Corylus* l pa subz (975–745 cm)

Large amounts of *Alnus* pollen (15–29%). *Corylus* values range between 2 and 6%. The top boundary of the subzone is connected with a clear decrease in *Carpinus* and an increase in *Pinus* pollen.

10:2 *Quercus* l pa subz (745–605 cm)

Quercus pollen curve decrease from 11% to 4%. *Carpinus*, *Alnus*, *Fagus*, *Ulmus*, *Tilia* and *Fraxinus* pollen values also show decreasing tendencies. The top boundary overlaps the zone boundary.

Age: The zone comprises the end of the early, the middle and the beginning of the late Sub-Atlantic period.

Sediment: Algal gyttja changing, in the middle of the zone, into fine detritus gyttja with carbonates.

11 *Pinus* l paz (605–445 cm)

Description: A dominance of *Pinus* pollen. *Quercus*, *Carpinus* and *Fagus* pollen curves gradually decrease. The amounts of NAP pollen, especially those of *Cerealia*, *Rumex* and *Gramineae* clearly increase.

Top boundary: The sediment surface. Division: The zone has been divided into the following subzones:

11:1 *Quercus-Pinus* l pa subz (605–515 cm)

High values of *Pinus* (50–60%), 6–8% of *Betula* pollen. A clear increase in NAP (to 32%). *Quercus* pollen values range from 2–4% and *Alnus* - from 6–11%. The top boundary – the clear decrease in *Quercus*.

11:2 *Pinus* l pa subz (515–445 cm)

Pinus values decrease (50–40%) and NAP curve increases to 43%. An insignificant increase in *Juniperus* pollen (in the beginning of the subzone).

Age: The zone corresponds to the younger part of the late Sub-Atlantic period.

Sediment: Fine detritus gyttja, initially with carbonates.

Lake Kęsowo (Fig. 12) *

7 *Pinus-Betula-Corylus-Alnus-Ulmus* l paz (1500–1405 cm)

Description: Almost equal values of *Betula* and *Pinus* pollen. 2–5% of *Ulmus* and 16–21% of *Alnus* pollen. Small changes in *Corylus* (5–7%), *Quercus* (6–10%), *Tilia* (0.5–2.0%) and *Fraxinus* (1.0–2.5%) curves.

Division: Taking into account the results from the other sites only one subzone has been distinguished.

7:2 *Quercus-Tilia-Fraxinus* l pa subz (1500–1405 cm)

Top boundary: The clear increase in *Quercus* and an insignificant decrease in *Pinus* pollen.

Age: Late Atlantic period.

Sediment: Clayey gyttja with carbonates.

8 *Pinus-Betula-Quercus-Corylus-Alnus* l paz (1405–1125 cm)

Description: A clear dominance of *Betula* over *Pinus* pollen (in the first half of the

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* Fig. 12 under the cover

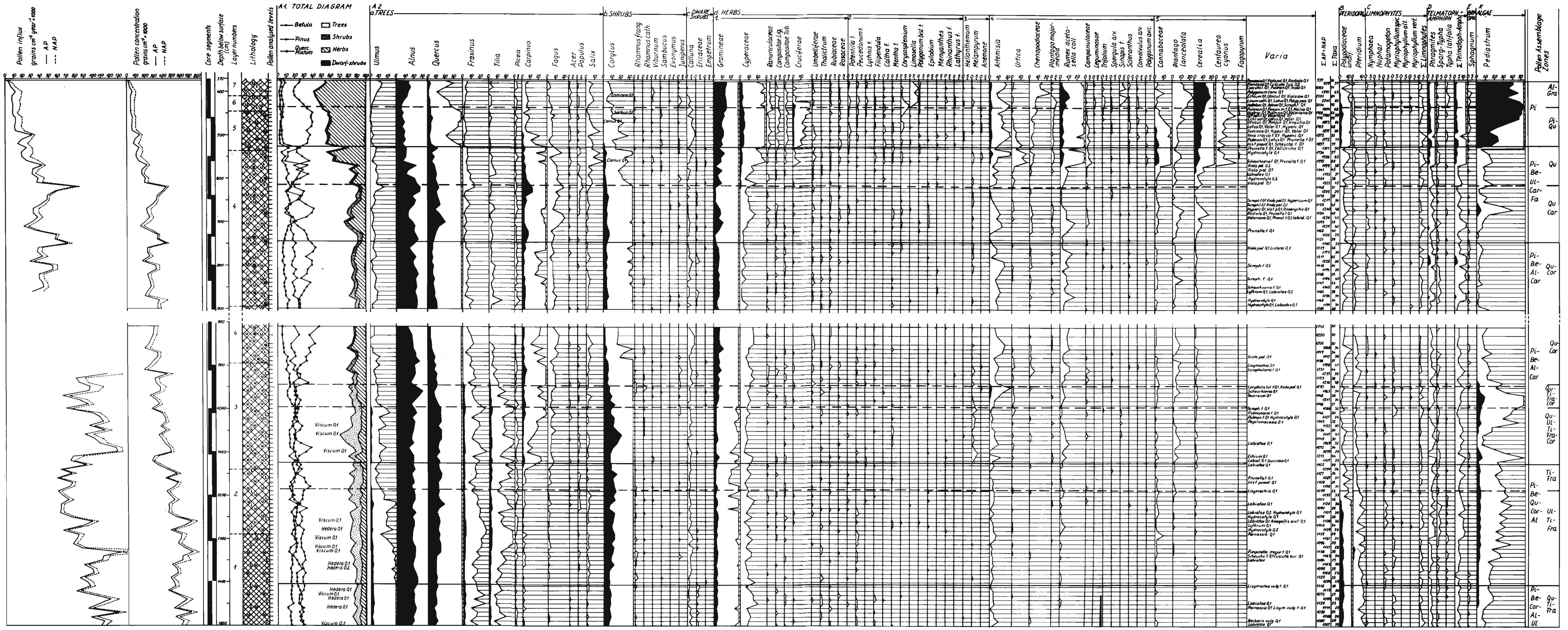

Fig. 12. Lake Kęsowo. Pollen percentage diagram

zone). Regular and high values of *Alnus* and *Quercus* pollen curves and low values of *Fraxinus*, *Tilia* and *Ulmus*. Small amounts of pollen grains of *Carpinus*.

Top boundary: The increase in *Carpinus* and *Ulmus* pollen.

Division: The zone is divided into two subzones:

8:1 *Ulmus-Tilia-Fraxinus* l pa subz (1405–1185 cm)

An increasing tendency of *Quercus* pollen curve. Percentage amounts of *Ulmus* pollen (1–3%). A small increase in *Tilia* and *Fraxinus* pollen (in the middle part). The top boundary – the disappearance of percentage values of *Ulmus*.

8:2 *Tilia-Fraxinus* l pa subz (1185–1125 cm)

Regular presence of *Fraxinus* and *Tilia* pollen. Continuous curve of *Carpinus* and *Fagus* appear. The top boundary is the zone boundary.

Age: The entire zone corresponds to the end of the Atlantic period and the early or partly the middle Sub-Boreal period.

Sediment: Clayey gyttja with carbonates, in the younger part with ferric concretions.

9 *Pinus-Betula-Alnus-Carpinus* l paz (1125–745 cm)

Description: Dominance of *Pinus* pollen. In the second half of the zone, a clear decrease of *Quercus*, *Fraxinus*, *Tilia* and *Corylus* pollen curves. An increase, especially in the middle part, of *Carpinus* values.

Top boundary: The beginning of a clear maximum of *Carpinus*.

Division: Three subzones have been distinguished within this zone.

9:1 *Quercus-Ulmus-Tilia-Fraxinus-Corylus* l pa subz (1125–995 cm)

An increase in the amount of *Pinus* pollen to 38%, constant values of *Betula* (about 20%), *Ulmus* (1–2%) and also *Alnus*, *Quercus* and *Fagus* pollen. A clear increase of *Carpinus* and a maximum of *Corylus* (to 20%) values. The top boundary – the disappearance of percentage values of *Ulmus*.

9:2 *Quercus-Tilia-Fraxinus-Corylus* l pa subz (995–945 cm)

Curves of deciduous trees show a decreasing tendency. The disappearance of percentage curves of *Tilia* and *Fraxinus* is the top boundary of the subzone.

9:3 *Quercus-Corylus* l pa subz (945–745 cm)

Pinus pollen is dominant. Decreasing amounts of *Quercus* and *Corylus* pollen. The top boundary overlaps the zone boundary.

The subzone has been distinguished almost entirely from both the younger and older part of the core (cf. Fig. 12).

Age: The zone begins in the middle Sub-Boreal period and continues until the early Sub-Atlantic period.

Sediment: Clayey gyttja with carbonates and pieces of mollusc shells in the younger part.

10 *Pinus-Betula-Alnus-Carpinus-Fagus* l paz (745–525 cm)

Description: Values of *Pinus* pollen range between 18 and 42% and *Betula* between 9 and 35%. At the beginning and in the middle part of the zone a clear maximum of *Carpinus*. An increase in Populus and *Salix* pollen curves. The role of NAP increases. Top boundary: A clear increase in *Pinus* pollen and NAP.

Division: The zone is divided into two subzones:

10:1 *Quercus-Corylus* l pa subz (745–615 cm)

In the middle part a clear decrease in *Alnus* and *Carpinus* pollen convergent with the peak of *Pinus*. The top boundary corresponds to a clear decrease in values of *Carpinus* pollen.

10:2 *Quercus* l pa subz (615–525 cm)

High values of *Pinus* pollen (to 35%). A decreasing tendency of *Alnus*, *Quercus*, *Carpinus*, *Fagus* and *Corylus* pollen curves. NAP curves increase; especially *Cerealia*, *Rumex* and *Artemisia*. The top boundary is the zone boundary.

Age: The entire zone corresponds to the end of the early, middle and older part of the late Sub-Atlantic period.

Sediment: Clayey gyttja with carbonates and pieces of mollusc shells. The top boundary of the zone overlaps almost entirely the lithological boundary connected with the disappearance of mollusc shells in the sediment.

11 *Pinus* l paz (525–375 cm)

Description: High values of NAP (to 60%) and *Pinus* (20–40%) pollen. Small amounts of *Betula* (5–10%) pollen and other deciduous trees.

Top boundary: The sediment surface. Division: The zone is divided into two subzones:

11:1 *Pinus-Quercus* l pa subz (525–435 cm)

A clear dominance of *Pinus* pollen (35–40%) and high values of NAP. *Carpinus* and *Corylus* pollen curves disappear. An increase in Calluna and *Quercus* (2–6%) pollen. The top boundary of the zone – a decrease in *Pinus* pollen and an increase in NAP curve.

11:2 *Pinus*-NAP l pa subz (435–375 cm)

A decrease in *Pinus* pollen values and a clear increase in NAP curve, mainly: *Cerealia*, *Rumex* and *Gramineae*. Values of *Alnus* pollen increase to 16%. Small amounts of *Quercus* (2–4%).

Age: The entire zone corresponds to the late Sub-Atlantic period.

Sediment: Clayey gyttja with carbonates.

POLLEN ASSEMBLAGE ZONES VERSUS THE NUMERICAL DIVISION

Numerical analyses were done only for the site Mały Suszek. Fig. 13 shows a dendrogram of CONSLINK program and the results of the divisions obtained after the ap-

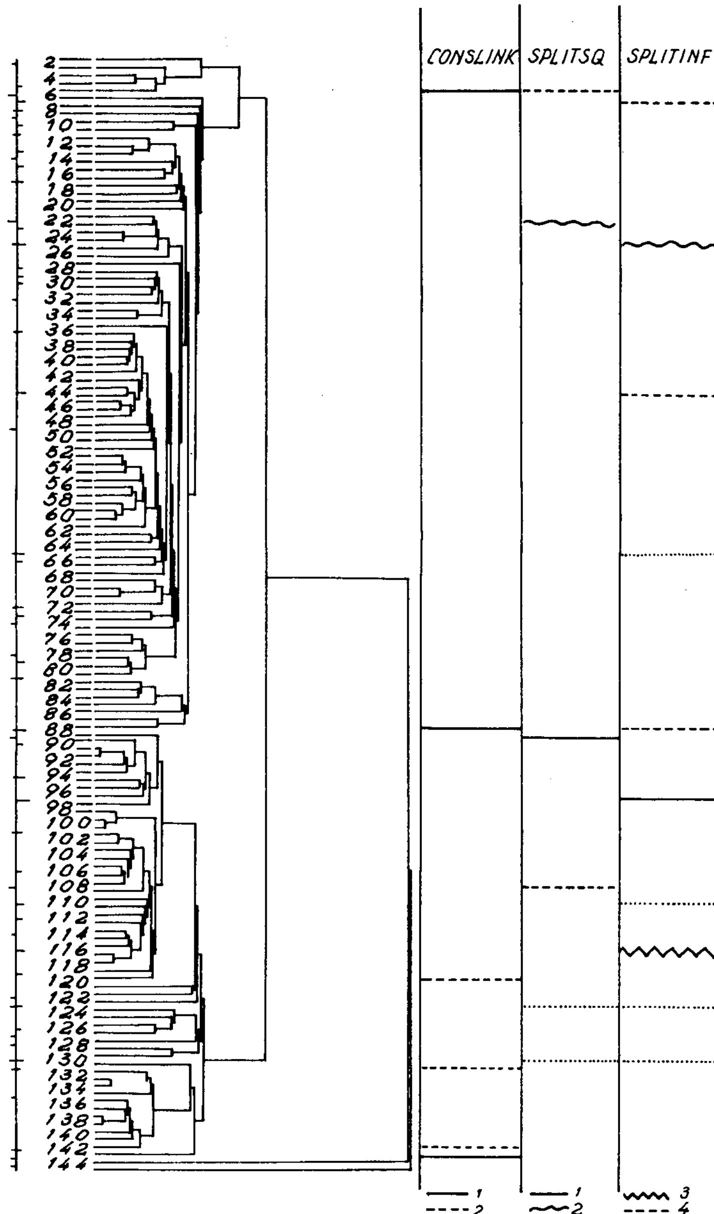

Fig. 13. Results of the numerical analyses (with *Alnus*). CONSLINK: 1 – a clear boundary, 2 – a weak boundary, SPLIT-s: 1 – scatter 20–25%, 2 – scatter 25–30%, 3 – scatter 30–35%, 4 – scatter 35 – 40%, 5 – above 40%

Table 3. SPLIT-s results as a scatter expressed in percentage (above 10%) a – with *Alnus*, b – without *Alnus*

SPLITSQ				SPLITINF					
No of sample	Disper sion %	No of sample	Disper sion %	No of sample	Disper sion %	No of sample	Disper sion %	No of sample	Disper sion %
a)									
5	25	126	12	4	12	29	11	93	15
10	11	129	22	6	26	35	17	96	52
21	37	141	14	7	15	43	25	100	16
35	11	142	10	9	12	64	21	105	13
48	17	143	10	10	14	65	14	109	20
66	12			12	12	71	16	111	11
73	10			14	17	72	17	115	33
80	16			16	18	78	15	118	13
88	46			22	14	80	19	122	22
97	13			24	38	82	13	125	12
107	29			27	11	87	29	129	23
122	20			28	12	89	11	130	14
								141	18
b)									
1	10	80	37	4	14	29	13	87	20
7	12	85	11	6	29	35	19	93	18
10	14	97	56	7	17	43	27	96	12
20	11	104	15	9	14	51	13	98	58
23	44	111	32	10	16	53	13	100	12
32	10	118	10	12	14	64	23	104	15
43	19	126	15	16	22	71	18	115	37
51	12	129	24	22	16	72	19	118	15
64	10	141	17	24	41	79	32	122	24
66	16	142	13	27	13	80	17	129	25
73	11	143	14	28	15	82	16	130	14
								141	22

plication of programs SPLITINF and SPLITSQ. The hierarchy of boundaries obtained after the application of the above programs has been also shown in the diagram. The scatter expressed in percentages is given in Tab. 3 and the percentage of particular taxa in the three main components is given in Tab. 4. The specification of boundaries obtained by the numerical analysis method with distinguished pollen zones on the scale of radiocarbon years is shown in Fig. 14.

Boundaries obtained in the numerical analysis not always correspond to the pollen zones distinguished. The only boundary clearly reflected in all three numerical procedures corresponds to the boundary between pollen zones MS 5 and MS 6. This clear change in the natural composition of the vegetation occured about 9000 years B.P. and was primarily connected with a fairly rapid spread of *Alnus*, an increase in the signific-

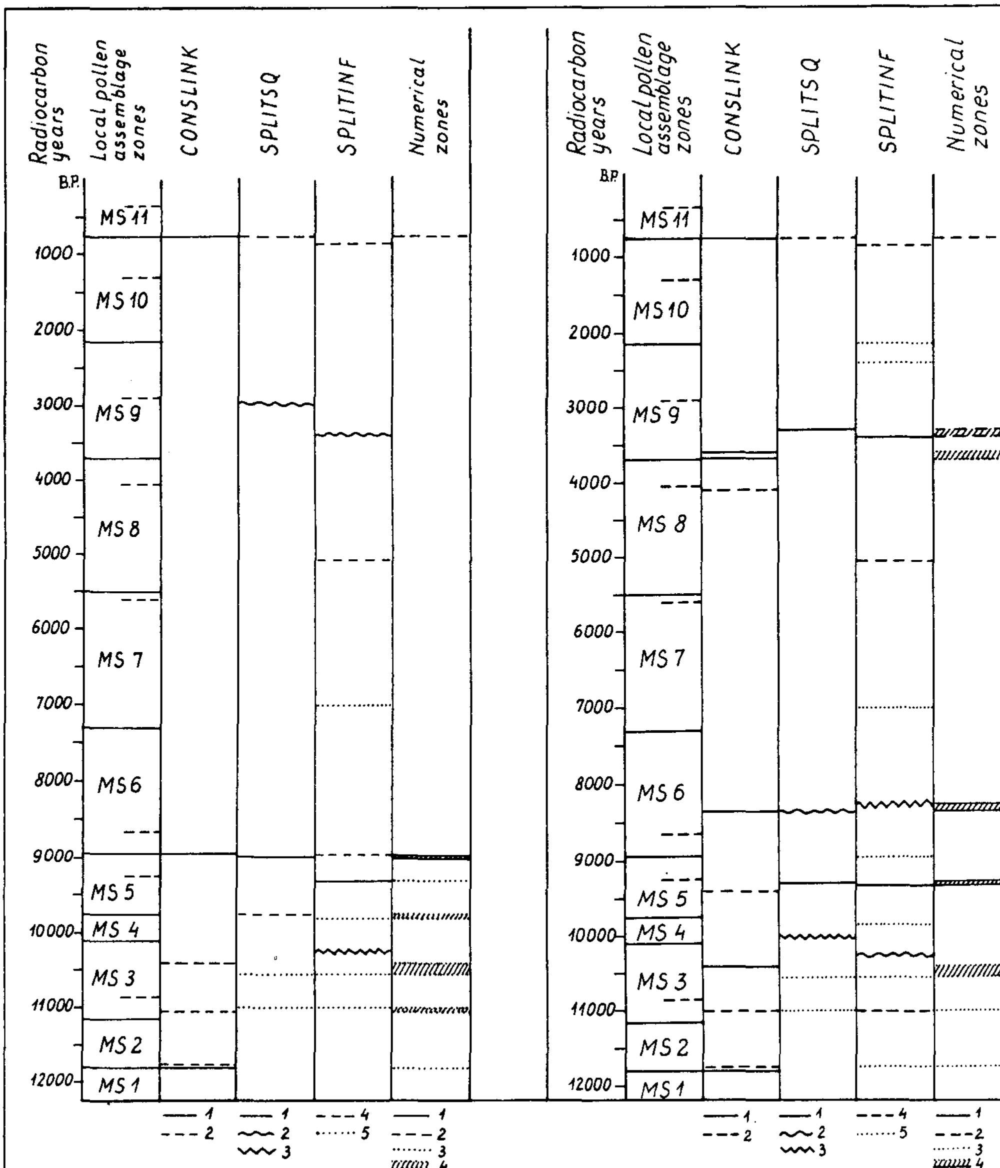

Fig. 14. Pollen assemblage zones and boundaries determined by the numerical analysis method: with *Alnus* (left) and without *Alnus* (right). CONSLINK: 1 – a clear boundary, 2 – a weak boundary, SPLIT-s: 1 – 20–25% scatter, 2 – 25–30% scatter, 3 – 30–35% scatter, 4 – 35–40% scatter, 5 – above 40%. Numerical boundaries 1 – a clear boundary (2 strong, 1 weak), 2 – a rather clear boundary (1 strong, 1 weak), 3 – a weak boundary (2, 3 weak or 1 strong), 4 – a boundary with a temporary zone

ance of *Quercus* and *Ulmus* and the disappearance of *Corylus* (cf. Fig. 15). Clear changes in the vegetation at the time are a phenomenon synchronous for the entire Polish Lowland (Ralska-Jasiewiczowa 1987). The boundary between pollen zones MS 10 and MS 11 was confirmed in numerical analyses to a lesser degree. The boundary is connected with the decrease in the occurrence of deciduous trees, mainly *Carpinus*, *Fagus*, *Quercus*, *Alnus* and *Betula*. The intensification of deforestation contributed to the development of meadow communities and arable lands and an increase in the significance of *Pinus*. All this took place about 750 years B.P. The boundary between zones MS 4 and MS 5 is even less clear; it is connected with the disappearance of *Betula* and herbs and spread of *Corylus* and *Pinus*. This took place about 9750 years B.P. The next boundary in the numerical analyses is recorded about 11000 years B.P., though this is not too clear. The boundary is connected primarily with the spreead of *Juniperus*, an increase in *Artemisia* and *Salix*. The boundary between pollen zones MS 2 and MS 3 was drawn slightly earlier when the significance of these plants increased. An equally clear boundary can be drawn in both places although it seems more appropriate to do this on the basis of pollen analysis since it stresses the beginning of changes in the vegetation whereas numerical analysis stresses more advanced changes.

Generally, the boundaries indicated significantly by all three procedures are important boundaries. On the other hand, not every significant boundary must be confirmed by each of the numerical procedures. The boundary between zones MS 1 and MS 2, connected with a decrease in *Cyperaceae* and *Pinus*, dated by the radiocarbon method at 11810±140 year B.P. was only recorded by CONSLINK program though it is very clear on the pollen diagram. The remaining boundaries between pollen zones were not confirmed by the numerical analyses. Additional changes discovered on the basis of this analysis are only recorded by one or two procedures and they are not very clear. Two other boundaries are rather clear, namely those determined by SPLIT-s. The first, about 3000 years B.P. almost overlaps the boundary between subzone MS 9:1 and MS 9:2 and is connected with a decrease in the contribution of *Alnus* and *Corylus* to the pollen spectrum and an increase in the significance of *Carpinus*. The second boundary occurring about 3400 years B.P. is connected with the disappearance of *Ulmus*, a decrease in the significance of *Alnus* and a decreasing contribution of *Quercus*. It has not been taken into account in the division into pollen zones. The weak boundary of about 10400–10500 years B.P. connected with a decrease in *Pinus*, *Juniperus* and *Salix* and an increase in *Betula* has also not been taken into account in the division into pollen zones. The boundary between subzones MS 3:1 and MS 3:2 was recorded about 300 years earlier when, on the basis of the pollen diagram, changes in the vegetation seem to be more significant.

Generally it can be said that the results of the numerical analysis confirm in principle the results of the pollen analysis. The majority of clear boundaries between pollen zones of up to about 9000 years B.P. have been confirmed to a greater or lesser degree by numerical procedures. The remaining boundaries drawn on the pollen diagram are related to less intensive changes in the vegetation. Slowly disappearing species were being replaced by new ones. Only a considerable change in the vegetation caused by the de-

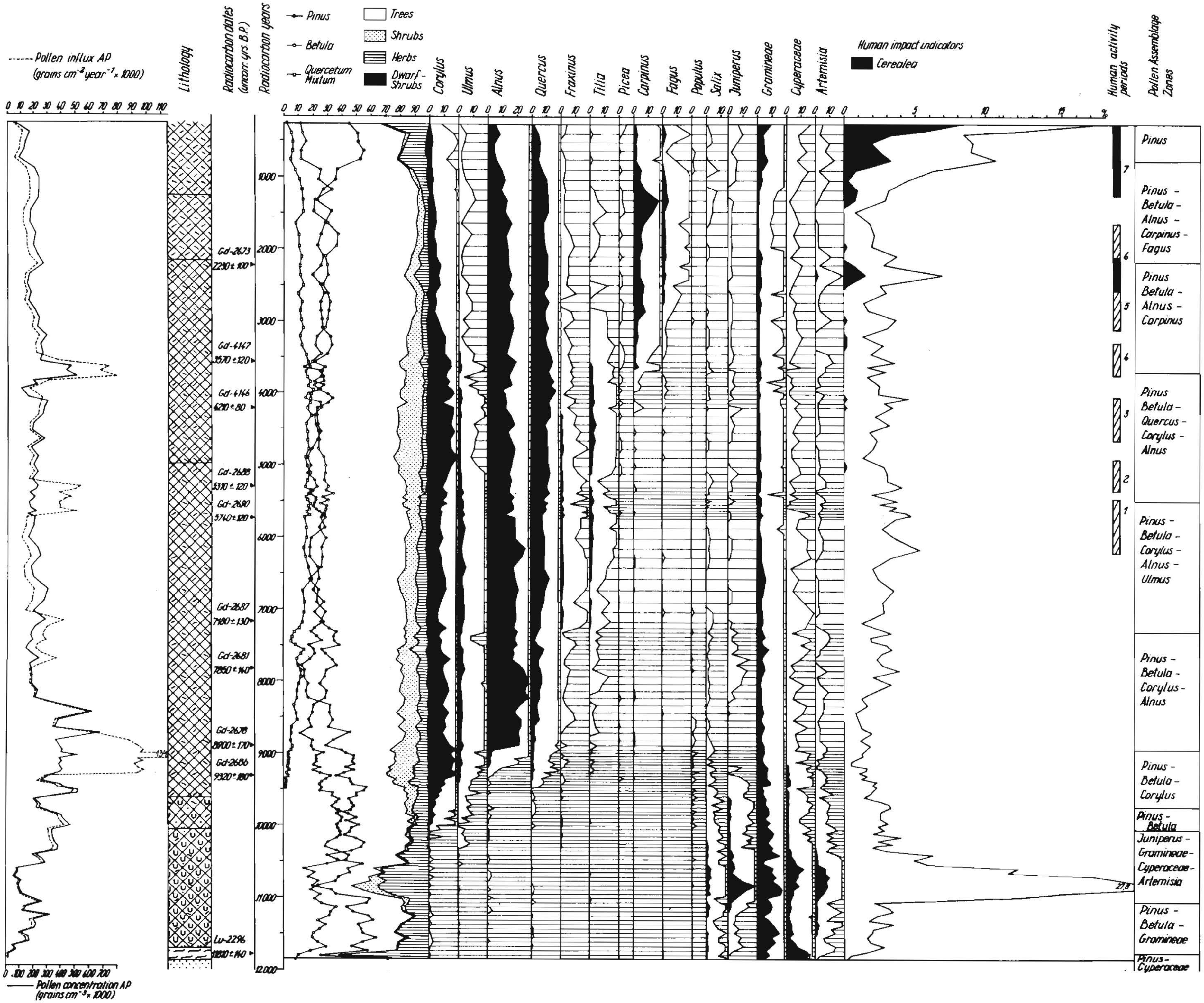

Fig. 15. Lake Mały Suszek – simplified pollen diagram. Curves of trees and selected taxa of NAP only. All values are percentages of AP+NAP. Radiocarbon age is based on uncorrected ^{14}C dates

Table 4. Weights of the taxons under analysis in the main components – with *Alnus* (top) and without *Alnus* (bottom)

PCA Nr = 63 (t = 19, u = 19)

61,73 %				61,73 %
9,85 %				71,58 %
9,73 %				81,31 %
1	2,151	0.247	−0,187	
2	−0,274	0,659	0,145	
3	0,295	−0,122	−0,851	
4	1,308	−0,471	0,733	
5	0,13	−071	−0.45	
6	0,465	049	,052	
7	−0,513	0,375	−038	
8	−0,926	−0,958	−0,102	
9	1,552	−04	−0,339	
10	−0,416	0,115	,032	
11	0,573	038	,076	
12	0,566	−023	0,333	
13	−0,421	0,287	−049	
14	−0,634	0,183	−01	
15	−0,734	0,159	0,175	
16	−005	−05	−0,206	
17	−043	001	−0,196	
18	−002	−0,112	−0,251	
19	0,467	0,1	0,114	

(63) Mały Suszek (Bory T) P 144 19 01

1 – *Alnus*	2 – *Betula*	3 – *Carpinus*
4 – *Corylus*	5 – *Fagus*	6 – *Fraxinus*
7 – *Juniperus*	8 – *Pinus*	9 – *Quercus*
10 – *Salix*	11 – *Tilia*	12 – *Ulmus*
13 – *Artemisia*	14 – *Cyperaceae*	15 – *Gramineae*
16 – *Rumex acetosa*	17 – *R. acetosella-t*	18 – *Secale*
19 – *Pteridium*		

PCA Nr = 631 (t = 19, u = 18)

Bez Alnus

53,49 %				53,49 %
13,64 %				67,13 %
12,17 %				79,3 %
2	,023	−0,41	−0,731	
3	0,293	0,92	−0,338	
4	1,583	−0,443	0,54	
5	0,122	0,481	−0,162	
6	0,51	−,073	−0,55	
7	−0,503	−0,143	−0,333	
8	−0,625	0,454	0,861	
9	1,709	0,375	−0,275	
10	−0,409	−,098	−,052	
11	0,637	−,082	−047	
12	0,648	−0,315	0,12	
13	−0,421	−,093	−0,234	
14	−0,63	−0,116	−,046	
15	−0,668	−0,299	,028	
16	−02	0,208	−,02	
17	−063	0,179	−,06	
18	−021	0,273	,017	
19	0,505	−0,164	−,062	

forestation of the area, has been reflected also in the numerical analysis.

Upon the principal component analysis one notices that in the first component containing 61.73% of the information provided by the diagram (Tab. 4), *Alnus* is very significant (2.151). Apart from that this component is defined mainly by *Quercus* and *Corylus* which show a positive correlation between each other and by *Pinus* and *Gramineae*, also correlated with each other but with a clear anticorrelation to species mentioned earlier. The existence of an anticorrelation between *Betula* and *Pinus* follows from the second main component. The third component is defined mainly by *Carpinus* and *Corylus* with an anticorrelation between them. All this is rather obvious and agrees with the succession of the vegetation. The only surprising fact was that of such a large contribution of *Alnus* to the determination of the first main component and such great

Fig. 16. Results of the numerical analyses (without *Alnus*). CONSLINK 1 – a clear boundary, 2 – a weak boundary, SPLIT-s: 1 – scatter 20–25%, 2 – scatter 25–30%, 3 – scatter 30–35%, 4 – scatter 35 – 40%, 5 – above 40%

significance of the taxon (25%). It is known that the significance of a taxon is defined primarily by its number, although it is proportional only to the square root of concentration $\sqrt{pl\%}$. This means that a taxon present in a profile in number exceeding four times the frequency of another has only a twofold higher significance in the main component.

This does not explain, however, an exceptionally high coefficient for *Alnus* in the first main component. Hence it was decided to perform the numerical analyses again excluding *Alnus* from them. The new first main component is almost identical with the former (Tab. 4). This indicates that *Alnus* constitutes a form of background for the changes of other components of the main component.

Results of the numerical analyses (without *Alnus*) determined new boundaries in the profile from Mały Suszek (Fig. 16). Some of these boundaries overlap those obtained earlier and some of them are new (Fig. 14, cf. Fig. 13 and 16). The most important boundary, about 9000 years B.P. is not confirmed since it was determined mainly on the basis of an increase in the significance of *Alnus*. A new important boundary, about 9250 years B.P. appeared, which corresponded almost to the boundary between subzone MS 5:1 and MS 5:2. It is connected with the disappearance of *Betula* and the beginning of *Corylus* maximum. In the former analysis this boundary was determined only by SPLITINF. The boundary of about 10400–10500 years B.P. has been confirmed, although it is not very clear. Rather obscure boundaries of about 1100 years B.P. and about 11750 years B.P. are also recorded, similarly to the earlier analyses. A rather clear boundary of about 750 years B.P. has been recorded again. Apart from this, three new boundaries have been also recorded. The most clear of them occurs at about 8250–8350 years B.P. and is connected with a decrease of *Pinus* and an increase in *Betula*. Other components of the vegetation do not show more significant changes and therefore the boundaries have not been taken into account when division into pollen assemblage zones were made. The next boundary determined on the basis of CONSLINK program overlaps the boundary between zones MS 8 and MS 9 (about 3700 years B.P.) and is connected with the spread of *Carpinus*. The next, rather obscure boundary, about 3300–3400 years B.P., has been determined on the basis of results of SPLIT-s programs while in the numerical analysis with *Alnus* the boundary is only recorded in SPLITSQ. The boundary is connected with the beginning of a decrease in *Corylus* and *Pinus* and with an insignificant increase in *Betula*. These changes have not been taken into account during the division into pollen assemblage zones.

Summing up the results of the numerical analyses we must state that in the case of the profile from Lake Mały Suszek they confirm the existence of really clear and significant changes in the vegetation. Some boundaries poorly recorded in the numerical procedures confirm the boundaries between pollen zones or indicate to other, less clear changes. The exclusion of *Alnus* from the numerical analyses helped obtain three new boundaries of which only one found its reflection in the division into pollen assemblage zones. However, a very important boundary of about 9000 years B.P., when *Alnus* was spreading over extensive areas and was an important element of the regional vegetation, has been lost. This points to considerable difficulties in the selection of appropriate data for the numerical analyses. Nevertheless, it seems obvious that these analyses facilitate to a considerable degree the divisions into pollen zones and therefore it is advisable that they be done prior to the divisions.

REGIONAL POLLEN ASSEMBLAGE ZONES

Pollen assemblage zones and subzones distinguished for four sites of Bory Tucholskie have been shown in Tab. 5. It follows from this table that the vegetation of the area under investigation developed in a similar way. This is indicated by a great similarity of the duration of particular pollen assemblage zones. The existence of local differences had its expression in the differentiation of subzones. The similarity of local paz was the basis for the construction of a regional division. For Bory Tucholskie the following regional (BT) pollen assemblage zones (R paz) are proposed:

BT 1	12000–11800	years B.P.	*Pinus-Cyperaceae*
BT 2	11800–11200	years B.P.	*Pinus-Betula-Gramineae*
BT 3	11200–10050	years B.P.	*Juniperus-Gramineae-Artemisia*
BT 4	10050–9725	years B.P.	*Pinus-Betula*
BT 5	9725–8950	years B.P.	*Pinus-Betula-Corylus*
BT 6	8950–7250	years B.P.	*Pinus-Betula-Corylus-Alnus*
BT 7	7250–5500	years B.P.	*Pinus-Betula-Corylus-Alnus-Ulmus*
BT 8	5500–3700	years B.P.	*Pinus-Betula-Quercus-Corylus-Alnus*
BT 9	3700–2100	years B.P.	*Pinus-Betula-Alnus-Carpinus*
BT 10	2100–750	years B.P.	*Pinus-Betula-Alnus-Carpinus-Fagus*
BT 11	750–0	years B.P.	*Pinus*

DEVELOPMENT OF BORY TUCHOLSKIE VEGETATION

Late Glacial

BT 1 *Pinus-Cyperaceae* R paz (12000–11800 years B.P.)

The zone corresponds to a period directly preceding Allerød. Hjelmroos (1981a) included it into Older Dryas but it seems to be better to use the term pre-Allerød. In the diagram from Wielkie Gacno (Hjelmroos 1981a) and that from Mały Suszek (Figs. 10, 15) there is only the younger part of the zone. The concentration of pollen grains and influx is very low, which is a characteristic feature of areas devoid of trees (Birks & Birks 1980). This suggests that *Pinus* and *Betula* originated from long-distance transport although single speciments of birch trees could have sustained the cold climate (Wasylikowa 1964). Moist soils were a good habitat for *Cyperaceae* and *Gramineae*. *Salix*, *Artemisia*, *Saxifraga* and *Umbelliferae* were not numerous and formed a treeless tundra, characteristic of this period.

BT 2 *Pinus-Betula-Gramineae* R paz (11800–11200 years B.P.)

The zone comprises early and middle Allerød. At the time birch forests were dominant; this is evidenced by reports from various parts of Poland (Wasylikowa 1964, Pawlikowski et al. 1982, Noryśkiewicz 1982, Tobolski 1983). It is assumed that *Pinus* began

Table 5. Local and regional pollen assemblage zones distinguished for Bory Tucholskie

Radiocarbon years B.P.	Local pollen assemblage zones: Wielkie Gacno (Hjelmroos-Ericsson M. 1981)	Mały Suszek	Suszek	Kęsowo	Regional pollen assemblage zones	Chronozones: Mangerud et al 1974	Starkel 1975
0	Pinus; Pinus-Betula-Alnus-Carpinus-Fagus (Qu-Pi)	Pinus (Pi; Qu-Pi)	Pinus (Pi-; Qu-Pi)	Pinus (Pi-NAP; Pi-Qu)	Pinus	SUBATLANTIC Late	SUBATLANTIC 2
1000, 2000	(Qu; Qu-Pic)	Pinus-Betula-Alnus-Carpinus-Fagus (Qu; Qu-Co)	Pinus-Betula-Alnus-Carpinus-Fagus (Qu; Qu-Co)	Pinus-Betula-Alnus-Carpinus-Fagus (Qu; Qu-Co)	Pinus-Betula-Alnus-Carpinus-Fagus	Middle; Early	1
3000	Pinus-Betula-Alnus-Carpinus (Qu-Pic; Qu-Ul-Pic-Co)	Pinus-Betula-Alnus-Carpinus (Qu-Co-Fa; Qu-Ti-Co)	Pinus-Betula-Alnus-Carpinus (Qu-Co; Qu-Ti-Frx-Co)	Pinus-Betula-Alnus-Carpinus (Qu-Co; Qu-Ti-Frx-Co; Qu-Ul-Ti-Frx-Co)	Pinus-Betula-Alnus-Carpinus	SUBBOREAL Late; Middle	SUBBOREAL 3; 2
4000, 5000	Pinus-Betula-Quercus-Corylus-Alnus (Ul-Frx; Ul-Ti-Frx)	Pinus-Betula-Quercus-Corylus-Alnus (Ul-Ti; Ul-Ti-Frx)	Pinus-Betula-Quercus-Corylus-Alnus (Ti-Frx; Ul-Ti-Frx)	Pinus-Betula-Quercus-Corylus-Alnus (Ti-Frx; Ul-Ti-Frx)	Pinus-Betula-Quercus-Corylus-Alnus	Early	1
6000, 7000	Pinus-Betula-Corylus-Alnus-Ulmus (Qu-Ti-Frx; Qu-Ti)	Pinus-Betula-Corylus-Alnus-Ulmus (Qu-Ti; Qu-Ti-Frx)		Pinus-Betula-Corylus-Alnus-Ulmus (Qu-Ti-Frx)	Pinus-Betula-Corylus-Alnus-Ulmus	ATLANTIC Late; Middle; Early	ATLANTIC 4; 3; 2
8000	Pinus-Betula-Corylus-Alnus (Qu-Ul; Ul-Qu)	Pinus-Betula-Corylus-Alnus (Qu-Ul; Ul-Qu)			Pinus-Betula-Corylus-Alnus	BOREAL Late; Early	1; BOREAL
9000	Pinus-Betula-Corylus (Ul-Al; Ul)	Pinus-Betula-Corylus (Ul-Qu-Al; Ul)			Pinus-Betula-Corylus	PREBOREAL Late	PREBOREAL 2
10000	Pinus-Betula	Pinus-Betula			Pinus-Betula	Early	1
11000	Juniperus-Gramineae-Artemisia (Pi-Be; Ju)	Juniperus-Gramineae-Cyperaceae-Artemisia (Pi-Be; Ju)			Juniperus-Gramineae-Artemisia	YOUNGER DRYAS	YOUNGER DRYAS
	Pinus-Betula-Gramineae	Pinus-Betula-Gramineae			Pinus-Betula-Gramineae	ALLERØD	ALLERØD
12000	Pinus-Cyperaceae	Pinus-Cyperaceae			Pinus-Cyperaceae	OLDER DRYAS	OLDER DRYAS

to play a considerable role in the formation of forests as late as the second part of Allerød (Wasylikowa 1964, Tobolski 1983). Macroanalysis of sediments from Lake Wielkie Gacno (Hjelmroos 1981a) showed that this tree came to the area of Bory Tucholskie at the beginning of this zone. *Salix*, *Juniperus* and locally *Populus* were the admixture of the forests. An increase in the AP influx testifies also to the presence of forest communities. A decrease in *Salix*, *Juniperus* and herbs in the middle part of the zone could have been connected with a development of the dominant pine-birch forests. The partition of Allerød has been described at different sites (Wasylikowa 1964, Pazdur & Pazdur 1986). More moist habitats, alongside streams, were taken by *Gramineae*, *Cyperaceae* and locally by *Filipendula* (Wielkie Gacno - Hjelmroos 1981a) and *Typha latifolia* (Mały Suszek). The presence of pollen grains of the latter species, included in indicator species in the warm periods of Late Glacial (Iversen 1954) provide information on the mean temperatures in July within the range of 14–15°C (Wasylikowa 1964, Ralska-Jasiewiczowa 1966). At the end of the zone the significance of *Salix*, *Juniperus*, *Artemisia* and other heliophilous plants increased. The change of the vegetation towards more open communities points to the limitation of the area of pine forest caused by the change of climate.

During BT 2 the melting of ice blocks began or was intensified. A change of the sediment from sandy to algal gyttja in Wielkie Gacno and from moss peat to calcareous gyttja in Mały Suszek took place. The same age of the changes is evidenced by the radiocarbon dates 11840±110 B.P. (Lu-1678, Hjelmroos 1981a) and 11810±140 B.P. (Lu-2296, Hakanson 1986).

BT 3 *Juniperus-Gramineae-Artemisia* R paz (11200–10050 years B.P.)

The zone corresponds to the end of Allerød and the period of Younger Dryas. The cooling of the climate caused the disappearance of the pine forest and the development of birch forests with the admixture of pine. Among shrubs the main role was played by *Juniperus*. Vegetation type of park tundra developed, with significant contribution of *Helianthemum*, *Artemisia*, *Chenopodiaceae* and *Rumex*. In the vicinity of Wielkie Gacno (Hjelmroos 1981) *Saxifraga* and *Dryas* were rather numerous. At the end of this zone the climate probably improved, which caused a greater density of birch-pine forests and a gradual disappearance of heliophilous vegetation. High values of *Gramineae* and *Cyperaceae* can be connected with the development of meadow associations.

The zone shows a clear duality, which is reflected in two local paz. In the older part open forests composed mainly of *Betula pubescens* (Hjelmroos 1981a) with some *Pinus* were dominant. This was a time of the maximum development of *Juniperus* in dry places. More humid habitats were overgrown by *Betula nana* (Hjelmroos 1981a) and *Salix*. Dune-formation processes became more intense at that time (Wasylikowa 1964, Tobolski 1966, Nowaczyk 1986). This was confirmed by the sand layer in the organic sediments of Wielkie Gacno and in the increase of sand in sediments of Mały Suszek. In the younger part of the zone a gradual dissapearance of heliophilous herbs testifies to the increase of the forest density. *Juniperus* continued to play a rather significant role in the composition of the vegetation, although it was much smaller than at the beginning of the zone. The appearance of a continuous curve of *Typha latifolia* indicates the progressive improvement of the climate in this part of the zone (Berglund et al. 1984).

Changes in the vegetation are confirmed by the pollen influx values, decreasing in the older part of the zone and increasing in its younger part.

A similar development of the vegetation at the period of Late Glacial was described for other sites of Bory Tucholskie (Kępczyński 1958, Kępczyński & Noryśkiewicz 1968, Noryśkiewicz 1982, 1983-unpubl.) and is probably typical of the entire region (cf. Berglund 1985).

Holocene

BT 4 *Pinus-Betula* R paz (10050–9725 years B.P.)

The zone corresponds with the early Pre-Boreal period. *Pinus* spread quickly and dominated especially on dry places and in newly formed dunes (Hjelmroos 1981a, 1982). More humid habitats were taken by *Betula* and by *Corylus* which arrived at that time (cf. Tab. 6). *Ulmus* could have constituted a small admixture to these forests. Despite the increase in the density of the tree layer, in open or higher located places *Juniperus* and *Artemisia* continued to grow, accompanied by other heliophilous plants although the latter were less numerous. Meadow associations mainly with *Gramineae* and *Filipendula*, which reached its Holocene maximum at that time in the vicinity of Lake Wielkie Gacno (Hjelmroos 1981a), were dominant on the river banks and lake shores. Relatively high values of influx AP decrease considerably at the end of the zone. *Typha latifolia* disappears. This can be connected with deterioration of the climate, which was especially true of the northern parts of Poland (Latałowa 1982).

BT 5 *Pinus-Betula-Corylus* R paz (9725–8950 years B.P.)

The zone continued until the end of the Pre-Boreal period. This was the time of the growing significance of *Pinus* which reached its local Holocene maximum (e.g. Mały Suszek, Zamrzenica – Noryśkiewicz 1982). In sandy areas it formed forests with *Ericaceae* in the undergrowth (Hjelmroos 1981a). Forests with *Betula* and a considerable contribution of *Corylus* were present on more fertile habitats. A strong expansion of this species did not permit any wider spread of *Ulmus* which arrived there almost at the same time (cf. Tab. 6). It could form small stands only on more fertile soils together with *Salix* and probably *Populus*, although the contribution of the latter in diagrams is negligible. In the younger part of the zone, *Ulmus* could have occurred together with newly arrived *Quercus*. The latter, as a light-demanding tree probably occurred also on the peripheries of forests. It seems that small time differences during the immigration of this tree to the area of Bory Tucholskie could exist (cf. Tab. 6). This is understandable in view of different habitat conditions. Certainly the neighbourhood of Lake Wielkie Gacno, where dune-formation processes were rather intensive in Younger Dryas and continued until about 9000 years B.P. (the completion of the dune accumulation in Kopernica near Lake Charzykowskie according to Nowaczyk 1986) were a less suitable habitat for *Quercus* than the neighbourhood of Mały Suszek, also sandy but lying close to the pradolina. The development of forests caused a definite disappearance of *Juniperus*.

Alnus arrived during the younger part of R paz in the area of Bory Tucholskie and spread along the banks of rivers and lakes, in areas previously occupied by meadows. In the diagrams this is reflected by a clear diminishing of the *Filipendula*, *Cyperaceae* and

Table 6. ^{14}C age (B.P.) for the most important events in the development of the forest trees, excluding *Betula* and *Pinus*

EVENTS	WIELKIE GACNO Hjelmroos-Ericsson M.1981 Corrected ^{14}C - ages	WIELKIE GACNO Hjelmroos-Ericsson M.1981 Uncorrected ^{14}C - ages	MAŁY SUSZEK Uncorrected ^{14}C - ages
CORYLUS:			
empirical limit			10200
rational limit	9750	9800	9900
first maximum	9150	9000	9300
last decrease	2800	2900	3000
ALNUS:			
empirical limit	9600	9600	9300
rational limit	9150	9000	9100
first decrease	7550	7750	7750
last decrease	1250	1600	1550
ULMUS:			
empirical limit			10100
rational limit	9750	9800	9650
first maximum	6950	6950	7850
first decrease	5450	5450	7500
"elm decline"	5050	5050	5100
second increase	4800	4750	4700
second decline	4450	4400	4000
final decrease	2800	2900	3400
QUERCUS:			
empirical limit	9550	9550	9550
rational limit	8950	8750	9250
last decrease	900	1200	900
TILIA:			
empirical limit	8750	8500	8250
rational limit	7150	7150	7200
decline	4300	4200	5250
disappearance	2850	2950	2850
FRAXINUS:			
empirical limit	9000	8800	8850
rational limit	6900	6900	7200
disappearance	3650	3700	4000
PICEA:			
first occurence	7350	7500	
	6000	6100	
rational limit	4000	4000	
maximum	2400	2500	
decline	1650	2000	
CARPINUS:			
empirical limit	5000	5000	3950
rational limit	3800	3800	3700
first maximum	3150	3300	3650
second maximum	2800	2900	2850
third maximum	2000	2250	2000
fourth maximum	1350	1650	1300
decline	300	700	750
FAGUS:			
empirical limit	5150	5150	3450
rational limit	2050	2250	2750
decline	300	700	750

Gramineae pollen values. Influx AP is high, which is a typical phenomenon during the spread of new species (Birks & Birks 1980). In this case however, the increase in the influx values is probably the result of the low-water period during this time (Fig. 17), which may have caused increased so-called sediment focusing and hereby enlarged influx values.

BT 6 *Pinus-Betula-Corylus-Alnus* R paz (8950–7250 years B.P.)

This zone comprises the Boreal period and the beginning of the Atlantic period. *Pinus* is still dominant in the composition of the forests and although its participation decrease about 8300 years B.P., it mainly occupies dry, sandy soils (cf. Fig. 15). The forests were not dense, which is evidenced by a high percentage of *Ericaceae* in the undergrowth. *Quercus* and *Betula* could have constituted a considerable admixture in the pine forests; the latter could have been the main component of the forest in the younger part of of the zone (Mały Suszek – Fig. 10 and 15). In more humid habitats *Quercus* competed with *Ulmus* which on more fertile moist soils probably formed forests with the admixture of *Alnus* and *Corylus*. *Tilia* and *Fraxinus* could have existed there as singly trees. *Alnus* was a tree rapidly spreading at the beginning of the zone and occupying humid habitats, often flooded, on the banks of rivers and lakes. It occurred in smaller numbers in the vicinity of Wielkie Gacno than Mały Suszek. This is probably connected with different habitat conditions. Among the herbs *Cannabaceae/Humulus*, *Compositae* and *Urtica* occured in *Alnus* communities. *Alnus* lost some of its significance in the younger Atlantic period expressed by a clear decrease of its percentages observed in the diagrams from all sites in Bory Tucholskie. This could have been caused by a change of climate to drier and warmer. This is evidenced by the occurence of pollen of *Viscum* and *Hedera* (Mały Suszek) (Iversen 1944).

At the end of the zone a gradual decrease in the influx value of both AP and NAP is observed. This indicates that the forests became more dense (Birks & Birks 1980, Aaby 1986).

BT 7 *Pinus-Betula-Corylus-Alnus-Ulmus* R paz (7250–5500 years B.P.)

The zone corresponds with the middle Atlantic period. *Pinus* and *Betula* still play a considerable role in the forests but compared to earlier zones their significance was clearly decreased. The occurrence of *Pinus* was most probably limited to areas with a thin layer of soil, situated higher. Large amounts of *Ericaceae* and *Pteridium* (Mały Suszek) indicate a small density of the forests. This forest type could dominate on dunes. In areas with better habitat conditions the significance of *Quercus* and *Ulmus* clearly grew. The latter reached its Holocene maximum at this zone. New trees spread – *Tilia* and *Fraxinus* - apart from trees occuring there earlier. In the vicinity of Mały Suszek, Osie and Zamrzenica (Noryśkiewicz 1982, 1983 – unpubl.) both taxa appeared at the same time (cf. Tab. 6) while in the vicinity of Wielkie Gacno (Hjelmroos 1981a) *Fraxinus* appeared earlier than *Tilia*. Local differences in the appearance of these taxa were caused by different habitat conditions. Pollen analyses of sites at Fletnowo (Kępczyński & Noryśkiewicz 1968), Korne (Kępczyński & Noryśkiewicz 1982) and Lake Godzi-

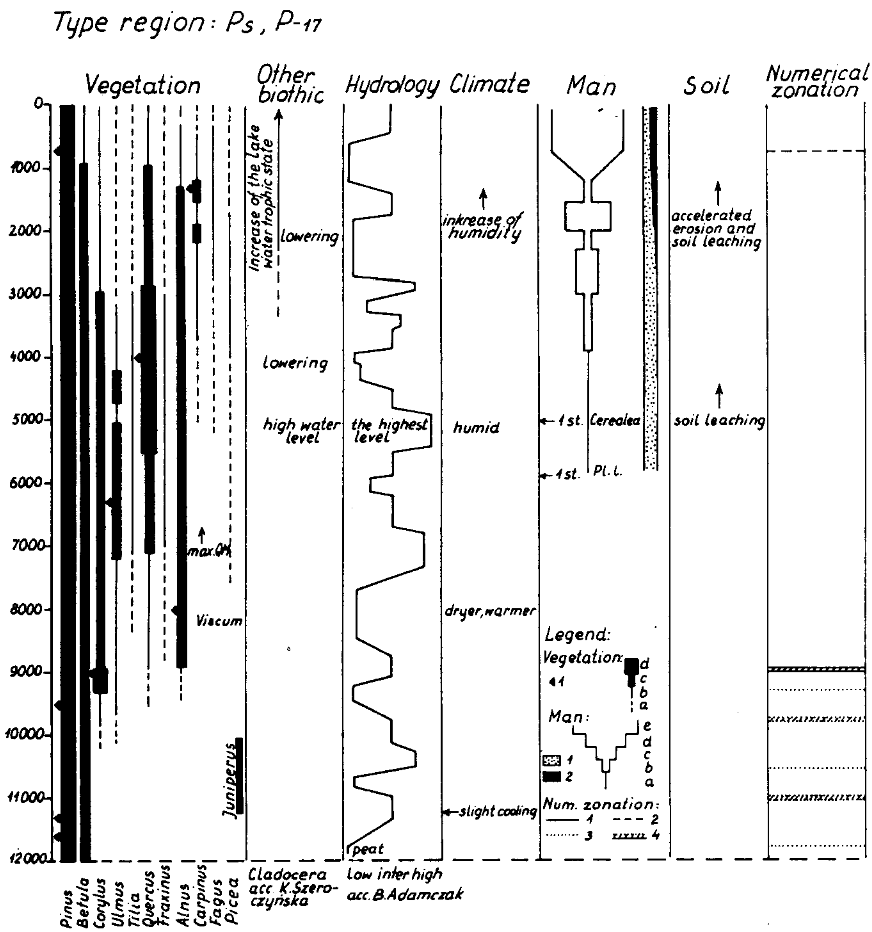

Fig. 17. Event stratigraphy. Vegetation – spread of trees and shrubs: a – presence hypothetical or slight, b – present, c – expansion or important part, d – common, 1 – maximum. Man – human impact: a – slight, b, c, d, e – increasing settlement or deforestation, 1 – grazing, 2 – agriculture. Numerical zonation: 1 – clear boundary, 2 – fairly clear, 3 – faint, 4 – boundary with transition zone

szewskie (Miotk 1986), in the direct neighbourhood of Bory Tucholskie and situated in areas with better soils, recorded earlier and more intense spread of *Tilia* which preceded the development of *Fraxinus* (cf. Tab. 6) Rather high values of *Fraxinus* on diagrams from Bory Tucholskie in comparison with neighbouring areas indicate that alongside rivers and lakes there were good habitats for this demanding tree. *Fraxinus* is a light-demanding tree and because of short life it loses in favour of *Tilia* and *Ulmus* which live longer (Iversen 1973). However, it tolerates greater humidity than *Tilia*, which may indicate that the habitats it occupies were too humid for linden which prefers well drained soils (Aaby 1986).

During this zone mixed deciduous forest (*Quercetum mixtum*) became settled and this marked the end of the progressive succession period, which was followed by an equilibrium between a few species. This was reflected in the constant influx values.

On more abundant sandy areas acidophilous forest, resembling the modern *Pino-Quercetum* (Medwecka-Kornaś 1972) probably develop which was composed, apart from *Pinus*, of *Quercus*, *Betula* and *Tilia*. Fertile habitats were occupied by forest communities with *Ulmus*, *Fraxinus*, *Quercus* and *Tilia*. In the undergrowth of these forests there were *Melampyrum* and *Mercurialis perennis*. In humid areas alongside rivers and lakes there were alluvial forests with *Fraxinus*, *Alnus* and *Ulmus*. The undergrowth layer was usually rather well developed and abundant in such plants as *Filipendula*, *Urtica*, *Cannabaceae/Humulus*, *Chrysosplenium*, *Compositae* and *Polypodiaceae*.

Together with the development of mixed deciduous forests the role of *Corylus* decreased. Its occurrence was probably limited to the river banks, lake shores and forest peripheries. It could have also occurred in the brushwood but because of too large shading its blooming was hampered (Wasylikowa et al. 1985, Godłowska et al. 1987). *Picea* probably occurred in small groups. Its increase is marked on diagrams from Lake Wielkie Gacno (Hjelmroos 1981a, 1982) and Zamrzenica (Noryśkiewicz 1982). The occurrence of this tree in Bory Tucholskie is controversial (cf. Hjelmroos 1981a). We should bear in mind that this pollen grains could have been transported from long distance. It seems, however, that relatively large amounts detected on the diagrams testify to the scattered small sites of this tree in this area (cf. Ralska-Jasiewiczowa 1983).

The climate continued to be warm, which is confirmed by the occurrence of *Viscum* and *Hedera*.

At the end of the zone we observe small disturbances in the curves of deciduous trees caused probably by man. This thesis seems to be confirmed by the continuous curve of *Plantago lanceolata* on the diagram from Lake Wielkie Gacno (Hjelmroos 1981a)

BT 8 *Pinus-Betula-Quercus-Corylus-Alnus* R paz (5500–3700 years B.P.)

The zone began at the end of the Atlantic period and continued to the middle Sub-Boreal period. *Pinus* still play an important role in the formation of forest in poor habitats. In the undergrowth of these forests *Pteridium* or *Melampyrum* were dominant. More fertile soils were still occupied by mixed deciduous forests. *Quercus* was the dominant tree in these forests. At the end of the zone it reached the highest values in Holocene. In more humid, fertile habitats *Alnus* and *Fraxinus* were dominant. *Acer*, appearing sporadically on the diagrams, could have occurred in these associations.

During the zone habitat conditions began to deteriorate. The climate became more humid, which caused a more intense processes of soil leaching (Iversen 1973), and made them more acid. On the diagrams this is reflected by the decrease of *Tilia*, *Fraxinus* and *Ulmus*. The *Ulmus* fall occurring at about 5100–5050 B.P. is a synchronous phenomenon in NE Europe (Troels-Smith 1953, Iversen 1973, Girling & Greig 1985, Aaby 1986, Goransson 1986 and others). Within a short time the trees reproduced but they never reached their former significance. The disturbance in the ecosystem brought about the dominance of *Quercus* and a clear increase in *Corylus*, which perhaps only increased the production of pollen grains due to a smaller density of the forest. At the end of the zone *Carpinus* entered Bory Tucholskie; on the pollen diagrams it occurs as a continuous curve. On the diagram from Lake Wielkie Gacno a small increase in *Picea* is recorded. Perhaps some of these changes were caused by human activity, which is indicated by the presence of pollen of *Plantago lanceolata*, increase in *Juniperus*, *Rumex acetosella* coll., *Artemisia* and single grains of *Cerealia*. This activity, however, was not very intense (cf. the next chapter) and therefore it seems that it is climatic-edaphic factors that constributed to the changes in the composition of the forest.

Initially low pollen influx values clearly increase at the end of the zone. This should be connected with a considerable opening of the forests.

BT 9 *Pinus-Betula-Alnus-Carpinus* R paz (3700–2100 years B.P.)

The zone extended from the middle Sub-Boreal period to the early Sub-Atlantic period. The increasing acidity of soils (Iversen 1973) created good conditions for the occurrence of *Quercus*, which together with *Pinus* occupied sandy areas and formed communities resembling the modern acidophilous *Pino-Quercetum*. Significant changes occurred in the composition of the mixed deciduous forest. This was partly caused by a change of edaphic conditions but also, to a large extent, by the economic activity of man (cf. the next chapter) who first destroyed forests that grew on better soils. On the pollen diagrams this is reflected in the decrease in *Ulmus*, *Tilia*, *Fraxinus* curves, until their percentage values disappear. The practical disappearance of *Tilia* and *Fraxinus* was synonymous for the area of the entire Bory Tucholskie and took place about 3000 years B.P. More or less at the same time *Ulmus* disappeared although there were greater local differences in this case. A smaller density of the forests caused small expansion of *Betula* which could have occurred as an admixture in pine-oak forests. Habitats left by mixed deciduous forests were invaded by new species, mainly *Carpinus*, *Fagus* and, locally, *Picea*. There were certain differences in the dissemination of *Fagus*. Although it appeared simultaneously in the area of the entire Bory Tucholskie earlier than in more fertile adjacent areas, its contribution to the formation of forest associations was different. Its greatest contribution was in the vicinity of Wielkie Gacno (Hjelmroos 1981a), Mały Suszek and Zamrzenica (Noryśkiewicz 1982). This should be explained by different soil conditions and different human activity. This species could have dominated in areas with weak human activity but its occurrence is limited to well drained soils (Aaby 1986). Richer soils were occupied by forests with dominant *Carpinus*, a tree characterized by great tolerance of soils (Ralska-Jasiewiczowa 1982) and with *Quercus*. They probably formed communities resembling the modern *Querco-Carpinetum* where *Fagus* could have occurred singly. On river and lake banks and moist places *Alnus* continued its dominance. The significance of *Corylus* decreased along with an increase in the forest density.

A decrease in *Carpinus* together with a clear increase in the amount of plants connected with the economic activity of man suggests that settlement was developing more and more intensively at this time (Ralska-Jasiewiczowa 1966). New areas for cattle grazing and farming were obtained through clearings of forests. This is expressed by an increase in values of NAP influx what is quite understandable because influx values should be proportional to the amount of plants in the landscape (Birks & Birks 1980). In other words they are the indicator of the landscape diversity (Gaillard 1984, Berglund 1986). Practically constant values of influx AP confirm that human activity in Bory Tucholskie did not cause decisive changes in the forest range.

BT 10 *Pinus-Betula-Alnus-Carpinus-Fagus* R paz (2150–750 years B.P.)

The zone began at the end of the early Sub-Atlantic period and continued till the middle of the Sub-Atlantic period. A clear expansion of *Fagus* is the characteristic feature of the period. The tree appeared in greater amounts already during the former period but only in the Sub-Atlantic period it reached its maximum values. Climatic changes, soil leaching (climatic-ecological cycles, Iversen 1954, Dzięciołowski & Tobolski 1982) and human activity contributed to the dominance of species which tolerated the acidity of soils and *Fagus*, apart from *Pinus* and *Quercus* is such a species (Aaby 1986). This tree found good conditions for development in open forest which also served as grazing areas but could have also formed independent associations in well drained areas. In poorer habitats *Pino-Quercetum* - type forest was dominant while in more fertile ones – *Querco-Carpinetum*. This forest community reached its greatest range at that time; this is evidenced by the relative maximum of *Carpinus* (12–18%). Increased values of *Juniperus* and *Calluna* indicate loose density of pine forests on poor sandy soils. A gradual disappearance of *Corylus* is observed during the entire zone and that of *Alnus* - at the end of the zone, which could have been connected with a change in soil conditions and a decrease in the climate humidity. Results of the diatom analyses (Bogaczewicz-Adamczak, cf. Fig. 17) indicate that from 1200 till 750 years B.P. a lowering of the water level in lakes took place. At the end of the zone *Picea*, occurring locally, disappeared completely (cf. diagrams for Lake Wielkie Gacno – Hjelmroos 1981a, Zamrzenica – Noryśkiewicz 1982). Large amounts of pollen of plants connected with grazing and farming, occurring during the entire zone and especially at its end, indicate that medieval settlement developed intensively and contributed to the complete disappearance of natural forest associations. An increase in *Pinus* at the end of the zone could have been caused by different factors. The tree could have spread in areas impoverished by long-term grazing; furthermore, in an open landscape the significance of pollen from long distance transport grew and finally the role of pine in the percentage composition of the forest could have been artificially increased due to a very small contribution of pollen of other trees. During the entire zone there were small variations of influx connected with the economic activity of man. At the end of the zone the values of concentration and influx AP clearly decrease. This should probably be related to a considerable deforestation of the area and perhaps with the deterioration of soil conditions and hence a decrease in the pollen production (Moore 1968, after Hjelmroos 1981a). This could have also resulted from a wrong calculation of the sediment accumulation rate due to the lack of ^{14}C dates for this part of the core.

BT 11 *Pinus* R paz (750 years B.P.)

The zone comprises the late Sub-Atlantic period. At that time Bory Tucholskie took their present character. *Pinus* was the absolutely dominating forest component. At the beginning of the zone *Quercus* appeared in greater amounts but its occurrence of was gradually limited. Other species of deciduous trees disappeared almost completely. *Betula* occurred in small quantities as an admixture of pine forests and *Alnus* occurred in humid habitats.

The expansion of pine was caused to a large extent by human activity (clearings, grazing). Forest clearings were especially intense once towns were granted independence on the basis of the so-called German law, i.e. since the 13th c. (Boiński 1985). The changes in the range of forests from that time onwards are shown in Fig. 18. It is seen in the figure that in the 12th and 13th centuries the areas adjoining Lake Kęsowo are deforested and successive intensive clearings took place in the 14th and 15th centuries. *Pinus* as a tree setting easily on fire sites, occupied habitats formely taken by hornbeam-oak forests and oak forests which contributed to their degradation. From the end of the 18th c. plantation of pine monocultures was very intensive in Bory Tucholskie, which definitively decided on the present composition of the forests.

During this zone values of NAP influx calculated for all sites are relatively high. Values of AP influx for Mały Suszek, Suszek and Kęsowo clearly decrease while they clearly increase at Wielkie Gacno (Hjelmroos 1981a). Differences in the sediment accumulation rate in these reservoirs could be the cause of this discord.

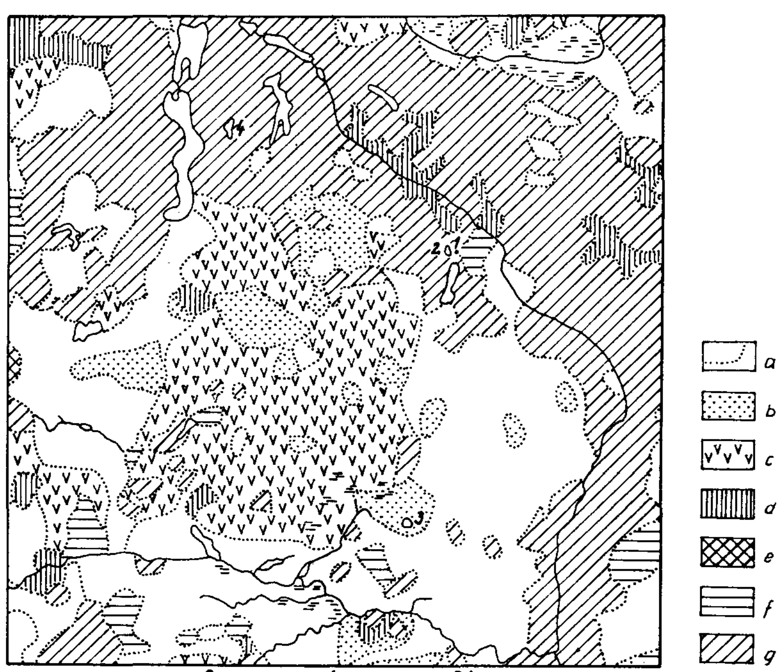

Fig. 18. Forests in the area of modern Bory Tucholskie (acc. Ślaski 1951): a – the extent, b – 12th and 13th centuries, c – 14th and 15th centuries, d – 1500–1700 years, e – 1740–1790 years, f – XIX c., g – modern forests. Reference lakes indicated (1 – Mały Suszek, 2 – Suszek, 3 – Kęsowo, 4 – Wielkie Gacno)

There are almost no differences between the duration of the last pollen assemblage zone (l paz) calculated at Lake Wielkie Gacno (Hjelmroos 1981a) and dates obtained at the three sites discussed when one compare the uncorrected radiocarbon dates. The corrected (Hjelmroos 1981a) and uncorrected times of more important events in the development of forests are visible in Tab. 6.

HUMAN IMPACT ON THE VEGETATION

PERIODS OF INTENSIFIED ECONOMIC ACTIVITY OF MAN

Changes in the curves of trees and herbs reflecting man's economic activity helped define periods of its increase in the neighbourhood of the lakes under study (Figs. 20, 21, 22). The time scale and the numbering of the periods are given in Fig. 19.

Period 1 (about 6200/6100 – 5450 years B.P.)

This period and the next one has been distinguished on the basis of investigations in Lakes Mały Suszek and Kęsowo (Fig. 20, 21). On the diagrams a small decrease in *Ulmus* and then in *Fraxinus* and *Tilia* is observed. *Betula* and *Gramineae* increase insignificantly. Pollen curves of *Calluna*, *Juniperus* and *Pteridium* increase. A very distinct increase in *Artemisia* is visible and single pollen grains of *Chenopodiaceae*, *Urtica*, *Rumex acetosa*, R. *acetosella* and *Plantago major-media* appear. The first pollen grain of *Plantago lanceolata* (Mały Suszek) and of *Hordeum*-type (Kęsowo) have been found (about 5500 years B.P.). All this indicates some human impact on the vegetation, connected probably with the migration of small human groups at the beginning of the Neolithic.

Period 2 (about 5400/5250 – 4900/4750 years B.P.)

The beginning of the period is determined by an increase in *Pteridium*, *Artemisia*, *Calluna* and *Juniperus* pollen. Single pollen grains of *Rumex acetosa*, R. *acetosella*, *Ranunculaceae*, *Chenopodiaceae* and *Plantago major-media* appear. At the same time a decrease in *Ulmus* and, on the diagram from Mały Suszek, also in *Tilia* and *Fraxinus* pollen is observed. At Kęsowo – first pollen grains of *Plantago lanceolata* (about 5150 years B.P.) and single pollen grains of *Hordeum*-type (about 4800 years B.P.) and *Triticum*-type (about 5300 years B.P.) appear and the number of charcoal fragments in the sediment increases. A greater number of *Cannabaceae* pollen (Kęsowo) was probably caused by the increasing significance of *Humulus*. This period may be correlated with the middle Neolithic.

Period 3 (about 4800/4600 – 4150/4050 years B.P.)

An increase in *Pteridium* spores and to small extent in *Calluna* and *Juniperus* pollen curves is observed. A pollen grain of *Vicia* (Mały Suszek) can indicate the use of fire (Berglund 1966, Goransson 1977 after Hjelmroos 1981a) or the development of

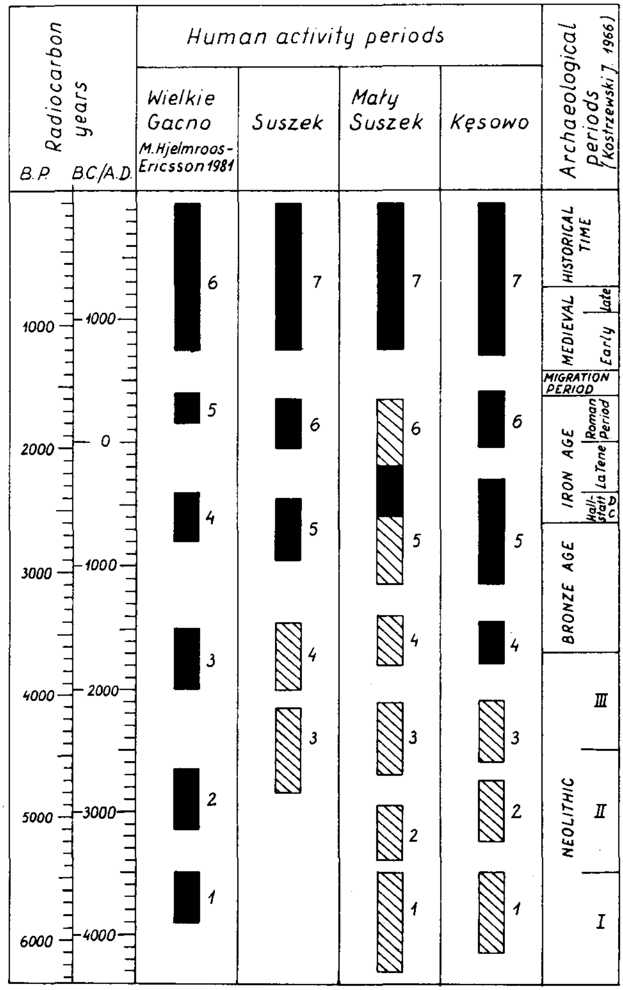

Fig. 19. Human activity periods in Bory Tucholskie. (black colour – periods strongly marked on pollen diagrams)

meadows. *Artemisia* shows a very distinct increase. The greater number of *Plantago lanceolata* and *Rumex acetosa* pollen is noticed and single grains of *Chenopodiaceae*, *Urtica*, *Plantago major-media*, *Rumex acetosella* and *Campanulaceae* appear. Pollen of *Hordeum*-type and *Triticum*-type (in Mały Suszek for the first time about 4200–4100 years B.P.) have been found in small amounts and the first grain of *Secale* appear (Mały Suszek – about 4000 years B.P.). Pollen values of *Ulmus*, *Fraxinus* and *Tilia* decrease. In case of Mały Suszek – *Fraxinus* decreases until its percentage values disappear completely. This happens simultaneously with the decrease in *Alnus* and is probably connected with the lowering of water level in the lake (cf. Fig. 17). This period corresponds to the turn of the middle and late Neolithic (Mały Suszek and Suszek) and the late Neolithic (Kęsowo).

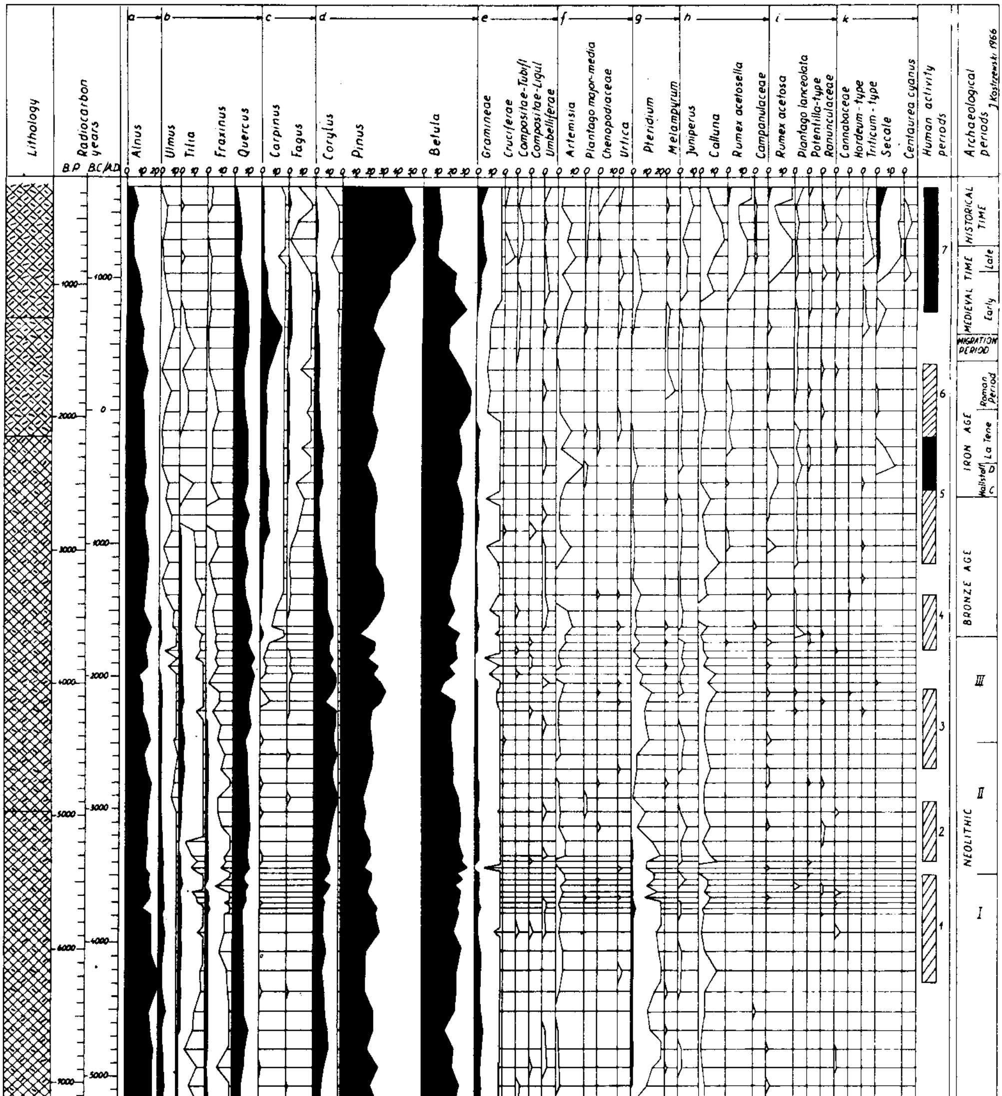

Fig. 20. Lake Mały Suszek. Special pollen percentage diagram showing the human impact on the landscape

Period 4 (about 3950/3750 – 3400/3300 years B.P.)

A clear increase in *Artemisia* and a small increase in *Chenopodiaceae*, *Urtica* and *Plantago major-media* pollen (Kęsowo) is visible. Insignificant higher values of *Pteridium* and *Juniperus* or *Melampyrum* are also observed. The greater number of pollen grains of *Plantago lanceolata* and single pollen grains of *Rumex acetosella* and *Lychnis*-type (Kęsowo) is noticed. Single pollen grains of *Cerealia*, *Hordeum*-type, *Triticum*-type and *Secale* (Kęsowo – about 3600 years B.P.) appear. At the same time there is a decrease or changes in *Ulmus*, *Tilia*, *Fraxinus* and *Quercus* pollen percentages. *Carpinus* appears in a greater amount at the beginning of this period and decrease in its middle part. A clear increase in *Gramineae*, higher values of *Betula* and *Corylus* are also observed. This period extent from the end of the Neolithic to the early Bronze Age.

Period 5 (about 31000/2900 – 2400/2250 years B.P.)

In this period a clear decrease in mixed deciduous forest (*Quercetum mixtum*), a fall in *Carpinus* and a visible increease in *Betula* and *Gramineae* pollen curves is observed. *Artemisia* pollen rises to percentage values, the number of *Chenopodiaceae*, *Urtica* and *Plantago major-media* increase. A greater amounts of *Calluna*, *Rumex acetosella* and in a less degree – *Juniperus*, indicates the expansion of dry pastures. An increase in *Plantago lanceolata*, *Rumex acetosa* and *Ranunculaceae* is an evidence of the enlargement of the area occupied by meadows. *Secale* pollen (for the first time in Suszek), *Triticum*-type, *Hordeum*-type and *Cerealia* appear singly although in larger quantities.

With respect to the intensification of man's economic activity, this period is not uniform. In case of Kęsowo (Fig. 21) two Sub-phases (1150–900 years B.C. and 650–300 years B.C.) can be distinguished which are separated by a period of a less intensive activity. This could have been connected with the rising of the water level in the lake, which on the basis of the diatom analyses (Adamczak, personal communication) took place about 900–750 B.C.

The whole period began in the second half of the Bronze Age and lasted till the beginning of the La Tene period in the early Iron Age.

A different situation is observed on the pollen diagram from Lake Mały Suszek (Fig. 20). The duration of the period (from the half of the Bronze Age to the end of the Roman period) correspods with two successive periods (5 and 6) of human activity distinguished for other sites in Bory Tucholskie and therefore it has been designated with two consecutive numbers (Figs. 22, 25). A clear increase in human indicators is marked most strongly in the middle phase of the period (600–200 years B.C.). At the same time a definite disappearance of *Tilia* and *Fraxinus* takes place. *Carpinus* initially increases and then clearly declines. All this is an indication of the forest clearance and turning of thus obtained areas into pasturage and, although to a lesser extent, to arable lands. At the end of the period there is a small intensifications of human impact. This episode reflects next (6-th) period of man's economic activity, visible in other pollen diagrams.

Period 6 (about 2000 – 1600/1550 years B.P.)

A rapid decrease in *Carpinus* and *Corylus* and an increase in *Pinus* pollen is observed. The amounts of *Quercus* and *Fagus* pollen also increase, which can indicate the spread of the trees in habitats formely occupied by other species, an increase in their blooming in a deforested area or that the trees were left there by man purposefully because of their fruits (acorns and beechmast). The pollen values of these trees rapidly decrease at the end of the period. *Gramineae*, plants of ruderal communities (*Artemisia*, *Chenopodiaceae*, *Plantago major-media* and *Urtica*), plants of dry pastures (*Calluna*, *Rumex acetosella*, *Campanulaceae*) and fresh meadows (*Plantago lanceolata*, *Rumex*

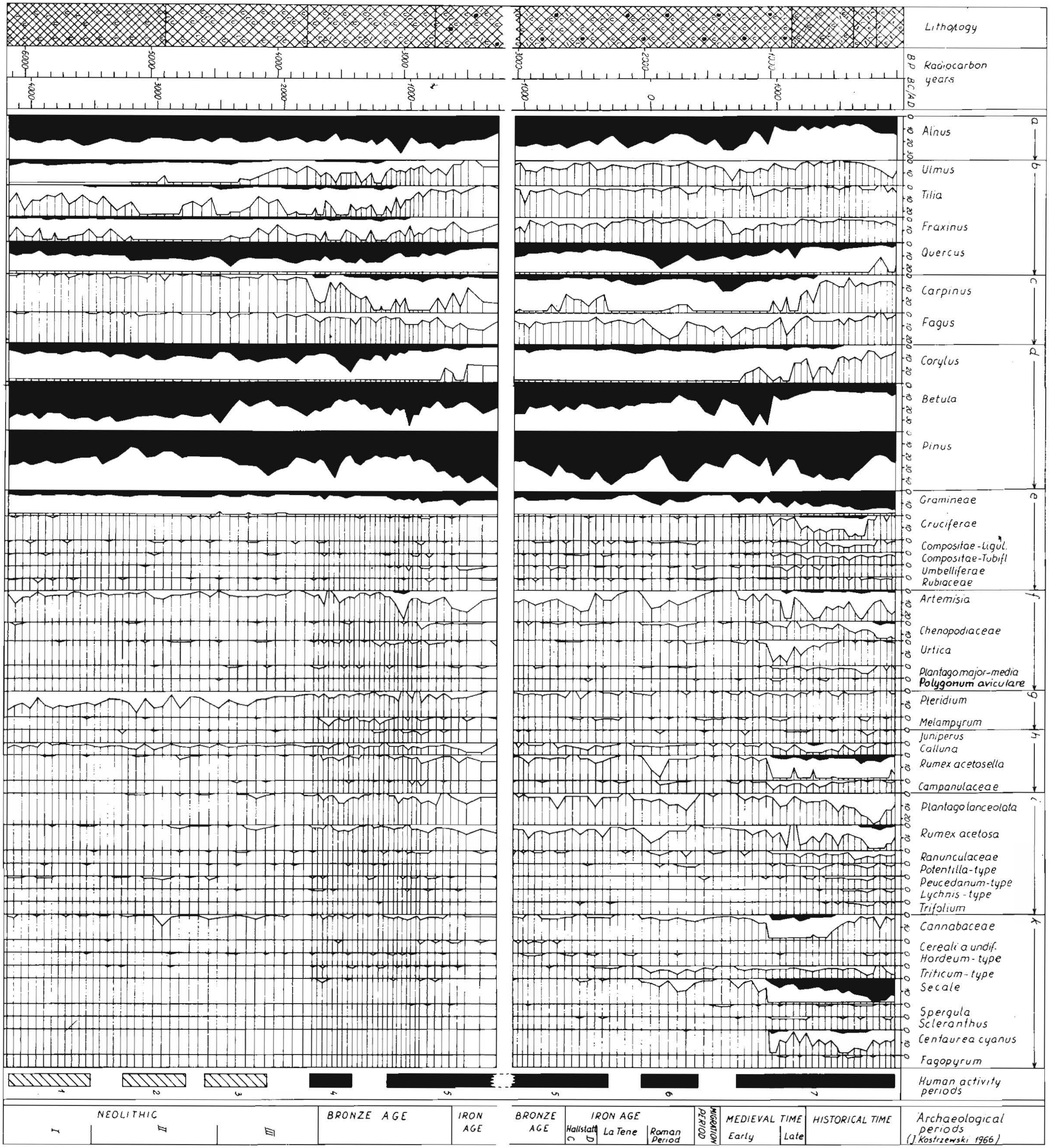

Fig. 21. Lake Kęsowo. Special pollen percentage diagram showing the human impact on the landscape

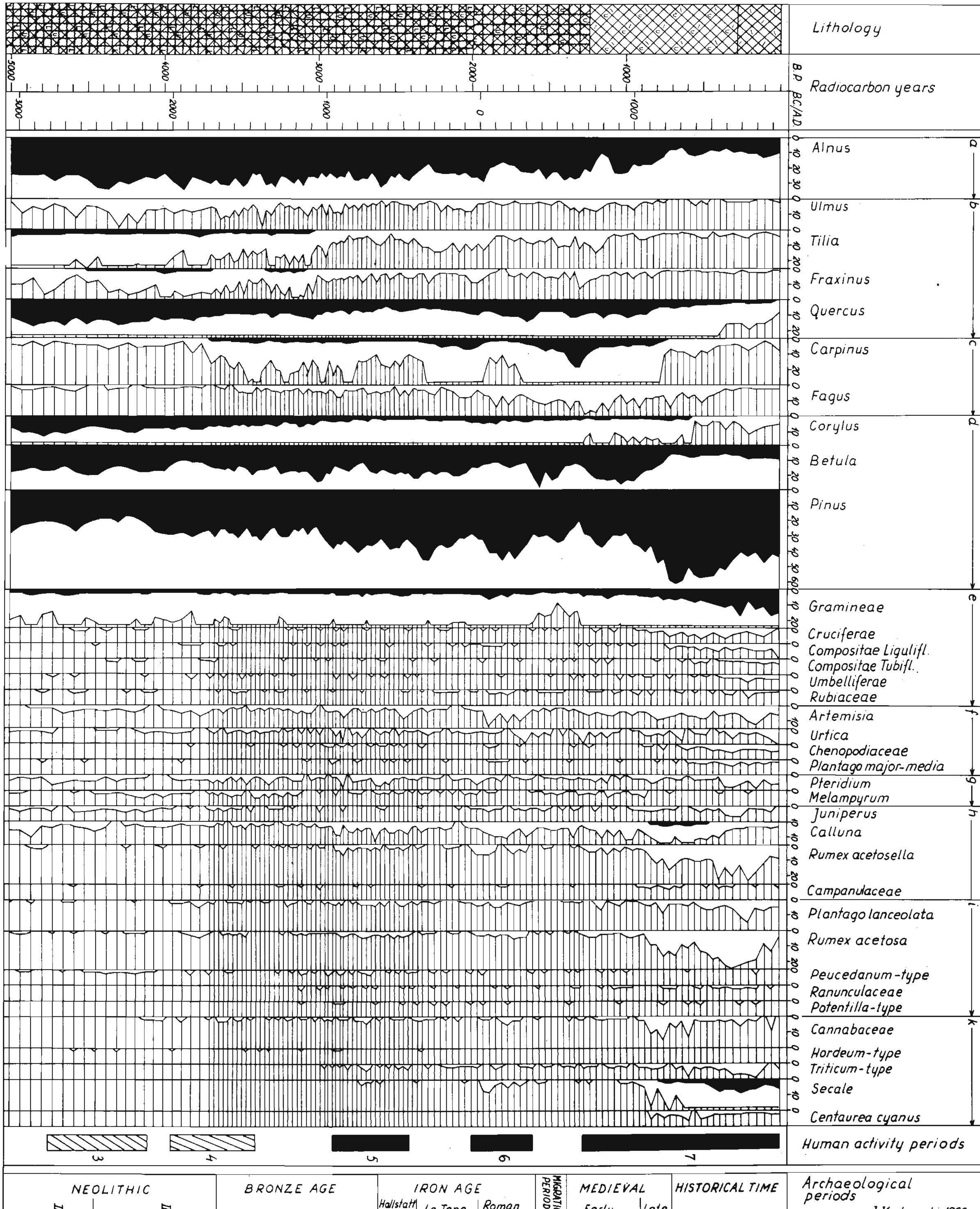

Fig. 22. Lake Suszek. Special pollen percentage diagram showing the human impact on the landscape

acetosa, *Ranunculaceae* and *Potentilla*-type) increase from the beginning of the period. *Cannabaceae*, *Triticum*-type and *Secale* increase as well, the first pollen grain of *Centaurea cyanus* (Kęsowo – Fig. 21) appears.

Archaeologically this period corresponds to the Roman period.

Period 7 (from about 1250/1200 years B.P.)

This period is characterized by a decrease or disappearance of percentage curves of *Carpinus*, *Fraxinus*, *Ulmus*, *Tilia*, *Corylus* and *Quercus*. *Pinus* and *Betula* increased considerably did the same at the beginning of the period. Together with a decrease in trees there is a clear increase in almost all plants connected with human impact. A very clear spread of ruderals, mainly *Artemisia* and *Urtica* is seen and the increase in *Juniperus*, *Calluna*, *Rumex acetosella*, *Campanulaceae*, *Rumex acetosa*, *Plantago lanceolata* and (Kęsowo) *Ranunculaceae*, *Potentilla*-type, *Lychnis*- type, *Trifolium*, *Vicia* and single pollen grain of *Linum catharticum* is also observed. *Secale* has the percentage curves and the values of *Triticum*-type and *Centaurea cyanus* considerably increase. Single grains of other field weeds (*Spergula* and *Scleranthus*) (Behre 1981) have been found (Kęsowo). *Fagopyrum* pollen appeared.

On the diagrams from Kęsowo (Figs 21, 24) after a visible increase of human activity in the 11th century, a certain short regression of economy can be noticed as late as A.D. 1150. *Pinus* decline then and a clear peak of *Quercus* appears. Most of the curves of indicators of human economy decrease. However, already at the turn of the 12th and 13th centuries settlement activity is again intensified. At the same time or a little earlier there was a clear intensification of human impact in both other sites.

This whole period began in early Middle Ages and lasted till modern time.

In order to compare the periods of increased economic activity of man, synthetic diagrams have been made for all sites (Figs. 23, 24, 25). A graphic representation of an increased economic activity in the vicinity of Lakes Mały Suszek, Suszek, Kęsowo and Wielkie Gacno and a generalization for the area of Bory Tucholskie is shown in Fig. 26.

CHARACTERIZATION OF HUMAN IMPACT

Archaeological investigations indicate that the area of Bory Tucholskie was penetrated by human groups as early as in the Paleolithic but such early activity cannot be practically proved by means of traditional palaeobotanical methods. It is also extremely difficult to detect in a pollen diagram changes caused by man during the Mesolithic (Ralska-Jasiewiczowa 1982). This is also the case with Bory Tucholskie, despite of a considerable amount of archaeological evidence (Bagniewski 1987) (cf. Fig. 6). Hjelmroos (1981a) in her discussion of her pollen – analytic results from Lake Wielkie Gacno indicates small changes in the vegetation during the early Atlantic period. One pollen grain of *Plantago major* has been found in the sediment from that period and a small increase in the number of *Artemisia*, *Urtica*, *Rumex* and *Cannabaceae* pollen grains have been observed. *Pteridium* increased while *Pinus* oscillates and *Picea* shows a small decrease. The age of these events is about 5500–5400 years B.C. It seems that on the

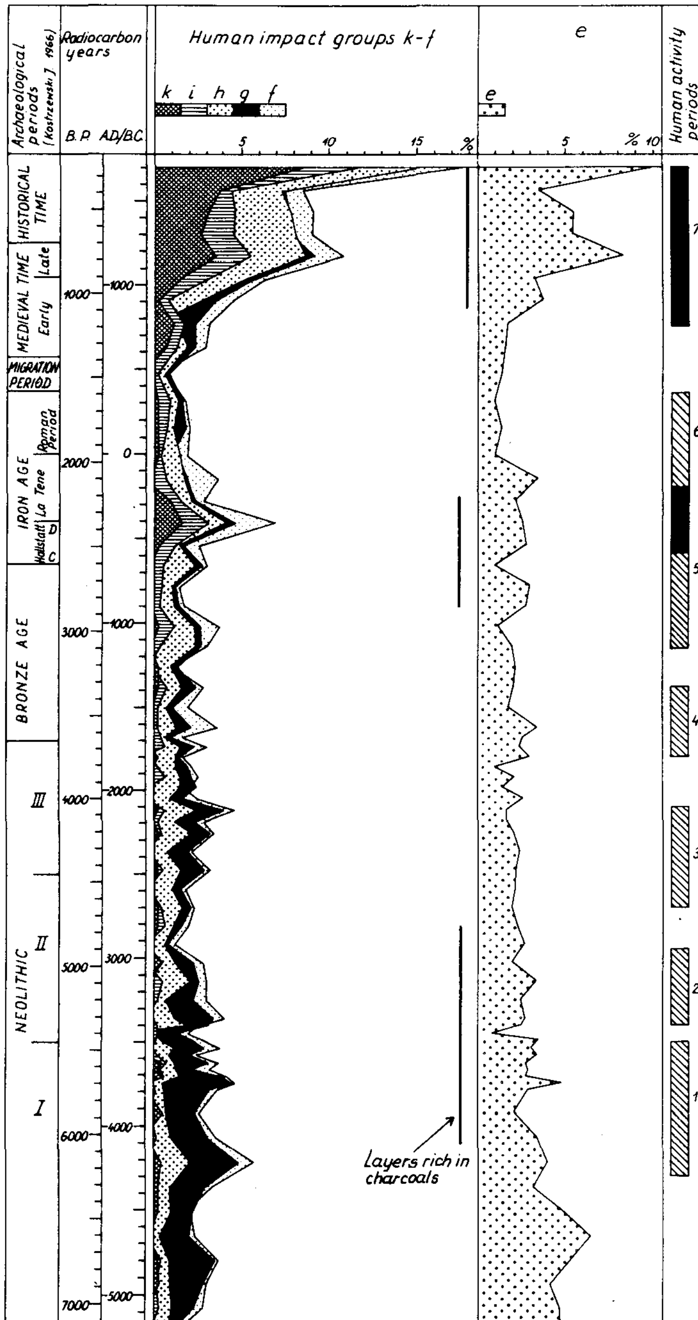

Fig. 23. Lake Mały Suszek. Synthetic human impact pollen diagram

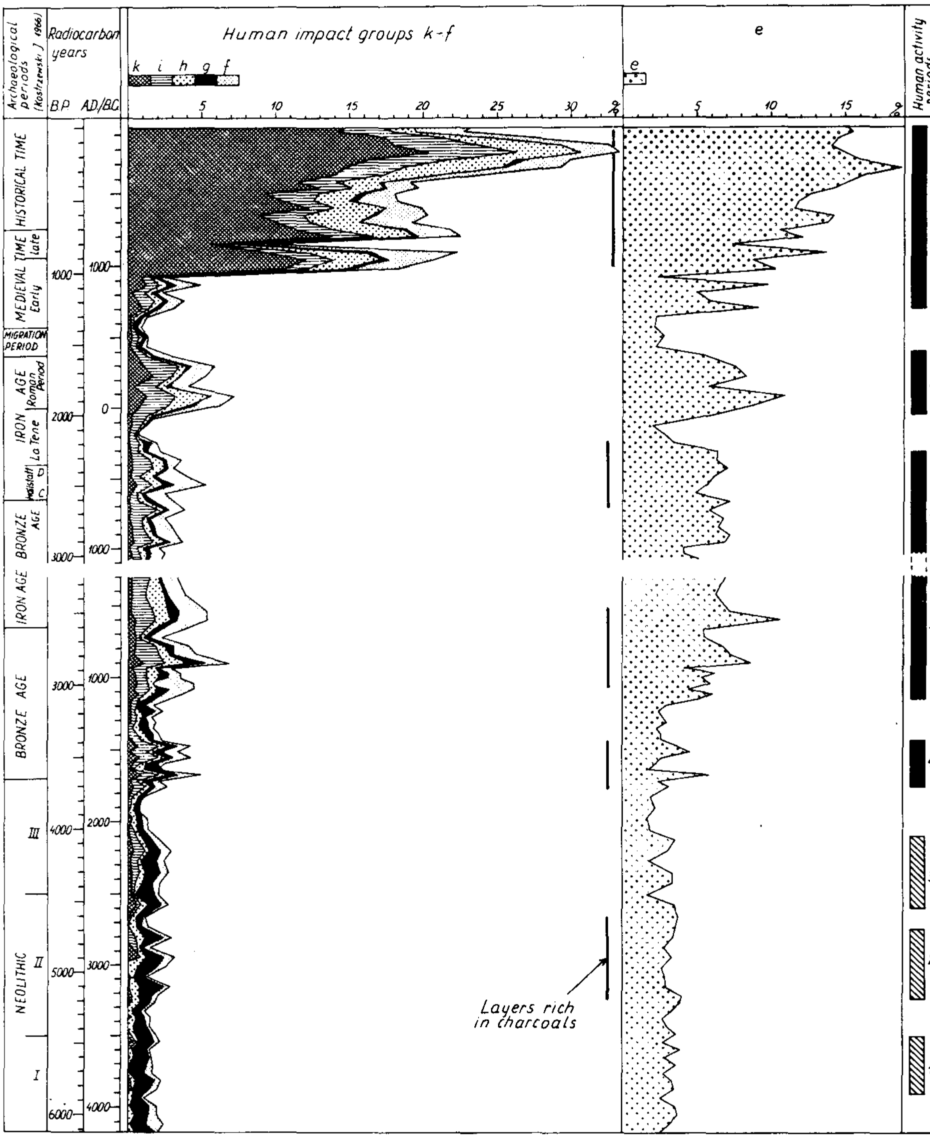

Fig. 24. Lake Kęsowo. Synthetic human impact pollen diagram

basis of such small changes we cannot state with absolute certainty the anthropogenic genesis of these transformations (Ralska- Jasiewiczowa 1982, Wasylikowa 1983a).

In connection with the change of the economy, during the Neolithic, the impact of man on the natural environment changed. However models useful in the interpretation of economic processes (Troels-Smith 1953, Iversen 1973). can hardly be applied to the area of Bory Tucholskie. Therefore we should rather accept the thesis about the adaptation of human groups to the natural environment they encountered (Groenman van

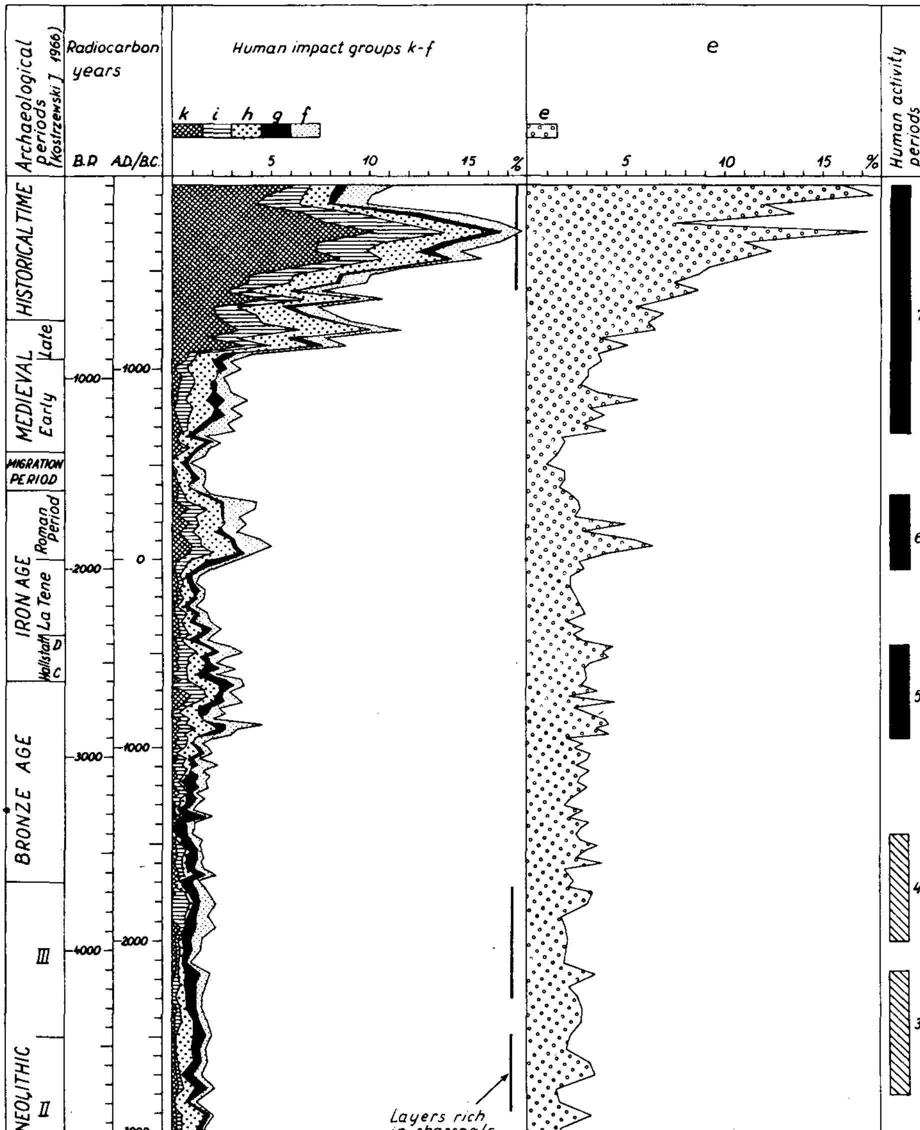

Fig. 25. Lake Suszek. Synthetic human impact pollen diagram

Waateringe 1978). Periods of human economic activity are recorded on pollen diagrams very weakly. Their identification both in the Neolithic and at the beginning of the Bronze Age is often problematic and therefore they have been marked differently on the pollen diagrams.

The identification of the 1-st period connected with the beginning of the Neolithic is mainly based on a small decrease in deciduous trees. The appearance or an increase in herbs – human indicators - are the evidence that these changes could be connected with human economic activity. In diagrams from Lakes Wielkie Gacno (Hjelmroos 1981a, b) and Mały Suszek first grains of *Plantago lanceolata* appears, a species commonly recognized as an indication of open pastures (Iversen 1973). Its appearance usually confirms the existance of cattle breeding (Behre 1981). It has been found (Berglund et al. 1986) that the quantity of this species in pollen spectra is too small with respect to its actual contribution to the vegetation. An increase in *Pteridium*, a species developing well on fire sites (Iversen 1949, Wasylikowa 1983a), clearly detectable on all diagrams, can suggest the use of fire, which is confirmed by the occurence of charcoal only locally (Mały Suszek). Hence an increase in the significance of *Pteridium* indicates rather that grazing was carried on within the forests (Vuorela 1983), which was especially widely practised during the middle and late Neolithic, mainly on lighter, sandy soils in less dense forests (Groenman van Waateringe 1978). Most probably the first pollen grain of *Hordeum*-type (Lake Kęsowo) came from the nearby moraine uplands.

The next two (2-nd and 3-rd) periods of economic activity of man, taking place in the middle and late Neolithic are recorded more clearly. In those periods a decrease in deciduous trees is more or less visible. The *Ulmus* fall has for many years been related with an increase in the intensity of human economy (Iversen 1949); later, however, a greater role was ascribed to climatic or pathogenic factors, perhaps in combination with human activity (Troels-Smith 1960, Iversen 1973, Groenman van Waateringe 1983, Goransson 1986). In Bory Tucholskie it is difficult to observe any clear relation between the decrease in *Ulmus* and human activity. Although both in Kęsowo and Mały Suszek this took place during the second period of the economic activity, yet human impact on the natural environment at that time was so insignificant that the disappearance of elm from this area can hardly be connected with it.

Simultaneously with disturbances in curves of deciduous trees, increased amounts of herbs connected with human activity appear. First of all the amounts of nitrophilous ruderal plants and plants connected with open pastures increase. Single pollen grains of cereals appear. Hjelmroos-Ericsson (1981a) associates these single pollen grains of cereals with the Neolithic agricultural economy. It is, however, very unlikely that this could also pertain to the immediate vicinity of the lakes under discussion. It should be rather supposed that they originate from long-distance transport. On the other hand, it is known that both *Triticum* and *Hordeum* produce large amounts of pollen but they are autogamous and, in contrast to *Secale*, their pollen is badly dispersed. Hence, even the absence of the cereal pollen of *Triticum - Hordeum* type is not sufficient evidence for the lack of cultivation (Behre 1981). However, there are no archaeological premises from this area on the development of Neolithic economy connected with land cultivation.

Generally, it can be stated that throughout the Neolithic the penetration of the outwash areas of Bory Tucholskie by small migratory human groups – cattle breeders is obvious. Perhaps the cattle was kept in enclosures, as is suggested by Troels-Smith (1955) and young sprouts of *Ulmus*, *Fraxinus* and *Tilia* were used as winter fodder for the animals. According to Groenman van Waateringe (1986) AP values exceeding 70%, and this is the case with all sites in Bory Tucholskie, indicate the existance of too dense forest which made grazing in the forests impossible. However it seems that on sandy soils where *Pinus* was always a dominating tree the forest was open to the extent which permitted grazing there. This is indicated also by high values of *Pteridium*. Sprouts of eagle fern could also be used as the source of food for Neolithic people (Wasylikowa 1983b). Sometimes they are called "potatoes and cereals" of the Neolithic (Goransson 1986). Changes in the curves of deciduous trees indicate that deforestations were insignificant and usually followed by the return of the former composition of the mixed forest, sometimes preceded by an increase in the occurrence of pioneer heliophilous species such as *Betula* and *Corylus*, which can also be characteristic of the periods of human activity (Berglund 1986). NAP values, changing to an insignificant extent, indicate an almost constant density of the forest. A poor development of the Neolithic economy in this area is confirmed by archaeological data. The typically Neolithic findings connected with the Funnel Beaker culture are very rare.

The 4-th period of human economic activity (Figs. 19, 26), corresponds to the Iwno culture in which cattle breeding was especially important (Godłowski & Kozłowski 1985). This period is recorded on the diagrams as decreasing values of deciduous trees with a simultaneous increase in NAP curve. In greater amounts pollen grains of *Melampyrum*, a species of heliophilous communities on deforested sandy soils (Ralska-Jasiewiczowa 1981), appear. *Pteridium* spores increases insignificantly what can suggest that cutting of trees was more freguent than burning in the deforestation processes. A considerable increase in the number of charcoal is observed only in the sediments of Lake Kęsowo. A pollen grain of *Succisa pratensis* (Kęsowo – Fig. 21), a species indicating grazing in more open forests on dry sandy soils (Ralska-Jasiewiczowa 1982), is an evidence that this changes can be related to the developing of forest pasturages. The forest clearings facilitated to a considerable degree the expansion of *Carpinus*, a tree which is characterized by a great regeneration capability from suckers and easily regenerates on fallow lands cleared by primitive methods. It is known that variations in the curve of this tree are closely connected with human activity (Ralska-Jasiewiczowa 1966, 1977). On the diagram from Lake Wielkie Gacno a clear maximum of *Picea* is observed, which also indicates that the area was deforested and that proper conditions for the development of the tree had been created (Hjelmroos 1981a) or that its pollen had been transported more easily.

During that period there was a certain differentiation in the intensity of human impact on the environment between particular sites. On diagrams from the central part of Bory Tucholskie (Mały Suszek, Suszek) (Figs. 20, 22) it is not very clear, as was the case with earlier periods. It is much clearer on the diagrams from Wielkie Gacno (Hjelmroos 1981a) and Kęsowo (Fig. 21) where, in addition to the increase in pollen values of ruderal plants, especially *Artemisia* and plants which are indicators of forest grazing, there is an increase in the occurrence of meadow plants. This refers primarily to an increase in *Plantago lanceolata*, *Rumex acetosa* and the appearance of new taxa, e.g. *Lychnis*-type (Kęsowo – Fig. 21). All this indicates the development of husbandry. On all sites slightly increased amounts of cereal pollen grains have been recorded. These single grains can indicate the existence of small fields on which wheat and barley were grown, especially in the vicinity of Lakes Kęsowo and Wielkie Gacno (Hjelmroos 1981b, 1982). They could have also been transported from the nearby moraine uplands where land was perhaps cultivated to a larger extent (Grzelakowska 1984). Results of the pollen analysis from the area of Leśno (Grzelakowska & Balwierz 1984) also recorded the occurrence of single cereal pollen grains and synantrophic plants in the early Bronze Age. However, there are no direct archaeological premises which would indicate the economy type in the area of Bory Tucholskie (Grzelakowska & Balwierz 1984) although it is known that at that time mainly *Hordeum, Avena, Triticum monococcum, T. aestivum, T. compactum* and sporadically *Secale cereale* were grown in Poland (Klichowska 1984)

After this period the forest was regenerated with a slightly changed species composition. The significance of *Carpinus* clearly increased. The next, 5th period of intensified economic activity is connected with the development of the Lusatian culture which, in the course of time, was transformed into the Pomeranian culture (Godłowski & Kozłowski 1985). This period is clearly visible on the diagrams from all sites but its duration differs. Its earliest record is on the diagram from Lake Kęsowo and the latest on the diagram from Lake Wielkie Gacno (Hjelmroos 1981a, b) (Fig. 19). The period is characterized primarily by the minimum of *Carpinus* and a clear decrease in, and often disappearance of, percentage curves of *Tilia, Fraxinus, Ulmus, Quercus* and also *Corylus.* A great number of charcoal in the sediments from Lakes Kęsowo and Mały Suszek (Figs. 24, 23) can indicate the using of fire in the deforestation but it could have come from body-burning ceremonies at the burial places (Godłowski & Kozłowski 1985) as well. At the same time there was an increase in *Pinus, Gramineae*, ruderal plants and grazing indicators. All this provide an evidence of an intensification of breeding economy (husbandry). Pollen grains of cereals continue to occur singly although their amounts increase at the end of the period (cf. Figs. 20, 21). Perhaps *Triticum* and *Hordeum* were grown in the close vicinity of the lakes, as is claimed by Hjelmroos (1981a) with reference to Lake Wielkie Gacno. A small number of pollen grains of *Secale* indicates that this crop was either an admixture of wheat or barley cultivations, or the pollen originate from long-distance transport. During the archaeological investigations, which comprised the settlement complex of the Lusatian culture in Leśno, a stone grinder was found, which can indirectly indicate the development of agrarian economy in this area (Grzelakowska, Balwierz 1985). Results of archaeological investigations are also an evidence of the cultivation during the Pomeranian culture, i.e. at the end of the period under discussion. Traces of ploughing, connected with this culture, were found at Odry (Kmieciński 1968). An imprint of spelt – a variety of wheat (*Triticum spelta*) was found on a clay cup at the Pawłowo site near Chojnice (Klichowska 1962, 1972), an imprint of barley (*Hordeum* sp.) was found on a clay bowl from the early La Tene period at the Stara Jania site near Smętowo Graniczne, an imprint resembling rye (*Secale cereale*) was found in Swornegacie near Chojnice (Klichowska 1962, 1968, 1972) and imprints of millet grains (*Panicum*), wheat (*Triticum*) and rye (*Secale*) were found on vessels from Brusy (Łuka 1966). Apart from that in Słupy near Chojnice a quern was found (Katalog stanowisk archeologicznych). All these archaeological sites, however, are located on moraine uplands or in their immediate vicinity.

Along with an increase in the number of cereal pollen grains, on the diagram from Lake Wielkie Gacno the occurrence of *Picea* pollen has been noted in numbers which help suppose that the tree grew in the close vicinity of the lake (Hjelmroos 1981a). It only confirms that the forest clearance was used on a large scale. *Picea*, apart from *Carpinus* and *Fagus* is a tree most connected with the development of economy in the northern areas of Poland (Ralska -Jasiewiczowa 1977).

The period under discussion is reflected in a similar way on the pollen diagrams from Lakes Wielkie Gacno, Suszek and Kęsowo. The duration in the case of different sites varies but in all cases it extended over the Bronze up Iron Age. It is different only on the diagram from Mały Suszek, where this is, in a way, an extension of the periods distinguished for the other sites, especially for Suszek. We can wonder why there are such great differences on the diagram from sites only 250 m away from each other. However, it is known that "there is a clear correlation between decreasing anthropogenic indicators and increasing distance"(Behre & Kucan 1986). Small amounts of these indicators were observed at the distance of 100 m to the settlement and 270 m to the field (Behre & Kucan 1986, Lange 1986). It seems obvious, therefore, that the differences in the duration of the periods distinguished for Suszek and Mały Suszek are of a typically local character. Perhaps this is a continuation of the same period, which would be evidence of the local "prolongation" of the Pomeranian culture and confirmation of archaeological investigations conducted in the vicinity of Leśno (Walenta 1988).

After the period of intensive clearances the forests were partially regenerated, which can be noticed on all diagrams. A clear peak in the curve of *Carpinus* occurs at about 2000 years B.P., i.e. about 50 years B.C. An oak-hornbeam forest became the dominant forest association at that time.

The 6th period of human impact is connected with the development of the Wielbark culture. On the pollen diagrams it is mainly marked by a rapid decrease in deciduous trees and an increase in *Betula* and *Gramineae*. This indicates intensive deforestations in the dominant association of *Querco-Carpinetum*, confirmed by another small increase in *Picea*, visible on the diagram from Lake Wielkie Gacno (Hjelmroos 1981a, b). A clear increase in continuous curves of plants connected with the human economic activity is an evidence of an intensive development of settlement, connected mainly with husbandry and thereby with a considerable development of meadows and dry pastures. In addition to husbandry, people also practiced land cultivation, which is evidenced by an increase in the cereal curves, mainly *Triticum*-type and *Secale*, which could be cultivated independently. This confirms to the universal view that rye as a corn more resistant than barley and wheat to worse climatic and soil conditions and, occurring earlier only as a weed of corn cultivations, became to be used universally as a cultivated plant as late as in the Roman period (Klichowska 1968, Wasylikowa 1983b). It seems that compared to the earlier period *Hordeum* was less significant. The occurrence of single pollen grains of *Centaurea cyanus* (Kęsowo and Wielkie Gacno) bear an evidence of corn-growing in the direct vicinity of the lakes.

The period is less clearly recorded on the diagram from Lake Mały Suszek, which is probably connected with the distribution of settlement around the nearby Lake Suszek.

Archaeological investigations conducted in Bory Tucholskie indicate that at the Roman period in addition to the development of transfer-type agriculture connected with slash and burn cultivation, sheep breeding was expanded. This is evidenced by finds connected with the development of weaving and spinning (Grzelakowska 1984).

Following this period of intensified economic activity of man the forests regenerated, which is evidenced by an increase in primarily *Carpinus*, *Fagus* and *Quercus* and that in *Ulmus* and *Tilia*, although to a less considerable degree. Simultaneously the amounts of *Betula*, *Pinus* and *Gramineae* decrease. This regression of economy described for many areas (Berglund 1969, Hammar 1986, Carlson 1986) is connected with the Migration Period.

The last, 7th period of man's economic activity began in early Middle Ages and has continued untill the present times. Settlement, developing very intensively, contributed to an almost complete deforestation of the area. This can be noticed in the diagram from all sites. There is a decrease in the curves of deciduous trees, initially accompanied by a clear increase in *Betula*. A complete disappearance of deciduous forests took place about 750 years B.P., i.e. at A.D. 1200. Since that time an absolute dominance of *Pinus* has been observed. The intensification of forest clearance was justified by the necessity to obtain new areas to be turned into arable lands and pastures.

The intensity of human economic activity during early Middle Ages and in historical times was different. Initially, till about A.D. 10th century, it resembled the earlier period. A gradual increase in the curves of ruderal plants and grazing indicators both on dry pastures and meadows is observed on the all diagrams. This is an evidence that in early Middle Ages husbandry was still the basic form of economy in Bory Tucholskie. Examinations of animal bones indicate that apart from pigs, the number of cattle grew and that of sheep decreased (Grzelakowska 1984). A clear increase in the curves of *Cerealia*, primarily *Triticum*-type and *Secale*, indicates that land cultivation developed alongside husbandry. Since the 11th century a clear increase in the intensity of human economic activity is noticed, manifested primarily by the extensive forest clearances. This tendency continued and even intensified throughout the 12th and 13th centuries (cf. Fig. 18). A clear increase in *Rumex acetosella* bear an evidence of the intensification of deforestation on sandy soils (Ralska-Jasiewiczowa 1966, 1982). The development of settlement at that period is confirmed by an increase in plants of fresh meadows and dry pastures (Suszek and Kęsowo), especially at the turn of Middle Ages and historical times. A considerable increase in the pollen grains of cereals and field weeds bear an evidence of an intensive development of cultivation in which *Secale* played the main role. Undoubtedly, the acceleration of soil leaching, contributed to high extent to the increase of the role of rye. The dominant role of this crop in the cultivations of early Middle Ages is confirmed also by archaeological investigations (Grzelakowska 1984, Kowalczyk 1986). Single pollen grains of *Fagopyrum* were found in sediments from Lakes Wielkie Gacno, Mały Suszek and Suszek whereas in Lake Kęsowo they occurred in greater amounts. This indicates the cultivation of buckwheat in the immediate vicinity of the sites under investigations because it produces small amounts of pollen which is not very well dispearsed (Behre 1981). Relatively high values of *Cannabaceae* can suggest the existence of hemp cultivations but due to difficulties in differentiating between pollen grains of *Humulus* and *Cannabis* it is impossible to conclude this which all certainty. It is known that hemp appeared for the first time in the cultivations in Poland during the Roman period (Wasylikowa 1983b, Ralska-Jasiewiczowa 1981, Klichowska 1984). Great outwash plain of Bory Tucholskie with poor soil did not provide sufficient conditions for such cultivations but they could have developed in river valleys. An increase in the intensity of the economy in the 12th and 13th centuries observed on the diagrams is confirmed by archaeological facts (cf. Fig. 7). A development of settlement with a tendency to populate deforested areas is noted. In addition to numerous settlements, strongholds such as Gostycyn, Obrowo and Raciąż are established (Kowalczyk 1986). Deforestations carried out in the 12th and 13th centuries are also very clearly visible on the fotrest map (Fig. 18) (Ślaski 1951). An increase in especially *Secale*, visible on the diagrams about the 16th c., is connected with the establishement of a great number of new settlements (Boiński 1985) and a considerable enlargement of field cultivations. Wasteful exploitation performed since the end of the 18th c. consisting in a mass use of wood (Boiński 1985) appeared to be most harmful. Pine monocultures which gave Bory Tucholskie its present appearance were planted on vast territories, in place of the cleared forests.

PERIODS OF HUMAN IMPACT VERSUS ARCHAEOLOGICAL INVESTIGATIONS

Archaeological investigations concerning Mesolithic societies conducted in the area of the southern part of the Kashubian Lakeland (Bagniewski 1987) provided surprising data. ^{14}C dates obtained from samples collected from fire places of six sites with Mesolithic flint materials are characterized by large span in time. The oldest date is 3829 years B.C. and is not surprising but the other dates are much younger: 1710 years B.C., 1955 years B.C., 1971 years B.C., 2156 years B.C., 2910 years B.C. and do not fit the time span adopted for the Mesolithic and recorded for other regions of Poland. The data obtained place the development of hunting-fishing societies of southern Kashubia at the time from about 6500 years B.C. to about 2000–1800 years B.C. (Bagniewski 1987). Similar young dates were obtained from the sites of the Mesolithic type in other regions of Poland, situated on analogous territories of extensive outwashes or in areas less fit for agricultural purposes (Bagniewski 1987). The location, morphology and a dense hydrographic network of Bory Tucholskie favoured the establishment of Mesolithic camps which were located mainly on moderately steep lake shores (Bagniewski 1987, Grzelakowska 1984). Specific physiographic and ecological conditions of the outwash land, excluding or at least limiting the possibility of agrarian adaptation, were the deleying factor of the Neolithic colonization of this area which took place rather late and only in a small area of inshore moraine uplands (Bagniewski 1987, Grzelakowska 1984). Archaeological data indicate the lack of permanent settlement (Grzelakowska & Balwierz 1985). Different development of settlement in Bory Tucholskie as compared with the scheme generally accepted for Polish lands results from a perfect adaptation of the local society to the possibilities created by the natural environment (Grzelakowska 1984). The results obtained by the pollen analysis method, discussed earlier, confirm these rather controversial results of archaeological investigations to a considerable degree. All this testifies to the so-called "long lasting" of Mesolithic cultures in the area of Bory Tucholskie and explains a relatively great number of archaeological sites with elements of the Komornice culture and the Chojnice-Pieńki culture. Elements of Neolithic cultures, mainly that of Funnel Beaker, are encountered sporadically (Bagniewski 1987, Walenta 1988). These elements could have been borrowed from Neolithic peoples by local population still engaged in economy of the Mesolithic type. It seems that the Mesolithic, like the Neolithic (Welinder 1985), should not be used here as a chronological concept. The first clear period of the economic activity connected with husbandry was recorded on the diagrams from Kęsowo (Figs 21, 24) and Wielkie Gacno (Hjelmroos 1981a, 1982) at the turn of the Neolithic and the Bronze Age. This is probably related to the vicinity of moraine uplands since in the central part of Bory Tucholskie (Suszek and Mały Suszek) this economic boom occurred as late as the end of the Bronze Age. The animation of the settlement activity was also discovered in expert palynological investigations from the area of Leśno (Grzelakowska & Balwierz 1985). This should most probably be related to the activity of the Iwno culture population whose development in Bory Tucholskie is dated on the basis of archaeological facts at the oldest part of Bronze Age, i.e. about 1600–1500 years B.C. In archaeological materials the settlement of this period is known from few sites and the barrow from Brusy (Grzelakowska & Balwierz 1985) is one of the best known. Thus there are no direct archaeological premises which would indicate the type of economy. After the development of the Iwno culture a certain regression of the economy is observed, as is indicated by the results of archaeological investigations (Grzelakowska 1984, Grzelakowska & Balwierz 1985). There are almost no finds connected with the development of the Trzciniec culture (about 1500–1300 years B.C.). This is fully confirmed by results of pollen analyses (Figs 19, 26). On the diagrams from all sites a rather clear depression of man economic activity is recorded in the middle part of the Bronze Age.

The next apparent increase in the settlement activity in Bory Tucholskie is related by archaeologists to the development of the Lusatian culture. This occurred from the IVth period of the Bronze Age (about 1100–1000 B.C.) till the Hallstatt C period (about 600 B.C.). In this case the results of the pollen analysis again show great convergence with archaeological premises (cf. Fig. 26). The period distinguished on the basis of the pollen analysis in all sites exceeds the duration of the Lusatian culture. This, however, is not concordant with archaeological data which indicate that the Lusatian culture directly transformed into the Pomeranian culture. In Bory Tucholskie this culture is represented by numerous burial places and graves; its settlement, however, is known relatively weakly (Fig. 7). On the basis of archaeological data it is difficult to determine the duration of the Pomeranian culture in Bory Tucholskie. Taking into account the results of the pollen analysis we can suppose that the end of the culture occurred at about 200 years B.C. when an apparent decrease in human economic activity is observed on the pollen diagrams. Archaeological data also record a decrease in the density of population, taking place at the late La Tene period (Walenta, personal communication), which was most certainly connected with the deterioration of the climate at that time (Klichowska 1962). Such a settlement crisis could have been caused by complete exploitation of sandy soils due to too intensive pasturage (Iversen 1973). On the basis of diagrams from Lake Mały Suszek we can conclude that locally the Pomeranian culture could last untill the Wiel-

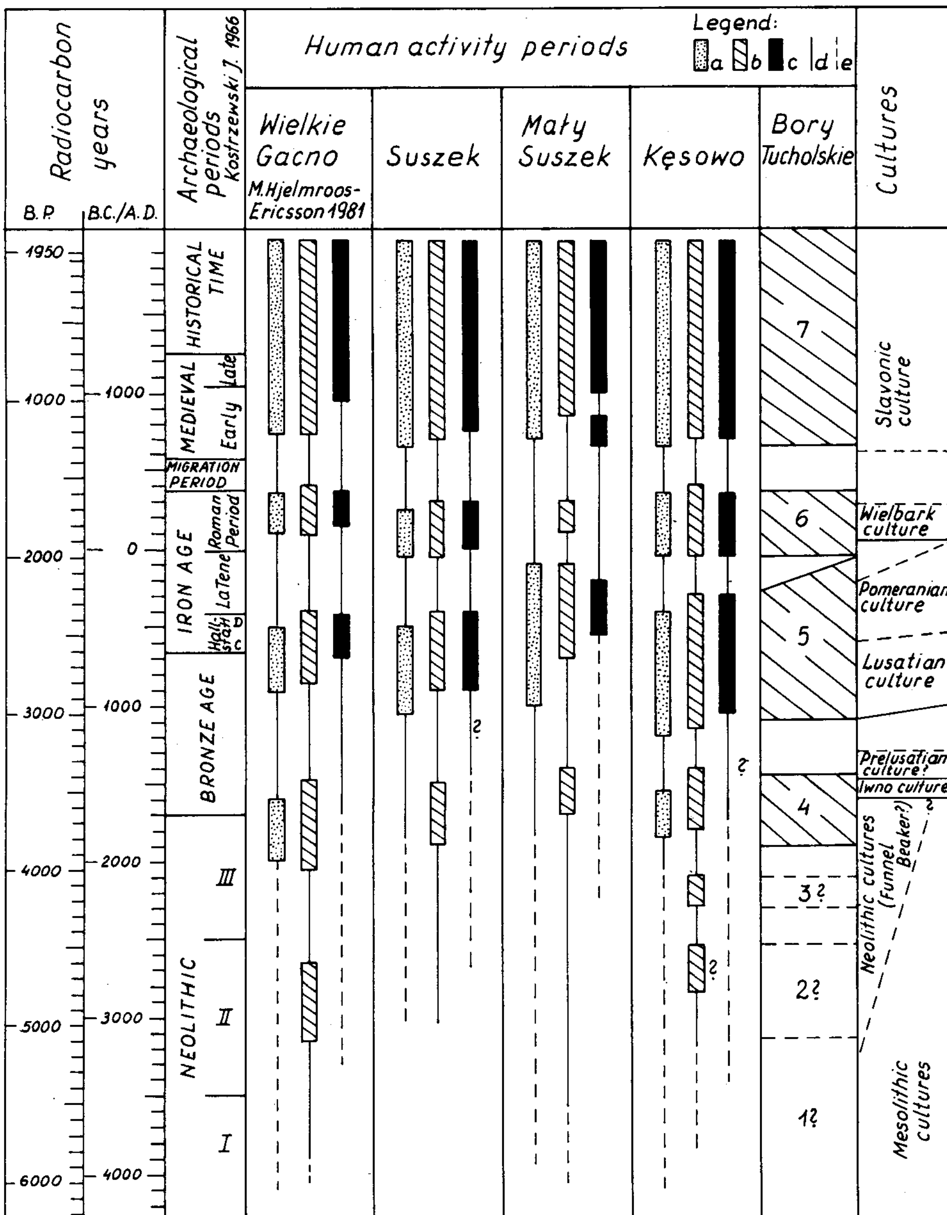

Fig. 26. Correlation of human activity periods in Bory Tucholskie (a – clearings, b – grazing, c – cultivation, d – weak impact, e – very weak impact)

bark culture developed. This settlement span was also found in archaeological investigations conducted in Leśno (Walenta 1988).

The duration of the Wielbark culture in Bory Tucholskie is dated on the basis of archaeological materials at about 50 – 300 A.D. The economic activity of this culture is reflected very clearly on the pollen diagrams from all sites under investigations. At the end of the Roman period settlement decreased. This is observed both in pollen profiles and in the archaeological material. This apparent settlement emptiness occurs at the Migration Period.

Another increase in human economic activity is connected with early Middle Ages (Hjelmroos 1981a, 1982, Grzelakowska 1984, Kowalczyk 1986, Walenta 1988). An increase in settlement is dated by archaeologists at the 13th c. (Grzelakowska 1984, Kowalczyk 1986). It can also be detected on the pollen diagrams.

AN OUTLINE HISTORY OF THE LAKES UNDER STUDY

THE RATE OF SEDIMENT ACCUMULATION

The rate of sediment accumulation depends on the productivity of aquatic vegetation, the type of plant communities occurring around the lakes, trophy of water, course of the denudation processes, climatic conditions, etc. The rate of sedimentationin the three lakes under study was expressed in cm/year (Figs. 27, 28, 29).

The mean rate of sediment accumulation for the bottom peat sediments and calcareous gyttja in Lake Mały Suszek is 0.0924 cm/year. This is a value similar to the mean rate of sediment accumulation of calcareous gyttja and calcareous detritus gyttja en-

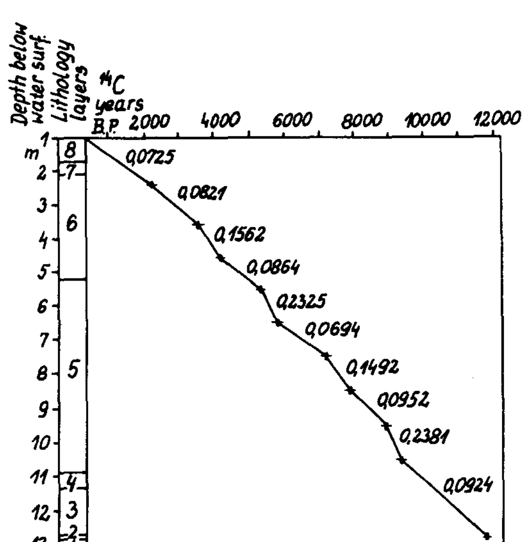

Fig. 27. Lake Mały Suszek. Graph showing the accumulation rate of sediments (in cm/year)

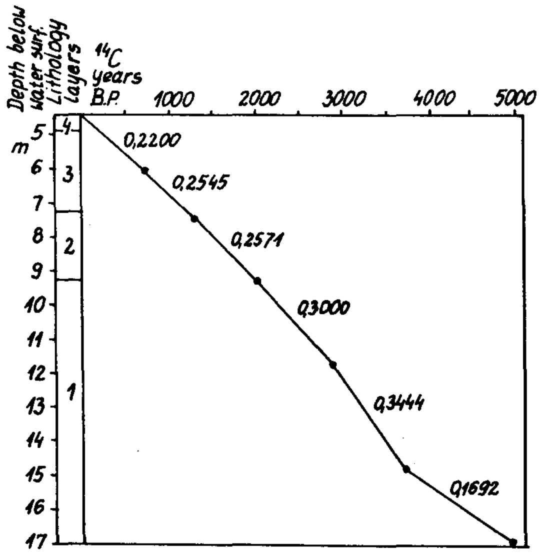

Fig. 28. Lake Suszek. Graph showing the accumulation rate of sediments (in cm/year)

countered in the profiles of Poland (0.0870 cm/year) and slightly lower than the rate of sediment accumulation of clayey calcareous gyttja of the same age in Lake Wielkie Gacno (0.1250 cm/year) (Żurek 1986). The rate of sediment accumulation of younger sediments of detritus gyttja in Lake Mały Suszek is differentiated. It was quickest (over 0.2300 cm/year) at the time of 9300 to 8900 years B.P. and 5700 to 5300 years B.P. (Fig. 27). The bottom and top parts of homogenous sediment of fine detritus gyttja was formed at those times. An increase in the rate of sediment accumulation occurred

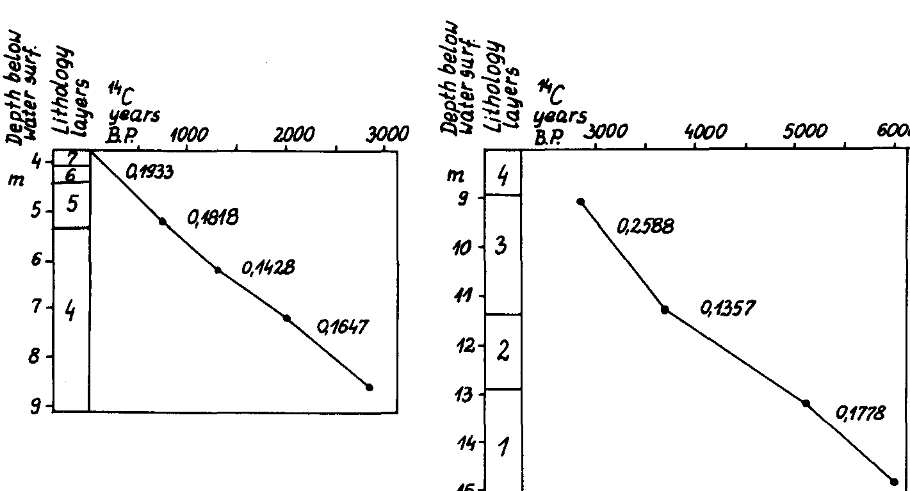

Fig. 29. Lake Kęsowo. Graph showing the accumulation rate of sediments (in cm/year)

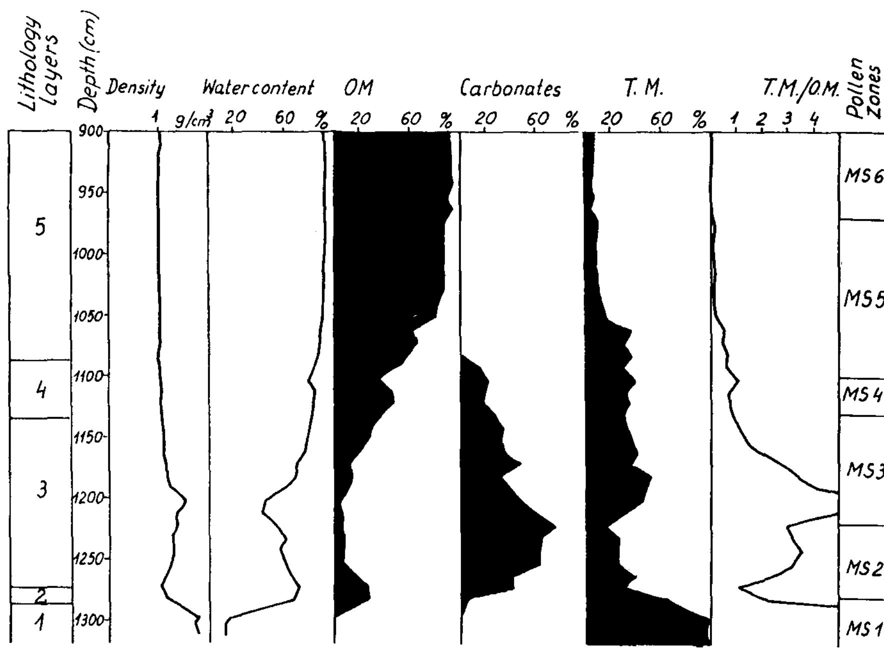

Fig. 30. Lake Mały Suszek. Results of physico – chemical analyses (acc. Kępińska). OM – organic matter, TM – terygenic matter

together with a clear change in the character of the sediment consisting in an increase of the organic matter, a decrease in the percentage of terrigenous material and carbonates (Fig. 30). This indicates a considerable increase in the production of plant communities connected with the improvement of the climate at the beginning of Holocene. The lack of physical and chemical analyses of the younger part of the sediments does not permit a more profound analysis of this problem, although an increase in *Pediastrum* indicates an increase in the trophy of the lake water during the climatic optimum (cf. Fig. 10). We should also take into account the possibility of certain inaccuracies when calculating the rate of sediment accumulation caused by temporal shift of ^{14}C dates. The rate of sediment accumulation of the other sediments of fine detritus gyttja and younger sediments of medium and coarse detritus gyttja (Fig. 30) ranges from 0.0694 to 0.1562 cm/year and is similar to the rate of sediment accumulation of the sediments of algal and fine detritus gyttja of Lake Wielkie Gacno (from 0.0620 to 0.1250 cm/year) and also similar to the mean rate of sediment accumulation of detritus gyttja in different lakes of Poland (0.0840 cm/year) (Żurek 1986).

The sediments of algal and fine detritus gyttja of Lake Suszek and gyttja of Lake Kęsowo are characterized by very high values of the rate of sediment accumulation, which ranged from 0.1692 to 0.3444 cm/year (Lake Suszek) and from 0.1357 to 0.2588 cm/year (Lake Kęsowo). Such a quick accumulation, not recorded from this kind of sediments in other areas of Poland caused the formation of sediments with almost 13 metre thickness during the Sub-Boreal and Sub-Atlantic periods. The lakes are situated in melt water channels (pradolina) and even today are connected through small water courses with neighbouring reservoirs, which partly explains such a large contribution of the terrigenous material in their sediments (Figs. 31, 32). Lakes of this type are usually characterized by large variations in the rate of sediment accumulation (Żurek 1986). The quickest rate of sediment accumulation in both lakes took place in the middle Sub-Boreal period, when the water level in the reservoirs was raised (cf. Fig. 17). At this time an increase in the ratio of the content of terrigenous material to organic matter (Figs. 31, 32) and an insignificant increase in the curves of sediment chlorophyll and *Pediastrum* are observed (Figs. 11, 12). All this indicates that at the time of the quickest rate of sediment accumulation there was a small increase in the trophy of water in the lakes connected with a considerable inflow of terrigenous substance.

THE DEVELOPMENT OF THE LAKES

Lake Mały Suszek

The peat layer under the lake sediments is dated at 11810±140 years B.P. (Lu-2296), which indicates the Allerød origin of this sediment. The presence of *Camptothecium nitens* indicates that this could have been a transition peatbog (in today's meaning of the word), at the last stage of formation. The lake, similarly to Lake Wielkie Gacno (Hjelmroos 1981) was formed as a result of the melting of ice blocks. This phenomenon was characteristic of this period and can be detected in the basins of many lakes (Starkel 1977). The calcareous gyttja overlying the peat contains 60–70% of carbonates, about 30% of terrigenous material and 8% of organic matter (of dry material). This indicates a small productivity of the lake and the existence of good conditions for the precipitation of calcium carbonate. The intensity of the accumulation of calcareous sediments in lakes was different at different times. Many lakes located in north-western Poland are known to have a high content of calcium carbonate in late-Glacial sediments (Nowaczyk & Tobolski 1980). In Bory Tucholskie lake chalk dated palynologically at the beginning of the Holocene is present in the channels of Lakes Małe Głuche and Duże Głuche (Słowański 1961, Borówko-Dłużakowa 1962, Prusinkiewicz & Noryśkiewicz 1975). In Lake Mały Suszek sediment accumulation with the greatest content of carbonates took place in Allerød and continued till the beginning of the Pre-Boreal period when a gradual change of the sediment to acid fine detritus gyttja occurred (Fig. 30). The percentage of organic matter (to 90% of dry matter) clearly increased and the amount of terrigenous material clearly decreased. This indicates an autochtonic origin of the sediment. It is homogeneous enough (fine detritus gyttja to coarse detritus gyttja) to suppose that till the Sub-Atlantic period inclusively the conditions for its accumulation in the lake were similar, and that from the Boreal period till the modern times this has been a dystrophic lake with only small variations in the water trophy. This is indicated by constant small pollen amount of aquatic and telmatic flora present in the sediment. A certain increase in *Potamogeton*, *Myriophyllum alternifolium*, *Phragmites* and *Pediastrum* at the time of human economic activity or directly following, can suggest a small increase in the trophy of lake water or its shallowing due to human impact. It could also have been caused by natural changes in the development of the reservoir. Large acidity of the sediments is confirmed by the lack of diatoms. They appear only in the youngest sediments, which indicates a certain increase in pH of the sediment caused by the general eutrophication of the environment. This is also indicated by an increase in aquatics (*Nuphar*, *Nymphaea*, *Potamogeton*) and rush plants (*Phragmites*) (Fig. 10).

Lake Suszek

The lake, similarly to Lake Kęsowo, lies in one of the melt water channels, so numerous in Bory Tucholskie. The sediments under investigation provide no information on the origin of the reservoir but, in accordance with the prevailing opinion, subglacial channel were preserved by the ice during the deglaciation processes and thus avoided being covered by moraine and outwash sediments (Galon 1982). The formation of Strzyżyny channel in Bory Tucholskie is dated by palynological and radiocarbon methods at the Allerød (Noryśkiewicz 1982).

Sediments of Lake Suszek are very homogeneous, which has also been confirmed by physical and chemical analyses (Fig. 31). The bottom part of the algal gyttja formed in the early and middle Sub-Boreal period is characterized by the 40–50% content of carbonates, about 20% of organic matter, 30–40% of terrigenous material. The sediment chlorophyll curve is constant. This indicates the existence of relatively constant conditions in the lake at that time. Similar conclusions are drawn from the results of the *Cladocera* analysis (Szeroczyńska 1991) although a small periodic increase in the significance of species connected with the littoral zone can suggest small changes in the water level. In the middle and late Sub-Boreal period (at the depth of about 1400 and 1250 cm) the development of *Cladocera* species indicating the progressing eutrophication of lake increased. An apparent increase in *Pediastrum* and in the percentage of *Phragmites* pollen was also recorded (Fig. 11). These changes are correlated in time with the periods of human economic activity (3 and 4, cf. Fig. 22). It seems, however, that climatic factors and not human impact, of low intensity at that time, are responsible for this change. Certainly they should be related to the Sub-Boreal lowering of the water level recorded for Lake Wielkie Gacno (Hjelmroos 1981a, cf. Fig. 17 – a curve of variations in the lake level after Adamczak). Some changes in the physical and chemical composition of the sediment were marked only at the depth of about 1180 cm, which corresponds to the end of the Sub-Boreal period. An increase in the content of organic matter in the sediment indicates a small increase in the production of plant communities of the lake. This can be related to the 5th period of human economic activity. However, this was not reflected in *Cladocera* analyses, which indicated a constant percentage values of plankton species. The lack of the heliophilous species of *Camptocercus rectirostris* in the sediments of the 1170–1070 cm layer can only suggest an insignificant cooling of climate (Szeroczyńska, personal communication). The composition of the aquatic pollen flora did not undergo an apparent change. Only *Phragmites* pollen values grew insignificantly. In the sediments of the Sub-Atlantic period there was an increase in the frequency of the majority of *Cladocera* species. A large amount of the species

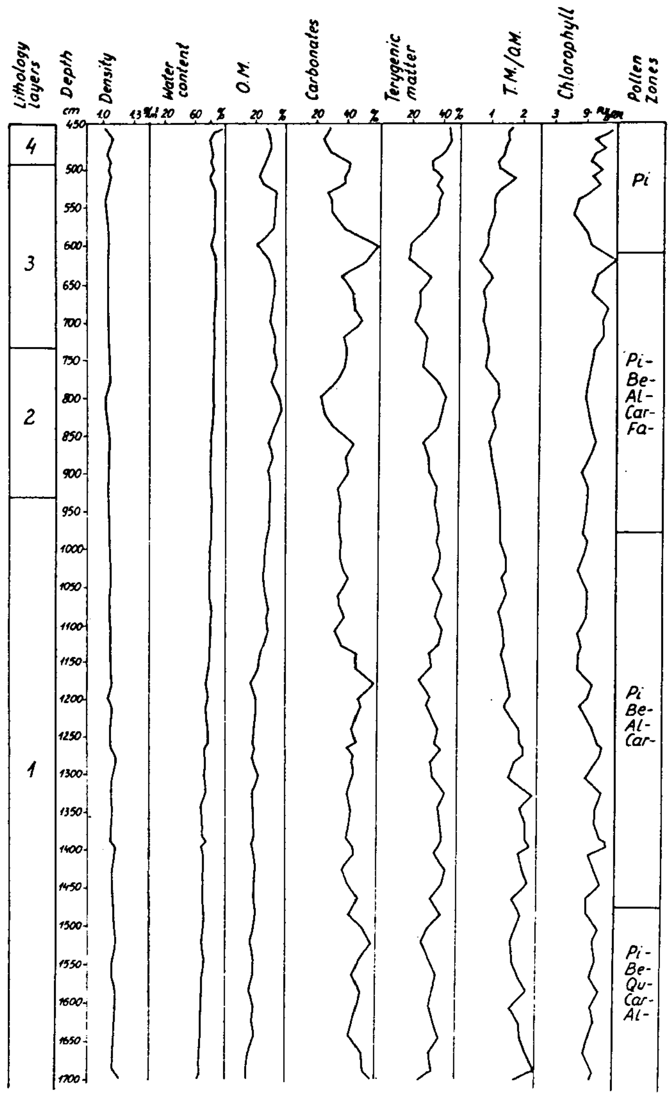

Fig. 31. Lake Suszek. Results of physico – chemical analyses (acc. Kępińska), OM – organic matter, TM – terygenic matter

indicating the development of the littoral zone was observed. A clear increase in the indicators of eutrophic conditions took place at the time of the two youngest periods of human economic activity (6 and 7 – cf. Fig. 22). Results of the pollen analysis also indicate an improvement in the trophic conditions of water (a mass development of *Pediastrum*, a greater number of pollen grains of aquatic flora) and an apparent tendency to lake shallowing (an increase in *Phragmites*, *Cyperaceae*, *Typha latifolia* and *Sparganium-Typha* pollen). This was also reflected in the physical and chemical composition of the sediment (Fig. 31). During the 6-th period of human economic activity (at the depth of about 850 cm) an increase in the percentage of organic matter was observed and a considerable deforestation of the area was reflected in the increasing amount of the terrigenous material. The most apparent changes in the physical and chemical composition of sediment are connected with the 7-th period of human economic activity (cf. Fig. 22). High values of sediment chlorophyll curve and a large content of organic matter indicate a considerable productivity of the lake. At the beginning of this time the clay content in algal gyttja decreased and the sediment changed to fine detritus gyttja, which was probably connected with the development of the telmatic flora following an increase in the trophy and a decrease in the water level of the lake. An increase in the terrigenous material can be related to a strong deforestation of the areas adjoining the lake. There was a rise of the water level between these two last periods (cf. Fig. 17) of human impact and at the same time a decrease in the lake trophy (a decrease in *Pediastrum*).

Lake Kęsowo

The bottom of the sediments of Lake Kęsowo was formed at the late Atlantic period. As physical and chemical analyses show (Fig. 32) the content of organic matter in this sediment is 30% of dry matter while in the youngest sediments it does not reach more than 20%. The content of carbonates in the sediments accumulated during the Atlantic period is 40–50% of dry matter and then grows to about 60–70%. This indicates a high productivity of the lake during the Atlantic period and an improvement of conditions for the sedimentation of carbonates at a later time. An insignificant increase in the percentage of the terrigenous material in the sediment at the depth of 1070–980 cm and an apparent increase in *Pediastrum* (Fig. 12) corresponds to the 4th period of human economic activity in this area (cf. Fig. 21). The physical and chemical composition of the sediments from the end of the Sub-Boreal period and the early Sub-Atlantic period does not show significant changes. The appearance of mollusc shells and an increase in the amount of *Phragmites* pollen suggests the shallowing of the reservoir, which should most probably corresponds with the lowering of the water level recorded at that time in Lake Wielkie Gacno (Hjelmroos 1981, cf. Fig. 17). The next lowering of water level and the eutrophication processes were reflected in a small increase in the terrigenous substance compared to organic matter and *Pediastrum* (at the depth of 720–660 cm). These changes should probably be related to human economic activity (the 6th period, cf. Fig. 21). After this period there was an improvement of conditions for the sedimentation of carbonates (Fig. 32). Apparent changes in the character of the lake were caused by an intensive activity of man in early Middle Ages (the 7-th period) (Fig. 12, 21). An increase in the percentage of organic matter and sediment chlorophyll took place then. (Fig. 32). In the pollen analysis an increase in *Cyperaceae*, *Phragmites*, *Typha latifolia*, *Nuphar*, *Nymphaea* and *Potamogeton* is oberved. The amount of *Pediastrum* also increased. This indicates a considerable increase in the water trophy and the shallowing of the lake (cf. Fig. 17). An increase in the amount of the terrigenous material in the sediment is connected probably with an almost complete deforestation of the area around the lake and the development of agriculture.

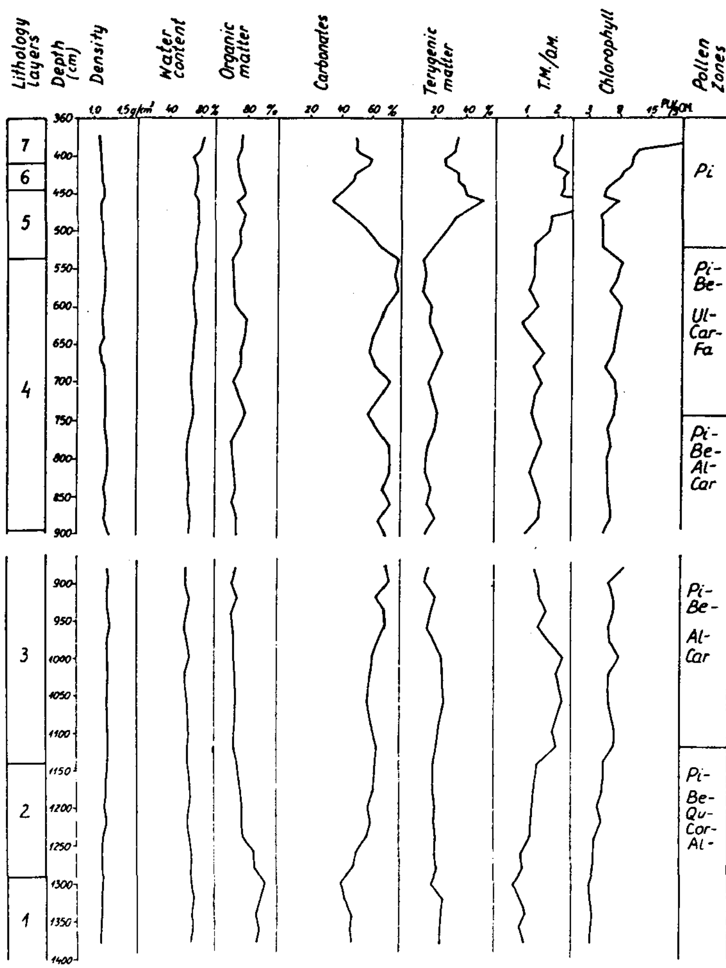

Fig. 32. Lake Kęsowo. Results of physico – chemical analyses (acc. Kępińska), OM – organic matter, TM – terygenic matter

CONCLUSIONS

The main features of the vegetational development in Bory Tucholskie area are illustrated in Fig. 15 by a simplified pollen diagram and in Fig. 17 by the event stratigraphy table. On the basis of pollen diagrams from four sites under discussion, it must be stated that the development of the vegetation in the entire Bory Tucholskie was very similar, although there were also small differences caused by different edaphic conditions. This is confirmed by pollen diagrams from sites investigated earlier by other authors.

During the pre-Allerød time Bory Tucholskie area was covered by treeless tundra. In the second part of Allerød, simultanously with an improvement of climatic conditions, *Pinus* began to play a considerable role in the forests and from this time remains the dominant tree in this region. At the same time the melting of ice blocks began or was intensified. This can have resulted in the rising of water level observed in diatom analyses (cf. Fig. 17). The cooling of the climate in the Younger Dryas caused the reduction of the forest. In this time the park tundra with heliophilous herbs and *Juniperus* developed and eolic processes became more intense. In the Pre-Boreal the water level was relatively low (cf. Fig. 17). *Pinus* dominated in dry places, while more humid and fertile habitats were gradually taken by *Betula* and trees which arrived at that time: *Corylus* (Holocene maximum), *Ulmus* and later on – also *Quercus* and *Alnus*. About 9700 years B.P. a certain deterioration of the climate is observed. This cooler oscillation noticed in Poland for the very first time in Żarnowieckie Lake (Latałowa 1982) was known earlier from other sites in Europe (Robertsson 1969, Behre 1978, Schneider & Tobolski 1985 and others). In the end of the Pre-Boreal *Pinus* locally reached its holocene maximum. Pine was still dominant tree on dry, sandy soils during the Boreal while more fertile moist soils were occupied by *Quercus*, *Ulmus*, *Corylus*, *Alnus* and in lesser extent by *Tilia* and *Fraxinus* which arrived at that time. The lowering of the water level (Fig. 17) caused the rapid spread of *Alnus* which about 8000 years B.P. locally reached its holocene maximum. During the Atlantic, especially when the ground water level is thought to have been higher (according to diatom analyses and *Cladocera* analyses there was the highest water level in the lakes in the whole Holocene – Fig. 17), the nemoral broad-leaved forest communities were able to expand onto higher ground and *Pinus* was forced onto the poorest places. At the end of this time small disturbances in the deciduous forests caused probably by man are observed. The humid climate caused the soil leaching which lead to gradual deterioration of edaphic conditions. Retrogressive development of the forest vegetation started in the Sub-Boreal. More fertile soils were still occupied by mixed deciduous forest and on poorer habitats acidophilous *Pino-Quercetum* association began to develop. *Quercus* reached its Holocene maximum. Participation of *Carpinus* and *Fagus* in the forest communities were gradually increasing. The changes in the vegetation were not only due to climatic deterioration and more active soil leaching but also due to human interference in the forests. During the early Sub-Atlantic *Pino-Quercetum*-type forest was dominant in poorer habitats, in more fertile ones – *Querco-Carpinetum* developed. In the middle and late Sub-Atlantic humidity increased and the exploitation of arable land resulted in accelerated erosion and soil leaching. *Pinus* became the absolutely dominating forest component. The modern forest communities of which the *Vaccinio myrtilli-Pinetum* is the most common were largely formed artificially by plantation.

Basing on the palaeoecological investigations conducted so far we can say that the modern flora of Bory Tucholskie is partly the result of climatic changes taking place during Holocene which brought about changes in the edaphic conditions, but to a considerable degree it is the result of the economic activity of man who indirectly (grazing contributing to a more rapid impoverishment of soils) and directly (clearings and burnings, and at the youngest times – forest plantation) contributed to the formation of the present – day vegetation.

A separate floristic character of Bory Tucholskie during the Holocene history of vegetation can be detected upon the comparison of selected curves of trees in diagrams from sites in Bory Tucholskie and areas directly adjoining them (Lake Godziszewskie in Kashuby Lakeland - Miotk 1986, Korne in Charzykowska Plain – Kępczyński & Noryśkiewicz 1982, and Fletnowo in the Grudziądz Basin – Kępczyński & Noryśkiewicz 1968). This was connected with the soil cover, poorer than in the neighbouring areas, formed on the extensive outwash plain of the Brda, specific hydrographic conditions and similar economic activity of man in this area.

The results of the pollen analysis confirmed the suppositions advanced by archaeologists about a considerable prolongation of Mesolithic-type economy in the area of Bory Tucholskie. Human impact on the natural environment is clearly reflected on the pollen diagrams from the Bronze Age and is connected with the development of the Iwno culture (Lakes Kęsowo and Wielkie Gacno) and in the middle part of Bory Tucholskie – with the Lusatian culture (Lakes Suszek and Mały Suszek) (Fig. 19). The basic form of economy in the area of the entire Bory Tucholskie was husbandry. Farming, as is evidenced by the results of pollen analyses and archaeological investigations, gained in significance as late as the beginning of the Iron Age, during the Pomeranian culture and it developed extensively in the Roman period during the Wielbark culture (Fig. 26).

Man economic activity is most strongly marked on pollen diagrams from the peripheries of Bory Tucholskie (Lake Kęsowo) (Figs. 21, 24). This is probably connected with the vicinity of moraine uplands.

All the periods of human impact, distinguished on the basis of pollen analyses, are compatible with archaeological data on the development of particular cultures in Bory Tucholskie (Fig. 26). The results of the physical and chemical, pollen, *Cladocera* (Lake Suszek) and diatom analyses reflected the Sub-Boreal and Sub-Atlantic lowering of the water level in the lakes of Bory Tucholskie (cf. Hjelmroos 1981a and Fig. 17). The Sub-Boreal economic activity of man caused very weak changes in the trophic condition of the lake water. During the Sub-Atlantic, man had a decisive influence on the development of the reservoirs under study.

The sediment accumulation rate of Lake Mały Suszek is similar to that of Lake Wielkie Gacno (Hjelmroos 1981a) and other lakes of Poland (Żurek 1986). The accumulation of the Sub-Boreal and the Sub-Atlantic sediments in the through-flow lakes (Lakes Suszek and Kęsowo) was very rapid. Such rate was not recorded in other reservoirs.

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STRESZCZENIE

Wstęp

Badania, których wyniki zostały przedstawione w niniejszej pracy, rozpoczęto w 1982r. w ramach problemu resortowego R-III-15 -"Procesy ekologiczne w obrębie wybranych jednostek krajobrazowych oraz bilans energetyczny tych jednostek", a od 1986r. kontynuowano w podprogramie centralnym 04.10.01. - "Przyrodnicze podstawy ochrony i kształtowania środowiska". Badania te były kontynuacją i rozszerzeniem paleoekelogicznych badań jeziora Wielkie Gacno (Hjelmroos-Ericsson 1981, 1982). Jeziora Wielkie Gacno i Mały Suszek zostały włączone do sieci punktów wzorcowych International Geological Correlation Programme (IGCP) nr 158B.

Celem tych rozszerzonych badań paleoekologicznych było pogłębienie wiadomości o historii roślinności tego terenu ze szczególnym uwzględnieniem roli człowieka ingerującego w pierwotną szatę roślinną, a także poznanie rozwoju badanych jezior, wpływu działalności ludzkiej na zmiany trofii ich wód, porównanie otrzymanych wyników z danymi archeologicznymi i wreszcie próba uogólnienia tych zmian na teren całych Borów Tucholskich. Równolegle z analizą pyłkową prowadzone były badania subfosylnych okrzemek (dr B. Bogaczewicz-Adamczak).

Przy opisie regionalnej historii roślinności i interpretacji działalności gospodarczej człowieka oprócz trzech badanych stanowisk (jeziora: Mały Suszek, Suszek i Kęsowo) uwzględniono też wyniki badań jeziora Wielkie Gacno (Hjelmroos 1981, 1982) (rys. 1).

Charakterystyka Borów Tucholskich

Bory Tucholskie są największym obszarem leśnym na Pomorzu Zachodnim. Zajmują one powierzchnię 2106 km^2 (Kondracki 1978) i leżą na obszarze sandru zwanego Sandrem Brdy, w obrębie którego zachowało się szereg wysp i półwyspów morenowych (rys. 2).

Cechy klimatu panującego w Borach Tucholskich przedstawiono w postaci diagramu klimatycznego (rys. 3) i na rys. 4. Rozległe pola sandrowe stwarzają warunki dla rozwoju głównie gleb bielicowych (rys. 5). W szacie leśnej przeważają zbiorowiska borowe. Rozmieszczenie ważniejszych drzew, krzewów i krzewinek na terenie Borów Tucholskich przedstawia rys. 6. Na rys. 7 zaznaczono stanowiska archeologiczne obrazujące rozwój osadnictwa na tym terenie.

Metody badań

Rdzenie przeznaczone do szczegółowych analiz laboratoryjnych pobierano przy pomocy sondy tłokowej Livingstone'a w modyfikacji Wright'a (Livingstone 1955, Wright 1967). Części spągowe tych rdzeni pobierano świdrem torfowym a półpłynne osady powierzchniowe przy pomocy próbnika opisanego przez Digerfeldt'a i Lettevall'a (1969).

Osady klasyfikowano w oparciu o system opracowany przez Troels- Smith'a (1955). Symbole użyte w kolumnach stratygraficznych diagramów są także zgodne z tym systemem.

Wyniki analizy pyłkowej przedstawione zostały w postaci diagramów pyłkowych skonstruowanych według zaleceń Berglunda i Ralskiej-Jasiewiczowej (1986). Diagramy mające na celu ukazanie działalności gospodarczej człowieka wykreślono na skali czasowej ustalonej w oparciu o niekorygowane daty ^{14}C (jezioro Mały Suszek) lub metodą interpolacji.

Diagramy podzielone zostały na jednostki biostratygraficzne charakteryzujące się spektrami o podobnych zespołach pyłkowych. Jednostki te nazwane zostały za Jańczyk-Kopikową (1987) "poziomami zespołów pyłkowych" i odpopwiadają angielskim "pollen assemblage zones". Lokalne poziomy zespołów pyłkowych wyróżnione dla jeziora Mały Suszek i regionalne poziomy zespołów pyłkowych dla Borów Tucholskich oznaczone zostały skrótami MS i BT oraz numerami wskazującymi na pozycję danego poziomu poczynając od spągu profilu. Poziomy zespołów pyłkowych wyróżnione dla jezior Suszek i Kęsowo opatrzono numerami odpowiadających im poziomów regionalnych. Poziomy podzielono na podpoziomy zespołów pyłkowych.

Podstawą do obliczania tempa sedymentacji osadów jeziora Mały Suszek były daty ^{14}C. Dla jezior Suszek i Kęsowo, których osady nie nadawały się do datowań metodą radiowęglowa, ustalono wiek bezwzględny dla pewnych zdarzeń drogą porównań. Za zdarzenia synchroniczne dla wszystkich stanowisk przyjęto: spadek krzywej *Ulmus* - 5100 lat B.P., i zmiany krzywej *Carpinus* - 3700, 2850, 2000, 1300 i 750 lat B.P.

Analizy numeryczne wykonane zostały w Instytucie Fizyki Politechniki Śląskiej w Gliwicach w oparciu o program ZONATION składający się z trzech podprogramów: CONSLIK, SPLITSQ i SPLITINF. Wykonano je jedynie dla danych palinologicznych z jeziora Mały Suszek.

Analizy okrzemkowe (dr B. Bogaczewicz-Adamczak), *Cladocera* (dr K. Szeroczyńska) i fizyko – chemiczne (mgr U. Kępińska) wykonane zostały metodami wymaganymi przez IGCP 158 B. Szczegółowe ich wyniki będą tematami osobnych opracowań.

Charakterystyka zbiorników

Zgodnie z założeniami pracy, do szczegółowych badań paleoekologicznych wybrano jeziora leżące w centralnej, zalesionej części Borów Tucholskich (jeziora Suszek i Mały Suszek) oraz poza zasięgiem współczesnej granicy lasu (jezioro Kęsowo) (rys. 1). Jezioro Mały Suszek wypełnia niewielkie wytopisko (rys. 8). Pobrano z niego rdzeń osadów o miąższości 12 m. Jeziora Suszek i Kęsowo są jeziorami przepływowymi i leżą w pradolinach (rys. 8 i 9). Duża ilość osadów organicznych w tych jeziorach była powodem pobrania jedynie osadów młodszych o miąższości 13 m i 11 m.

Datowania ^{14}C

Metodą radiowęglową wydatowano 10 prób z bezwęglanowej części osadów jeziora Mały Suszek. Datowania te zostały wykonane w Laboratorium ^{14}C Instytutu Fizyki Politechniki Śląskiej w Gliwicach (9 prób) i w Laboratorium Datowań Radiowęglowych Zakładu Geologii Czwartorzędu w Lund (1 próba). Wyniki tych analiz wraz z opisem poszczególnych prób zawiera tab. 1.

Historia szaty roślinnej

W oparciu o analizę diagramów pyłkowych wydzielono lokalne poziomy i podpoziomy zespołów pyłkowych (rys. 10, 11, 12). Pełną sekwencję poziomów począwszy od pre-Allerødu wyróżniono w oparciu o diagram z jeziora Mały Suszek. Rdzenie osadów z jezior Suszek i Kęsowo obejmują znacznie krótszy odcinek czasu i zawierają tylko młodsze poziomy. Maksymalne i średnie wartości procentowe ziarn pyłku wybranych taksonów w wyróżnionych poziomach zespołów pyłkowych z poszczególnych stanowisk przedstawiono w tab. 2.

Wyniki analiz numerycznych wykonanych dla stanowiska Mały Suszek przedstawiono na rys. 13 oraz w tab. 3 i 4. Zestawienie granic uzyskanych tą metodą z wyróżnionymi poziomami pyłkowymi na skali lat radiowęglowych zawiera rys. 14. Duża waga *Alnus* w pierwszej składowej głównej (tab. 4) zadecydowała o wykonaniu powtórnych analiz numerycznych z pominięciem tego taksonu (rys. 16, tab. 4b). Uzyskano w ten sposób kilka nowych granic (rys. 14), ale podział ogólny nie uległ zmianie. Wskazuje to, że *Alnus* stanowi jakby tło dla zmian innych składników składowej głównej.

Wyniki analiz numerycznych potwierdziły istnienie jedynie naprawdę wyraźnych i ważnych zmian w szacie roślinnej.

Zestawienie lokalnych poziomów i podpoziomów zespołów pyłkowych dla czterech stanowisk Borów Tucholskich (tab. 5) wskazuje na bardzo podobny rozwój roślinności badanego terenu. Odrębności lokalne znalazły odbicie w zróżnicowaniu podpoziomów zespołów pyłkowych. To podobieństwo pozomów lokalnych (l paz) było podstawą do wyróżnienia regionalnych (BT) poziomów zespołow pyłkowych (R paz) (tab. 5). Podstawowe cechy rozwoju roślinności, typowe dla całych Borów Tucholskich przedstawia skrócony diagram z Małego Suszka (rys. 15) oraz rys. 17. Czas ważniejszych wydarzeń w rozwoju lasów zawiera tab. 6.

Współczesny obraz florystyczny Borów Tucholskich jest po części wynikiem zachodzących w holocenie zmian klimatycznych, ale w dużej mierze jest skutkiem działalności gospodarczej człowieka.

Wpływ człowieka na szatę roślinną

Zmiany w przebiegu krzywych drzew i roślin zielnych związanych z działalnością gospodarczą człowieka pozwoliły na wydzielenie okresów wzmożonej jego aktywności w bezpośrednim sąsiedztwie badanych jezior (rys. 20, 21, 22). Skalę czasową i numerację tych okresów zawiera rys. 19. W celu porównania aktywności gospodarczej człowieka skonstruowano dla wszystkich stanowisk diagramy syntetyczne (rys. 23, 24, 25), na których zaznaczono również poziomy bogate w węgielki drzewne. Graficzny obraz wzmożonej działalności gospodarczej w okolicach jezior: Mały Suszek, Suszek, Kęsowo i Wielkie Gacno oraz uogólnienie dla obszaru całych Borów Tucholskich przedstawiono na rys. 26.

Wyniki analizy pyłkowej potwierdziły przypuszczenia archeologów o znacznym przedłużeniu trwania gospodarki typu mezolitycznego. Działalność gospodarcza człowieka zaznaczyła się najsilniej na diagramach pyłkowych z obrzeża Borów Tucholskich, co ma zapewne związek z bliskością wysoczyzn morenowych. Wyraźne oddziaływanie człowieka na środowisko naturalne rozpoczęło się od epoki brązu i związane było z rozwojem hodowli. Uprawa roli nabrała większego znaczenia dopiero na początku epoki żelaza, a znaczny jej rozwój nastąpił w okresie rzymskim (por. rys. 17, 26).

Okresy wzmożonej działalności gospodarczej wydzielone na podstawie analizy pyłkowej są zgodne z danymi archeologicznymi dotyczącymi rozwoju poszczególnych kultur (rys. 26). Na diagramach pyłkowych daje się także zauważyć wzrost intensywności osadnictwa w XIII w. (Grzelakowska 1984, Kowalczyk 1986) (por. rys. 7, 17, 18 i 23, 24, 25).

Zarys historii badanych jezior

Stwierdzono, że tempo sedymentacji osadów wytopiskowego jeziora Mały Suszek (rys. 27) jest zbliżone do opisywanego z jeziora Wielkie Gacno (Hjelmroos 1981) i innych terenów Polski (Żurek 1986). Akumulacja subborealnych i subatlantyckich osadów w jeziorach Suszek i Kęsowo (rys. 28, 29) przebiegała w bardzo szybkim tempie, nie notowanym dotychczas w innych zbiornikach.

Potwierdzono, że powstanie zbiorników wytopiskowych w Borach Tucholskich miało miejsce w Allerødzie (por. Hjelmroos 1981).

Subborealne i subatlantyckie obniżenia poziomu wód zbiorników (por. Hjelmroos 1981) znalazły odbicie w wynikach analiz fizyko-chemicznych (rys. 30, 31, 32), pyłkowej (rys. 10, 11, 12), *Cladocera* i okrzemkowej.

Mało intensywna działalność gospodarcza człowieka w okresie subborealnym spowodowała jedynie nieznaczną zmianę warunków troficznych w jeziorach. W okresie subatlantyckim zdecydowany wpływ na rozwój zbiorników miał człowiek.