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KRYSTYNA BAŁAGA

# VEGETATIONAL HISTORY OF THE LAKE ŁUKCZE ENVIRONMENT (LUBLIN POLESIE, E. POLAND) DURING THE LATE-GLACIAL AND HOLOCENE

## Historia roślinności okolic jeziora Łukcze w późnym glacjale i holocenie

ABSTRACT. Two profiles from the Łukcze Lake were studied by means of pollen and chemical analyses and radiocarbon dating. On this basis the plant communities which might have existed in the surroundings of Łukcze Lake during the Late-Glacial and Holocene are described. It is assumed that karstic phenomena played the chief role in the lake formation.

## INTRODUCTION

The Lublin Polesie is one of those regions of Poland where no detailed works had been done with respect to the history of Late-Glacial and Holocene vegetation. The earlier pollen-analytical investigations in the Polesie area (Kulczyński 1930; Paszewski & Fijałkowski 1970; Marek 1965) and in the neighbouring regions (Macko 1946; Scherwentke 1939 MS.) were based on the tree pollen only. Now, within the IGCP 158 B program, the palaeobotanical investigations in the region of the Łukcze Lake, situated in the Łęczna Lake District, the south-western part of the Polesie, have been undertaken. Two profiles have been examined: the profile Łukcze I taken from the bottom of the lake and the profile Łukcze III taken from the adjacent peat-bog. Further palynological analyses will concern the second profile from the peat-bog (Łukcze II). From the profile Łukcze III the radiocarbon datings, pollen concentration analysis, and analyses of physical and chemical properties have been made.

## THE REGIONAL NATURAL ENVIRONMENT OF LUBLIN POLESIE

According to Mojski (1972) the Lublin Polesie may be devided into four geomorphological units: the Łomazy Depression, the Parczew Plain, the Włodawa Hump and the Łęczna Lake District. Chałubińska and Wilgat (1954) include here also Dorohuck Depression and Kondracki (1967) — the Dubienka Valley. The Łomazy Depression is the lowest and flattest part of the Polesie. It is covered by forest and meadow communities. The Parczew Plain, situated southwards, has more of cultivated land. The Włodawa Hump is the most elevated area, reaching more than 200 m above sea level. The southernmost area of the Łęczna Lake District is distinguished by abundance of lakes and peat-bogs.

Geology. The Lublin Polesie is situated on the Pre-Cambrian platform, that is overlain by the Jurassic and the Cretaceous formations and a thin Cainozoic cover (Mojski 1972). The Tertiary deposits are found there in sheets varying in the extent and thickness. The Pre-Quaternary relief plays an important role in the topography of this area. It consists of Maestrichtian calcareous rocks, mainly chalkstone and marl. The Pleistocene deposits are composed mainly of fluvio-glacial sands, gravels and of lacustrine, mostly mineral sediments. The Holocene series form the organogenic sediments filling up the vast lacustrine depressions. Their thickness amounts to 20 m (Mojski 1972). They consist of peat, gyttja, lake-marl and mud deposits.

Geomorphology. The Lublin Polesie is very little diversified with respect to their hypsometry. The typical feature of the Łęczna Lake District are the aggradation plains formed into two levels of varying height (Mojski 1972). The higher level is formed by peat-bogs and lakes. The plains of denudation are much more diversified in their relief. In the Lake District they have been mostly formed on the limestone. The landscape of these large plains is varied, with chalky hills, sand-gravel hillocks, dunes and sinkholes.

Soils. The dominant soils in the Łęczna Lake District are podsols developed from outwashed sands and clay sands (Map of soils in Poland 1:300 000 and Zawadzki 1963). The podsols which developed from clay of fluvial origin occupy only small areas; calcareous rendzinas originated from limestone are also of limited extent. Slightly larger are areas of marsh soils which occur in the large river valleys and in the flat depressions of the region. These are: swamp-mud soils, peaty soils and marsh soils. They occur in complexes with prevalence of peaty soils.

Climate. Romer (1949) includes the Łęczna Lake District into the climatic region of great valleys and Gumiński (1948) to the eastern climatic region. The mean annual temperatures are 8°C—8·4°C with the maximum in July and minimum in January. The mean annual precipitation is not more than 600 mm, with the maximum in July and minimum in January and February. The dominating winds are westerlies. The vegetation season lasts about 211 days (Zinkiewicz 1963).

Vegetation. The Łęczna Lake District is a vast area of lakes and mires. The lakes occupy about 3000 ha, the forests 20 000 ha, and the peat-bogs about 50 000 ha (Fijałkowski 1960, 1972). The vegetation of lakes is considerably diversified, what results from the different trophic conditions. In the eutrophic lakes communities of *Charetum medii*, *Myriophyllo-Nupharetum*, *Hydrocharo-Stratiotetum* occur, and in their marginal zones *Scirpo-Phragmitetum* and *Glycerio-Sparganietum*. *Charetum asperii* and *Charetum contrariae* are typical for the oligotrophic lakes and *Charetum fragilis* for dystrophic lakes. A part of mires is left uncultivated by man and covered by shrubs; the others are being systematically mown by man. All types of mire communities are found here: ombrotrophic bogs, poor and rich fens and intermediate forms. The wood areas are composed mainly of the coniferous communities with dominant *Vaccinio myrtilli-Pinetum* growing on podsols, and *Cladonio-Pinetum* growing on sandy hills. On podsols and crypto-podsols with a rather high ground-water level there occur mixed forests *Pino-Quercetum*. The more fertile soils, situated in the vicinity of the rivers, streams and periodical streams, with a high level of ground-water, are covered by the deciduous forests *Tilio-Carpinetum medioeuropaeum*. The river and stream valleys are occupied by the communities of *Ficario-Ulmetum campestris* and by alder-woods *Carici elongatae-Alnetum*.

## ARCHAEOLOGICAL AND HISTORICAL DATA

Very little is known about the prehistoric settlement of the Polesie region. The archaeological findings come mainly from the neighbouring regions; the Vistula Valley and the Lublin Upland. The earliest traces of human activity in those areas go back to the Palaeolithic (Nosek 1957). The earliest traces of agriculture are known from the Vistula and Bug Valleys and are dated at about 3000 BC (Nosek 1957). These were tribes of Incised Pottery culture and Painted Pottery culture as well as Funnel Beaker and Globular Amphorae cultures. At the close of the Younger Stone-Age, the Strzyżów group of Corded Ware culture developed in the Polesie area (Gardawski & Susłowski 1974). In the Bronze-Age there developed the Lusatian culture which reached this area in the Hallstatt period. About 500 BC the Scythians made an invasion upon the area and in the La Tene period, the Pomeranian culture was brought over here from the north. The presence of the Celts has not been ascertained although there exist some traces of their migration here. The data known from the Early Middle Ages point to the fact that the Polesie region has been a waste area between the areas inhabited by different tribes.

Nowadays, the Lublin Polesie is the most sparsely populated area in Poland, with the smallest proportion of cultivated land (Uhorczak & Szczepanik 1963).

The description of the investigated lake. The Łukcze Lake, ca.

56·5 acres in area, is situated in the western part of the Lake District. The lake is composed of two parts (Fig. 1); the southern part is circular in shape with the tapering slopes forming a 8·9 m deep depression. The northern part is elongated with the slopes descending steeply and the flat bottom, and its maximum depth is 6·4 m. These two parts are linked by a channel, 2·4 m deep (Wilgat 1953). The north-eastern, eastern and southern lake shores are covered by alderwoods. In the south-eastern part, there are fragments of a devastated pine-forest *Vaccinio myrtilli-Pinetum* and mixed forest *Pino-Quer-*

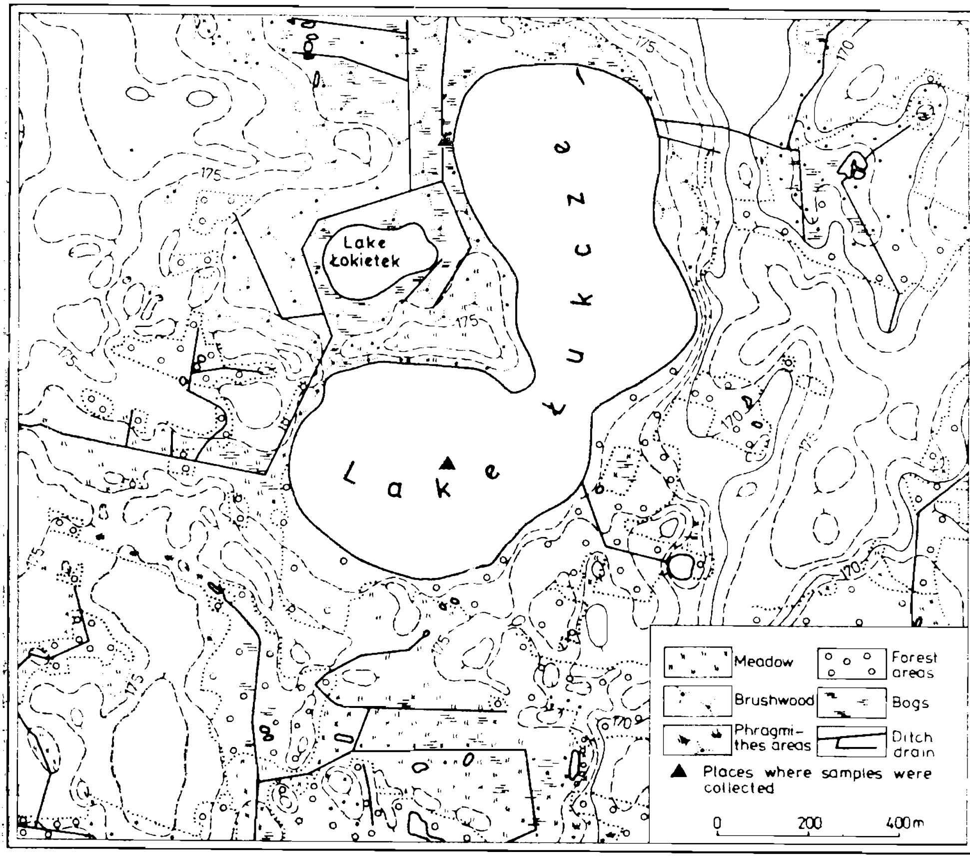



Fig. 1. Sketch map showing the location of the Łukcze Lake

*-cetum*. From the north-west and south-west the community of *Salici-Franguletum* connects the lake with the peat-bog which is covered by fragments of *Caricetum lasiocarpae*, *Caricetum limosae*, *Caricetum diandrae* and *Sphagnetum medio-rubelli*. Today, the lake is eutrophic. The aquatic vegetation is represented by two communities of order *Potametalia: Myriophyllo-Nupharetum* and *Hydrocharitetum morsus-ranae*. The facies of *Myriophyllo-Nupharetum* with dominating *Nuphar luteum* occurs along the western and south-western lake shore and the facies with *Myriophyllum alterniflorum* and *M. spicatum* occurs

on sandy places within the reedswamp zone. The largest stands of *Hydrocharitetum morsus-ranae* growing on the western and south-western shore of the lake are dominated by *Hydrocharis morsus-ranae* and *Potamogeton natans*. The reedswamps are represented mainly by *Phragmitetum* forming small stands of *Typha angustifolia* and *T. latifolia* with *Equisetum limosae* near the peaty shore. From the east and north-east the sandy shore is overgrown by the stands of *Phragmites communis*, *Schoenoplectus lacustris* and *Heleocharis palustris*.

## THE PALAEOECOLOGICAL INVESTIGATIONS

Methods. The cores for palaeocological investigations were taken from the bottom of the lake (Łukcze I) with the aid of a piston-sampler (Więckowski 1961) and from the peat-bog (Łukcze III) with the aid of a Russian sampler. Samples for pollen analysis from the Łukcze III profile were taken with a container of 1 $cm^3$ at intervals of 5 cm and the samples for physical and chemical analyses at intervals of 10 cm. Samples for pollen analysis were treated by Erdtman's acetolysis method, with pre-treatment by HCl and HF for mineral sediments and HCl for carbonate sediments (Faegri & Iversen 1964), and *Lycopodium* pellets added for pollen concentration counting (Stockmarr 1971). In the profile Łukcze I pollen and spores were counted at intervals of 1 mm of cover-slip. In the profile Łukcze III the whole cover-slip surface was searched, and pollen concentration calculated. Tree pollen sum was calculated using Andersen's (1970) correction factors for *Pinus, Betula* and *Alnus* (reduction by 4). The physical and chemical analyses were made by means of the methods generally adopted in pedology (Dobrzański & Uziak 1966): water content by drying in the temperature of 105 C, organic matter by ashing at $550^0$ C, $CaCO_3$ using Scheibler's method, pH using electrometric method, nitrogen using Kjeldahl's method, organic-C using Tyurin's method.

Sediment lithology. The stratigraphy of sediments was described according to Troels-Smith (1955) system.

Łukcze I — simplified description. The boring was made in the southern part of the lake, at the water depth of 5·5 m.

| Layer no. | Depth in cm | Description of sediment |
|---|---|---|
| — | 0– 140 | Detritus gyttja, green-brown, semifluid |
| 5 | 140– 982 | Detritus gyttja, green-brown, soft, changing downwards consistent<br>lim. s. 0, nig 2, strf 0, $Ld^24$ |
| 4 | 982–1007 | Moss peat, black-brown, very strongly decomposed<br>lim. s.0, nig 3, strf 0, $Tb^22$ |
| 3 | 1007–1027 | Detritus gyttja, black-brown<br>lim. s. 0, nig 3, strf 0, $Ld^22$ |

| | | |
|---|---|---|
| 2 | 1027–1072 | Moss peat, brown, slightly decomposed<br>lim. s. 0, nig 2, strf 0, $Tb^{2}$2 |
| 1 | 1072–base not seen | Silt with detritus, grey<br>lim. s. 0, nig 2, strf 0,<br>As 2, Ag 2, Dh+ |

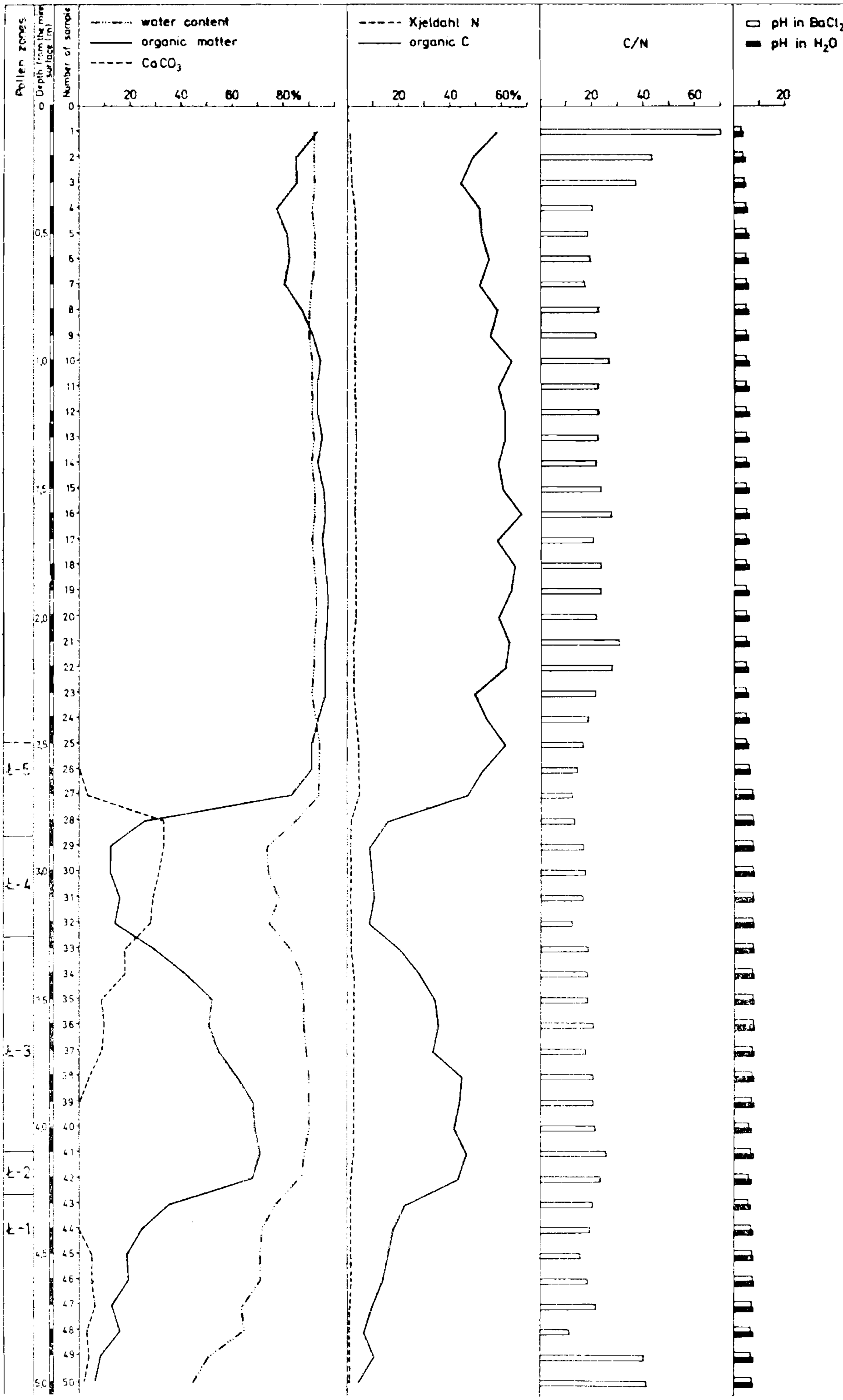
Łukcze III

| | | |
|---|---|---|
| 10 | 0–20 | Sedge-moss peat, light-brown, slightly decomposed<br>lim. s. 0, nig 2, strf 0, elas 3, sicc 2, $Tb^{1}$2, $Th^{1}$2, Ld+ |
| 9 | 20–37 | Sedge-moss peat, brown, moderately decomposed<br>lim. s.0, nig 2++, strf 0, elas 3, sicc 2, $Tb^{2}$, $Th^{2}$2 |
| 8 | 37–50 | Sedge-moss peat, black-brown, very strongly decomposed<br>lim. s. 0, nig 3, strf 0, elas 2, sicc 2, $Th^{2}$3, $Tb^{2}$1, Ld+ |
| 7 | 50–230 | Sedge-moss peat, black-brown with some gyttja<br>lim. s.0, nig 3, strf 0, elas 3, sicc 2++, $Tb^{2}$2, $Th^{1}$1, $Ld^{3}$1 |
| 6 | 230–260 | Peaty-gyttja, black-brown<br>lim. s. 0, nig 3, strf 0, elas 2, sicc 2, $Ld^{2}$2, $Tb^{2}$1, $Th^{2}$1 |
| 5 | 260–320 | Calcareous-detritus gyttja, grey-yellow<br>lim. s. 0, nig 1, strf 1, elas 2, sicc 2++, Lc 3, $Ld^{3}$1, Th+ |
| 4 | 320–340 | Detritus-calcareous gyttja, grey-brown<br>lim. s. 0, nig 1, strf 1, elas 3, sicc 2+, $Ld^{2}$2, Lc2, Tb+ |
| 3 | 340–380 | Peaty-gyttja, brown<br>lim. s. 0, nig 2++, strf +, elas 1, sicc 2, $Ld^{2}$2, $Tb^{2}$1, $Th^{2}$1, Lc+ |
| 2 | 380–430 | Sedge-moss peat with gyttja, black-brown<br>lim. s. 0, nig 3, strf 0, elas 1, sicc 2, $Tb^{2}$2, $Th^{2}$1, $Ld^{2}$1, Ag+ |
| 1 | 430–450 | Silt with some gyttja, grey-brown<br>lim. s. 0, nig 2, strf +, elas 0, sicc 2++, As 2, Ag 1, $Ld^{3}$1, Tb+ |

Physical and chemical investigations. The physical and chemical properties of sediments in the Łukcze III profile are shown in Fig. 2.

Organic matter — the content of organic matter increases upwards the profile and decreases slightly in the carbonate layer; in the sedge-moss peat is about 90%.

Fig. 2. Changes in physical and chemical properties in the profile Łukcze III



Pollen zones
Depth (from the mire surface) (m)
Number of sample
water content
organic matter
$CaCO_3$
20 40 60 80%
Kjeldahl N
organic C
20 40 60%
C/N
20 40 60
pH in $BaCl_2$
pH in $H_2O$
20
0 0,5 1,0 1,5 2,0 2,5 3,0 3,5 4,0 4,5 5,0
Ł-5
Ł-4
Ł-3
Ł-2
Ł-1

Organic-C shows a positive correlation with the content of organic matter and negative correlation with the content of $CaCO_3$.
Kjeldahl-N — the content of nitrogen in the carbonate-gyttja and in the mineral layers of the profile is never $> 1\%$. In the peaty-gyttja and in the sedge-moss peat it ranges between 1% and 3·9%.
C/N ratio shows also a positive correlation with the organic carbon and organic matter. Hansen (1961) treats this ratio as an indicator for different kinds of sediments. C/N=10 is assumed to be characteristic for the transition from gyttja to dy sediments. In the whole profile of Łukcze III the ratio is $> 10$.
$CaCO_3$ has been found in two layers: in the basal silt, and at the depth of 270–380 cm where it is a component of detritus gyttja. $CaCO_3$ has not been found in the sedge-moss peat, accumulated over the carbonate stratum. In the profile Łukcze I $CaCO_3$ has not been found at all. The precipitation of calcium carbonate may be a result of various physical, chemical, and biological processes. First of all it is conditioned by the lack of free $CO_2$ in the water. Shallow water is more favourable for the precipitation of $CaCO_3$, especially in the vicinity of shores and bays where waving facilitates liberation of $CO_2$ into the atmosphere. This factor has had the greatest influence on the formation of the carbonate layer in the profile Łukcze III.
pH values of sediment change along with the depth. It is neutral in the mineral layers and acidic in the sedge-moss peat.
Water content — in the basal deposits amounts to 45–80%; in the peaty-gyttja to 90%, whereas in the calcareous-gyttja it decreases to 70–80%. In the sedge-moss peat it increases again to 95%.

## THE DESCRIPTION OF THE POLLEN ASSEMBLAGE ZONES (FIG. 3)[1]

Zone Ł—O (Ł—III 450–427·5 cm)
The dominant tree pollen type is *Betula*, up to 40%. *Pinus* pollen values are low, ca. 15%, and *Salix* pollen proportion is up to 20%. NAP percentages are 40–50%, with *Cyperaceae*, *Gramineae* and *Artemisia* as prevalent pollen taxa. *Hippophaë* pollen occurs sporadically.
Ł—O/Ł—1 boundary: decline in *Betula* and *Salix* pollen values and increase in *Pinus* and *Gramineae* percentages; 12 330±160 BP.

Zone Ł—1 (Ł—I 1090—1052·5 cm)

*Pinus* pollen is dominant, up to 60%. *Betula* pollen values are low, up to 20%. NAP percentages are 20–60%, with the same dominant pollen types as in Ł—O. *Juniperus* pollen values are $< 5\%$.
Ł—1/Ł—2 boundary: the rise in *Betula* and *Gramineae* pollen values and fall in *Pinus* and *Salix* percentages.

Zone Ł—2 (Ł—I 1052·5–1027·5 cm, Ł—III 427·5–412·5 cm)
The pollen frequencies of *Gramineae* are high and pollen values of *Salix* decrease.

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[1] Fig 3 under the cover.

NAP pollen reaches high values comprising mainly *Gramineae, Cyperaceae* and *Artemisia.* Single pollen grains of *Hippophaë* are found.

Ł—2/Ł—3 boundary: rise in pollen frequencies of *Artemisia* and fall in pollen values of *Gramineae*; 11 116±210 BP.

Zone Ł—3 (Ł—1027·5–1002·5 cm, Ł—III 412·5–327·5 cm)

The pollen values of *Artemisia* increase up to 30%. The pollen percentages of *Salix* are > 2%. The pollen values of *Pinus* amount 41% and of *Betula* up to 30%. NAP consists mostly of *Artemisia, Cyperaceae* and *Chenopodiaceae.*

Ł—3/Ł—4 boundary: fall in pollen values of *Artemisia* and empirical limit of *Ulmus* pollen; 10 900∓100 BP.

Zone Ł—4 (Ł—I 1002·5—972·5 cm, Ł—III 327·5—287·5 cm)

This zone is characterized by the substantial pollen percentages of *Ulmus*. The pollen values of *Betula* reach up to 55%, those of *Pinus* to 40%. The decrease in pollen values of NAP results mainly from the reduction of *Artemisia* (less than 10%), *Gramineae* and *Cyperaceae* pollen percentages. The pollen curves of *Filipendula* and *Polypodiaceae* rise.

Ł—4/Ł—5 boundary: fall in pollen values of *Pinus* and empirical border of *Corylus* pollen.

Zone Ł—5 (Ł—I 967·5—942·5 cm, Ł—III 287·5—250 cm)

*Ulmus* pollen frequencies increase up to 6%, there is a maximum of *Pinus* pollen, the values of *Betula* are 30–40%. There appears a continuous but very low (< 1%) *Fraxinus* pollen curve, and *Corylus* pollen appears too.

Ł—5/Ł—6 boundary: the maximum rise in pollen values of *Corylus*; 9080±85 BP.

Zone Ł—6 (Ł—I 942·5—897·5 cm)

*Corylus* pollen frequencies are high. The pollen values of *Pinus* and *Betula* are like in Ł—5. *Quercus* pollen percentages increase. The pollen values of *Fraxinus* and *Alnus* are low. There appears *Tilia* pollen.

Ł—6/Ł—7 boundary: rise in pollen frequencies of *Betula, Alnus* and *Quercus.*

Zone Ł—7 (Ł—I 897·5—857·5 cm)

This zone is characterized by the domination of *Betula* pollen values over those of *Pinus.* The pollen frequencies of *Alnus* and *Quercus* increase gradually. The pollen percentages of *Corylus* decline slightly. The pollen values of *Fraxinus* are up to 3% and pollen percentages of *Tilia* increase.

Ł—7/Ł—8 boundary: increase in pollen frequencies of *Quercus* and *Alnus*, fall in pollen values of *Pinus; Pteridium aquilinum* spores appear; 7790±65 BP.

Zone Ł—8 (Ł—I 857·5—657·5 cm)

The dominant pollen curves are those of *Ulmus, Quercus* and *Corylus*, the latter with the tendencies to decline. The pollen values of *Betula* are up to 27%. The pollen frequencies of *Pinus* are slightly lower than in Ł—7. There is some rise in pollen percentages of *Fraxinus* and *Tilia* but they still occur in low values. *Carpinus* and *Fagus* appear for the first time about 6420±70 BP, first as single pollen grains, and later in the continuous curves. *Acer* pollen occurs sporadically. First pollen grains of *Plantago lanceolata* and Cerealia appear in this zone.

Ł—8/Ł—9 boundary: fall in pollen values of *Ulmus* and rise in pollen frequencies of *Pinus*.

Zone Ł—9 (Ł—I 657·5—492·5 cm)

The pollen frequencies of *Carpinus* and *Fagus* increase, but pollen values of *Fagus* remain low. *Pinus* pollen predominates. Pollen values of *Betula* are 13–21%. Pollen frequencies of *Ulmus, Corylus, Tilia* and *Fraxinus* decrease. There is a noticeable increase in pollen frequencies of the indicators of human activities.

Ł—9/Ł—10 boundary: considerable rise in *Carpinus* pollen frequencies.

Zone Ł—10 (Ł—I 492·5—140 cm)

In this zone the *Carpinus* pollen plays more important role. The frequencies of *Fagus* are never higher than 6·2%. Pollen values of *Betula* and *Pinus* are similar to those in zone Ł—9. Pollen percentages of *Ulmus*, *Fraxinus* and *Tilia* decrease. This zone has been further subdivided into six subzones that may be characterized as follows:

Subzone Ł—10a (Ł—I 492·5—467·5 cm)

Appreciable increase in pollen frequencies of *Carpinus* (up to 8%).

Subzone Ł—10b (Ł—I 467·5—402·5 cm)

Fall in pollen values of *Carpinus* and slight rise in NAP pollen percentages which consist mainly of *Gramineae.* Pollen percentages of *Plantago lanceolata* and *Urtica* increase too.

Subzone Ł—10c (Ł—I 402·5—357·5 cm)

Small maximum in pollen frequencies of *Carpinus*, fall in pollen percentages of NAP caused by a decrease in pollen values of *Plantago lanceolata*, *Rumex* and *Urtica.*

Subzone Ł—10d (Ł—I 357·5—262·5 cm)

Decrease in pollen frequencies of *Carpinus*, rise in pollen values of NAP, mainly of *Gramineae* and *Artemisia*, but also of *Plantago lanceolata*, *Rumex* and *Urtica.*

Subzone Ł—10e (Ł—I 262·5—222·5 cm)

Rise in pollen values of *Carpinus* and *Quercus*, fall in pollen frequencies of *Corylus*. The NAP values decrease.

Subzone Ł—10f (Ł—I 222·5—140·0 cm)

Fall in pollen frequencies of *Carpinus* and *Quercus*. The values of *Corylus* pollen decrease, percentages of NAP increase (mainly *Gramineae* and *Artemisia*). The pollen frequencies of *Plantago lanceolata*, *Rumex* and *Urtica* decrease. In this subzone *Secale cereale* pollen appears first, at 975±55 BP.

## VEGETATIONAL HISTORY OF THE AREA

In the zone Ł—0 the landscape of the Łukcze Lake surroundings was of a parkland type, dominated by *Salix* shrubs with groups of *Betula* trees. *Pinus* pollen was probably brought over here from a long distance. Sandy places were occupied by communities with dominant *Artemisia*, *Juniperus* and *Hippophaë.*

In the zone Ł—1 *Pinus* forests developed in the area, with the increasing proportion of *Betula*. The damp places were occupied by *Salix* shrubs. The steppe-like communities with dominant *Artemisia* and *Juniperus* expanded on sunny and sandy habitats covering rather large areas.

Zone Ł—1 occurs only in the profile Łukcze I, and is probably lacking in the profile Łukcze III.

In the zone Ł—2, about 12 333±140 BP, *Salix* communities got reduced and *Betula* woods expanded gradually. Vast areas were occupied by herb communities with dominant *Gramineae*, *Cyperaceae* and *Artemisia*, with some *Hippophaë* thickets still existing.

In the zone Ł—3, about 11 116±210 BP, the landscape resembled a park tundra with steppe communities dominated by *Artemisia* and *Chenopodiaceae*, with groups of trees consisting of *Betula*, *Pinus* and probably *Larix*. Wet areas were occupied by *Salix* communities.

In the zone Ł—4 the expansion of forest communities began. High NAP values point to the fact that the forests were still open. The moister soils were covered by birchwood with some elm proportion and with *Filipendula* and *Polypodiaceae* in its undergrowth. According to the radiocarbon dates the elm appeared in this region around 10 900 BP, preceding the spread of *Corylus*, what has also been observed in the eastern part of Sandomierz Basin (Mamakowa 1962). On the hills pine-birch woods developed, with an admixture of *Populus*. The lake shores were covered with willow shrub communities. On sunny slopes some fragments of steppe communities with *Artemisia* and *Chenopodiaceae* might have survived.

In the zone Ł—5 pinewoods became the dominant forest type, elm began to play more and more important role on the humid soils and *Fraxinus* occurred as an admixture in those forests. On sunny slopes *Corylus* thickets started to expand.

The zone Ł—6 is characterized by further development of pine and birchwoods. On the wet slopes of the river valleys, there developed riverside forests with *Ulmus*, *Fraxinus* and *Alnus*. On sunny, fertile soils *Corylus* thickets reached the maximum development.

In the zone Ł—7 *Quercus* and *Alnus* began to play a more crucial part in the forests. Alder occupied at that time the river valley floors, forming the initial alder communities with *Dryopteris thelypteris*, *Humulus* and *Filipendula* in the herb layer. When oak and lime appeared, deciduous forests began to spread gradually on more fertile soils. Besides, the oak encroached also pine forests, forming *Pino-Quercetum* on sandy soils. The sunny slopes were covered by hazel thickets.

In the zone Ł—8 deciduous forests reached their maximum development. The distribution of deciduous trees was determined by soil conditions. The sandy soils were still occupied by pine-birch woods with *Pteridium aquilinum* in the herb layer (about 7790 BP). The oak began to play more and more important part in mixed forests *(Pino-Quercetum)*. *Quercus robur* could also grow on dried up peat-bogs (Iversen 1960). *Quercus petraea* occurs nowadays in the area of the lake district only sporadically, avoiding wet and strongly podsolized habitats (Fijałkowski 1957). The humid soils were still occupied by forests consisting of alder, elm and ash, with *Humulus*, *Urtica* and *Filipendula*. It is in this zone that single pollen grains of *Viscum* and *Acer* appeared. By the end of zone first indicators of human activities, *Plantago lanceolata*, *P. major/media* and Cerealia, have been found.

During the zone Ł—9 pine and oak-woods still dominated on sandy soils. The composition of the forests on more fertile soils began to change. The change was brought about by the expansion of hornbeam that began at the expense of elm and lime, initiating the development of present *Tilio-Carpinetum* community (Fijałkowski 1960). The hornbeam appeared in this area very early, about 6220 BP. The undated pollen diagrams from the neighbouring areas (Macko 1946; Scherwentke MS; Mamakowa 1962) are suggestive of the same phenomenon. At the same time deciduous forests were cleared by man on a large scale. On the cleared areas shrub communities with hazel developed. In this zone pollen curve of *Picea* reached its highest values, but never exceeding 1%. Nowadays the area of lake district is outside the area of spruce distribution (Jedliński 1922, 1927). By the end of zone, after a long break, the indicators of human activities appeared again. These are *Plantago lanceolata*, *Rumex* and Cerealia.

In the zone Ł—10 the role of *Carpinus* and *Fagus* increased. Today, *Fagus* does not grow in the area of lake district (Fijałkowski 1957). The pollen analysis of the surface samples from the lake shore revealed the presence of single *Fagus* pollen. The nearest recent *Fagus* stands can be found in the north-western part of Łuków Plateau and in the southern part of Lublin Upland (Browicz 1976). It might be supposed that in the earlier times the range of beech distribution was wider and that pollen grains of that tree in the profile of Łukcze Lake was carried over here from a short distance. The development of vegetation in this zone was influenced by both climate and man. The *a*, *c* and *e* subzones were characterized by poor human activities, enabling the regeneration of forest communities. The most susceptible tree to the changes brought about by human activities was *Carpinus*, and the least susceptible — *Quercus* and *Corylus*. The *b*, *d* and *f* subzones were characterized by intensive human activities, with the increased frequency of cultural indicators. The most important were: *Plantago lanceolata* — a component of primitive meadow communities, *Artemisia* — a weed characteristic of primitive fields, growing also near man's settlements, and *Rumex (acetosella)* — a weed of acidic, poor soils (Ralska-Jasiewiczowa 1968). The area of wood communities was reduced, especially on fertile soils.

## HISTORY OF THE LAKE

The question of the origin of lakes in Łączna District has been discussed by Sawicki (1919) and Wołłosowicz (1922), who regard them as remnants of the large Pleistocene ice-dam lake. Sawicki has not explained the reasons of preservation of those remains. Wołłosowicz has tried to explain it with the uplift of the area of middle Nadbuże. Lencewicz (1931) and Maruszczak (1966) point to the possible connection between the formation of lakes and the karst-bed. Więckowski and Wojciechowski (1971) emphasize the fact that during the Allerød time (the dating of peat from the bottom of Białe-Sosnowieckie lake sediments is 11 235±140 BP) — the processes of the deepening of lake basins were faster than the rate of peat accumulation, therefore they got filled up with water. The existence of peat layer underlying the gyttja sediment, has been discussed by Kulczyński (1930), Tołpa (1935), Tymrakiewicz (1935) and Okruszko et al. (1971) who connect this phenomenon with the sinking of karst bedrock. On the base of the present palynological studies and radiocarbon datings it may be supposed that ca. 12 300 years ago the investigated area was occupied by mires with small open pools where calcareous-gyttja could have been deposited. It is evidenced by the occurrence of moss-peat composed of *Drepanocladus revolvens*, *D. fluitans*, *D. sendtneri*, *Calliergon giganteum* during the zones Ł—1 and Ł—2 in the profile Łukcze I and of sedge-moss peat with some gyttja in the profile Łukcze III. During the zone Ł—3 in the profile Łukcze I detritus-gyttja was accumulated and in the profile Łukcze III sedge-moss peat was covered with the detritus-calcareous-gyttja. During the zone Ł—3 (11 116±210—10 900±100 BP) the mire got flooded due to the sinking of chalky bed combined possibly with the melting of "dead ice". This process was best recorded in the profile Łukcze I, taken within the area where a permanent lake was formed then. The lacustrine phase evidenced in the profile Łukcze III by the accumulation of calcareous-gyttja was temporary; about 9080±85 BP gyttja was replaced again by the sedge-moss peat recording the development of a mire in the marginal zone of the lake.

## CONCLUSIONS

1. On the basis of pollen analytical data obtained from 2 profiles the history of vegetation near Łukcze Lake during the Late Glacial and Holocene has been reconstructed.

2. Eleven local pollen assemblage zones have been defined. The description for five of them was based on data from both profiles: Łukcze I and Łukcze III.

The vegetational history of the area may be summarized as follows:

Zone Ł—0: parkland landscape with groups of birch trees and willow shrubs. Herb communities dominated by *Gramineae*, *Cyperaceae* and *Artemisia*. Ca. 12 330 BP.

Zone Ł—1: spread of pine, development of forests, with still large areas of steppe-like communities with *Hippophaë* and *Juniperus*.

Zone Ł—2: domination of grasslands with spreading birch. Reduction of *Salix* shrubs.

Zone Ł—3: prevalence of steppe-like communities with *Artemisia* and *Chenopodiaceae.*

Zone Ł—4: the development of pinewoods and spread of *Ulmus* (about 10 900±100 BP).

Zone Ł—5: further development of pinewoods and appearance of *Corylus.*

Zone Ł—6: maximum development of hazel shrubs (9080±85 BP); spread of *Quercus*, *Alnus*, *Fraxinus* and *Tilia.*

Zone Ł—7: increasing role of *Quercus* and *Alnus*. Formation of *Pino-Quercetum* and alderwoods.

Zone Ł—8: development of deciduous forests and appearance of *Carpinus* and *Fagus*. First human indicators: *Plantago lanceolata* and Cerealia.

Zone Ł—9: spread of *Carpinus* and *Fagus*, and decreasing proportion of *Ulmus* and *Tilia* in deciduous forests.

Zone Ł—10: further decrease in *Ulmus*, *Tilia* and *Fraxinus* proportion. *Carpinus* plays more and more important part. The changes in the composition of woods are caused both by climate and man's activities.

3. It has been assumed that karstic phenomena played the chief role in the formation of lake.

*Institute of Earth Sciences, Maria Curie Skłodowska University, ul. Akademicka 19, 20-033 Lublin*
*Instytut Nauk o Ziemi UMCS*

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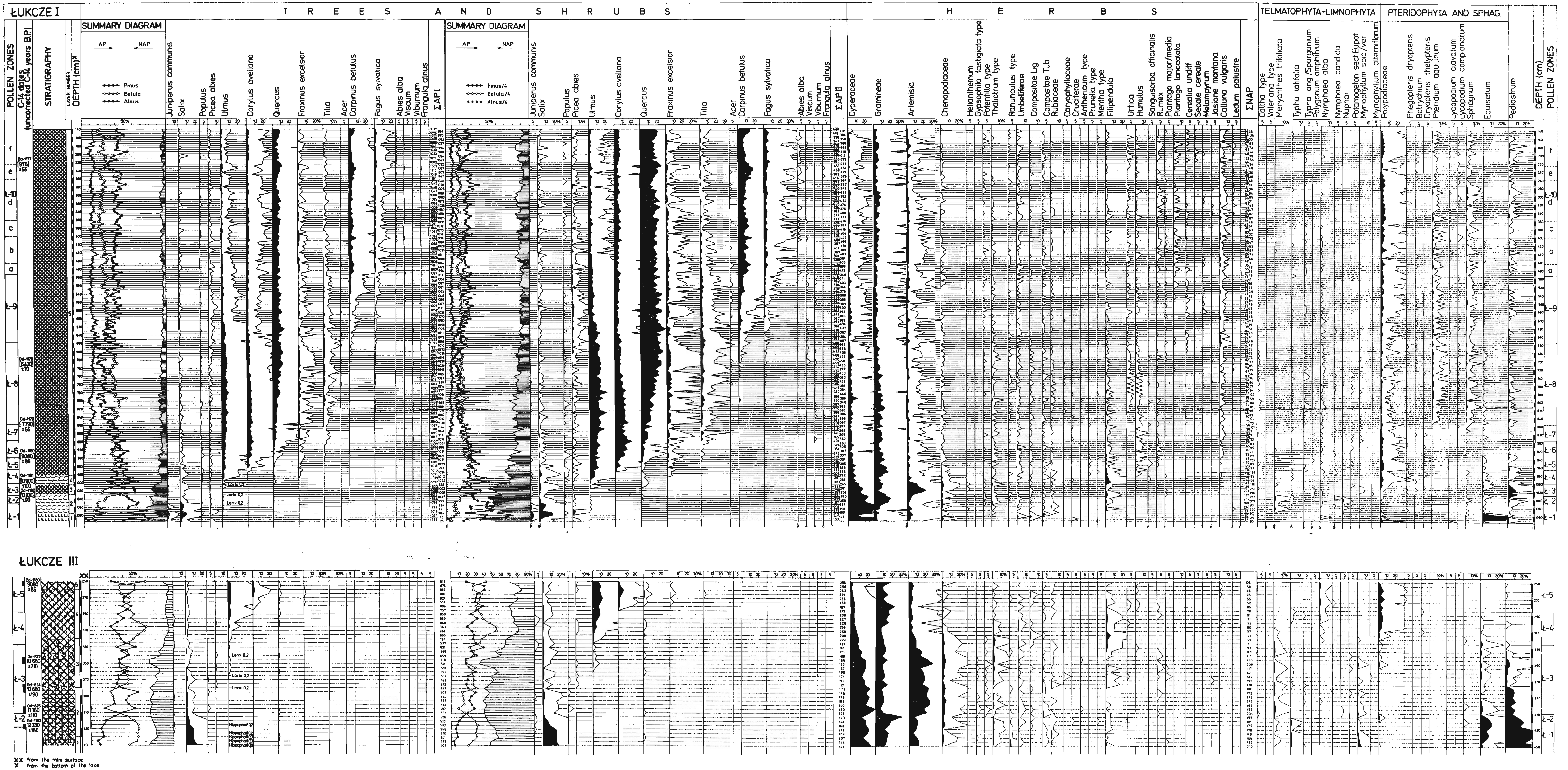


Fig. 3. Pollen diagrams from the profiles Łukcze I and Łukcze III. The symbols used in the stratigraphy column follow Troels-Smith (1955)