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THE DEVELOPMENT OF LAKE ŁUKCZE AND CHANGES IN THE PLANT COVER OF THE SOUTH-WESTERN PART OF THE ŁĘCZNA-WŁODAWA LAKE DISTRICT IN THE LAST 13 000 YEARS

Rozwój jeziora Łukcze i zmiany szaty roślinnej południowo-zachodniej części Pojezierza Łęczyńsko-Włodawskiego w ostatnich 13 000 lat

ABSTRACT. This work is a continuation of the studies started earlier in the Lake Łukcze region. Three profiles from a peatbog and one from the bottom sediment of the lake were analysed palynologically. One profile was examined for its macrofossils and chemically analysed. The palaeobotanical results were supplemented with ten radiocarbon dates. Three numerical methods (CONSLINK, SPLITINF and SPLITSQ) were used to establish zonation of the pollen diagrams. Eleven pollen assemblage zones were distinguished and they made the basis for a description of vegetational history from the Oldest Dryas till the present time. No cool oscillation of the climate, corresponding with the Older Dryas, was observed. An attitude was assumed towards the history of the ranges of trees important to this region (*Abies alba*, *Picea abies* and *Fagus sylvatica*). It is belived that both the processes of ground-ice melting (thermokarst) and karst phenomena contributed to the formation of the Lake Łukcze basin.

CONTENTS

INTRODUCTION

Although the area of Lublin Polesie lies out of the extent of the last glaciation, it abounds in numerous lakes and peatbogs. The abundance of sediment, particularly well suited for studies on vegetational history, caused that this region has been attracting attention of palynologists since long ago. However, few sites have received elaborate publications, of which here we should mention works by Kulczyński (1930, 1939-1940), Marek (1965) and Paszewski and Fijałkowski (1970). Furthermore, a number of unpublished pollen diagrams, worked out mostly by S.M. Scherwentke, are stored in the archives of the Institute of Botany, Polish Academy of Sciences, in Kraków. Figure 1 gives a list of sites at which palaeobotanical studies on the late-glacial and Holocene vegetational history of Lublin Polesie and neighbouring areas were conducted. The value of these materials is relatively small at the present stage of investigation, for the diagrams or tabulated data generally include only pollen of main trees, herbs being not identified, and the sampling intervals were too big. There are hardly any radicarbon datings. Only for the profile from Durne Bagno (Paszewski & Fijałkowski 1970) two C^{14} dates were obtained but, as has been stated by the authors themselves, they are to be treated as approximates because too large profile sections were dated.

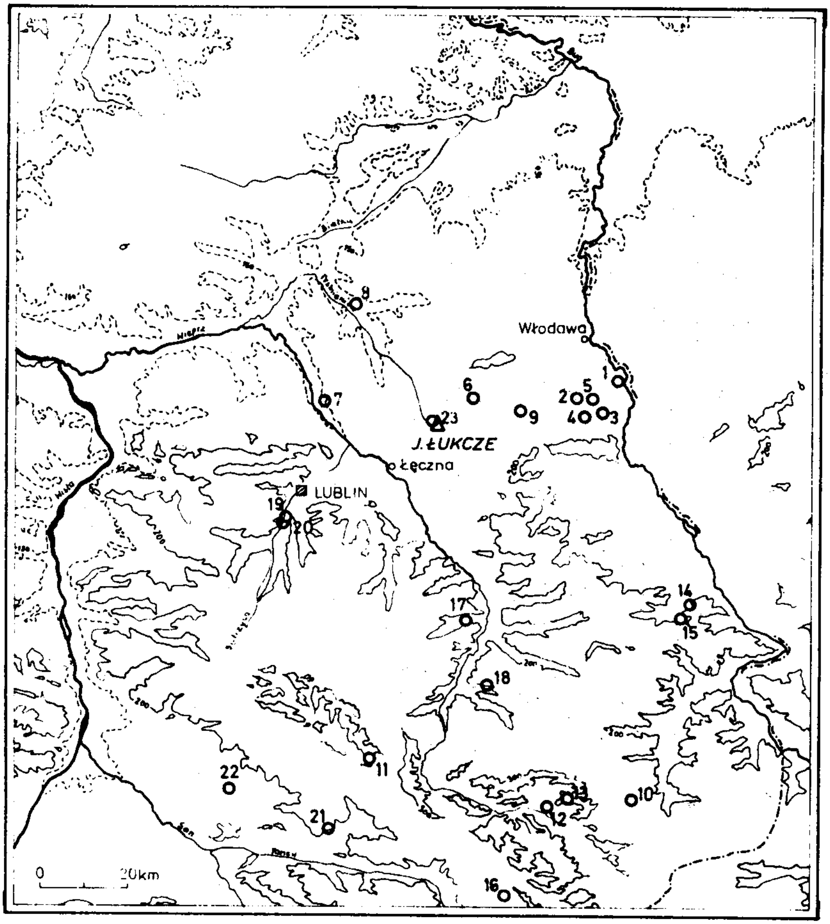

Fig. 1. A map showing the palynologically studied sites of the late glacial and Holocene sediments in Lublin Polesie and the neighbouring area: 1. Sobibór near Włodawa (Lublinerówna 1934), 2. Lake Perespilno (Marek 1965), 3. Lake Płotycz (Tołpa, Arch. IB PASc), 4. Osowa (Marek 1965), 5. Lake Brudzieniec (Marek 1965), 6. Durne Bagno (Fijałkowski & Paszewski 1970), 7. Wola Ruska (Scherwentke, Arch. IB PaSc), 8. Glinny Stok (Scherwentke, Arch. IB PASc), 9. Krowie Bagno (Scherwentke, Arch. IB PASc, Bałaga et al. 1983), 10. Wożuczyn (Macko 1946), 11. Jędrzejówka near Biłogoraj (Bremówna 1950), 12. Zaboreczno (Macko 1946), 13. Krynice (Scherventke, Arch. IB PASc), 14. Strzelce (Scherwentke, Arch. IB PASc), 15. Raciborowice (Scherwentke, Arch. IB PASc), 16. Huta Różanecka near Susiec (Marek 1965), 17. Białka near Krasnystaw (Marek 1965), 18. Stary Zamość (Scherwentke, Arch. IB PASc), 19-20. Zemborzyce (Marek 1965, Bałaga & Maruszczak 1981), 21. Obary (Mamakowa 1962), 22. Imielty Ług (Mamakowa 1962), 23. Lake Łukcze (Bałaga 1982)

The studięs on the post-glacial and Holocene history of the vegatation of the Lake Łukcze region in the south-western part of the Łęczna-Włodawa Lake District have been continued (Bałaga 1982). This site is numbered as a reference site in IGCP Project 158 b, dealing with the palaeohydrological changes in the last 15 000 years on the basis of studies of peat and limnic sediments (Berglund & Digerfeldt 1976, Berglund 1979, Berglund 1986 (ed)).

In addition to the investigation of the late-glacial and Holocene history of the plant cover of the area under study, the other object of the present work is to reconstruct the genesis of Lake Łukcze.

The study covers four profiles: one from bottom sediment in the southern part of the lake and three from the peatbog adjacent to the western shore of the lake.

CHARACTERISTICS OF LUBLIN POLESIE

Physiography

In accordance with Szafer's (1972) geobotanic division Lublin Polesie lies in the Belt of the Great Valleys, which is a subdivision of the Baltic Division. In the north it bordes on the Podlasie Province, which is characterized by the nearly complete lack of Atlantic species and sessile oak localities, in the west on the Mazovian Province, which is distinguished by the occurrence of single localities of fir, and in the south on the Lublin Upland with a characteristically high proportion of xerothermic species from the class *Festuco-Brometea* and the occurrence of open oak forests *Querco-Potentilletum albae*, whereas Lublin Polesie itself is characterized by an abundance of peatbogs and lakes. From Polesie proper, which extends east of the Bug (USSR) it differs, among other things, in the occurrence of some species of aquatic plants like *Myriophyllum alterniflorum*, *Najas flexilis*, *Isoëtes lacustris*, and peat-forming plants: *Lycopodium inundatum*, *Drosera intermedia*, *Hydrocotyle vulqaris* and others (Fijałkowski 1972).

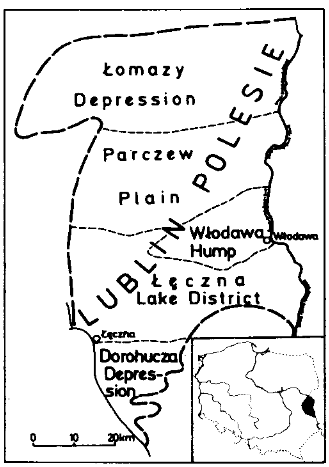

Fig. 2. Map showing the division of Lublin Polesie into subregions (Chałubińska & Wilgat 1954)

Various investigators (Chałubińska & Wilgat 1954 – Fig. 2, Kondracki 1967, Mojski 1972) divided Lublin Polesie into smaller physiographic units. During his geobotanical studies of the Lublin Province, Fijałkowski (1972) distinguished three subdistricts: Łomazy Depression, Parczew Upland and Łęczna-Włodawa Lake District.

The Łomazy Depression, situated farthest to the north, is the lowest and flattest part of Polesie. Stands of poor oak-hornbeam forests are dominants here (Solińska-Górnicka & Fazlajew 1978). The forest cover consists chiefly of mixed oak-pine forests, with pine forests on elevations and wet alderwoods in depressions without outflow. Meadows with the dominant associations *Poo-Festucetum*, *Festuco-Cynosuretum*, *Molinietum medioeuropaeum* and *Carici-Agrostietum* are other important components of the landscape (Fijałkowski 1966, 1972).

The high proportion of lime-oak-hornbeam forest is a chracteristic feature of the Parczew Upland (Fijałkowski 1972, Kozak 1967a). Cultivated fields also cover large areas, which is connected with relatively fertile soils.

With its greatest number of lakes and peatbogs, the Łęczna-Włodawa Lake District comprises nearly all rare species of the flora and fauna of Lublin Polesie (Fijałkowski 1972, Izdebski & Grądziel 1981). There are differences in the vegetation between the east and west parts of the area. The western part is characterized by oak forests similar to the mixed pine forest (*Pino-Quercetum*) (Solińska-Górnicka & Fazlajew 1978) and by a higher proportion of Atlantic elements in the plant communities (Fijałkowski 1972). On the other hand, continental pine forest (Peucedano-Pinetum) dominates in the eastern part, where such species as *Myriophyllum alterniflorum*, *Rhynchospora fusca* and the like vanish.

Geological structure

Lublin Polesie is situated in the marginal zone of the East-European Plateau. In the Bug Depression the pre-Cambrian is capped by Carboniferous formations from several hundred metres in thickness in the south-western part to a several times smaller thickness in the Włodawa region. The Carboniferous is overlain by the Jurassic carbonates and Cretaceous formations. The Tertiary formations occur in patches varying in area and thickness. They are mostly quartzite-glauconite sea-sands dating from the Oligocene and lacustrine sands and silts from the Miocene and Pliocene (Mojski 1972).

The sub-Quaternary relief has a great influence upon the Quaternary relief of the area. The sub-Quaternary surface is built of carbonate rocks, mainly limestone, marl and chalk. The differences in its level reach 30-50 m (Harasimiuk & Henkiel 1980, Buraczyński & Wojtanowicz 1981, 1982). The relief was shaped by many factors, such as karst processes, fluvial erosion, neotectonic movements and, finally, destructive activity of glaciers during earlier glaciations (Jahn 1956, Wilgat 1957, Maruszczak 1966b, Buraczyński & Wojtanowicz 1981 and others).

The Pleistocene formations are differentiated in respect of age and genesis. They occur as a continuous cover in the northern and middle parts of Polesie, but are missing in many places in the southern part (Mojski & Trembaczowski 1975). The Pleistocene sediments reach several tens of metres in thickness. The deposits dating from the Middle-Polish glaciation are the thickest. They are locally covered by a thin layer of lacustrine sands and silts connected with the Vistulian glaciation.

The Holocene formations occupy relatively large areas. They include fluviatile silts and sands, which build the flood plains in the valleys of the Bug, its major tributaries and the

Tyśmienica, and lacustrine sands and silts filling the extensive depressions. Peats are the commonest Holocene deposits: here they form one of the largest areas in Poland, described in detail by Churski (1963) and Okruszko et al. (1971).

Relief

The Lublin Polesie region is flat country with differences in level of the order of several metres (Wilgat 1963). Plains of fluvio-periglacial accumulation from the Mazovian-Podlasian stadial and the younger stadials of the Middle-Polish glaciation occur mainly in the

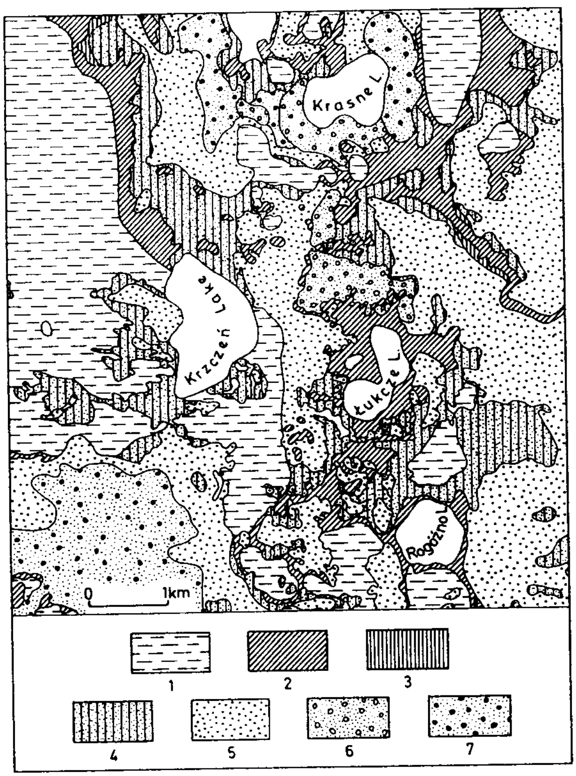

Fig. 3. Geomorphologic sketch map of the Lake Łukcze region (after Liszkowski 1979): 1 — fens and transition mires, 2 — peaty silts, 3 — fluvial and flood-water silts and clays, 4 — river sands and silts of terraces raised above flood-plains of the North-Polish glaciation, 5 — lake-flood water sands of the Mazovian-Podlasian and younger stadials, 6 — sands and sands with gravels and silts of kame terraces of the maximum stadial, 7 — lower and upper fluvioglacial sands and sands with gravels of the maximum stadial

western part of the Lake District (Fig. 3), and those build of organic accumulation are situated in its middle part. The morainic hills dating from the Middle-Polish glaciation, called the Włodawa Hump, lie to the north of it. Strips of out wash sands diverge from this zone of glacial accumulation. The forms which owe their origin to karst processes are the oldest in the relief of Lublin Polesie. They are funnel — and cup — shaped sink-holes, uvalas, and karst -level lings (Maruszczak 1966b). The age of karst relief varies from form to form (Jahn 1956, Mojski 1972). The karst processes continued with varying intensity during the decline of the Tertiary and throughout the Quaternary and probably they proceed also recently (Mojski 1972), Mojski & Trembaczowski 1975, 1977) The plains of proglacial-lacustrine accumulations of the Vistulian glaciation are in places 2-4 m lower than the plains formed during the Middle-Polish glaciation. In such places the plains of Middle-Polish glaciation age correspond hypsometrically with the river terraces. At the decline of the last glaciation there were better conditions for the formation of dunes on the surface of these terraces. The dunes stabilized by vegetation rise to 6-8 m (Mojski 1972).

The Holocene forms occupying the largest areas of the Lake District are valley bottoms, Holocene terraces and peatbog plains.

Hydrography

The Lake District lies in the water-shed area between the catchment basins of the Bug and Wieprz Rivers. The natural river system is very poor. The main natural streams is the Tyśmienica with its tributaries, being itself a tributary of the Wieprz, whereas the Włodawka opens into the Bug. All the smaller rivulets are mostly transformed into the small ditches with seasonal flow.

The water conditions of the area are determined by its relief and geological structure. The level character of the relief and exceedingly small downgrades impede surface runoff and cause the formation of extensive swampy areas. The occurence of numerous and rather thick silt series amidst the Quaternary deposits reduces the permeability of the substratum and intensifies the processes of bog formation (Wilgat 1963, Buraczyński & Wojtanowicz 1981). Lakes and mires are the commonest elements of the hydrological system. Although considerably transformed by man (land reclamation), the wet areas still occupy 40% of the total area and determine its „Polesian character" (Wilgat 1963). The largest mire is Krowie Bagno, 30 km^2 in area. The lakes vary very much in size, Lake Uściwierz being the largest (284 ha in area, 6.6 m deep) and Lake Piaseczno the deepest (84.7 ha, 39.8 m deep) (Wilgat 1954). The depth of ground water is closely linked with the relief. The first ground water table occurs at a depth of 2 m below land surface.

Climate

The climate of Lublin Polesie has been included by Romer (1949) into the Central Upland-type of climate and by Gumiński (1948) and Kondracki (1967), in the 13th Chelm climatic province. In their opinion, the Polesie region is characterized by great variation of

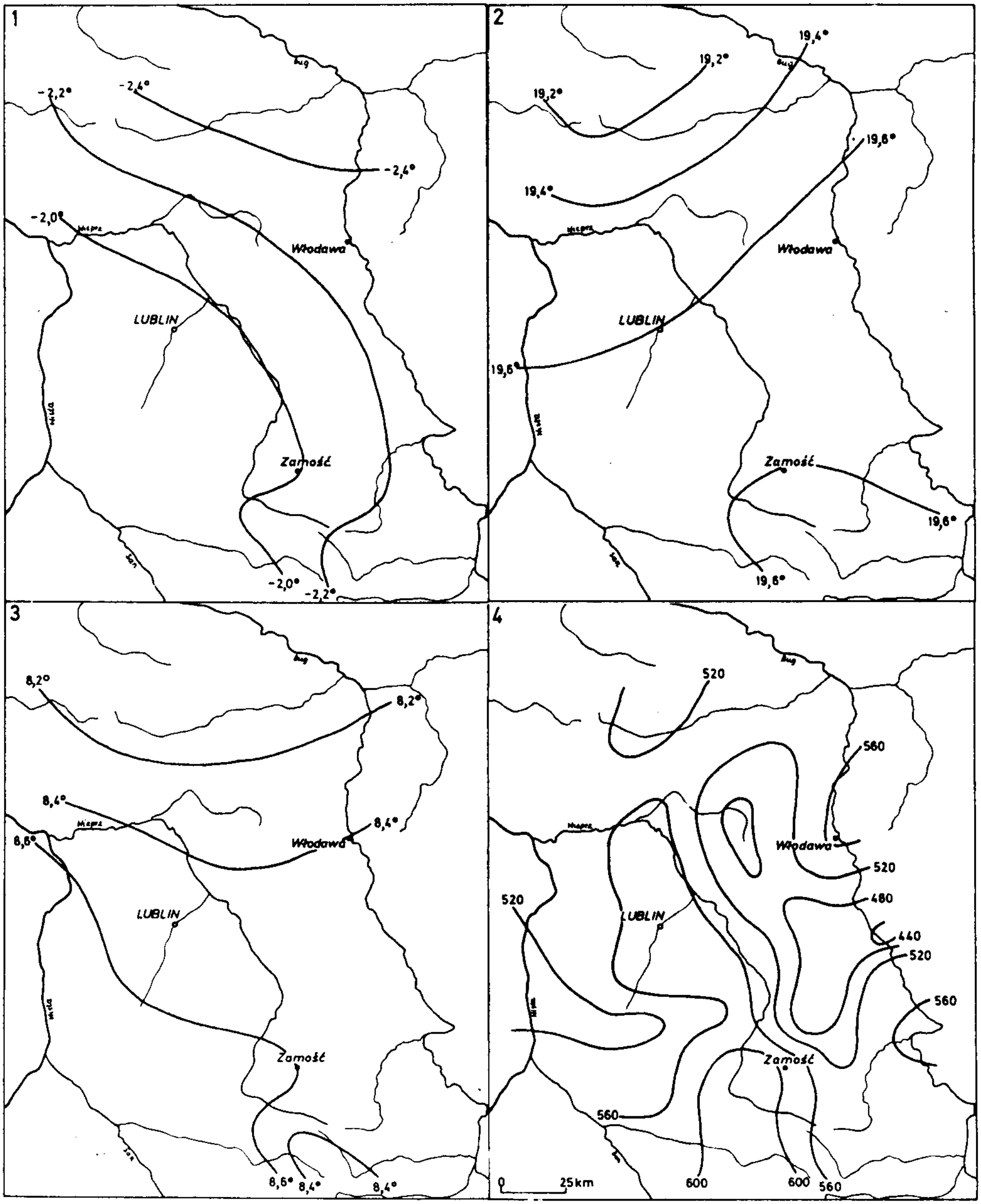

Fig. 4. Some climatic data for the area of Lublin Polesie (after A. Zinkiewicz & W. Zinkiewicz 1975): 1 — January isotherms, 2 — July isotherms, 3 — annual isotherms, 4 — annual precipitation

climatic parameters in both the annual and the daily scale. The continentality of climate is expressed, among other things, by a high annual amplitude of temperatures reaching 22-23 °C. The mean annual temperatures range between 8 and 8.4 °C, with a maximum in July and a minimum in January (Zinkiewicz 1963). The mean annual rainfall does not exceed 600 mm. The rainfalls reach a maximum in July and a minimum in January and February. The July, January and annual isotherm and the isolines of annual rainfall are illustrated in Fig. 4. The westerly winds prevail here. The growing season usually begins in the first decade of April and ends at the beginning of November, lasting about 211 days. There are 12-15 days with ground frost in this season (Michna et al. 1978).

Soils

The distribution of soils is shown in Fig. 5. Podzols, developed from loose sands and clayey sands, predominate (about 80 % of the area - map of soils, scale 1 : 300 000, Zawadzki 1963, Dobrzański & Uziak 1969). Small areas lying east of Ostrów Lubelski have podsol soils, developed from dust deposits of aquatic origin. Podsols on loess or loess-like formations occur in small areas in the region of Łęczna.

Brown soils, developed on deposits of aquatic origin and on loess and loess-like formations in a complex with podsols, occupy small areas in the region of Ostrów Lubelski and Łęczna.

Bog soils line the river valleys and local depressions. Mud soils have been formed in the river valleys. Peat soils, which occupy the largest area of the bog soils, are fen soils and marsh soils which have developed from peat soils in consequence of a fall in the ground water level.

Chalky rendzinas, developed from calcareous rocks, occur chiefly in the southern part of the Lake District.

Light, medium and heavy muds have been formed in the Bug valley.

The present-day vegetation

The flora of Lublin Polesie is well know mainly owing to studies carried out by Fijałkowski (1957a, b, 1958a, b, 1959, 1960a, b, 1961, 1966, 1972).

The vegetation of lakes and peatbogs, which make up nearly 50% of the total area of the Lake District, is strongly differentiated, in connection with the varying trophic conditions, determined by local geomorphology, chemical water properties and movements of surface waters (Fijałkowski 1960a, Radwan et al. 1974, Kowalczyk 1976).

Aquatic vegetation. *Myriophyllo-Nupharetum* is the commonest association in the eutrophic lakes. According to dominant species, it makes several varieties, with *Ceratophyllum demersum*, *C. submersum*, *Nuphar luteum* or *Nymphaea alba* as well as with *Myriophyllum spicatum* and *M. verticillatum* or *Elodea canadensis* (Fijałkowski 1960a). *Hydrocharitetum morsus-ranae*, with dominant *Hydrocharis morsus-ranae* and *Stratiotes aloides* grows along the silted and sheltered shores of the lakes. *Potametum lucentis* develops in deeper parts of the lakes with a poorly silted bottom and transparent water, whereas *Hottonietum palustris* and *Sparganietum minimi* occur in silted and shaded shallow places.

The association *Myriophyllum alterniflori* with *M. alterniflorum*, *M. spicatum*, *Ceratophyllum demersum* and *Schoenoplectus lacustris* occurs in the oligotrophic lakes. It forms a belt along the sheltered shallow inshore parts of the lakes with a sandy bottom.

Communities of *Characeae* are encountered in all types of lakes (Karczmarz 1975, 1980, Karczmarz & Malicki 1971).

Reed-swamp communities. They develop as a vegetational belt in the inshore parts of water bodies, mostly eutrophic, extending to a depth of about 1.5 m. The association Scirpo-Phragmitetum is most common; it is differentiated into several facies: with Equisetum limosum in shallower places, with Phragmites communis and Sparganium on the sandy substratum and with Typha angustifolia on peat or gyttja.

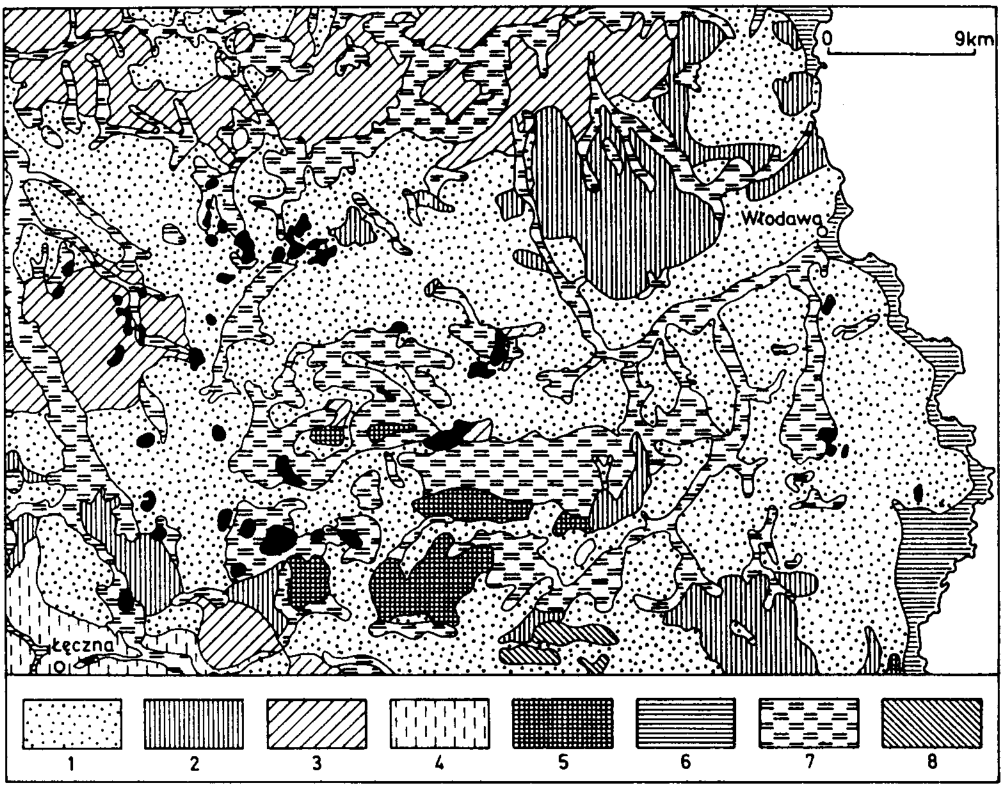

Fig. 5. Distribution of important types of soils in the area of Lublin Polesie (Map of Polish Soils, 1 : 300 000): 1 — podsolic soils on loose slightly clayey and clayey sands, 2 — podsolic soils on boulder clays and clay- and loam-overlying sands, 3 — podsolic and brown solis on dusty formations of aquatic origin, 4 — podsolic and brown soils on loess and loess-like formations, 5 — chalky rendzinas, 6 — light, medium and heavy muds, 7 — bog soils, 8 — black earths on loams and clays of different origin

Mires. Fens which are the most common mires here, develop in low situations, usually in river valleys. The largest areas of fens are occupied by the communities of high sedges from the *Magnocaricion* alliance: *Caricetum elatae*, *Caricetum approprinquatae*, *Caricetum gracilis* and *Mariscetum*, this last association growing over many-hectare areas of Krowie Bagno - mire.

Mesotrophic mires are particularly frequent in the vicinity of dystrophic lakes and in the laggs of raised bogs. The associations occuring in them are *Rhynchosporetum albae*, *Caricetum lasiocarpae*, *Caricetum limosae* and *Caricetum diandrae*.

The raised bogs occupy trough-shaped depressions without outflow, often in the close proximity of dystrophic lakes. They have a hummock-pool structure and consequently show a mosaic arrangement of vegetation. Plants of the subassociation *Sphagnum medio-rubelli-Pinetosum*, like dwarf pine and birch, dwarf shrubs of the family *Ericaceae* as well as *Sphagnum apiculatum* and *S. magellanicum* grow on the drier hummocks, and *Carex stellulata*, *C. limosa*, *Rhynchospora alba* and *Sphagnum cuspidatum* in the water-logged pools.

Forest communities. The forest coverage of the Lake District is low, the forests being distributed irregularly. Fairly large forest complexes are grouped in the regions of Parczew, Włodawa and Sawin (Fijałkowski 1957b, Kozak 1966, 1967a). These forests are very strongly degraded, only 10% of their total area has its natural composition preserved in the stands more than 60 years old.

The coniferous forests occupy the largest areas (about 90%), *Peucedano-Pinetum* is the commonest pine forest. It grows in flat or wavy areas on podsols formed from loose sands and, more rarely, clayey sands. Stands of *Cladonia rangiferinae-Pinetum* develop in dry habitats and on dunes, and stands of *Vaccinio uliginosi-Pinetum* occur in the vicinity of raised bogs or within the pine forests. This association is connected with peat soils. Mixed pine forests (*Pino-Quercetum*) grow in more fertile habitats. They occupy, above all, the wavy terrains with podsolic soils developed from loamy sand. Patches of moist mixed coniferous forest (*Querco-Piceetum*) may grow in transitional situations between pine forests and wet alderwoods. They occupy the moderately fertile habitats with a fairly high groundwater level.

Oak-hornbeam forests occur in eutrophic habitats, in flat or slightly sloping terrains with a high groundwater level in the proximity of streams. They grow on cryptopodsolic and brown soils developed on loamy sands, and belong to the association *Tilio-Carpinetum*, with theree subassociations: *T.C. typicum*, *T.C. corydaletosum* and *T.C. stachyetosum*.

Riverine woods represented by small patches of elm carr (*Ficario-Ulmetum campestries*) occupy fertile and periodically flooded habitats, mostly on brown soils and muds in river valleys.

Wet alderwoods in typical form (*Carici elongatae-Alnetum*) occur on swampy, marsh and peat mineral soils. The groundwater level is high and shows periodical fluctuations, which favours the formation of the hummock-and-pool structure of alderwood communities and the mosaic arrangement of vegetation. There occur, besides, two scrub associations belonging to the *Alnion glutionosae* alliance: of which *Salici-Franguletum* is more common, wheras *Betuletum humulis* is encountered more rarely.

Meadow communities. In connection with the soil moisture, two groups of meadow associations can be found in the Lake District: wet meadows and fresh meadows.

The associations of periodically wet meadows *Filipendulo-Geranietum* and *Molinietum coeruleae* occur on mineral and peat soils in low-lying areas with a high groundwater level. The subassociation *Molinietum coeruleae-Caricetosum paniceae* develops in drier places.

Fresh meadows develop mostly on mineral soils with the deeper groundwater level. Fairly large areas are occupied by the association *Arrhenatheretum elatioris* which occurs chiefly on muds in river valleys. The association *Poo-Festucetum rubrum* grows in somewhat wetter and less fertile habitats.

History of settlement

Prehistoric settlement in the territory of Polesie is very poorly known. The archaeological finds described so far are for the most part connected with the neighbouring terrains – the Vistula Valley and the loess regions of the Lublin Upland.

The earliest traces of human activity found in Polesie come from the Palaeolithic (Nosek 1957). Mackiewicz (after Gardawski & Susłowski 1974) presents the distribution of the Mesolithic localities in the north-eastern part of Polesie and Gurba (1960), partly, in its south. Most of sites are situated on dunes in river valleys. Mesolithic man acquired main means of subsistence by gathering, hunting and fishing.

The distribution of sites from the Neolithic onwards is presented by Nosek (1957) (Fig. 6). At the begining of the Later Stone Age the tribes of the Early Danubian culture appeared in the region between the Vistula and the Bug. They moved from the south by the loess areas along the left bank of the Vistula, crossing the river upstream of the mouth of the Wieprz. About 3800-3000 B.C., in the middle phase of the Lengyel and Polgar cultural cycle (Gurba 1973), a regional group of the Lublin-Volhynian culture (painted pottery) was separated in the Lublin Upland, probably without reaching Polesie (Gardawski & Susłowski 1974). During the following period 3000-2500 B.C., the area was settled by groups of the Lengyel and Polgar cultures, the Funnel-Beaker culture, Globular Amphora culture and Pit-comb and Corded Ware cultures. The older, more primitive group of the Funnel-Beaker culture inhabited Lublin Polesie, while its younger group moved to the southern areas between the Vistula and the Bug. Pottery fragments belonging to the Funnel-beaker culture were found in the direct vicinity of Lake Łukcze and traces of a settlement of this culture in the region of Lake Piaseczno (Nosek 1957). In the northern group, occupying the areas of poor soils stock-farming was the most important base of economy. Klichowska (1975) however mentions fossil cereals: wheat and barley, from the sites of this culture in the Chełm region. The population of the Globular Amphora culture occupied mostly fertile areas to the south, between the Vistula and the Bug. In Polesie the tribes of this cultural group led a more primitive, nomadic way of life, moving from place to place in search of food and pitching temporary camps on dry sandy dunes. The culture of these people is poorly known. Arrow-heads belong to the most frequently encountered implements (Balcer & Kowalski 1978). The Gorded Ware culture appeared towards the end of the late period of the Stone Age. The population of this culture was originally nomadic or seminomadic, mainly engaged in stock-raising and hunting. In a later phase, influenced by contact with a settled agricultural population, the groups of this culture began to cultivate the soil and assumed a more settled way of life (Nosek 1957).

At the beginning of the Bronze Age the Strzyżów group of the Mierzanowice culture, which was a continuation of the Corded Ware culture, developed in Lublin Polesie (Gardawski & Susłowski 1974). Some axes associated with this cultural group were found in the Włodawa District.

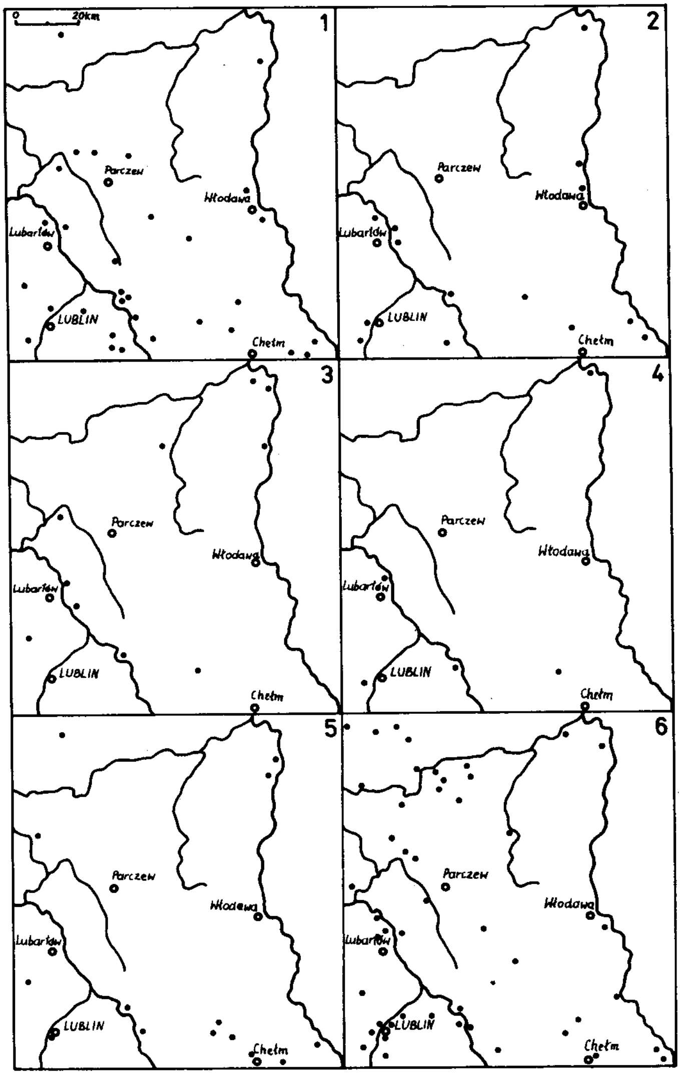

Fig. 6. Distribution of archaeological sites in Lublin Polesie (Nosek 1957): 1 — Neolithic, 2 — Bronze Age, 3 — Lusatian culture, 4 — Pomeranian culture, 5 — Venedian culture, 6 — Early Middle Ages

In Bronze Age II some tribes of the Trzciniec culture appeared in the study area. Most of their sites were found on sandy dunes (Nosek 1957). The frequent occurrence of settlements on dunes permits the supposition that these people led a half-resident way of life, being chiefly engaged in stock-raising, hunting and, to a lesser degree, in soil cultivation.

Starting from Bronze Age III, the Lusatian culture began to develop from theTrzciniec culture. In the Hallstatt period it reached a maximum of its development and towards the end of the second millenium underwent a breakdown, most probably in consequence of the Scyths invasion (Nosek 1957).

The decline of the Lusatian culture in the early Iron Age made it possible for the Pomeranian tribes to encroach upon the territory of Polesie. The Pomeranian culture was poorer than the Lusatian, which was certainly connected with the economic deterioration caused by wars (Nosek 1957).

The Venedian culture developed in Polesie in the late La Téne period. This period is represented by very few archaeological sites so far found and nothing at all is known of its settlements.

As in other regions, the Migration period was marked by a successive decline in economy.

The archaeological finds from the early historic times show the connection of the Polesie tribes with Mazovia. In the 11th c. the Polish colonization was destroyed by the Yatvingians (Gardawski & Susłowski 1974).

In the Middle Ages Polesie was sparsely populated (Uhorczak & Szczepaniak 1963), just as it is at present.

STUDY METHODS

Materials for palaeoecological studies were obtained from the lake bottom by means of a piston-sampler (Więckowski 1961) (profile Łukcze I (Ł-I)) and from the peatbog by means of Russian sampler with a box diametr of 5 cm (profile Łukcze II and III (Ł-II and Ł-III) (and of 10 cm (profile Łukcze IV (Ł-IV)).

The Troels-Smith system (1955) was used in the description of sediments. A simplified description was applied for profile Łukcze I, because no complete core was available but only pollen samples collected earlier and stored in glass tubes, besides the 50-cm sections of completely dried core.

Pollen analysis

In all profiles samples for pollen analysis were taken in 5 cm intervals. For profiles Ł-III and Ł-IV a 1 cm^3 container was used for sampling to make calculation of pollen concentration possible. The material for pollen analysis was prepared by various methods, according to the character of sediment (Faegri & Iversen 1964, Wasylikowa 1973). Peat and gyttja samples were treated with boiling 10% KOH for 10 min. prior to acetolysis. The material containing calcium carbonate was pre-treated with 10% HCl whereas boiling hydrofluoric acid was applied for 5-7 min. for silty sediment or organic sediment with a mineral content. A modification with pellets containing *Lycopodium* spores was used for 1 cm^3 samples, two pellets for each sample, to count the pollen concentration (Stockmarr 1971, 1973).

About 1000 tree pollen grains were counted in each sample from profile Ł-1, except bottom samples with the low pollen frequencies. In the remaining profiles about 500 tree pollen grains were counted. Determinations were made with an Amplival microscope at a magnification of x 400 and x 1000 using immersion oil.

In the profiles Ł-I and Ł-II pollen was counted in strips at intervals of 1 mm. In profiles Ł-III and Ł-IV the whole area of the coverslip was counted using *Lycopodium* pellets to calculate pollen concentration.

A correction factor for trees with the highest pollen production was applied in profile Ł-I as an additional variant for *Pinus*, *Betula* and *Alnus*, (dividing by 4, as suggested by Andersen (1970) (Fig. 8).

The diagrams were constructed in the way recommended by the IGCP 158 B guide (Berglund 1979 ed.) The sum AP + NAP was used as the basis to calculate the values for the curves of *Limnophyta-Telmatophyta* and spores.

Numerical zonation

The pollen data from all profiles were zonated by means of a numerical analysis (Gordon & Birks 1972) carried out by Dr. A. Walanus.

Description of method (after Walanus MS). The programme ZONATION consists of three subprogrammes: CONSLINK, SPLITINF and SPLITSQ.

CONSLINK – the basis of this programme is the numerical measure of similarity between two samples. The action of CONSLINK lies in the successive combination of levels or neighbouring groups of levels combined before. Levels or their groups are joined together by means of brace at a height which is the greater the less similar they are. The measure of similarity between groups is the value of similarity between two most similar levels from two groups. The results obtained with this programme are presented in the form of dendrograms (Figs. 8,9,10, and 11)

SPLITSQ and SPLITINF – unlike the procedure of CONSLINK, the action of the SPLIT-s consists in successively dividing the profile into smaller sections. The arbitrarily assumed number of divisions equals a quarter of the number of samples. The profile has certain mean numbers of particular taxa: it has also a certain dispersion dependent on how much in various samples the contents of the taxa differ from the mean value. If the profile is divided at any place and the contents of the taxa are calculated separately for either part obtained in this way, the global dispersion in either part, computed in relation to its mean, will be smaller. The succesive divisions of the profile are situated in such places that the dispersion shall be increased to a maximum extent. If the dispersion found before any divisions have been made is assumed to be equal to 100, then it will be smaller after each successive division and it will be possible to express its size as a percentage of that original value. The division is of the greater consequence the higher is the number qualifying the dispersion. The results of the SPLIT-s are given in Tables 2,3,4 and 5, and placed on the left side of the dendrograms. In interpreting the results I assumed the 20 % values of SPLIT-s as distinct boundaries.

Plant macrofossil analysis

Profile Łukcze II was designed for macroscopic analyses. Samples were taken in 10-cm sections. The samples were boiled in 10% KOH, and flushed through a 0.4-0.2 mm mesh sieve. The samples from carbonate sediments were made with the help of atlases published by Dombrovskaya et al. (1959), Szafran (1957, 1961), Kac et al. (1975) and Berggren (1969).

The results are presented in the form of a diagram (Fig. 14).

Physical and chemical analyses

Ten-centimetre sections of the core of Łukcze III were used for physical and chemical examinations. Water content determined by drying at 105 °C, loss on ignition by burning at 550 °C, calcium carbonate by Schreibler's methods, pH – potentiometrically in H_2O and HCl, and organic carbon by Tyurin's method.

For the profile Łukcze I the sample representing half-metre core sections were analysed for organic carbon content and for ignition residue and the results are shown in Table I.

DESCRIPTION OF THE LAKE ŁUKCZE

Lake Łukcze (163 m a.s.l.) is situated in the south-western part of the Łęczna-Włodawa Lake District, about 11 km north-east of Łęczna town. The lake is 1.4 km long, ca 500 m wide and 56.5 ha in area. It consists of two parts (Fig. 7). The southern part is more or less circular in shape, with regular slopes, forming a funnel, 8.9 m in depth. The northern part is elongate, with slopes falling steeply to a depth of 4 m. The bottom is flat and the greatest depth is 6.4 m. The two parts are joined by a shallow narrows, reaching 2.4 m in depth.

The lake is a water-body without outflow, partly over grown. In many places along the shore there occurs a wide belt of aquatic and reedswamp vegetation. The lake shore is sandy at places, especially on the south-eastern side.

Vegetation

Lake Łukcze is a eutrophic lake (Wilgat 1954, Fijałkowski 1960 a, Radwan et al. 1974, Kowalczyk 1976). The aquatic vegetation is represented by two associations of the order *Potametalia*: *Myriophyllo-Nupharetum* and *Hydrocharitetum morsus-ranae*. *Myriophyllo-Nupharetum* divides into two facies, with dominant *Nuphar luteum* or *Myriophyllum alterniflorum* and *M. spicatum*. The facies with *Nuphar luteum* develops among reed and bulrush swamps by the western lake-shore and forms patches, several metres in area, by the south-western shore. The facies with *Myriophyllum spicatum* and *M. alterniflorum* occurs in breaks of the reedswamp belt, where on sandy places of the lake-bottom it forms the underwater meadows to a depth of 1.3-2.0 m.

Hydrocharitetum morsus-ranae grows on the silty bottom, in water of different transparency at a depth up to 1.5 m. Its largest concentrations develop by the western shore. It is chiefly composed of *Potamogeton natans* with contribution of *Ceratophyllum demersum* *Elodea canadensis* and *Stratiodes aloides*.

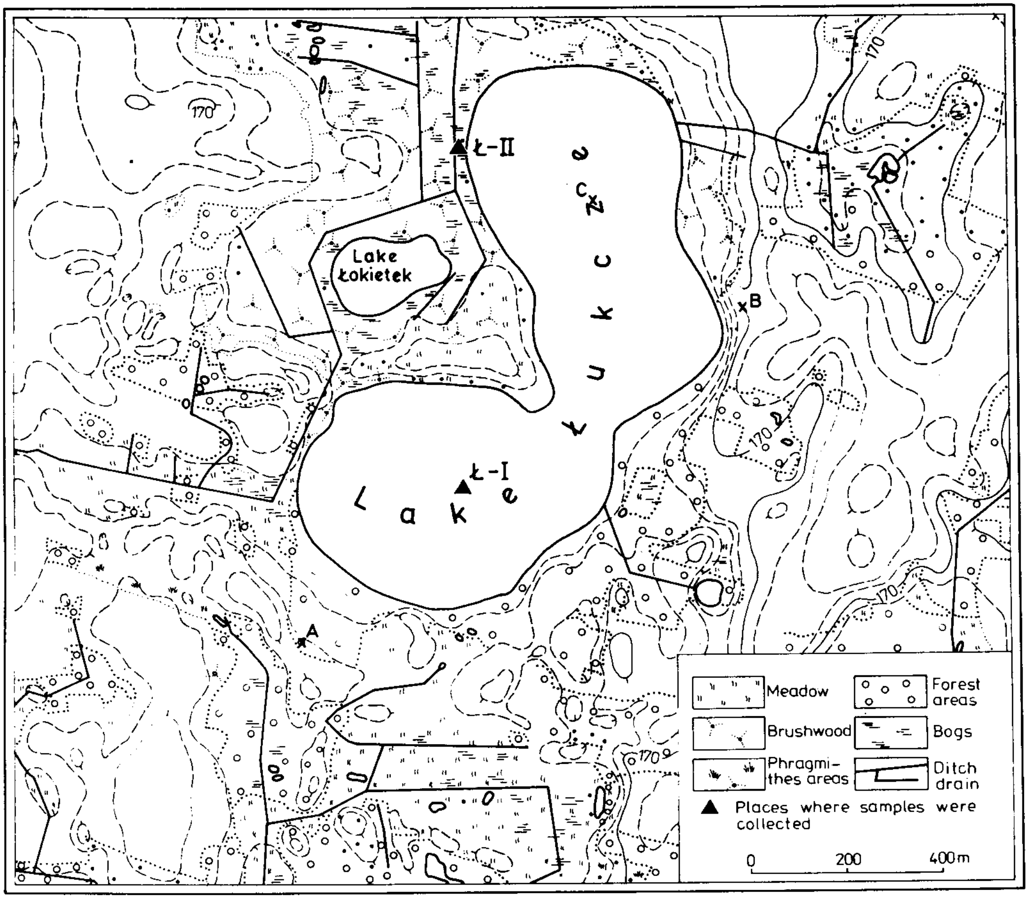

Fig. 7. Sketch map showing the location of Lake Łukcze (1: 10 000)

The reedswamp vegetation is represented by two associations: *Scirpo-Phragmitetum* and *Acoretum calami*, which occurs sporadically. *Scirpo-Phragmitetum* shows a distinct differentiation into facies. On swampy and heavily silted sandy soils the number of species increases considerably, whereas on the slightly silted sandy substratum their number undergoes a reduction. In shallow places and on the shore this association is enriched in species from the *Magnocaricion* alliance, while in deeper parts of the lake it sometimes forms nearly monospecific groupings. The peaty shores are accompanied by stands of *Typha latifolia* and *T. angustifolia*, in places with *Equisetum limosum* and *Phragmites communis*, *Schoenoplectus lacustris* and *Heleocharis palustris* occur mainly on sandy sections of the shore-line on the eastern and southern sides.

The swampy places by the north-western, western and south-western lake-shores are chiefly occupied by mire communities: *Sphagnetum medio-rubelli* and *Caricetum lasiocarpae*, *C. limosae, C. diandrae* and *Carici-Agrostietum caninae*. They are separated from the lake by, a narrow and in places interrupted belt of *Salici-Franguletum* with *Dryopteris thelypteris*.

In less swampy areas on the north-eastern, eastern and southern sides of the lake the communities from the class *Alnetea glutinosae* are better developed, especially in the south-eastern part. Several hundred metres south-west, west and south-east of the lake the fragments of devastated forests originating from fresh pine forest (*Vaccinio-myrtilli-Pinetum*) and mixed coniferous forest (*Pino-Quercetum*) occur.

Description of profiles

Łukcze I. A boring was made in the southern part of the lake at a depth of 5.5 m (simplified description – Fig. 8)*.

Layer No.	Depth, in cm	Sediment description
–	0 – 140	Detritus gyttja, olive, brown, semifluid Detritus gyttja,
5	140 – 982	brown-black, with a gradually increasing degree of compactness
4	982 – 1007	Moss peat, brown-black, strongly decomposed, with Drepanocladus revolvens, *D. sendtneri* and *Calliergon giganteum*
3	1007 – 1027	Detritus gyttja, brown-black
2	1027 – 1072	Moss peat, brown, weakly decomposed, with *Drepanocladus revolvens*, *D. sendtneri*, *D. fluitans*, *Calliergon giganteum*
1	1072 – 1085	Silt, grey, with an admixture of plant detritus

Łukcze II. A boring was made in the peatbog 20 m west of the lake (Fig. 9)**. The bog has a hummock-and-pool structure, with *Andromeda polifolia*, *Ledum palustre*, *Oxycoccus quadripetalus*, *Sphagnum sp.* and its shrub layer contains dwarf pine, birch and aspen.

Layer No.	Depth, in cm	Sediment description
8	0 – 20	*Sphagnum* peat, pale brown matted nig 2, strf 0, elas 3, sicc 2, $Tb^1$2, $Th^1$2, Ld+, Anth+
7	20 – 50	Sedge-moss peat, brown, matted lim.s.0, nig 2+, strf 0, elas 3, sicc 2, $Tb^2$1, $Th^2$3, Ld+, Anth+
6	50 – 100	Sedge-moss peat, black-brown, matted

* Fig. 8 under the recover.

** Fig. 9 under the recover.

		lim.s.0, nig 3, strf 0, elas 2, sicc 2, Tb^{2}1, Th^{2}3, Ld++
5	100 – 245	Sedge-moss peat, black-brown, of fibrous structure lim.s.0, nig 3, strf 0, elas 3, sicc 2++, Tb^{2}1, Th^{3}2, Ld^{2}1
4	245 – 291	Calcareous gyttja, grey-brown, of nodular structure lim.s.0, nig 1, strf 1, elas 3, sicc 2+ Ld^{2}1, Lc 3, Tb+
3	291 – 405	Sedge-moss peat, black-brown lim.s.0, nig 3, strf 0, elas 3, sicc 2++, Tb^{2}2, Th^{3}1, Ld^{2}1
2	405 – 450	Clay with an admixture of gyttja, grey brown lim.s.0, nig 2, strf+, elas 0, sicc 2++, As 2, Ag 1, Ld^{2}1, Th+, Lc+
1	450 – 660	Clay, grey, with an admixture of sand lim.s.0, nig 2, strf+, elas 0, sicc 2++, As 2, Ag 2, Th+, Ld+, Lc+
	660 – ?	Sand, grey

Łukcze III. This boring was made in the peatbog a hummock-and-pool structure, at a distance of about 20 m to the west from the lake-shore. It was to be a repetition of profile Ł-II, but the identical location appeared impossible (Fig. 10)*. Detailed description of the profile – Bałaga 1982.

Layer No.	Depth, in cm	Sediment description
10	0 – 20	*Sphagnum* peat, pale brown, weakly decomposed
9	20 – 37	Sedge-moss peat, brown, matted
8	37 – 50	Sedge-moss peat, black-brown, matted
7	50 – 230	Sedge-moss peat, black-brown, of fibrous structure
6	230 – 260	Peaty gyttja, black-brown, of nodular structure
5	260 – 320	Calcareous gyttja, grey-yellow, of nodular structure
4	320 – 340	Calcareous detritus gyttja, grey-brown, of nodular structure
3	340 – 380	Peaty gyttja, brown, of nodular structure
2	380 – 430	Peaty gyttja, brown, of nodular structure
1	430 – 500	Clay, grey-brown, with an admixture of gyttja

* Fig. 10 under the recover.

Łukcze IV. A boring was made about 10 m north of profile Łukcze III (Fig. 11)*.

4	0 – 20	*Sphagnum*-moss peat, pale brown, weakly decomposed lim.s.0, nig 2, strf 0, elas 3, sicc 2, Tb^{1}Sph 2, Th^{1}2, Ld+
3	00 – 35	Sedge-moss peat, dark brown lim.s.0, nig 2, strf 0, elas 3, sicc 2, Tb^{2}1, Th^{2}3, Ld+
2	35 – 80	Sedge-moss peat, black-brown, fibrous lim.s.0, nig 3, strf 0, elas 2, sicc 2, Tb^{2}1, Th^{3}3, Ld++
1	80 – 350	Sedge-moss peat, black-brown, fibrous lim.s.0, nig 3, strf 0, elas 2, sicc 2, Tb^{2}2, Th^{3}2, Ld+
—	350 – ?	Silt, grey, with increasing proportion of sand

Radiocarbon datings

Samples from profiles Łukcze III and IV were radiocarbon dated in the Laboratory of Isotope Chronometry of the Silesian Politechnic University at Gliwice. The age of samples was determined on the basis of C^{14} half-life of 5568 years.

Sample code	Depth, in cm	Lab. No.	Age BP
Łukcze IV			
TŁ-1	48–57	Gd 1177	980 50
TŁ-2	88–97	Gd 1178	6420 70
TŁ-3	175–195	Gd 1179	7790 70
TŁ-5	250–255	Gd 1181	10900 100
TŁ-6	280–290	Gd 1182	10930 90
Łukcze III			
TŁ-4	245–266	Gd 1180	9080 90
TŁ-III/1	340–350	Gd 822	10660 210
TŁ-III/2	375–385	Gd 824	10680 190
TŁ-III/3	400–410	Gd 825	11160 110
TŁ-7	425–430	Gd 1183	12330 160

Physical and chemical properties of Lake Łukcze sediments on the basis of profiles Łukcze III and Łukcze I

Profile Łukcze III (Fig. 12)

Organic matter. The organic matter content ranges between 5.9 and 12% at a depth of 500-450 cm, reaching a maximum of 34.8-71.5% at a depth of 430-410 cm to fall next to 42%. In

* Fig. 11 under the recover.

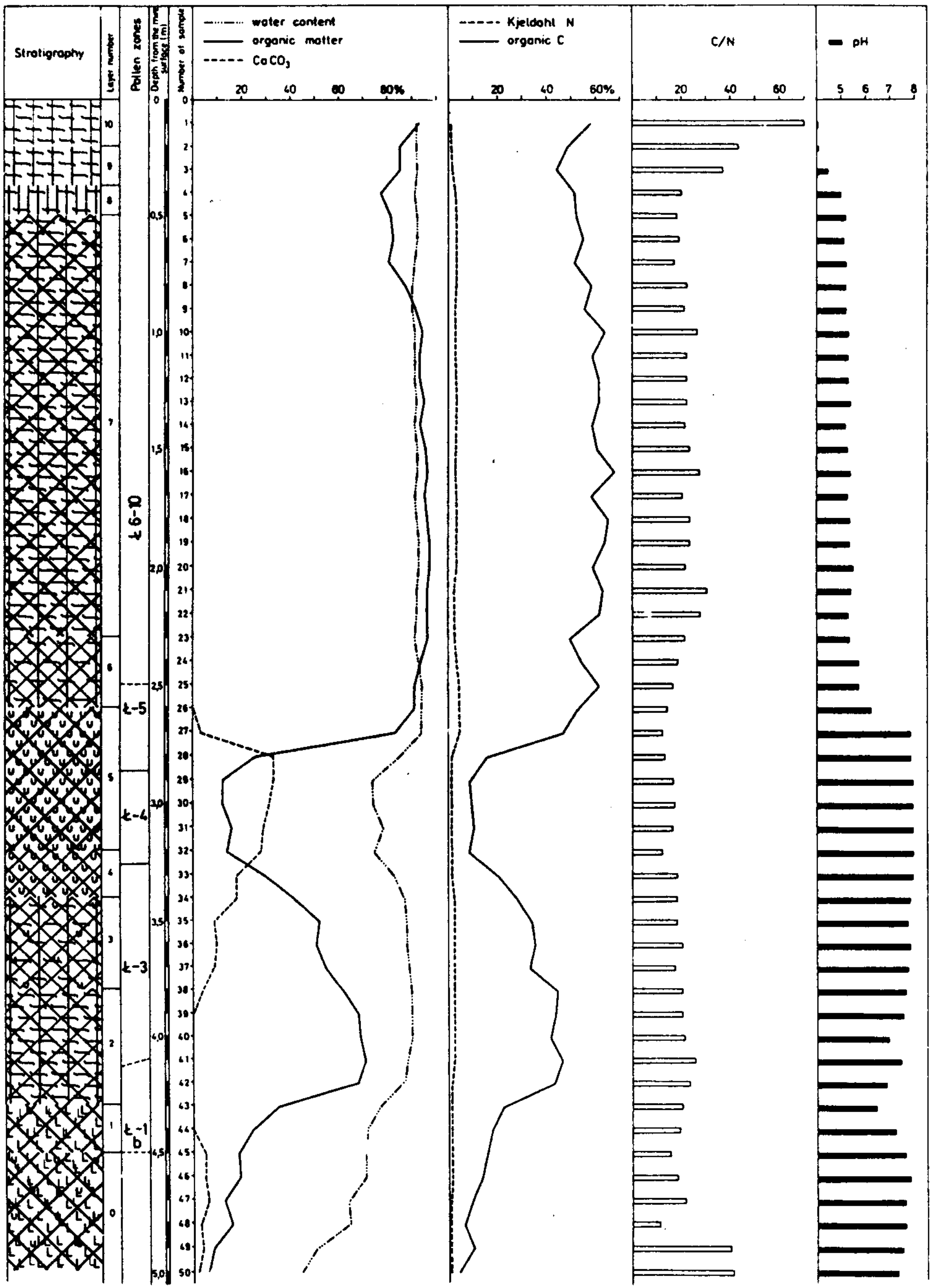

Fig. 12. Profile Łukcze III. Physical and chemical properties of peatbog sediments

the layer of calcareous detritus gyttja (depth: 320-290 cm) the organic matter content is very small (12.2-16.4%); starting from a depth of 280 cm it again grows rapidly, reaching about 90% at a depth of about 260 cm and maintains similar values up to a depth of 70 cm, which indicates a very small silting of the peatbogs. A higher proportion of mineral parts (about 20%) appers only in the top part, at a depth of 70-40 cm, in the layer of sedge-moss peat.

Organic carbon. Organic carbon is positively correlated with the organic matter content. In the bottom part, to a depth of 430 cm, it has low values (4.5-17.1%), which rise at a depth of 430-410 cm (13.0-46.0%) to decrease gradually at 370-320 cm (46.0-20.1%). In the calcareous detritus gyttja at a depth 320-290 cm organic carbon reaches only 2.9-7.2%. From 280 cm up its content increases again to 60%, showing – like organic matter – a small fall in the top part at a depth of 70-20 cm (50.0-40.0%).

Organic nitrogen. The nitrogen content is low throughout the profile. In the bottom layer to 420 cm its value is below 1%. At a depth of 420-340 cm the proportion of nitrogen rises somewhat (1.53-2.07%) and in the calcareous gyttja detritus it falls again to the 1% value. In the sedge-moss peat starting from a depth of 20 cm nitrogen reaches its maxima, without exceeding 4%, though at the top its value falls again below 1%.

C:N. The carbon to nitrogen ratio in the deposit is mainly dependent upon their contents in the deposit – forming plants. Hansen (1961) assumes this ratio to be a sediment type indicator, C:N=10 being the border value between gyttja and dy. In the Łukcze III profile this ratio exceeds 10 and shows the positve correlation with organic carbon and organic matter.

Calcium carbonate. Calcium carbonate was found in two sections of the profile. It occurs in small amounts in the bottom clays at a depth of 500-450 cm (3.2-6.1 %) and at a depth 380-270 cm, where it is a component of peaty gyttja and calcareous detritus gyttja. Its highest value occurs at 320-380 cm (18.9-33.1%).

pH. The pH varies with sediment type and depth. In the mineral bottom part and in the peaty gyttja it is neutral and in the carbonate gyttja slightly basic. From a depth of 260 cm the peats show a weakly acid reaction. This proves that water supply to the peatbog contained a sufficient amount of calcium to neutralize humic acids throughout the period of peat formation.

Water content. In the mineral bottom layer at a depth of 500-430 cm it is 45.0-80.8%. It rises in the peaty gyttja at a depth of 430-320 cm (71.1-92.2%), and next decreases in the calcareous-detritus gyttja (320-280 cm) to about 70% to rise again to 90% in the sedge-moss peat starting from 270 cm.

Profile Łukcze I (Table 1)

Analyses for ignition residue and organic carbon content for profile Ł-I were made only tentatively, in 0.5 m sections (Table 1). The bottom layers of peat show large proportion of mineral matter (36.9%). In the gyttja the proportion of mineral matter ranges from 13.4 to 50.8%, the lowest values being noted at a depth of 4.5-7.5 m (16.1-19.5%) and the highest ones at a depth of 7.5-8.5 m. At a depth of 4.5-1.5 m the proportion of mineral matter is 20-30%.

The organic carbon content shows a negative correlation with the loss on ignition. In the peat it is 46.9% (at a depth of 9.8-10.0 m), in the gyttja 35.7-58.2% (at a depth of 8.5-1.5 m).

Calcium carbonate does not occur in profile Ł-I.

Table 1. The organic-C and organic matter content in profile Łukcze I

Depth m	Organic-C %	Organic matter %
1.5 - 2.0	49.99	69.65
2.0 - 2.5	50.25	71.70
2.5 - 3.0	52.59	73.39
3.0 - 3.5	52.85	76.44
3.5 - 4.0	56.99	81.82
4.0 - 4.5	56.21	79.61
4.5 - 5.0	56.21	83.94
5.0 - 5.5	58.28	86.57
5.5 - 6.0	57.25	84.87
6.0 - 6.5	54.44	81.46
6.5 - 7.0	53.36	78.30
7.0 - 7.5	54.66	80.48
7.5 - 8.0	41.45	57.92
8.0 - 8.5	35.75	49.25
9.0 - 10.0	46.89	63.13
10.0 - 10.2	30.05	37.01
10.7 - 10.8	6.80	9.04

CHANGES OF THE PLANT COVER OF THE LAKE ŁUKCZE REGION

Zonation of pollen diagrams

The pollen diagrams have been divided into biostratigraphic units, termed „pollen assemblage zones", and characterized by the uniform combination of pollen and spore taxa (West 1970,. Briks & Berglund 1979). The names of zones are derived from the dominant or characteristic taxa in the given part of the diagram. Some of the pollen assemlage zones have been divided into subzones. The description of the zones is based mainly on profiles Ł-I and Ł-II and in the postglacial part also on Ł-III (cf. Bałaga 1982). A palaeoecological numerical programme ZONATION was applied to all the four pollen diagrams and thus stratigraphic schemes resulting from the numerical analyses of palynological data were correlated with the stratigraphic divisions based on the traditional method. Their comparison with the traditional divisions suggests a series of interesting inferences. Besides the Blytt-Sernander biostratigraphic system (Środoń 1972) was also used for comparisons with other older diagrams.

Description and correlation of numerical zonation of pollen diagrams

Łukcze I. The results of numerical analyses are presented in Fig. 8 and Table 2. The numerical procedures most distinctly register the boundaries of zones Ł-2/Ł-3, Ł-3/Ł-4, Ł-4/Ł-5, Ł-8/Ł-9 and Ł-9/Ł-10. The differences shown by numerical SPLIT divisions at levels 192-180 in zone Ł-2 (Figs 9 and 13), but not employed in the division of the pollen diagram, are induced by great fluctuations in the pollen frequencies of NAP and *Pinus* and fall in the percentage of *Salix*. The programme CONSLINK joins zones Ł-2 and Ł-3 together. In SPLITSQ and SPLITINF analyses no boundary occurs between zones Ł-5 and Ł-6, whereas the programme CONSLINK joins zones Ł-4, Ł-5 and Ł-6. On the other hand, the Ł-6/Ł-7 boundary is marked by a fairly broad area in three programmes. The Ł-7/Ł-8 boundary is very weakly expressed by numerical data, while a very distinct boundary appers at a depth of 820 cm, where the percentage of *Ulmus* pollen decreases and those of *Betula* and *Tilia* rise, distinguishing the older part of the zone, characterized by large proportions of *Alnus* and *Corylus* pollen. Similarly, the older part of zone Ł-9, with high proportion of *Ulmus* and *Corylus* pollen, is distinguishable in the division of the diagram but only in the description of changes in the vegetation.

In zone Ł-10 SPLITSQ and SPLITINF establish many boundaries of lower orders, whereas CONSLINK joins the levels of the same zone into three larger groups. The boundary between subzones c/d and d/e is the least distinct.

Łukcze II. The results of numerical analyses are given in Fig. 9 and Table 3. The boundaries between zones Ł-0 and Ł-1 a, Ł-1 b and Ł-2, Ł-2 and Ł-3, Ł-3 and Ł-4 as well as Ł-7 and Ł-8 are shown most distinctly by all the three numerical programmes though the boundary between Ł-1 and Ł-2 was originally placed 15 cm higher, in a layer where the changes in the curves for *Pinus*, *Betula* and *Salix* pollen seem to be more conspicuous. The boundary between zones Ł-3 and Ł-4 was originally 10 cm lower, where the proportions of NAP and *Artemisia* pollen show a maximum fall, while the numerical boundary indicates the minimum values of NAP and *Artemisia*. The results of numerical analyses for levels 98-96% (Fig.9) record changes between zones Ł-0 and Ł-1 brought about by a peak of the *Salix* pollen curve. In zone Ł-2 the numerical data record changes caused chiefly by the fluctuations of *Pinus* and *Betula* pollen regarded as local ones. The boundaries between zones Ł-5 and Ł-7 in the Pre-Boreal and Boreal periods are weakly marked in SPLITSQ and SPLITINF, and CONSLINK clearly unites this group of levels. The differences demonstrated inside zone Ł-8 are induced mainly by fluctuations in the frequencies of *Pinus* and *Alnus* pollen, which are due to local rather than regional vegetational changes. In the lacustrine profile (Ł-I), based on more regional pollen values, in comparison with the shore-peatbog profiles, the numerical analyses show no similar changes in this zone.

From a depth of 120 cm CONSLINK isolates a group of levels with the presence of *Carpinus* and *Fagus* pollen and the boundary at a depth of 80-90 cm in SPLITSQ and SPLITINF coincides with the boundary of zones Ł-9 and Ł-10.

Łukcze III. The results of the numerical zonation presented in Fig. 10 and Table 4 confirm the boundaries Ł-1b/Ł-3 and Ł-3/Ł-4, the latter being placed somewhat higher, at a depth of 330 cm. In zone Ł-3 the numerical boundary at a depth of 375 cm, recording a fall in the proportion of *Betula* pollen and an increase in *Pinus*, divides the Younger Dryas into two subzones, a pine part and a birch part, which have not been distinguished in the diagram. The Younger Dryas, thus differentiated, appeared only in this profile. As a littoral profile it probably records local changes in pollen rain. Originally, the upper boundary of the Younger Dryas was placed at the first significant fall in the *Artemisia* pollen values, at a depth of 345 cm, In both SPLIT-s and in CONSLINK this boundary is marked higher, at a depth of 330-325 cm, in place of a maximum fall in the *Artemisia* and *Pinus* pollen frequencies and a rise in *Betula* values.

Table 2. Profile Łukcze I. The results obtained with the SPLIT-s of the programme ZONATION

Sample No.	Depth cm	SPLITSQ	SPLITINF
4	155	11.00	11.09
5	160	10.77	-
11	190	10.20	8.53
13	200	10.49	9.54
16	215	11.67	-
17	220	-	10.70
20	235	9.64	8.93
21	240	12.95	10.16
23	250	8.85	-
26	265	-	9.22
30	285	11.31	9.87
39	330	-	8.28
40	335	-	7.59
44	355	-	7.48
53	400	16.21	-
55	410	-	12.10
61	440	8.74	-
62	445	8.54	-
66	465	13.77	10.89
71	490	27.97	22.80
78	525	7.84	-
80	535	-	13.06
91	590	-	8.17
93	600	51.61	-
95	610	-	39.45
102	645	14.38	11.30
104	655	9.47	-
105	660	24.56	16.49
107	670	26.88	17.26
109	680	-	8.40
110	685	9.14	-
116	715	9.31	9.08
120	735	-	7.26
123	750	8.96	7.94
124	755	17.35	14.21
126	765	-	8.66
129	780	-	8.80
136	815	-	27.50
138	825	32.97	-
142	845	18.46	-
144	855	8.43	12.41
147	870	13.21	9.37
150	885	13.49	15.83
152	895	69.42	-
154	905	-	57.22
156	915	9.82	-
157	920	16.47	9.70
158	925	-	7.70
159	930	10.02	-
160	935	-	13.75
166	965	20.88	21.07
167	970	7.95	-
170	985	8.07	8.05
171	990	8.32	-
172	995	22.71	15.20
173	1000	19.94	12.72
175	1010	36.13	30.17
176	1015	14.04	-
178	1025	15.67	13.39
179	1030	14.75	14.68
182	1045	30.51	7.37
183	1050	-	25.06
184	1055	16.06	-
186	1065	17.87	11.53
187	1070	19.11	11.62
188	1075	23.61	18.37
190	1085	29.15	19.73

Table 3. Profile Łukcze II. The results obtained with the SPLIT-s of the programme ZONATION

Sample No.	Depth cm	SPLITSQ	SPLITINF
3	15	59.68	50.35
4	20	-	14.67
5	25	11.67	-
9	45	-	18.82
15	75	21.60	-
17	85	-	26.95
24	120	8.94	12.89
25	125	-	12.24
27	135	10.87	19.81
30	150	9.68	10.69
33	165	17.91	11.24
37	185	9.30	10.21
38	190	19.15	16.16
41	205	17.20	13.45
44	220	52.84	-
46	230	-	65.52
49	245	26.69	14.02
56	280	20.81	8.80
57	285	36.08	30.33
59	295	-	17.84
60	300	12.80	-
67	335	23.43	23.25
72	360	16.58	9.17
74	370	15.11	-
75	375	-	9.81
77	385	14.24	21.07
78	390	13.41	-
79	395	27.24	-
81	405	-	11.33
85	425	72.45	39.34
92	460	12.22	24.83
96	480	11.18	15.36
97	485	19.92	16.99

The other distinct numerical boundaries occur at a depth of 295-285 cm, at a level where the proportion of *Betula* pollen falls and those of *Pinus* and *Ulmus* rise. The corresponding boundary was originally marked at a depth of 265 cm only where *Corylus* pollen appears, its proportion being a distinctive feature of zone Ł-5. The numerical boundary is marked in this palce less distinctly (Table 4).

Łukcze IV. The results of the numerical zonation (Fig. 11 and Table 5) establish distinct boundaries between zones Ł-2 and Ł-3, Ł-5 and Ł-6 and Ł-7 as well as between Ł-7 and Ł-8. The boundary corresponding with the lower boundary of the Younger Dryas is placed 15 cm higher, in the place where the frequencies of NAP, *Cyperaceae* and *Artemisia* pollen show a maximum rise and *Pinus* values fall. Originally it was based on the first increase in the *Artemisia* pollen frequencies. The boundary between Ł-3 and Ł-4 is marked only by SPLITINF, and SPLITSQ and SPLITINF do not show any boundary between Ł-4 and Ł-5, which is marked only by CONSLINK. In zone Ł-8 the numerical data show a number of differences, which were not taken into account in the division of the diagram: they record local changes in the pollen values of *Alnus*, *Pinus* and *Gramineae*, and are lacking in the profile from the lake centre. The numerical boundaries at a depth of 50-70 cm agree with that of zones Ł-8 and Ł-10.

Table 4. Profile Łukcze III. The results obtained with the SPLIT-s of the programme ZONATION

Sample No.	Depth cm	SPLITSQ	SPLITINF
1	250	22.82	13.01
3	260	12.86	-
4	265	-	11.15
8	285	28.25	-
10	295	9.70	21.39
14	315	11.46	17.78
16	325	36.63	9.00
17	330	14.32	60.95
26	375	42.02	26.17
33	410	17.74	32.00
34	415	61.06	10.06
36	425	-	14.74
39	440	-	7.95
40	445	8.82	-

Table 5. Profile Łukcze IV. The results obtained with the SPLIT-s of the programme ZONATION

Sample No.	Depth cm	SPLITSQ	SPLITINF
3	15	72.10	69.50
6	30	-	22.53
9	45	19.88	-
12	65	22.48	17.75
14	80	-	42.10
17	100	37.44	-
19	120	29.00	-
20	130	32.94	-
21	140	-	31.25
23	160	42.54	20.15
25	180	46.55	25.28
26	190	25.29	52.32
31	240	-	35.87
34	270	58.85	28.17

Discussion. The numerical procedures confirmed more or less distinctly most of the stratigraphical boundaries fixed by the traditional method. The numerical boundaries are sometimes shifted somewhat higher or lower than the original boundaries, for they often show the minimum or maximum pollen values, whereas the traditional division takes into cosideration the first increase or decrease of those values (e.g. the Ł-3/Ł-4 and Ł-4/Ł-5 boundaries in profiles Ł-II and Ł-III).

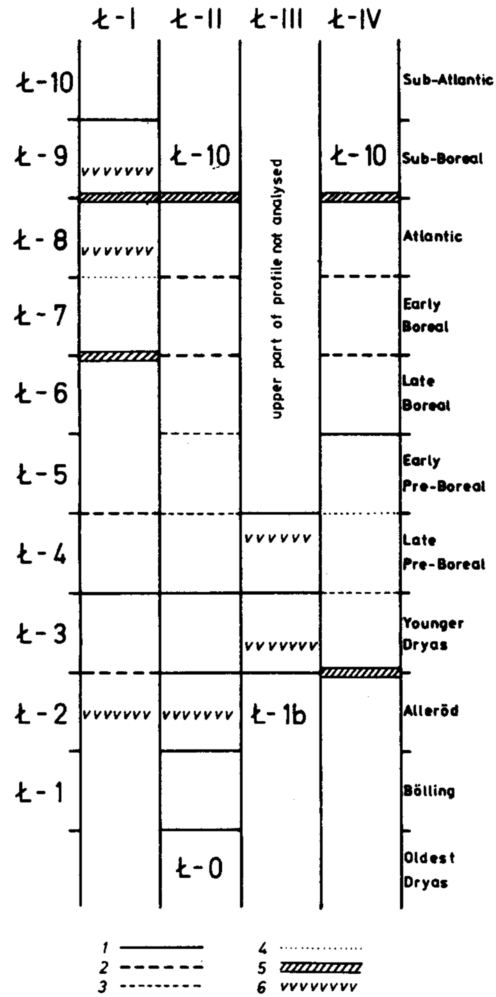

Fig. 13. A comparison of the boundaries distinguished by the numerical methods in particular profiles and their correlation: 1- three distinct boundaries or two distinct + one weakly marked, 2 — two distinct boundaries or one distinct + two weakly marked, 3 — one distinct boundary or one distinct + one weakly marked, 4 — weakly marked boundaries, 5 — boundaries marked by a transitional zone, 6 — boundaries distinguished by numerical analyses but not shown in pollen diagrams

In comparison with the lake profile Ł-I, more boundaries expressed by higher SPLIT values were obtained in the lake-shore peatbog profiles (Ł-II, III and IV), which would indicate that the shore profiles record rather local changes in pollen rain. This is also demonstrated by a comparison of the numerical boundaries of particular profiles (Fig. 13). In the lake profile no numerical boundary was established between zones Ł-5 and Ł-6, i.e.between the Younger Pre-Boreal and Older Boreal, while the boundary between zones

Ł-6 and Ł-7, or between the Older and the Younger Boreal occurs as a broad area in all the three programmes. However these boundaries were distinguished by numerical analyses in the peatbog profiles. This difference may be statistically explained by the then still small changes in the *Ulmus*, *Corylus* and *Alnus* pollen curves in the lake profile recording more regional pollen values.

Many additional boundaries, not distinguished with traditional division, have also been marked by numerical procedures. However, not all these boundaries seem to be significant. Some changes in the pollen curves reflect rather local than regional vegetational changes (e.g. numerical boundaries in zone Ł-2 in profiles Ł-I and Ł-II or in zones Ł-4 and Ł-5 in profile Ł-III). On the other hand, the numerical boundaries in zones Ł-8 and Ł-9 in profile Ł-I, delimiting the older and younger parts of the Sub-Boreal, should be accepted. This change was mentioned only in the description of vegetational changes, and was not marked in the pollen diagrams.

Description of pollen assemblage zones (PAZ)

Zone Ł-0 *Artemisia-Salix* PAZ Ł-II (500.0-477.5 cm)

This zone has been described only from profile Ł-II (cf. Bałaga 1982). It is characterized by a high proportion of herb and shrub pollen. *Artemisa* (max. 14.5%), *Cyperaceae* (max. 17.7%), *Gramineae* (max. 12.7%), *Ranunculus*, *Chenopodiaceae* and *Helianthemum* type pollen dominate in NAP sum. *Salix* is the main component of shrub pollen, with a maximum of about 22% at a depth of 485 cm followed by a rise of the *Betula* curve. Preliminary measurements showed that *Betula* pollen exceeding 25 μ in size prevailed. Aquatic plants are represented chiefly by *Myriophyllum verticillatum/spicatum* (2.0-8.0%) and considerable amounts of *Pediastrum* (42%).

The upper boundary of the zone is placed at the rise in *Betula* pollen, the fall of *Salix* values and the apperance of *Hippophaë* pollen.

Zone Ł-1 *Betula-Salix* PAZ

Betula and *Salix* pollen is dominant. *Hippophaë* pollen appears. The proportion of *Pinus* pollen is lower than in the preceding zone. The sum of herb pollen contains above all *Cyperaceae*, *Gramineae*, *Artemisia*, *Ranunculus*, *Thalictrum*, *Chenopodiaceae* and *Helianthemum*. Two subzones, a and b, have been distinguished in profile Ł-II, subzone Ł-1a being absent from Ł-III.

Subzone Ł-1a *Hippophaë- Ranunculus* PASZ Ł-II (477.5-452.5 cm)

Betula values increase, while the fall in NAP percentages is caused by the decrease in *Artemisia*, *Cyperaceae* and *Gramineae* pollen. *Hippophaë* has its maximum values (0.6-1.9%), its occurence being restricted to zone Ł-1 only. *Typha latifolia* pollen (max. 2.7%) appears. *Myriophyllum verticillatum/spicatum* pollen is still present but in lower frequencies (2.3%) than in the preceding zone.

The upper boundary is placed at the increase of *Salix* pollen, the fall in *Hippophaë* values and the rise of *Thalictrum*.

Subzone Ł-1b *Hippophaë-Thalictrum* PASZ Ł-II (452.5-417.5 cm), Ł-III (450.0-412.5 cm)

This subzone is found in two profiles only. Values of *Betula* pollen fall and those of *Pinus* rise, while *Thalictrum* pollen proportion reaches a maximum (1.7%). *Salix* pollen values increse and *Hippophaë* pollen occurs only sporadically. Small quantities of *Juniperus* pollen were found in profile Ł-II. *Cyperaceae* and *Gramineae* have the highest pollen values in the NAP sum. The proportion of *Typha latifolia* and *Myriophyllum* pollen does not exceed 1%.

The upper boundary of the zone is placed at the rise of *Pinus* pollen and the fall of *Betula* and *Salix*.

Zone Ł-2 *Pinus* — *Betula* PAZ Ł-I (1052.5-1027.5 cm), Ł-II (417.5-342.5 cm)

This zone was not observed in profile Ł-III. *Pinus* pollen is dominant, birch pollen values show a gradual decrease. The herb pollen sum reaches relatively high frequencies, especially in the lake profile, Ł-I, (up to 60.4%), with *Cyperaceae* pollen dominant. *Artemisia* pollen occurs in small amounts and proportions of shrub pollen decline: *Juniperus* and *Populus* appear sporadically and *Salix* values are below 1%, except for the older part of the zone in Ł-I, where percentages of *Salix* and *Juniperus* are higher. *Typha latifolia*, *Nymphaea alba*, *N. candida* and *Nuphar* sp. pollen appears.

The upper boundary is placed where *Artemisia* and NAP values increase. This level (depth 375-385 cm) was radiocarbon dated at 11 160 + 110 BP.

Zone Ł-3 *Pinus-Artemisia* PAZ Ł-I (1027.5-1002.5 cm), Ł-II (342.5-297.5 cm), Ł-III (412.5-332.5 cm), Ł-IV (287.5-245.5 cm)

Hight proportions of Artemisia pollen are a characteristic feature of the zone. They reach maxima of 20.4, 13.3, 13.7 and 9.8% in respective profiles. Pollen values of Salix, Chenopodiaceae, Helianthemum sp., Gypsophila fastigiata pollen also increase. Pinus pollen predominantes, showing however a downward tendency, the birch curve ascends. Larix, Populus and Ulmus pollen appear sporadically. Typha latifolia, Typha angustifolia/Sparganium, Myriophyllum spicatum/verticillatum pollen is present. There are four radiocarbon dates for this zone in profiles Ł-III and Ł-IV. In profile Ł-III, the first rise in Artemisia was dated at 11 160+ 100 BP (depth 375-385 cm), the rise of birch and the fall of pine at 10 680+ 190 BP (depth 340-350 cm). In profile Ł-IV the dates were 10 930+ 90 BP at the increase of Artemisia pollen (depth 280-290 cm) and 10 900 100 BP at its fall (depth 250-255 cm).

The upper boundary is placed at the fall in frequencies of *Pinus* and NAP and the rise in *Betula* pollen values.

Zone Ł-4 *Betula-Ulmus* PAZ Ł-I (1002.5-972.5 cm), Ł-II (287.5-257.5 cm), Ł-III (332.5-282.5 cm), Ł-IV (245.0-225.0 cm)

The dominance of *Betula* pollen and a gradual increase in proportions of *Ulmus* pollen are characteristic of this zone. Values of *Pinus* pollen fall. Proportions of herb pollen are cosiderably reduced, particularly those of *Artemisia* and *Cyperaceae*. There are high percentages of *Filipendula* pollen most distinctly marked in profile Ł-I (6.3%). Proportions of *Polypodiaceae* spores rise.

The upper boundary is placed at the appearance of *Corylus* pollen.

Zone Ł-5 *Betula-Ulmus-Corylus* PAZ Ł-I (972.5-942.5 cm), Ł-II (257.5-232.5 cm), Ł-III (282.5-250.0 cm), Ł-IV (225.0-195.0 cm)

This zone is characterized by the appearance and next the rise of *Corylus* values. Proportions of *Ulmus* pollen in the lake profile increase consistently, whereas in the peatbog profiles they show a small fall. *Quercus* and *Fraxinus* pollen appear sporadically.

The upper boundary is placed at the rise of *Corylus* pollen, radiocarbon dated at 9080±80BP.

Zone Ł-6 *Pinus-Corylus-Ulmus* PAZ Ł-I (942.5-897.5 cm), Ł-II (232.5-212.5 cm), Ł-IV (195.0-185.0 cm)

Corylus pollen reaches its first maxima of 19.6% in profile Ł-I and 5.7% in profile Ł-II. *Alnus* pollen appears. Pollen percentages of other thermophilous species, like *Quercus*, *Fraxinus* and *Tilia* rise. *Pinus* pollen is increasingly dominant while birch values show a fall.

The boundary between zones Ł-6 and Ł-7 is placed at the fall of *Corylus* pollen.

Zone Ł-7 *Pinus-Alnus-Quercus* PAZ Ł-I (897.5-857.5 cm), Ł-II (212.5-192.5 cm), Ł-IV (185.0-175.0 cm)

Pinus pollen predominates, while *Betula* and *Corylus* values decline. Proportions of *Alnus* and *Quercus* pollen rise and so do frequencies of *Tilia* and *Fraxinus* pollen, whose values do not exceed 4% and in the peatbog profiles are still smaller.

The upper boundary is placed where *Corylus* values increase and *Pteridium aquilinum* appears. This level in profile Ł-IV was radiocarbon dated at 7790±70 BP at a depth of 195-175 cm.

Zone Ł-8 *Corylus-Quercus-Ulmus-Tilia* PAZ Ł-I (857.5-662.5 cm), Ł-II (192.5-80.0 cm), Ł-IV (175.0-80.0 cm)

Betula pollen is dominant in the lake profile, its values in the peatbog profiles being lower than those of *Pinus*. The dominance of *Corylus*, *Ulmus* and *Tilia* is characteristic of this zone. These species reach higher frequencies in the lake profile than in the peatbog profiles. *Carpinus* and *Fagus* pollen appears in the upper part of the zone, first as single grains, and next continuously. The beginning of the continuous curves for these species was dated at 6420 70BP. *Viscum* and *Acer* pollen appears sporadically. In the peatbog profiles *Gramineae* pollen is an important constituent of the NAP sum. This is presumably due to the contribution of *Phragmites* pollen, which was not separated from *Gramineae* pollen. The peatbog profiles are also characterized by considerable values of *Polypodiaceae*, *Dryopteris thelypteris* and *Pteridium aquilinum* spores. The first pollen grains of *Plantago lanceolata* and *Cerealia* were also noted here.

The upper boundary can be distinguished only in the lake profile, and is placed at the fall of *Ulnus* pollen and the rise of frequencies of *Pinus* pollen.

Zone Ł-9 Ł-I *Pinus-Quercus-Picea* Ł-I (662.5-492.5 cm)

This zone was distinguishable only in the lake profile Ł-I. *Pinus* and *Quercus* pollen predominates in it. Proportions of *Carpinus* and *Fagus* also rise, whereas frequencies of *Ulmus* and *Corylus* decrease. Frequencies of *Picea* pollen, very low throughout the profile, reach maximum values (to 3%). *Acer* and *Viscum* pollen occurs occasionally. Frequencies of anthropogenic pollen indicators: *Plantago lanceolata*, *Rumex*, and *Cerealia* increase as well. Besides dominant *Gramineae* and *Cyperaceae* pollen, *Calluna vulgaris* pollen is represented more abundantly.

The upper boundary is placed at the rise in *Carpinus* pollen frequencies.

Zone Ł-10 *Pinus-Quercus-Carpinus* PAZ Ł-I (482.5-140.0 cm), Ł-II (80.0-0.0 cm), Ł-IV (80.0-0.0 cm)

This zone has been described from the lake profile, and its fragments representing historical times from 980±50 BP onwards are present in the peatbog profiles. It is characterized by the dominance of *Pinus* and *Quercus* pollen. The zone has been subdivided into 6 subzones, recording changes in anthropogenic indicators and *Carpinus* pollen values (Tables 6 and 7).

Subzone Ł-10a (482.5-467.5 cm)

Percentages of *Carpinus* pollen rise, being accompanied by a small increase in *Fagus*, *Ulmus*, *Fraxinus* and *Tilia* and a fall in *Corylus*, *Betula* and NAP pollen frequencies.

Subzone Ł-10b (467.5-402.5 cm)

Carpinus, *Ulmus*, *Fraxinus* and *Pinus* pollen values fall and those of *Corylus*, *Betula* and NAP rise, particulalry of *Gramineae*, *Artemisia*, *Plantago lanceolata*, *Rumex*, *Calluna vulgaris* pollen and *Pteridium aquilinum* spores.

Subzone Ł-10c (402.5-375.5 cm)

Carpinus, *Ulmus*, and *Pinus* pollen percentages rise, those of *Betula* and NAP decrease. Proportions of anthropogenic taxa average 1.8%, *Cerealia* pollen occurs singly.

Subzone Ł-10d (375.5-297.5 cm)

Carpinus pollen values show conspicuous fluctuations and are lower than in the preceding subzone. Towards the end of subzone the *Quercus* declines and *Betula*, *Pinus* and *Picea* pollen values rise. *Rumex*, *Calluna vulgaris*, *Umbellifereae*, *Ledum* pollen and *Polypodiaceae* and *Sphagnum* spores attain higher values. *Plantago lanceolata* and *Rumex* dominate among synanthropic plants (averaging 2.2%).

Table 6. Mean and maximum percentage values of the chosen taxa in the distinguished subzones of zone Ł-10

Genera / Subzones	a 492.5 - 467.5		b 467.5 - 402.5		c 402.5 - 357.5		d 357.5 - 297.5		e 297.5 - 225.5		f 225.5 - 140.0	
	mean%	max.%	mean%	max.%	mean%	max.%	mean%	max.%	mean%	max.%	mean%	max.%
Pinus	25.0	30.5	19.4	25.0	25.4	31.0	27.0	39.7	23.4	30.7	26.5	36.8
Betula	14.4	14.8	16.5	19.0	13.6	15.0	15.0	19.0	14.5	17.9	15.4	18.7
Alnus	6.8	7.8	8.2	10.6	7.7	10.5	7.9	10.8	8.5	10.3	7.8	10.5
Ulmus	4.0	4.4	2.5	3.5	2.8	5.0	2.4	3.5	2.5	4.5	1.8	2.7
Corylus	4.2	7.1	4.7	8.6	5.7	5.8	4.9	7.7	4.1	7.8	5.3	7.1
Quercus	17.0	20.1	16.9	19.3	18.5	19.5	16.5	23.5	19.2	25.0	16.5	20.5
Fraxinus	2.6	3.5	1.9	3.2	1.6	2.9	1.3	3.2	1.2	2.8	1.1	1.5
Tilia	1.1	1.5	1.2	2.0	0.8	1.5	0.7	1.3	0.8	1.5	0.7	1.4
Carpinus	11.0	14.7	8.9	16.3	9.0	11.5	7.7	10.2	14.6	18.0	8.5	14.9
Fagus	2.5	4.3	2.7	5.0	2.3	4.0	2.8	4.3	3.5	4.6	3.8	6.2
NAP	9.2	11.6	11.8	17.5	10.3	16.0	12.7	17.8	7.2	9.7	11.2	17.7
Gramineae	3.5	4.8	4.9	7.6	4.7	7.8	5.7	9.5	2.7	5.1	4.5	6.9
Cyperaceae	1.3	1.7	2.6	3.1	1.5	3.0	1.9	3.4	1.1	3.0	1.4	2.8

Subzone Ł-10e (297.5-222.5 cm)

Carpinus and *Quercus* pollen values rise and those of *Pinus*, *Betula* and *Corylus* decrease. Proportions of culture indicators fall and average 1.05%.

Subzone Ł-10 f, Ł-I (222.5-140.0 cm), Ł-II (80.0-0.0 cm), Ł-IV (70.0-0.0 cm)

This subzone is characterized by a fall in *Carpinus*, *Quercus* and *Ulmus* pollen frequencies. *Betula* and *Corylus* pollen and NAP is increasingly dominant. Culture indicators form 2.7%,with *Plantago lanceolata* and *Rumex* attaining the highest proportions. *Centaurea cyanus* and *Fagopyrum* pollen appears in the peatbog profiles.

Table 7. Mean percentage values of pollen of *Fagus* and synanthropic taxa in particular subzones of zone Ł-10

Genera / Subzones	a	b	c	d	e	f
Artemisia	1.26	0.17	1.60	1.53	0.92	1.74
Plantago lan.	0.30	0.43	0.02	0.28	0.02	0.74
Rumex	0.16	0.31	0.17	0.43	0.08	0.31
Ceiealia	0.12	0.03	0.02	0.05	0.03	0.16
Carpinus	11.03	8.99	9.03	7.71	14.60	8.46

Plant macrofossils

The results of plant macrofossil analysis of profile Ł-II are presented in Fig. 14. The list of taxa identified is rather poor, nevertheless, it was possible to distinguish several zones differing in plant macrofossil content. They were termed macrofossil assemblage zones (MAZ).

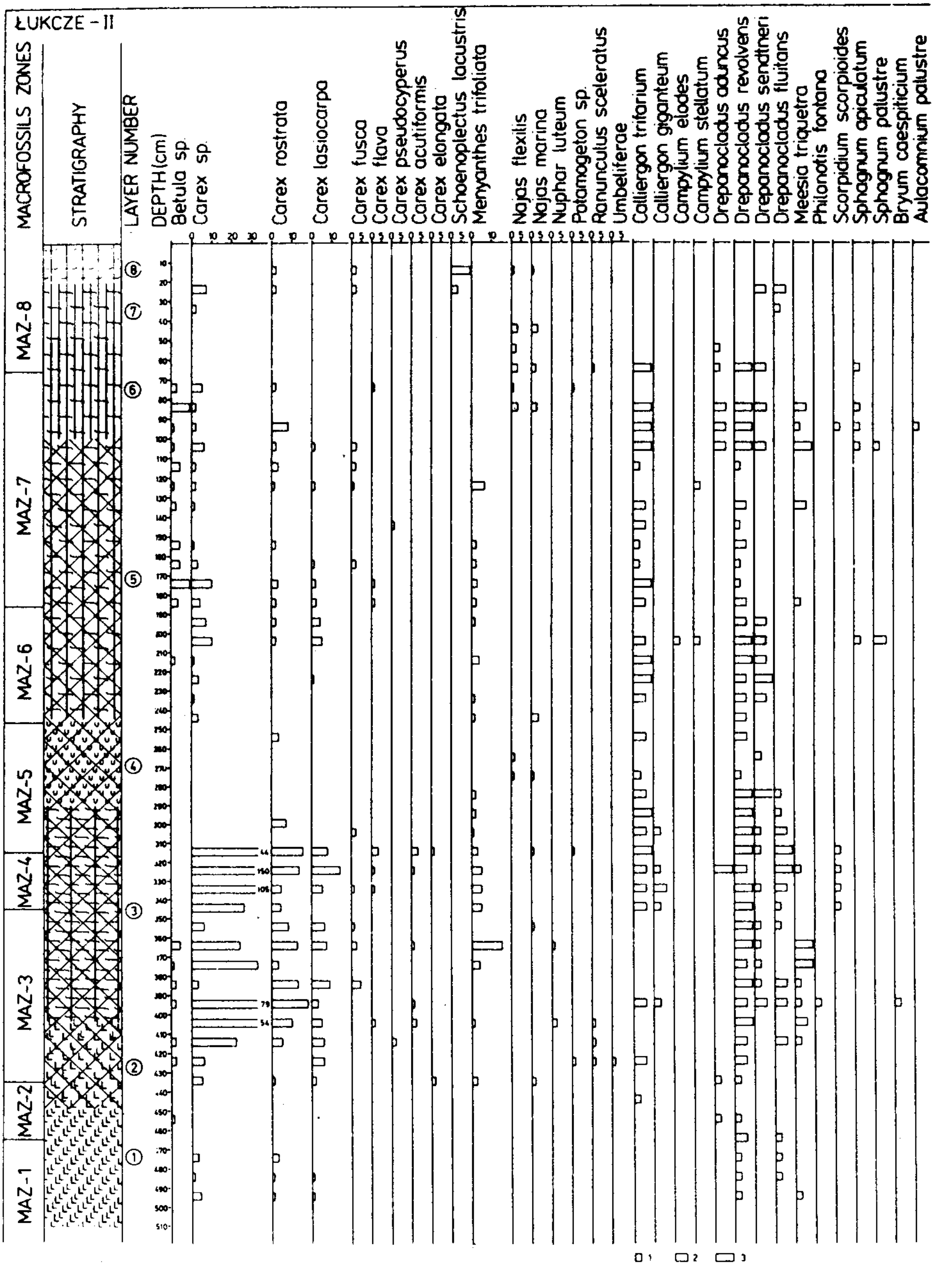

Fig. 14. Profile Łukcze II. Macrofossil diagram: 1 — specimens occurring singly, 2 — moderately abudantly, 3 — very abudantly

Ł-1 MAZ (500.0-465.5 cm)

This zone is characterized by the dominance of mosses *Drepanocladus revolvens* and *D. fluitans*, the sedges *Carex rostrata* and *C. lasiocarpa* being also present.

Ł-2 MAZ (465.5-435.0 cm)

Contribution of mosses decline. There are single specimens of *Calliergon trifarium*, *Drepanocladus aduncus* and *D. revolvens*. No nutlets of sedges were found and only one nutlet of *Betula sec. albae*.

Ł-3 MAZ (435.0-345.0 cm)

High proportions of various moss and sedge species and *Betula* nutlets. Macrofossils of *Drepanocladus revolvens*, *Meesia triquetra*, *Carex rostrata*, *C. lasiocarpa*, *Menyanthes trifoliata*, *Potamogeton* sp. and *Nuphar luteum* attain the highest amounts.

Ł-4 MAZ (345.0-315.0 cm)

Scorpidium scorpioides appears. *Carex lasiocarpa*, *C. rostrata*, *C. fusca*, *C. acutiformis* and *Menyanthes trifoliata* occur in abundance.

Ł-5 MAZ (315.0-245.0 cm)

The numbers of sedge and moss taxa decrease. *Najas flexils* and *N. marina* are present.

Ł-6 MAZ (245.0-185.0 cm)

The brown mosses *Drepanocladus revolvens*, *D. sendtneri*, *Calliergon trifarium* as well as *Carex* sp. and *Menyanthes trifoliata* are prominent.

Ł-7 MAZ (185.0-65.0 cm)

Calliergon trifarium, *Drepanocladus revolvens* and *Meesia triquetra* predominate in this zone. Here also occurs the highest proportion of *Betula* nutlets.

Ł-8 MAZ (65.0-0.0 cm)

Frequencies of moss and sedge macrofossils diminish. *Najas flexilis*, *N. marina* and *Schoenoplectus lacustris* are present.

Regional history of vegetation

Zone Ł-0 PAZ. The landscape of the studied region at the time of lake formation was a treeless tundra with clusters of willows and, probably, shrub birches. *Betula* pollen corresponding in size with *Betula* sect. *albae*, comes probably from not very distant areas where tree birches begin to spread gradually, not appearing however in the vicinity of Lake Łukcze before the next zone. Loose patches of steppe vegetation with various species of *Artemisia*, *Chenopodiaceae*, *Ranunculus* and *Helianthemum* developed in dry and sandy places.

The lake was then shallow with dominant *Myriophyllum spicatum/verticillatum* and *Pediastrum*. The development of *Pediastrum* was most abundant in the terminal stage of overgrowing of the open water surface. Sedge-moss mires with *Drepanocladus revolvens*, *D. fluitans* and *Meesia triquetra* and *Carex rostrata*, and *C. lasiocarpa* developed in the marginal depressions around the lake. The high ignition residue of the peat indicates rather open plant cover. Zone Ł-0 may correspond to the Oldest Dryas, which period has been recorded from a small number of sites in Poland (Koperowa 1958, Tobolski 1966, Wasylikowa 1964). Its vegetation most resembles phase I-a of the Oldest Dryas at Witów (Wasylikowa 1964, the presence of *Myriophyllum verticillatum/spicatum* and *Filipendula* suggests that the mean July temperature was not lower than 10°C (Cleveringa et al. 1977).

The high values of *Cyperaceae* and *Pediastrum* may evidence a low water level and so a rather dry climate with low precipitation.

Zone Ł-1 PAZ. The Lake Łukcze region was gradually occupied by tree birches, which is expressed by a rise in the *Betula* pollen curve and appearance of its macrofossils. The areas of open communities with *Artemisia* had diminish. At the Ł-0/Ł-1 transition there is a high rise of *Salix* pollen (22%) and *Hippophaë* appears at once in high values. Such phenomena are frequently observed at the transition to interstadial forest phases in the late glacial (Lang 1971, Wegmüller 1972, Welten 1972, Ralska-Jasiewiczowa 1980). This zone should presumably be referred to the Bölling.

Subzone Ł-1 a PASZ. The landscape of the Lake Łukcze region had changed into park tundra with a considerable contribution of tree birches. That was probably a period of the tree-line shifting to the north, which line was presumably formed by *Betula pubescens*, as in Central Poland (Wasylikowa 1964). This statement finds however no support from direct evidence, for the only *Betula* sect. *albae* nutlet found here was not identifiable to species. Towards the end of this zone and at the begining of the next one groups of birches expanded on larger areas. The proportion of steppe-like communities, in which the sea buckthorn was prominent, decreased on sandy habitats, indicating the approaching forest limit. Depressions in wet places supported peatbog communities, in which calciphilous and eutrophic mosses, like *Drepanocladus revolvens*, *D. aduncus*, *D. fluitans* and *Meesia triquetra* as well as *Equisetum* played an important role. In the communities of aquatic plants the proportion of *Myriophyllum* decreased and *Typha latifolia* appeared, which may indicate an improvement in climatic conditions (Iversen 1954). *Typha latifolia* pollen was found in the Bölling layer at Witów (Wasylikowa 1964) and in the older part of pre-Alleröd period in Lake Mikołajki (Ralska-Jasiewiczowa 1966). According to Wasylikowa (1964) the presence of *Typha latifolia* indicates the July temperature of the Bölling in Central Poland at about 15°C.

Subzone Ł-1 b PASZ. In this subzone the birch attained a maximum of its expansion dated at 12 330 years BP: afterwards its role began to diminish in favour of willow thickets, which spread again. The diagram shows some rise in *Gramineae* pollen and also a transitional rise in *Cyperaceae*. The increase of *Cyperaceae* and *Gramineae* values and the fall of those of *Betula* and *Hippophaë* was often interpreted as resulting from a cooling in the Older Dryas. Wasylikowa (1964) assumes the mean July temperature at 10-12°C basing on the occurence of *Ceratophyllum*, *Betula pubescens* and *Hippophaë*. In the diagrams from Lake Łukcze the presence of *Typha latifolia*, steeply rising *Pinus* curve and relatively low values of NAP together with the declining frequencies of *Artemisia* do not permit us to accept a similar interpretation. The changes in these curves do not suggest any climatic cooling at that time.

The presence of *Pleurospermum austriacum* shows that the mean January temperature was not higher than -2°C (Iversen 1954, Środoń 1970). The rise of *Cyperaceae* and *Gramineae* pollen and the fall of *Myriophyllum* frequencies may be due to the fact that the lake with an open water surface was being overgrown and a peatbog developed. This may be evidenced by the presence of *Carex lasiocarpa*, *C. rostrata*, *Menyanthes trifoliata* as well as of some species of *Thalictrum* and *Filipendula cf. ulmaria*. The high *Gramineae* curve may include undistinguished pollen of *Phragmites*, for reeds centrainly contributed to the lake overgrowing in its initial phase. Verbruggen (1977) records the occurrence of such rather thermophilous species as *Typha latifolia*, *Nymphaea alba* and *Nuphar luteum* in Belgium from Bölling and Alleröd, finding no cooling of the Older Dryas and suggesting that only the Younger Dryas represents a climatic regress. On the other hand, the decrease in *Betula pubescens* and *Hippophaë* and the rise of NAP in the Older Dryas sites in Denmark was explained by Kolstrup (1982) by an increasing drought, changes in the prevailing wind directions and resulting soil processes rather than low summer temperatures. Pennington (1977), in her study carried out in western England, assumes a continuous improvement in climatic conditions from about 13 000 BP for ca 2000 years, and defines this period, including the Bölling and Alleröd, as the Windermere interstadial. Studies on the ^{18}O isotope content in the late-glacial carbonate deposits in Switzerland and France carried out by Eicher & Siegenthaler (1976) and Eicher (1980) and Eicher et al. (1981), show no cool phase between the Bölling and the Alleröd. The distinct temperature changes are indicated at the transition from the Oldest Dryas to the Bölling (warming) and from the Alleröd to the Younger Dryas (cooling). The evidence of the Older Dryas cooling lacks also from the profiles from the Alps and the Swiss Plateau (Bortenchlager 1976, Ammann et al. 1984). Keeping in mind the climatic differences between the study area and the areas quoted, especially the maritime climate of Belgium and England an alternative interpretation may also be offered: If we find that the date 12 330 years BP is old owing to the reservoir effect (Donner et al. 1971), zones Ł-0 and Ł-1 may represent a birch phase of Alleröd. The inclusion of this diagram section into the Bölling was to a great degree dictated by the high birch pollen values. However, the Bölling can also be characterized by the presence of pine what is the case in western Poland (Tobolski 1966, 1977, Borówko-Dłużakowa 1969, Krajewski & Balwierz 1985), which is connected with the edaphic and hydrological conditions.

Zone Ł-2 PAZ. Pine forests with a gradually decreasing contribution of birch expanded in this zone. Birch-willow communities occurred probably in more wet places, but the role of willow in this zone was much smaller then in the preceding one. *Populus* (presumably *P. tremula*) may have occurred in both these types of communities. The development of pine forests led to a futher reduction in area occupied by heliophyte communities. The generally high ground water level in the lake district areas favoured the development of peatbogs (Więckowski & Wojciechowski 1971, Bałaga et al. 1983). These were mostly eutrophic sedge — moss mires with *Drepanocladus revolvens, D. sendtneri, D. fluitans, Calliergon giganteum*, with a high contribution of *Meesia triquetra*, and the sedges *Carex rostrata, C. fusca, C. flava* and *C. lasiocarpa* as well as *Scirpus sylvaticus* and *Menyanthes triofoliata*. According to Rybniček (1973), the plants of mesotrophic mires like *Meesia triquetra* and *Carex cf. fusca* indicate habitats undisturbed for a fairly long time. *Myriophyllum* was not recorded in the communities of aquatic plants, whereas there appeared *Nymphaea alba* and *Nuphar* sp., regarded as indicator plants of a milder climate. This zone can be correlated with the Alleröd.

An older part with the dominance of birch and a younger one with the dominance of pine are often distinguished in the Alleröd. In the study area the pine played the main role throughout the period and its fast expansion at the begining of the zone may suggest fairly high temperatures. A similar situation, the dominance of pine with contribution of birch, has been found for this period by Artiuszenko (1975) in the profiles from the lakes Makowicz and Swiatoje in the eastern part of Polesie belonging to USSR. According to Wasylikowa (1964) the occurence of *Typha latifolia* and *Nymphaea alba* in the Alleröd of Central Poland indicates the mean temperatures of only July at about 16°C and of January not below -4°C. The presence of both those indicator species in the sediments of Lake

Łukcze at the begining of Alleröd would indicate that at that time the temperatures in Lublin Polesie were similar. Nevertheless, allowing for the situation of the study area in relation to Central Poland it should be assumed that the climate of Lublin Polesie was more continental.

Zone Ł-3 PAZ. This period was characterized by a parkland landscape with dominant steppe-like communities, in which species of *Artemisia* and *Chenopodiaceae* played the essential part. They were accompanied by *Heliantheum* sp. and *Gypsophila fastigiata*. The trees — *Pinus*, *Betula* and *Larix* — occurred singly. Fens composed chiefly of sedges, horsetails and mosses developed in wet places. An increased proportion of *Calliergon trifarium* and *C. giganteum* as well as the new species *Scorpidium scopioides* were recorded from these communities. Nowadays in Central Europe the communities composed of such brown mosses as *Scorpidium scorpioides*, *Drepanocladus revolvens* and *D. sendtneri* are regarded as relict communities (Jasnowski 1957, 1959, Karczmarz 1963, Rybniček 1973). This zone may be correlated with the Younger Dryas. The recession of forests and spread of herb communities indicates a considerable deterioration of climatic conditions. The relatively low values of *Juniperus* pollen, as compared with the diagram from other parts of Poland (Wasylikowa 1964, Ralska-Jasiewiczowa 1966, Tobolski 1966, 1977, Hjelmroos 1981, Latałowa 1982, Noryśkiewicz 1982, Pawlikowski et al. 1982, Szczepanek 1982 and others), with the simultaneous great role of *Artemisia* seem to evidence the drier and more continental climate of this part of the country. In the younger phase of zone *Typha latifolia* and *Nymphaea alba* appear in the communities of aquatic plants. Their presence would indicate the climate becoming milder. The appearance of elm towards the end of the zone may also point to a progressive improvement of climatic conditions.

Zone Ł-4 PAZ. Birch communities prevailed in this zone. *Betula* mostly formed forests in more wet places, whereas drier sandy areas were occupied by pine. The appearance of elm pollen forming a continuous curve, evidences the local occurrence of this tree. The zone corresponds with the older part of the Pre-Boreal period.

The early appearance of elm is a characteristic phenomenon in the south-eastern regions of Poland (Macko 1946, Mamakowa 1962, Scherwentke 1939) and is connected with the migration of this tree from Podolia and Volhynia (Ralska-Jasiewiczowa 1983). It may be supposed that we are concerned with *Ulmus glabra*, which is less thermophilous than other elm species. *Ulmus laevis* and *U. campestris*, having greater thermic demands (Kanerwa 1956), may have appeared later, when the climatic conditions became more favourable. The forests were rather open at that time; ferns from the family *Polypodiaceae* and remnants of the late-glacial heliophilous communities occurred at their edges and in openings occupying still rather large areas, particularly relicts of the steppe communities with *Artemisia* and *Chenopodiaceae*. The high proportion of *Filipendula* (*cf. ulmaria*) may indicate the development of meadow-type communities in openings of moist forest (Berglund 1966, Digerfeldt 1972, Ralska-Jasiewiczowa 1980, Hjelmroos 1981). Willow scrub occurred in wet places at the margins of the lakes, probably with *Dryopteris thelypteris*, *Humulus lupulus* and *Filipendula cf. ulmaria* in its herb layer. The presence of *Typha latifolia* and *Nymphaea alba* evidences that the July temperatures were not lower than in the optimum of the Alleröd and the occurrence of *Pleurospermum austriacum* suggests a continental climate.

Zone Ł-5 PAZ. This zone is characterized by the progressing development of birch-pine forests. The proportion of elm in the forests rises consistently. Elms may have been a component of the communities on rather moist soils, richer in nutrients. Hazel appeared in places at the edges of the forests. Oaks and ashes, whose pollen appears in small quantities at that time, did not play an essential role, if they occurred on the spot at all.

Zone Ł-5 corresponds with the late Pre-Boreal, which in the pollen diagrams from Central Europe was represented by a dominance of pine and continuous elm and hazel pollen curves. In the middle part of the Pre-Boreal, about 9600 years BP, a short cool oscillation is sommetimes distinguishable (Behre 1967, Iversen 1973, Latałowa 1982, Pawlikowski et al. 1982). The regular occurrence of *Nymphaea alba* and *Typha latifolia* in the deposits of Lake Łukcze testifies against any decline of temperature, neither are there any other signs of cooling. On the other hand, the evidence of the lower level in the younger part of the Pre-Boreal when the lake became overgrown may suggest a drier climate with a reduced precipitation. The local dominance of pine or birch was most probably conditioned by edaphic and hydrological factors. In Lang's (1952) opinion, large amounts of birch pollen appear frequently in the earliest periods of the Holocene in areas where birch encroached upon peatbogs. The fall of *Filipendula* pollen values at that time may suggest that trees, in all probability birch, overgrew open moist places.

Zone Ł-6 PAZ. Pine-birch forest was still dominant in this period but starting from about 9000 BP the contribution of hazel started to rise distinctly. The zone corresponds with the early Boreal. The spread of hazel preceding the development of mixed deciduous forests is a commonly encountered phenomenon, although its importance vary depending on the type of soils (Berglund 1966, Ralska-Jasiewiczowa 1966, Latałowa 1982). In the diagrams from Lake Łukcze the *Corylus* pollen values are low, typical of poor soils overgrown by pine-woods. On the more fertile soils hazel may occurred in the undergrowth of pine forests. At that time oak spread in pine and birch forests and also in habitats with a certain proportion of elm. The pine forests were probably rather open, with *Calluna vulgaris* in their herb layer. Pollen of *Ephedra distachya* found here most probably comes from a long distance transport from the south-east or south, from the forest-steppe regions. The nearest sites of this shrub occur now in Podolia.

The expansion of alder proceeded in the lake district at the same time. It extended its area along the river-banks and lake-shores. It may also have invaded the habitats originating form the dried-up and overgrown small water-bodies or shallow parts of larger lakes (Jørgensen 1963). Its was certainly *Alnus glutinosa* (Marek 1965). The declining pollen values of *Gramineae* and *Filipendula* may suggest the reduction of moist meadow areas by the expansion of alder. Its spread was stimulated by the progressive lowering of the ground-water level, leading to peat formation in the shallow parts of the lakes, connected with the drier climate, less abundant precipitation and, may be with the melting of still existing remnants of permafrost.

Zone Ł-7 PAZ. This zone, corresponding with the Late Boreal period, is characterized by the reduction of hazel communities owing to the invasion of deciduous trees, especially oak and, to a lesser degree, lime, and the increase of elm proportions in the forest communities. Oak and lime occupied soils richer in nutrients and less permeable. On permeable soils in sandy areas the pine birch forests were still dominant and so were the alderwoods in wet areas. Firbas (1949) emphasizes that the spread of alder was dependent on the formation of suitable habitats, and that was possible only after a fairly long period of a relatively dry climate, with great annual fluctuations in humidity. According to Jørgensen (1963), the retardation or acceleration of alder expansion depends largely on local factors. A distinct rise of *Fraxinus* pollen values at that time evidences its contribution to the forests of that wet areas together with alder and elm. *Humulus* and *Dryopteris thelypteris* may have spread in the herb layer of these forests.

Zone Ł-8 PAZ. The maximum development of deciduous forest with oak, lime, elm and hazel, in the study area, is characteristic of this zone, which corresponds with the Atlantic period. In the older part of the Atlantic hazel pollen attained its second post-glacial peak, while in the younger part its values began to fall. Hazel was probably being ousted by oak, which in the younger part of the zone reached its maximum expansion. It formed mixed forests with elm, lime and ash and, on poorer soils, oak-pine mixed forests with hazel in the understory. The dominance of oak pollen, observed in most Central-European diagrams in the younger phase of the Atlantic, may, to a considerable degree, be connected with the overgrowing of lakes and drying of boggy places, resulting in the extension of the habitats suitable for *Quercus robur*, which, unlike lime and elm, can grow on peaty soils. Another factor responsible for the expansion of oaks was presumably the gradual degradation of soils, especially sandy soils, owing to the long-lasting processes of weathering and outwashing (Iversen 1960). In the lake district, which abounds in sandy soils, both these factors may have been the essential cause of the late Atlantic spread of oak. Recently *Quercus robur* occurs frequently in fertile pine forests and so in the Atlantic time, when the soils were not yet so heavily degraded as they are today, it may have constituted a conspicuous contribution in pine forests. High values of *Pteridium aquilinum* spores and presence of *Calluna vulgaris* and *Lycopodium clavatum* evidence openness of those forests. *Anthericum ramosum* grew in the most xerothermic habitats.

Lime has low values (5%) in the diagram from Lake Łukcze. It should however be kept in mind that it is a poor pollen producer and its proportion in pollen spectra is always lower than the proportion of this tree in the forest (Müller 1953, Iversen 1958, 1960). According to Andersen (1970) the correction factor R=x2 for the lime pollen renders its actual proportion in the forests. Lime contributed to the mixed deciduous forests and perhaps formed an admixture in the pine-oak forests with hazel, alder buckthorn, *Viburnum* and other shrubs in the understory.

The new tree species *Carpinus* and *Fagus* appeared in the middle part of the zone. Such an early appearance of these trees is characteristic of the south-eastern part of Poland and has already been observed by Scherwentke (1939) and Macko (1946) for the Lublin Upland and by Mamakowa (1962) for the Sandomierz Basin: it was connected with the migration routes of these trees (Ralska-Jasiewiczowa 1983). Their role in the forests was however small at that time. The communities of riverine forests and wet alderwoods with elm, alder and ash dominated in moister areas. The pollen indicator of climatic optimum, *Hedera* and *Viscum* (Iversen 1960), with the prevalence of the latter, suggest a rather continental climate. *Plantago lanceolata* and *Cerealia* pollen signal the begining of human interference in the so far natural plant succession.

Zone Ł-9 PAZ. This zone corresponding with the Sub-Boreal, occurs only in the lake profile. The high pollen concentration in profile Łukcze IV (Fig. 15) and the rise in the ignition residue (Fig. 12) suggest the lowering of water level and the reduction of deposit accumulation in the peatbog profiles, resulting in the lack of Sub-Boreal layer in these profiles.

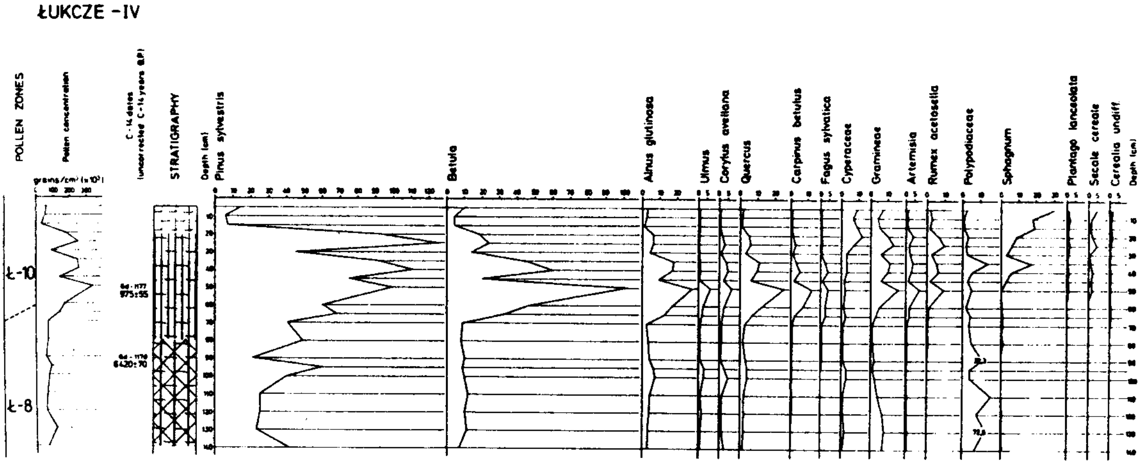

Fig. 15. Profile Łukcze IV. Pollen concentration diagram

In the older part of zone Ł-9 the proportions of elm, lime and hazel in the deciduous forests decrease gradually. In the younger part the obvious decrease of elm and hazel pollen values evidence a progressively declining role of these trees in the forest communities in favour of spreading hornbeam. The new forest communities resembled the present-day *Tilio-Carpinetum* (Fijałkowski 1957b). The density and shadiness of the forest interior restricted the florescence of hazel. At the same time deciduous trees,especially elm, were being destroyed by man (Iversen 1941, Troels-Smith 1954).

The spruce also entered the mixed and pine forests on heavier soils and in this very zone reached its maximum spread in the study area. The spreading of spruce was connected with the rise of humidity and cooling of climate. Today in the lake district spruce with oak forms small stands of mixed forest (*Querco-Piceetum*) and occurs in typical wet alderwoods (Fijałkowski 1957b). The *Alnus* pollen values are still high, evidencing the presence of swampy areas. Alder together with elm and ash formed extensive woods which could be classified in the alliance *Alno-Padion* in more fertile and moist habitats, on waterlogged soils and in places periodically flooded along streams and rivers. Despite the presence of man, marked by the occurrence of indicator pollen *Plantago major-media*, *Rumex acetosella*, *Cerealia* and in the younger part also *Plantago lanceolata*, the deforested areas were still small, as show by the predominance of tree pollen.

Zone Ł-10 PAZ. This zone, corresponding with the Sub-Atlantic, is characterized by the optimum development of hornbeam. In the Lake District it attains lower values (max. 18.0%) than in the other parts of the country, what is obviously connected with the edaphic conditions, for the prevailing sandy soils did not favour the development of hornbeam forests. In addition to transformations undoubtedly caused by man, the changes induced by climatic and soil processes (including advancing podsolization) occur also in the forests.

The dominant components of the forests — pine and oak form pine and mixed forests. In the deciduous forests the role of elm and lime is taken over by hornbeam and oak. In the oak-hornbeam communities beech may occur as a local component. The wet areas in the vicinity of the lake and the riverbanks are still occupied by carr and wet alderwood communities. Three phases of deforestation (b,d,f) caused by man's economic activities, alternating with the regeneration phases of forest communities (a,c,e) can be distinguished.

Subzone Ł-10 a. This subzone is characterized by the development of forest on soil richer in nutrients, as evidenced by the rise in pollen values of *Carpinus*, *Ulmus*, *Fraxinus* and *Tilia*. The development of deciduous forests limited the spread of the heliophilous communities of hazel and herbs. The pollen values of culture indicator taxa diminished.

Subzone Ł-10 b. The reduction of the tree pollen sum and the rise in herbs including anthropogenic taxa indicate a reduction of wooded areas owing to man economic activities. These processes took place chiefly on rather fertile soils, as shown by reduced proportions of hornbeam and elm. Hazel scrub developed in forest clearings. Cleared places on poor soils were occupied by *Calluna vulgaris*. The percentages of fern spores, especially of *Pteridium aquilinum* rise also. *Pteridium aquilinum*, regarded as the species invading the places after a fire (Iversen 1973, Huttunen & Tolonen 1975), may indicate the use of fire clearance.

Subzone Ł-10 c. The regeneration of forest communities is here less distinct than in subzone 10 a. The rising of hornbeam and elm is accompanied by a certain fall in the anthropogenic taxa frequencies, what suggests diminished activity of man, however the presence of *Cerealia* pollen may be related with the continuous residence of man in the lake region.

Subzone Ł 10 d. Initially, oak attains significant values in the forest communities, but towards the subzone end its amonts decrease considerably, together with the proportions of hornbeam. These changes are accompanied by the development of the pine and birch communities and the expansion of hazel. Spruce becomes somewhat more significant, what may be connected with the rise of groundwater level induced by the cutting of forests. The increase of *Sphagnum* spores values and *Ledum palustre* pollen provides evidence of developing peatbogs.

Subzone Ł-10 e. The decrease in herb pollen frequencies is connected with the near development of forest communities, particularly the oak-hornbeam forests with lime, elm and ash. Even pine was outsted from soils richer in nutrients by oak and hornbeam. The occurrence of hazel was restricted due to the extension of shady deciduous forests.

Subzone Ł-10 f. In this subzone the forests composed of hornbeam, oak and elms suffered a degradation. The role of pine-birch communities and hazel increased again the latter finding favorable conditions for development in thinned forest areas. High values of *Rumex acetosella* pollen indicate increased areas of deforested soils poor in nutrients.

The influence of prehistoric man on the plant cover – a discussion

In the profiles from Lake Łukcze the influence of prehistoric man is far less distinctly recorded than in the pollen diagrams from north-western (Ralska-Jasiewiczowa 1968, 1977, Tobolski 1975, 1982, Hjelmroos 1982, Latałowa 1982, Noryśkiewicz 1982) and north-eastern Poland (Ralska-Jasiewiczowa 1964, 1981). During the period preceding the beginning of agriculture man did not affect natural vegetation in an essential way. *Plantago major*, *Rumex acetosa*, *Urtica* and *Sanguisorba officinalis* pollen appearing in that period, may indicate local penetrations by groups of Mesolithic people, favouring the spread of nitrophilous plants in disturbed habitats enriched with nitrogen compounds. The first *Plantago lanceolata* pollen appears in zone Ł-8 at depth of 725 cm, 65 cm below the first *Ulmus* fall and slightly below the beginning of the continuous beech and hornbeam pollen curves, dated at 6400 years BP. The first *Cerealia*-type pollen occurs 10 cm below the first *Ulmus* fall. Wasylikowa (1982) reports some examples of early traces of settlement referred to the Early Danubian and Lengyel cultures, present at about 6300 BP in the pollen diagrams from the Kraków region. Since the study area has been poorly investigated by archaeologists, it is hard to interpret the above-mentioned single finds of anthropogenic pollen. However, it might have been penetrated by some Early Neolithic groups, which moved from the south along the belt of fertile loess soils in the Vistula Valley (cf. Gurba 1960, Kruk 1980).

The next *Plantago lanceolata* pollen appears at the *Ulmus* fall. This widely discussed decline of elm pollen frequencies at the boundary between the Atlantic and Sub-Boreal (Iversen 1941, 1949, 1960, Troels-Smith 1954, 1960, Tauber 1965, Heitz-Weniger 1976, von Groenman Waateringe 1983 and many other later works) is distinctly marked in the lake profile only, and accompanied here by a distinct fall of *Fraxinus*, a small fall of *Tilia* and *Quercus* pollen values, and a slight rise of *Corylus*. There is also a rise of *Artemisia* and *Calluna vulgaris* pollen frequencies, while *Plantago lanceolata*, *P. major/media*, and *Cerealia* pollen is present. These unquestionable traces of Neolithic man may be associated with the activities of population representing the Funnel Beaker culture, whose traces have been found in the close vicinity of the lake.

In an overlying section, in zone Ł-9, the elm curve rises slightly after its first fall but starting from a depth of 605 cm it declines definitively. At the same time there is a fall of lime and ash, a slight one, of oak pollen values which reflects a more extensive deforestation. A period of „Land Occupation" (Iversen 1941) for cultivation and breeding animals begins in the study area. *Cerealia* pollen appears first, followed by *Plantago lanceolata* and *Rumex acetosella*. The *Artemisia* pollen frequency rises: this weed can grow around homesteads and is also connected with primitive cultivation.

Man economic activity is probably responsible also for a small rise of hazel pollen occurring at that time. Light-demanding and fast regenerating hazel occupied cleared areas, particularly on fairly fertile soils and besides it flowered more abundantly in open forests. Towards the end of zone Ł-9 birch pollen frequencies increased, this tree being a pioneer species, colonizing places abandoned by man. This phase of colonization should presumably be referred to the Late Bronze Age, as suggested by its location in the younger par of the Sub-Boreal. The Polesie territory was then inhabited by a population of the Lusatian culture engaged in animal breeding and agriculture.

Man activity declined at the begining of the Sub-Atlantic allowing the regeneration of some deciduous forest communities with hornbeam, ash and beech. It was supposedly a period of economic decline, when man abandoned the lake region.

In the middle part of the Sub-Atlantic there are two maxima of culture indicators (subzones b and d), separated by a phase of forest regeneration (subzone c). They are characterized chiefly by increasing frequencies of *Plantago lanceolata* and *Rumex acetosella*. The latter, being a weed primarily invading poor and acid soils, suggests activities extended also over the areas of prevailing sandy soils. The single *Cerealia*-type pollen evidences agricultural practices, but the distinct prevalence of *Plantago lanceolata* suggests the domination of animal-raising. Weeds (*Plantago major/media*, *Chenopodiaceae* and *Urtica*) accompaning human settlements are also present. The rise of *Filipendula* pollen values and the presence of *Melampyrum* may be connected with the forest clearings. The change of *Rumex – Plantago lanceolata* ratio in the Sub-Atlantic expresses the accelerated processes of soil leaching in consequence of the rising humidity of climate (Iversen 1941, 1958, Andersen 1961, Berglund 1966). It reduced habitats suitable for *Plantago lanceolata*, whereas *Rumex*, especially *R. acetosella*, could spread on acid soils. The small fall of culture indicators with *Cerealia* pollen present all the time in subzone d may indicate local shifts of settlements rather than a real economic breakdown, connected probably with the colonization by Pomeranian and Venedian tribes.

The decline of herbs including anthropogenic indicators and the regeneration of oak-hornbeam communities in subzone e indicate diminished economic activity. This period should possibly by referred to the Migration period (cf. Berglund 1969, Iversen 1973, Ralska-Jasiewiczowa 1977, Andersen 1978).

The following phase of man activity, falling in historic times (980±50 BP), is expressed by a distinct regression in the forest communities on rich soils, with high values of anthropogenic taxa, both cereals and weeds. The predomination of *Rumex acetosella* inicates a progressing process of soil podsolization and the large acreage of poor acid soils utilized by husbandry.

Pollen analysis of surface samples from the marginal zone of Lake Łukcze

The pollen spectra of surface samples collected from the floating vegetation mat overgrowing the lake are presented in Table 8. Surface samples 1 and 2, were taken where a belt of alder thicket has been destroyed over a space of several metres and the lake borders directly upon open herb communities and next cultivated fields. Samples 3 and 4 represent an area overgrown by alder, brich and pine, with small patches of *Sphagnum* bog in the proximity of the sampling place. The pairs of spectra obtained from the same habitat show no essential differences. Clearer differences can be found between the samples from different habitats. This refers above all to herbs, particularly those growing in the close neighbourhood of the sampling place. In spectra 1 and 2 there is a high proportion of *Polypodiaceae* spores representing most probably *Dryopteris thelypteris*, occuring in masses in the adjacent thicket, whereas spectra 3 and 4 are characterized by high values of *Sphagnum* spores. Differences in pollen proportions of other plant taxa are less distinctly marked. Spectra 1 and 2 are distinguished by higher frequencies of *Gramineae*, *Artemisia*, *Chenopodiaceae* and *Quercus* pollen and spectra 3 and 4 by higher proportions of *Cyperaceae*, *Betula* and *Alnus*.

Phytosociological records of the forest communities described by Kozak (1966, 1967a) were used for comparisons of the representativeness of tree pollen in the surface spectra. These communities are composed mainly of *Pinus*, *Quercus*, *Alnus*, *Betula* and *Carpinus*. Of the trees more significant for the study area only the spruce appears in larger numbers, the fir occurring sporadically. The occurrence of beech was found only in a village park (Fijałkowski & Kseniak 1982).

Table 8. Pollen spectra of the surface samples taken from the vegetable coating overgrowing the lake on the adjoming peatbog side (NW).

Genera	Saple			
	1	2	3	4
AP	46,6	55,4	41,6	51,1
NAP	53,4	44,5	58,3	48,8
Pinus	20,8	24,6	23,2	18,6
Betula	6,8	8,4	15,5	11,7
Alnus	3,0	2,5	4,0	4,8
Quercus	6,6	10,0	3,2	5,8
Ulmus	0,5	0,3	0,2	0,2
Corylus	2,2	1,5	1,2	0,4
Carpinus	1,2	1,5	1,2	1,0
Fraxinus	0,1	0,9	0,1	0,2
Salix	1,4	8,4	1,4	1,3
Fagus	0,5	0,9	0,4	0,1
Picea	0,3	1,9	0,9	0,2
Tilia	0,3	–	0,2	–
Populus	0,5	–	0,1	–
Abies	–	0,3	–	–
Acer	–	0,3	–	–
Cyperaceae	5,7	3,1	13,3	11,6
Gramineae	16,4	16,2	11,6	12,6
Artemisia	5,5	2,5	1,7	2,7
Chenopodiaceae	3,8	2,5	1,7	0,6
Rumex acetosella	5,2	6,2	5,1	5,8
Plantago lanceolata	1,6	2,2	1,3	2,4
Secale cereale	4,9	4,0	5,2	5,6
Polypodiaceae	150,0	338,4	3,6	1,7
Sphagnum	15,6	6,8	28,9	34,7

The percentage coverage of all the above-mentioned trees in layer a was calculated from 157 phytosociological records and compared with the mean pollen percentages of these trees in the surface samples.

The results are as follows:

	Pinus	*Quercus*	*Alnus*	*Betula*	*Carpinus*	*Picea*
coverage	23.5	5.7	5.6	3.5	1.7	1.4
percentage of pollen	21.3	6.4	3.6	9.1	1.2	0.8

Remarks on the distribution ranges of some trees

Picea abies

Lublin Polesie is situated in the area with the dispersed occurrence of the spruce (Browicz 1980, Fig. 16) in the close neighbourhood of the so-called „Middle Polish spruce-less belt", extending across the Podlasie Lowland (Szafer 1972). The discontinuous distribution of spruce in Poland has been given much attention for years. In Jedliński's opinion (1922, 1927) the spruce-less areas of Middle Poland, did not existed in the past, and the destruction of the continuous distribution of spruce resulted from the improper management of forest resources. Paczoski (1925, 1930) supported this view assuming that owing to the exploitation of forests

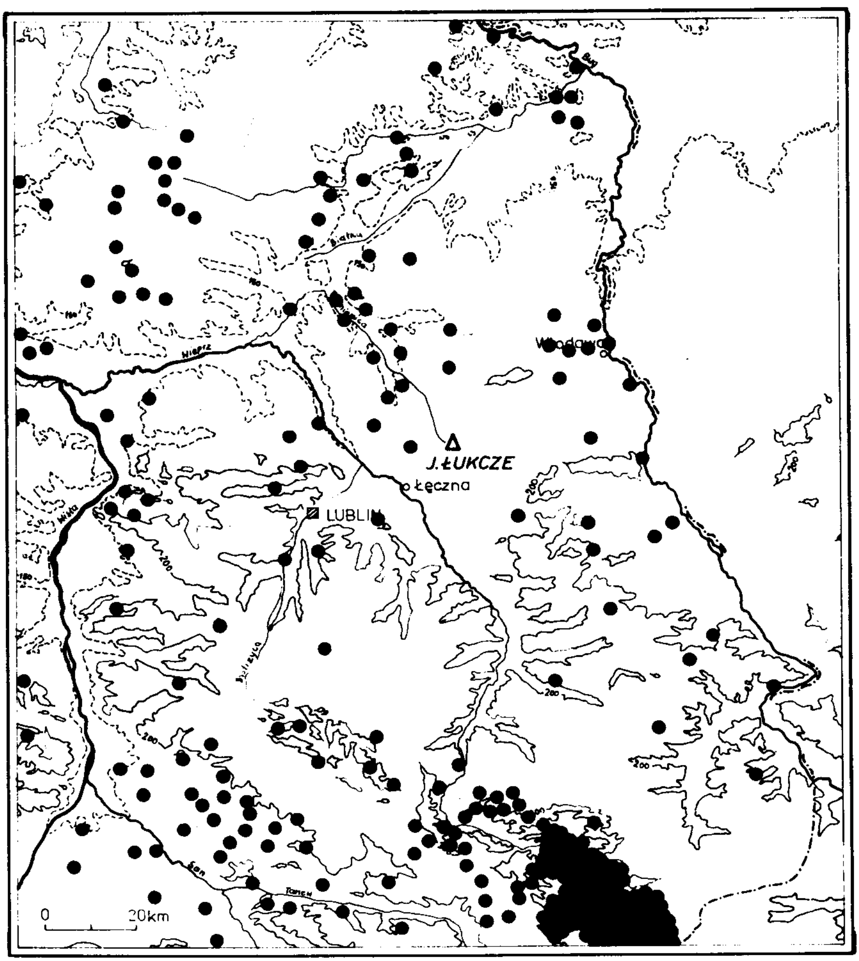

Fig. 16. Present-day distribution of *Picea abies* in the Lake Łukcze region (after Browicz 1980)

on sandy soils the spruce, being their minor component only, was utterly exterminated. The question of its distribution has been considered repeatedly ever since. According to Szafer (1931) there were two independent ranges of this tree throughout the Holocene in South and North-Eastern Poland. This question was discussed at length by Środoń (1967. 1977), who assumes two separate centres of spruce expansion. The older centre was in the Carpathians, from where at the decline of the late glacial the spruce started its migration to the north. Its spread from the north-eastern centre occurred later, beginning in the Boreal. Both ranges come to the contact during the Atlantic. In the Sub-Boreal the spruce reached its maximum spread simultaneously with its strong expansion from the north-east.

The spruce produces rather small amounts of pollen in comparison with the pine, birch or alder (Faegri & Iversen 1964). According to Środoń (1967), the mean proportions of spruce pollen between 0.6 and 1.0% may indicate the presence of this tree in situ, whereas the means between 1.1. and 3.0% prove this beyond question. On the other hand Moe (1970) concludes from Scandinavian data that only the values 5-10% indicate some *Picea* stands scattered at a distance of 5-10 km. Birks (1983) assumes that pollen values about 5% suggest the local presence of spruce, and about 25%- the dominace of this tree in the forests.

The values of spruce pollen in the whole diagram from Lake Łukcze is small, not exceeding generally 1%. The highest values od 3% fall in zone Ł-9, corresponding with the Sub-Boreal (cf. Ralska-Jasiewiczowa 1963).

Nowadays the spruce forms small stands of the *Piceo-Quercetum*-type communities in the study area and its pollen values in the surface samples averages 0.5% (0.2-1.9%). Keeping in mind the data presented by the above-named authors, it may be supposed that in the Holocene forests of Lublin Polesie the spruce was only scattered reaching a small spread during the Sub-Boreal.

Abies alba

Today the fir does not participate in the forest communities of the studied lake district (Fijałkowski 1959). Its nearest stands occur in the Łuków Plateau and near Parczew (Browicz 1972, Fig. 17), where it grows in the degraded coniferous forest *Pino-Vaccinietum myrtilli* (Kozak 1961, 1967b): however still remnant herbs typical of oak-hornbeam forests and humid mixed coniferous forests accompanying it, give evidence of entirely different forest communities in which the fir grew in the past. They were presumably *Querco-Carpinetum* and *Querco-Piceetum*. In Kozak's (1961, 1967b) opinion, man activity was responsible for the reduction of fir stands. The distribution of this tree was discussed in many publications (Jedliński 1922, 1927, Wierdak 1927, Brzyski 1957, Środoń 1983 and others).

Only one pollen grain of *Abies alba* was found in the surface samples from the vicinity of Lake Łukcze (Table 8). In the pollen diagrams its pollen values were limited to the Sub-Atlantic and did not exceed 1%. Fir pollen was also found in other diagrams from the Łęczna-Włodawa Lake District and Polesie (Kulczyński 1930, Lublinerówna 1934, Bałaga et al. 1983) but always as single grains. According to Welten (1954), even 1% values of *Abies alba* pollen evidence the presence of this species in situ. Birks (1983) assumes that fir pollen values of about 2% indicate its local presence, and about 5% suggest that the fir

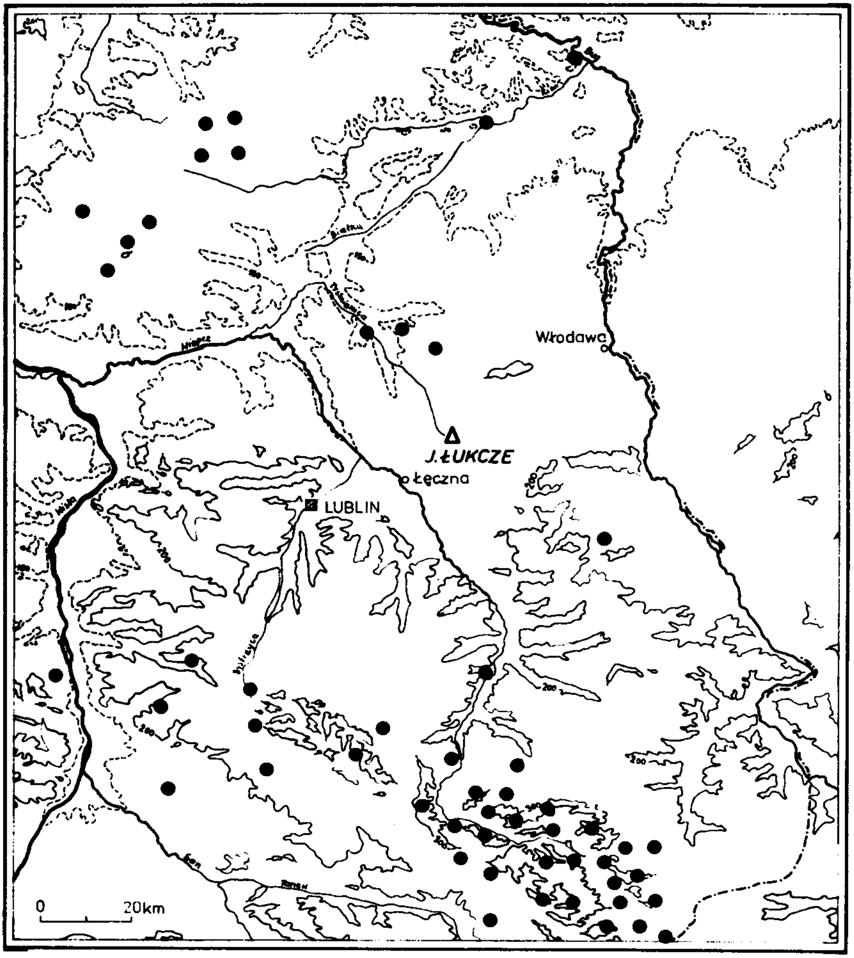

Fig. 17. Present-day distribution of *Abies alba* in the Lake Łukcze region (after Browicz 1972)

was an essential component of the surrounding forests. Taking into consideration the foregoing data it may be assumed that the fir has never taken part in the formation of forest communities in the Lake Łukcze region (cf. Ralska-Jasiewiczowa 1983).

Fagus sylvatica

The beech appears as a continuous pollen curve in the diagram from Lake Łukcze since the level dated at 6400 BP, together with the hornbeam. This was connected with its early migration from the south-east and the south, via the Eastern Carpthians and Opole to the Roztocze area (Szafer 1959, Ralska-Jasiewiczowa 1983). Now the beech forest is the dominant community in the Roztocze (Izdebski 1962, 1965, 1966, 1967), the beech approaching here the north-eastern range of its continuous distribution (Brzyski 1959). Today the beech is absent from the lake district (Fijałkowski 1957b). Its nearest stands are to the south-east, in the Lublin Upland (Fig. 18) (Sławiński 1946) and in the Roztocze. There it occurs in *Tilio-Carpinetum* and *Fagetum-carpaticum* forests, chiefly on slightly podsolized brown soils and on chalky rendzinas, mostly on the hill slopes. A series of papers on the distribution and ecology of beech in this area have been published (Szafer 1919, Sulma 1933, Motyka 1953, Fijałkowski 1957b). The mentioned main causes of its shrinking range are severe winters, especially ground frost, preventing the renewal of this tree, and the hydrological conditions determined by the land relief and man economic activities.

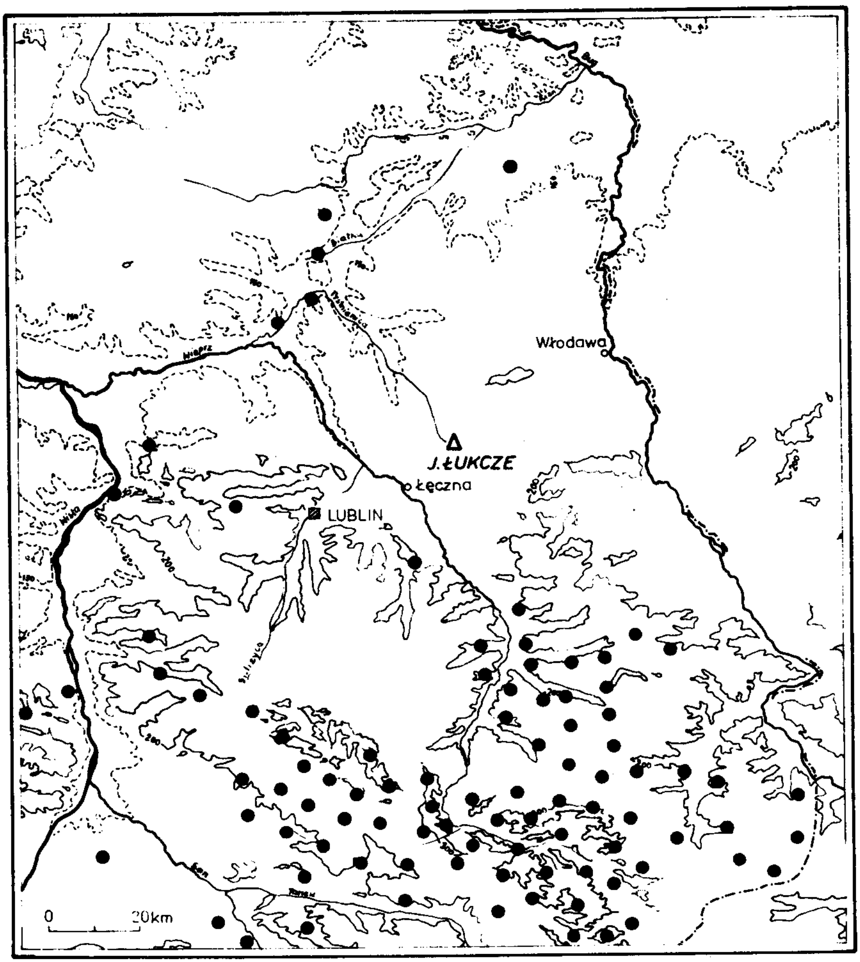

Fig. 18. Present-day distribution of *Fagus sylvatica* in the Lake Łukcze region (after Browicz 1976)

The pollen analysis of surface samples from the Lake Łukcze shores shows the proportions of *Fagus* pollen ranging from 0.1-0.9%. In the subfossil samples of znone Ł-10 it attains a maximum of 6.2%. According to Birks (1983) *Fagus* pollen values of about 2% indicate its scattered local stands, whereas 5% may evidence the regional presence of forests dominanted by beech. It may therefore be assumed that the amounts of beech pollen occurring in zone Ł-10 represent its stands in situ, or that the eastern range of this tree in the Sub-Atlantic was shifted futher to the east. A similar situation was found by Artiuszenko et al. (1980) in the diagrams from Polesie. A comparison of the beech pollen values in profiles of Lake Łukcze and the peatbog Krowie Bagno (Bałaga et al. 1983) permits the statement that the further to the east the smaller are the proportions of this species.

ORIGIN AND DEVELOPMENT OF LAKE ŁUKCZE

At the beginning of the late glacial there occurred in the study area some small water-bodies accumulating silts with organic matter (bottom layers of profiles Ł-II and Ł-III): they were referred to the Oldest Dryas. The genesis of these depressions is rather hard to explain. The presence of depressions without outflow in the bed of biogenic sediments in this area is often associated with the degradation of permafrost (Liszkowski 1979) or with karst phenomena (Wilgat 1954, Nakonieczny 1965). In the case in question it may be supposed that they were formed as a result of permafrost degradation in connection with the advancing warming. They were shallow, so that at the beginning of the Alleröd they became overgrow and existed as mires throughout the Alleröd and Younger Dryas. The development of mires at that time seems to have been a widespread phenomenon in the lake district (Więckowski & Wojciechowski 1971, Bałaga et al. 1983). The peat formation proceeded till the end of the Younger Dryas. At the beginning of Holocene the groundwater level raised, the mire was over flooded, and the lake began to form. The rise of water level and the beginning of gyttja accumulation at the Younger Dryas – Pre-Boreal transition seem to have been also a characteristic phenomenon in the whole lakeland (cf. Krowie Bagno, Fig. 19; Bałaga et. al. 1983). The part of the lake where profiles Ł-II and Ł-III were taken was at the time most probably a small bay or a small lake let within the

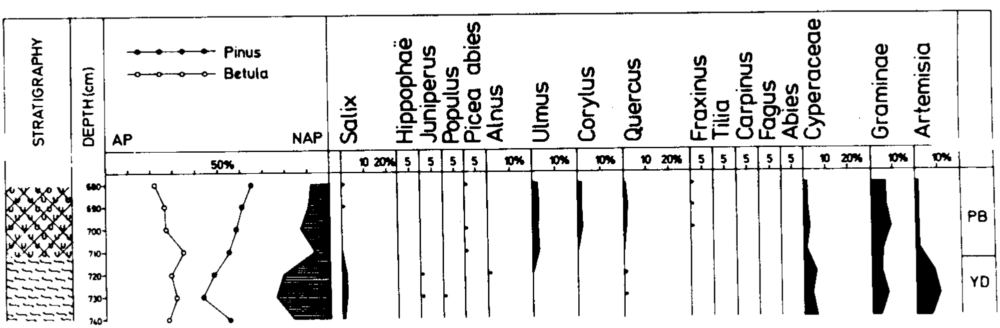

Fig. 19. A fragment of the pollen diagram from the Krowie Bagno peatbog (Bałaga et al. 1983) showing the transition from the Younger Dryas to the Pre-Boreal period

mire developing in the north-western part of the depression. In both profiles detritus-calcareous gyttja was accumulated. In the profille Ł-IV collected about 25 m to the north of profile Łukcze II neither a gyttja layer nor any traces of $CaCO_3$ have been found; neither does calcium carbonate content occur in the lake profile Ł-I.

The interbeddings of peat with carbonate gyttja deposits are not rare in Polesie (Kulczyński 1939-40, Tymrakiewicz 1935, Wilgat 1954, Okruszko et al. 1971). They are possibly connected with the changes in the groundwater level. The precipitation of calcium carbonate and the carbonate gyttja formation may result from different physical, chemical and biological processes. Much room has been devoted to this question in the description of the bottom sediments of the Mazurian lakes (Więckowski 1966, Stasiak 1971) and the lakes of north-western Poland (Nowaczek & Tobolski 1981, Rzepecki 1985). Shallow waters in the littoral zone or in bays, where waves facilitates the escaping of CO_2 into the atmosphere, are more favourable for $CaCO_3$ sedimentation. This factor may have had the greatest influence on the formation of the carbonate layer in profiles Ł-II and Ł-III. The lack of gyttja interbeds in profile Ł-IV, only ca 30 m away from profile Ł-II, may be explained by the lack of thick enough series of hardly impermeable silts at its bottom, present in profiles Ł-II and III, what may have caused a higher local inundation. However, this phenomenon is certainly of more complex character.

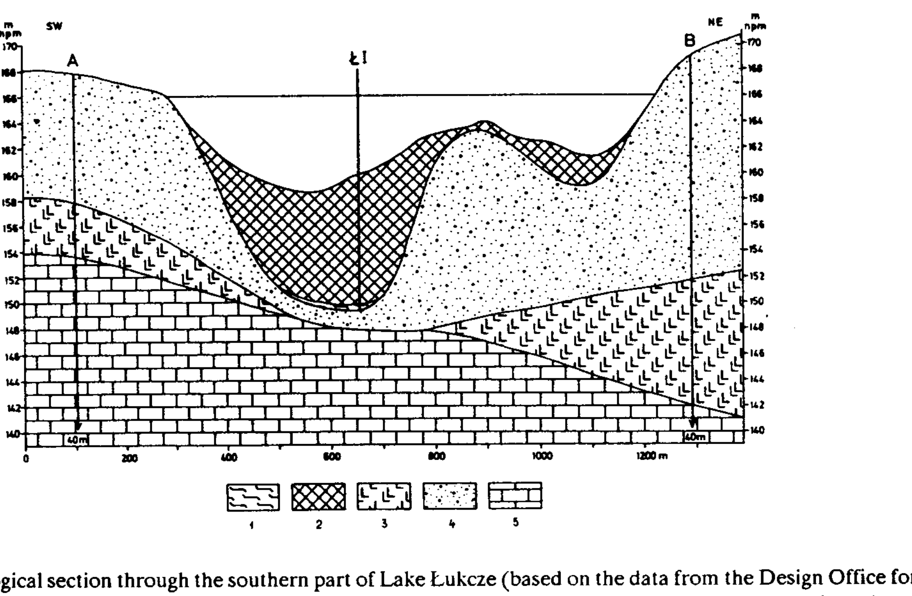

Fig. 20. Geological section through the southern part of Lake Łukcze (based on the data from the Design Office for Hydro-engineering and Land Reclamation and the Office of Geology at Lublin): 1 — peat, 2 — gyttja, 3 — clay, 4 — sand, 5 — chalk

In the Boreal the water level in the lake was lowered considerably, as shown by the accumulation of peat in shore profiles. Sedge-moss mires with *Calliergon trifarium*, *Drepanocladus revolvens*, *D. sendtneri*, *Carex rostrata*, *C. lasiocarpa* and *Menyanthes trifoliata* were developing at that time. During the Atlantic the plant succesion on mires advanced and they became overgrown with birch, probably *Betula pubescens* and *B. humilis*. The lack of the Sub-Boreal layer in the peatbog profiles was presumably brought about by the lowering of the water level. The reduction of peat accumulation process is suggested also by the high concentration of pollen (Fig. 15); the rise of water level in the Sub-Atlanic is marked by the renewed growth of the peatbog. Więckowski & Wojciechowski (1971) draw attention to the fact that the sediments of karst lakes are poor in calcium carbonate, while its content in water is high. The question arieses whether the origin of the Lake Łukcze basin was connected with karst processes. The essential role of karst phenomena is here theoretically possible, because chalk occurs under a 1.25 m layer of sand in the bottom of the lake. A geological section through the southern part of the lake (Figs 20 and 21) shows however that the top of the chalk in this part of the lake slopes down to the north-east and the water-body is situated in sandy deposits. Clay deposits which have not been found in the central profile Ł-I, from the bottom of the lake, reach a fairly large thickenees at its margins (Fig. 21).

The chalk substratum is very differentiated in the Lake Łukcze region (Fig. 22) and so the reconstructed patterns of the configuration of the chalk layer top based on a small number of borings is undoubtedly simplified. Nevertheless, it shows generally the relief of the substratum and the position of Lake Łukcze and other lakes in its neighbourhood on

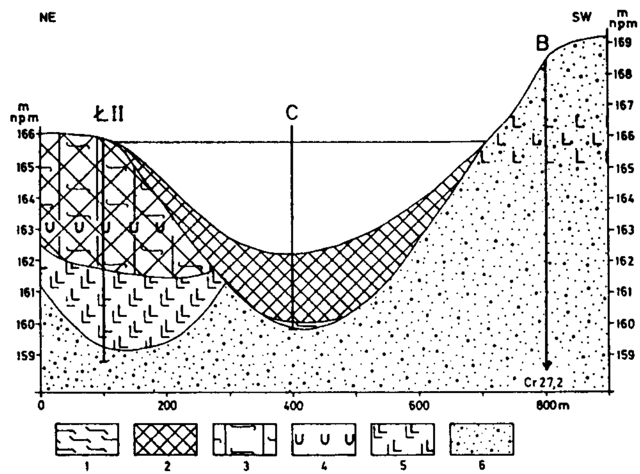

Fig. 21. Geological section through the northern part of Lake Łukcze (based on the data from the Design Office for Hydro-engineering and Land Reclamation and the Office of Geology at Lublin): 1 — sedge-moss peat, 2 — gyttja, 3 — sedge-reed peat, 4 — $CaCO_3$, 5 — clay, 6 — sand

the slopes, and not in the centre of karst depressions. On the southern shore of Lake Łukcze the chalk formations occur about 30 m lower than in the neighbouring boreholes (Fig. 21). It is therefore possible that such sink-holes are also present in the lake bottom. The accumulation of biogenic sediments in karst depressions began when the sucking openings had become sealed and the ground waters had formed a lake. The presence of impermeable clay layers in the marginal parts of the Lake Łukcze caused probably the rise of water level in sandy depressions, as the climate became milder and the ground-ice

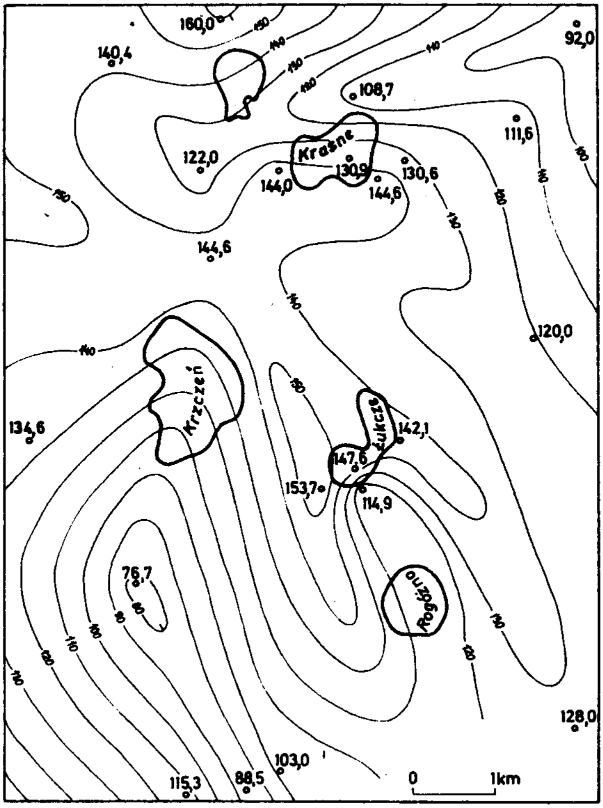

Fig. 22. Depth of the top surface of chalk in the Lake Łukcze region (based on the data from the Design Office for Hydro-engineering and Land Reclamation, Office of Geology and Liszkowski 1979)

melted. If the sink-holes are still being deepened owing to the processes of karst renewal, some disturbances in the organic sediment accumulation occur (Kulczyński 1939-40, Szczepanek 1971). If we agree that the deposition of sediment that fill the depressions began soon after their origin, it may be assumed that the karst forms developed, as Wilgat (1954) thinks early as the late glacial. These processes must have been particularly intense in the areas where the Upper Cretaceous rocks were covered by loose Quaternary deposits, because in consequence of the karst processes in the substratum the overlying material was sucked in and the arising depressions were filled with water. Maruszczak (1966b) remarks that the formation of the fairly large lake funnels in Lublin Polesie needed a rather long time, for the rate of chemical denudation was very slow in this region. He suggests that the basins of the Łęczna-Włodawa lakes might have been cosiderably older than Alleröd age.

Geological borings in the Lake Łukcze region show that the chalk formations may border almost directly on the lake basin or they may be located several dozen meters deeper. Impressed by the great thickness of the Quaternary sediments, one cannot reject, especially on the basis of single borings, the possibility of the participation of karst phenomena in the arising of lakes in this very peculiar area. Remembering the slow rate of chemical denudation (Maruszczak 1966b), we may assume that the thermokrast phenomena could contribute to the origin of the small lake depressions in the late glacial. The Lake Łukcze basin was most likely formed as a result of chemical processes occurring in the limestone rocks.

THE RATES AND CONTINUITY OF PEAT AND LACUSTRINE SEDIMENT ACCUMULATION

The sediment accumulation rate is expressed by the ratio the seadiment thickness to the time in which it was deposited. Its proceeding depends on many factors. The thickness

ŁUKCZE - III

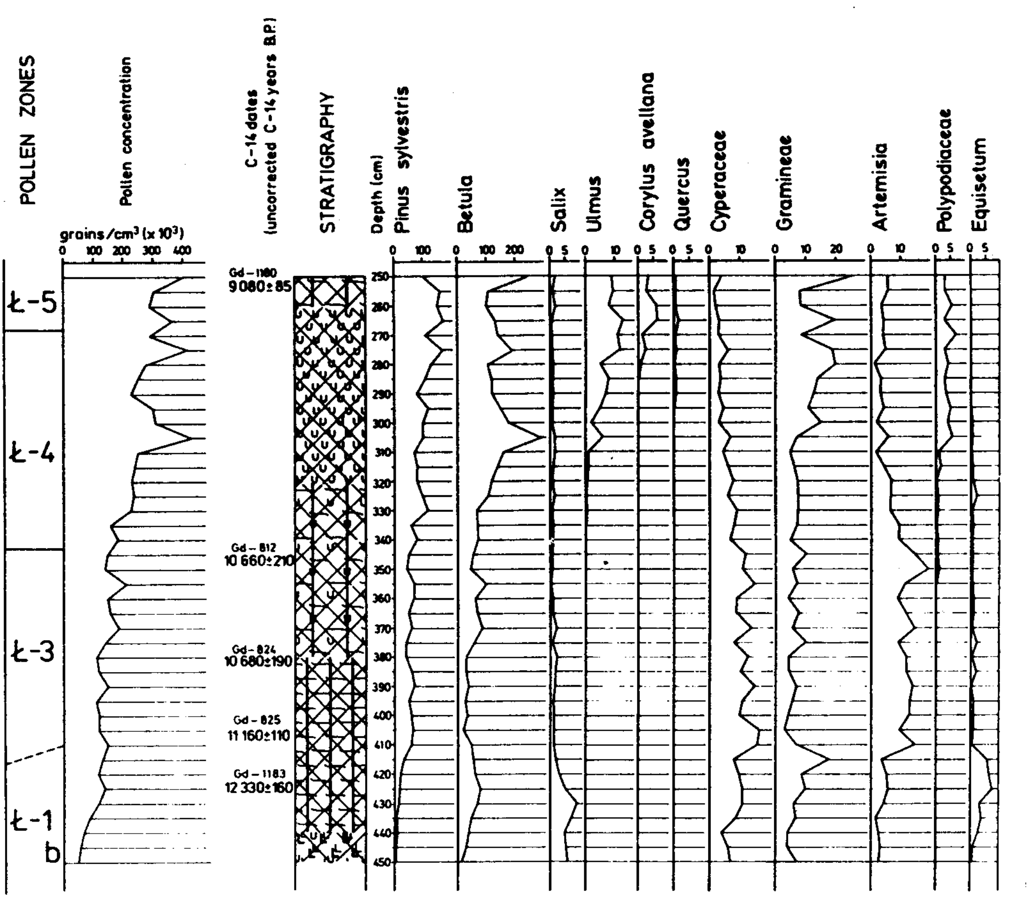

Fig. 23. Profile Łukcze III. Pollen concentration diagram

of peat deposits is determined by such factors as hydrological conditions, types of peat-forming communities, climate etc. The thickness of lake deposits is determined, among other things, by the lake trophy and the intensity of organic production connected with it, depth, amount of material of allochthonous origin, size and character of the drainage area etc.

A comparison of pollen diagrams Ł-II, Ł-III and Ł-IV derived from the mire with each other and with the diagram from the lake centre shows discontinuities of the sedimentation processes. This is also confirmed by radiocarbon dating. Profile Ł-II provides the best-developed late glacial section. Profile Ł-III has presumably a hiatus during the Alleröd, although the pollen concentration diagram (Fig. 23) does not indicates a decrease in the accumulation rate. It may be supposed that we are concerned with a partial peat fluction, which may be explained by the situation of the profile in the littoral zone of the lake with the diversified relief of the substratum. A hiatus covering the Sub-Boreal and a part of the Sub-Atlantic, is also visible in profiles Ł-II and IV. A pollen concentration diagram of profile Ł-IV (Fig. 15) shows a break in the peat accumulation in the Sub-Boreal, most probably induced by the lowering of the groundwater level. The pollen concentration at a depth of 50-60 cm rises from 145 269 to 334 853 grains x cm^3, and the mineral content in the peat rises as well (Fig. 12).

Since the number of the radiocarbon dated levels in the peatbog profiles is insufficient, the calculation of the peat accumulation rate is rather approximate. The rate of lacustrine sediment accumulation can be determined only provisionally, for there are no dates obtained directly from the lake profile. The highest yearly peat accumulation rate of about 1.2 mm, have been noted in zone Ł-3. The main peat components at that time were *Drepanocladus revolvens*, *D. fluitans*, *Calliergon giganteum* and *Scorpidium scorpioides*. During the Holocene the peat accumulation rates ranges from 0.39 to 0.53 mm/year (averaging 0.42 mm), being higher in zones Ł-4 to Ł-7 and Ł-10, and lower in zone Ł-8. Carbonate gyttja in profile Ł-III was deposited at a rate of 0.60 mm/year. The approximate rates in lacustrine sediment range between 1.09 and 0.62 mm/year, on the average 0.81 mm.

DISCUSSION ON THE ORIGIN OF THE ŁĘCZNA-WŁODAWA LAKES

Investigators have been interested in the origin of the Polesie lakes at least since the beginning of the 20th century. Sawicki (1918) and Wołłosowicz (1922) regarded those lakes as remnants of a Pleistocene ice-dam lake, which supposedly had come into existence in connection with changes in the drainage system during the period of continental ice-sheet transgression. In the thirties attention was given to the connection of Polesie lakes with the chalky substratum (Lencewicz 1931, Rühle 1935). According to the karst theory the depressions were formed by chemical processes occurring in limestone rocks. The reduction of the carbonate rock mass led to a collapse of the substratum. This theory met, for a time with a general acceptance (Wilgat 1954, Rühle 1961, Maruszczak 1966a). However, new facts about the geology of this region were obtained, such as the lack of a close relationship of the lake basins with the relief of the chalky substratum, or the occurrence of the lakes almost exclusively in sandy areas – whereas they are nearly utterly missing from the region (Cyców), where active karst processes occur in marl lying close under the surface, and the discussion of this problem revived.

Wilgat (1954, 1963), accepting the karst theory, found most of the lakes to be of late-glacial and Holocene age and referred the beginning of the lake-forming karst processes to the period of permafrost disappearance. Maruszczak (1966a) distinguishes two types of lakes: shallow lakes, with the basins formed by chemical corrosion and erosion, no role being played by groundwaters, under the conditions resembling those of subaerial forms of surface karst, and deep lakes where the subartesian waters contributed to the basin formation.

Lencewicz (1931) and Rühle (1961) paid attention to the role of artesian waters in the formation of karst depressions still earlier. Maruszczak (1966a) refers the origin of these lake basins to the period preceding the transgression of the Middle-Polish continental ice-sheet. According to Mojski (1972) the lake depressions in which the Polesie mires developed, resulted, from erosion and water accumulation and they are connected with the area of relief formed by the melt waters from the ice-sheet of the Mazovian-Podlasian stage flowing eastwards. This opinion is supported by Buraczyński and Wojtanowicz (1974b), who assume the origin of Uściwierskie lakes (central region of the lake-land) as consequence of the subglacial waters activity and the melting of dead-ice blocks. Their theory therefore assumes the survival of the lake depressions formed at the time of the Middle-Polish glaciation. The detailed analysis of the substratum relief of the organic deposits at Krowie Bagno- mire and the palynological dating of that peat- sequence (Bałaga et al. 1983) as well as the analysis of the geological sections presented by Lencewicz (1931) and Krygowski (1947), permits Buraczyński and Wojtanowicz (1983) to assume that most of the Polesie lakes, especially the deep ones, are of melting-thermokarst origin. They distinguish two developmental stages of the lake basins: 1) the melting out of basins in the final phase of the Middle Polish glaciation and 2) the degradation of permafrost and generation of thermokarst forms towards the close of the Vistulian. In this case melt-out basins would have been places predisposed to the formation of permafrost and the present-day lake basin would be effect of thermokarst phenomena.

Small and shallow lakes are considered to be of different karst origin. Explaining the genesis of Lake Głębokie (Cyców region), in addition to thermokarst processes, Wojtanowicz (1984) takes into account the possible action of subartesian ground water. The work by Woźniczuk (1973), in which he accepts the thermokarst origin of the lakes of Byelorussian Polesie is referred to. Jakuszko et al. (1975) and Jakuszko (1981) mention two groups of lakes in Byelorussian Polesie: older karst lakes (peat in Lake Moszno was dated at 10 280 110 BP and in Lake Czerwone at 10 190 140 BP) and younger barrier lakes formed in the Boreal and Atlantic.

Thanks to palynological analyses and radiocarbon dating the studies on the Polesie lakes carried out so far have documented age and developmental stage of at least some of these lakes, yet the genesis of lake depressions still remains an open problem and calls futher close investigation.

CONCLUSIONS

The objective of this study is an analysis of the vegetational history of the Lake Łukcze region from the Oldest Dryas till the present time and an attempt to reconstruct the genesis of this water-body on the basis of palaeobotanical, physical and chemical analyses, radiocarbon datings and descriptions of boreholes drilled for irrigation, drainage and geological purposes. The present study is based on the bottom sediment of Lake Łukcze (profile Ł-I) and those of the mires adjacent to the lake on the western side (profiles Ł-II, Ł-III and Ł-IV.

The sediments from the mires were radiocarbon dated (10 dates) at the Laboratory of the Silesian Polytechnic University at Gliwice.

The analysis of the vegetational development in the Lake Łukcze region in the late glacial and Holocene permits the following conclusions:

1. In the Oldest Dryas (Ł-0 PAZ) open landscape with willow scrub and steppe-like herb communities, marked by high proportions of *Artemisia* predominated in the neighbourhood of the lake.

2. Open birch woods developed in the Bölling (Ł-1 PAZ). Areas covered by communities of steppe-like vegetation, in which *Hippophaë rhamnoides* appeared, decreased: fens expanded. The maximum expansion of birch was dated at 12 330 BP.

3. No climatic oscillation corresponding with the Older Dryas was noted.

4. Open pine-birch forests prevailed in the lake district in the Alleröd (Ł-2 PAZ).

5. The plant succesion indicates a progressing warming from the Bölling throughout the Alleröd and in this connection the Bölling and Alleröd are treated as one interstadial in the way suggested by Pennington (1977) in Great Britain.

6. The alternative interpretation of the late glacial with zones Ł-0 and Ł-1 treated as a birch phase of the Alleröd is proposed, on the assumption of reservoir effect affecting the date 12 330 BP.

7. In the Younger Dryas (Ł-3 PAZ) parkland landscape with groups of birch trees and probably pines, and with extensive areas occupied by steppe-type vegetation predominated in the vicinity of Lake Łukcze. The beginning of the maximum development of steppe communities dated at 11 120 BP, gives evidence of a relatively dry continental climate.

8. In the older part of the Pre-Boreal period (Ł-4 PAZ) an early appearance of elm, characteristic of the south-eastern part of Poland, was observed.

9. In the younger part of the Pre-Boreal (Ł-5 PAZ) pine-birch forests dominated, elm spread and hazel appeared.

10. The older part of the Boreal (Ł-6 PAZ) is characterized by the dominance of hazel communities. The beginning of their development is dated at 9080 BP. The expansion of deciduous trees — elm, oak, lime, ash and alder is also evident.

11. A futher increase in the proportion of oak, lime and ash gradually replacing hazel, occurs in the younger part of the Boreal (Ł-8 PAZ).

12. The Atlantic (Ł-8 PAZ) is characterized by the maximum development of mixed deciduous forests with oak, lime, elm, maple and ash. Sandy places were overgrown by pine and pine-oak forests. Wet places were occupied by alderwoods. The appearance of hornbeam and beech is dated at 6420 BP.

13. In the Sub-Boreal (Ł-9 PAZ) the pine and mixed pine-oak forests occupied sandy areas and deciduous forests with dominant oak and hornbeam grew on more fertile soils. The spruce attained its Holocene maximum spread in the forests of the Łęczna-Włodawa Lake District.

14. In the Sub-Atlantic (Ł-10 PAZ) the composition of forests did not undergo any essential changes, but there were some quantitative changes favouring species with small demands and high expansiveness. Pine played a dominant role in the study area.

15. The following information on the influnce of prehistoric settlement on the natural vegetation of the Lake Łukcze neighbourhood was obtained:
a) The first uncertain traces of human economic activity were found is zone Ł-8. They may have been connected with penetration of early Neolithic groups, which moved from the south along the Vistula valley.
b) Next traces of settlement appearing at the *Ulmus* fall evidence the livestock husbandry and field cultivation most probably connected with the activity of Funnel Beaker culture people.
c) Towards the end of the Sub-Boreal (zone Ł-9) the records of livestock farming and corn growing, indicate the presence of people of Lusatian culture in the proximity of the lake.
d) In zone Ł-10 three phases of economic activities separated by the periods of reduced settlement have been distinguished. Phases b and d are probably related to the Pomeranian and next Venedian cultures. A period in between (subzone c) indicates a local shift of settlement rather than an economic collapse. Subzone f represents historic times, as evidenced by its radiocarbon date of 970 BP.

16. The history of distribution ranges of spruce, fir and beech in the study areas is discussed on the basis of pollen diagrams and surface samples with the following conclusions:
a) spruce attained a maximum range in the Sub-Boreal,
b) fir was most probably absent from the study area during the whole Holocene,
c) beech may have occurred locally in the area of Polesie in the Sub-Atlantic. Its eastern range was then shifted further to the east in comparison with the present situation,

17. The zonations of pollen diagrams based on traditional and numerical methods were compared:
a) the numerical analyses confirmed most of the boundaries marked out by the traditional method; however some of them are displaced several centimetres upwards or downwards, and are more or less distinct,
b) the numerical analysis suggests some new boundaries which are not shown in the traditional division (Fig. 13),
c) the levels of changes shown by numerical analyses in the marginal profiles were more numerous and expressed by higher values than those in the profile from lake centre representing mean pollen values.

18. On the basis of the foregoing studies an attempt was made to explain the genesis of the lake and to relate it to earlier theories. The present study dates the developmental stages of the lake but does not define the time of the basin formation. The almost direct contact of the Lake Łukcze basin with chalk deposits suggests the contribution of karst phenomena to the genesis of the lake. The small lake depressions containing Oldest Dryas and Bölling sediments may have been formed in consequence of the ground ice melting (thermokarst), which problem however needs further study.

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Tabela

Sample code	Depth, in cm	Lab. No.	Age BP
Łukcze IV			
TŁ-1	48–57	Gd 1177	980±50
TŁ-2	88–97	Gd 1178	6420±70
TŁ-3	175–195	Gd 1179	7790±70
TŁ-5	250–255	Gd 1181	10900±100
TŁ-6	280–290	Gd 1182	10930±90
Łukcze III			
TŁ-4	245–266	Gd 1180	9080±90
TŁ-III/1	340–350	Gd 822	10660±210
TŁ-III/2	375–385	Gd 824	10680±190
TŁ-III/3	400–410	Gd 825	11160±110
TŁ-7	425–430	Gd 1183	12330±160

eite rona	zeile - wiersz		ist jest	soll sein powinno być
	von unten od dolu	von oben od góry		
91	3		896080 BP	8960±80 BP
01		5	857090 - 7350160 BP	8570±90 - 7350±160 BP
	12		7350160	7350±160
02	20		367070 BP	3670±70 BP
03		11	4540150 bis 367070	4540±150 bis 3670±70
		15	367070 - 303060 BP	3670±70 - 3030±60 BP
04	17		303060	3030±60
08		9	303060 BP	3030±60 BP
		15	303060 BP	3030±60 BP

page trona	line - wiersz from bellow od dolu	is jest	should be powinno być
106	11	160+100 BP	160±100 BP
	10	10 680+190 BP	10 680±190 BP
	10	10 930+90	10 930±90
	9	10 900 100 BP	10 900±100 BP
107	6	6420 70 BP	6420±70 BP
132	10	280 110 BP	280±110 BP
	10	10190 140 BP	10190±140 BP

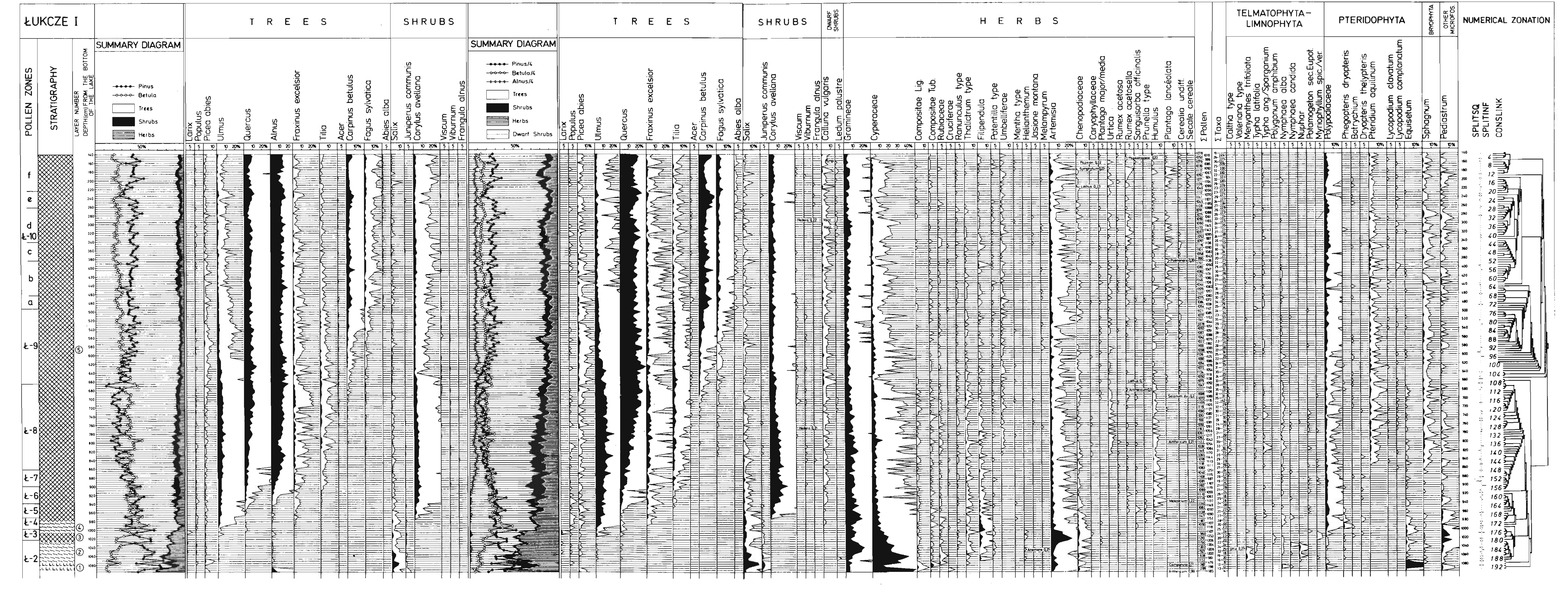

Fig. 8. Profile Łukcze I. Pollen diagram for bottom sediment of Lake Łukcze. Symbols used in stratigraphy column follow Troels-Smith (1955)

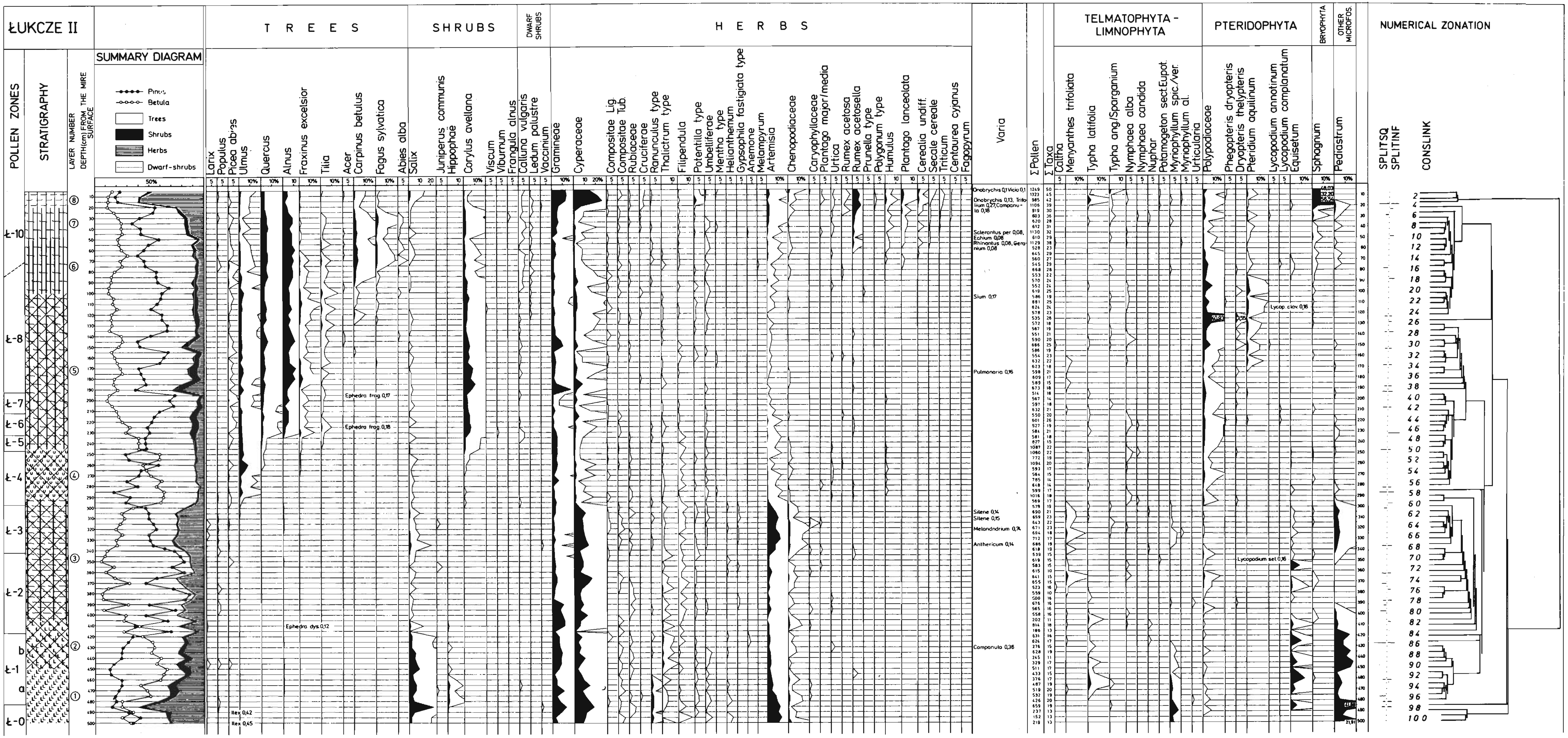

Fig. 9. Profile Łukcze II. Pollen diagram for peatbog sediments. Symbols used in stratigraphy column follow Troels-Smith (1955)

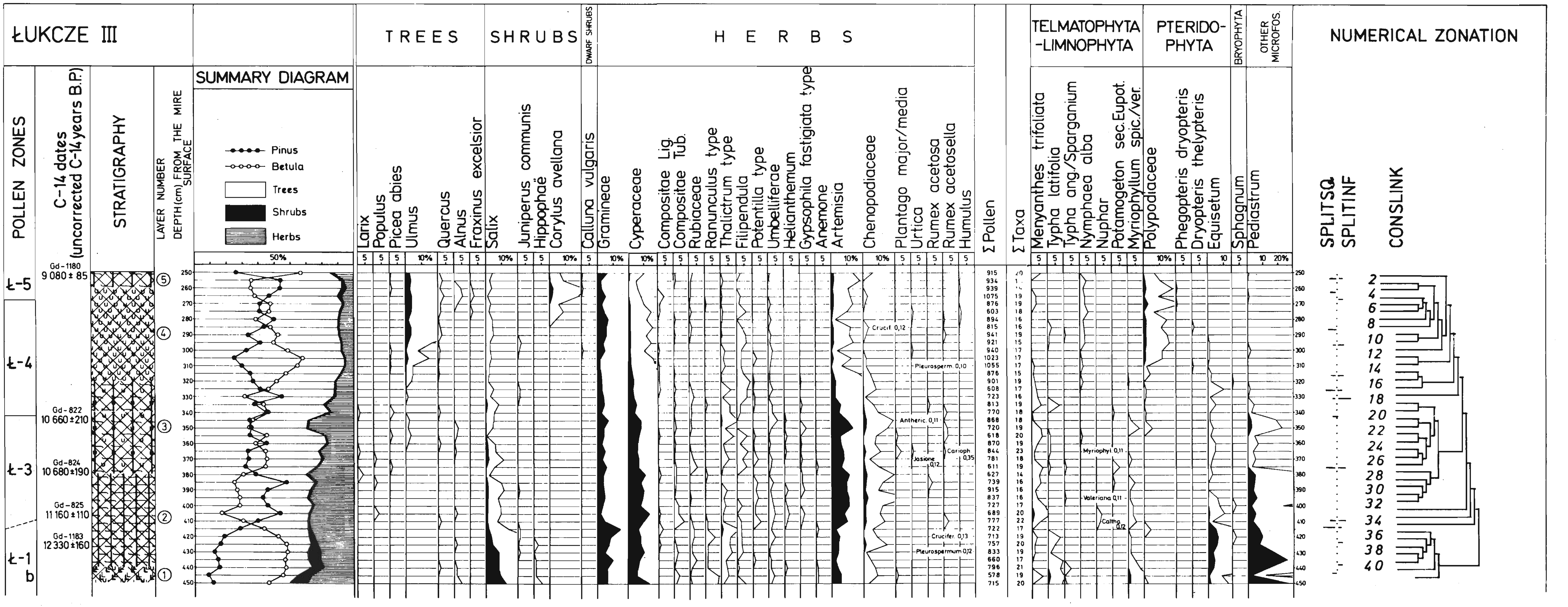

Fig. 10. Profile Łukcze III. Pollen diagram for peatbog sediments. Symbols used in stratigraphy column follow Troels-Smith (1955)

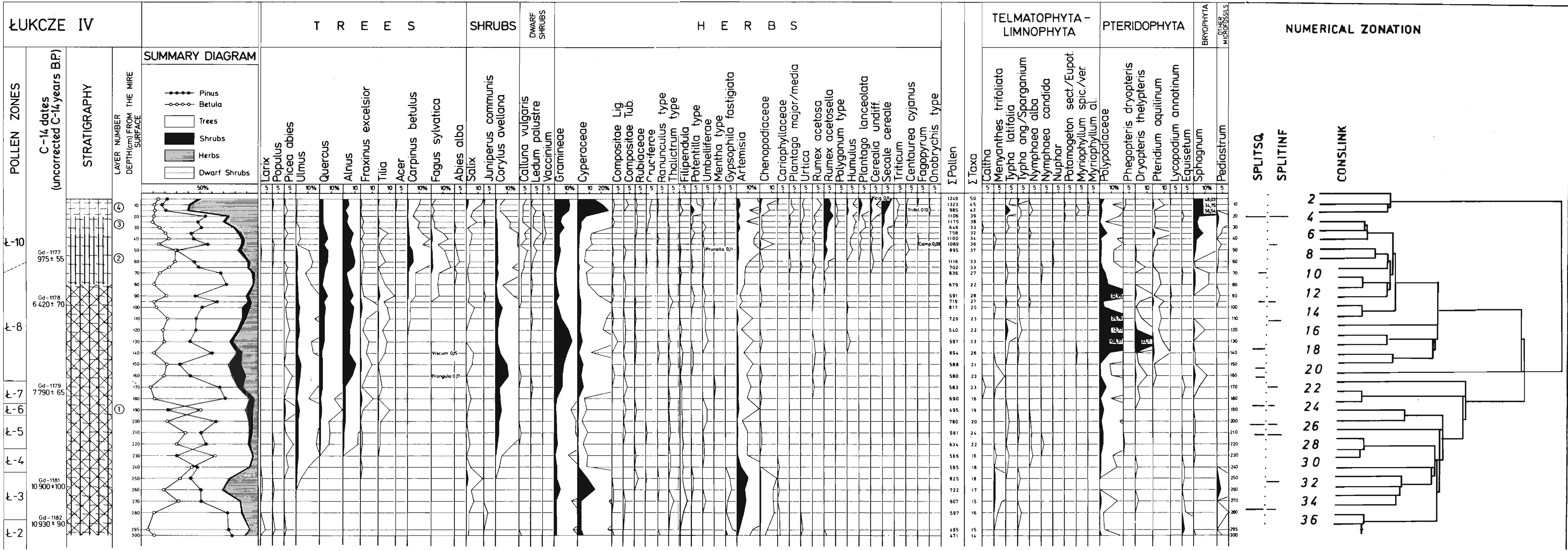

Fig. 11. Profile Łukcze IV. Pollen diagram for peatbog sediments. Symbols used in stratigraphy column follow Troels-Smith (1955)