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LAKE STEKLIN — A REFERENCE SITE FOR THE DOBRZYŃ-CHEŁMNO LAKE DISTRICT, N. POLAND REPORT ON PALAEOECOLOGICAL STUDIES FOR THE IGCP-PROJECT NO. 158 B

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ABSTRACT. The sediments of Lake Steklin were examined by means of pollen, macrofossil, physical and chemical analyses. Because of the high content of calcium carbonate in the whole profile except for the bottom part, only one sample from the basal peat was suitable for the radiocarbon dating. It gave the age of 11630±110 BP. 8 local pollen assemblage zones were defined and the development of vegetation on the areas surrounding the lake was described, starting from the Allerød Interstadial till the recent times. The impact of man on natural vegetation has been recorded since the Neolithic. The succesion of aquatic communities in the lake began during the Younger Dryas.

INTRODUCTION

The reference site Lake Steklin lies in the south-western part of the Dobrzyń Lake District (Dobrzyń Moraine Plateau). In the interwar period and after the World War II many detailed geomorphological, geological and hydrographic investigations were conducted in that area; the newer and more important of them are those of Niewiarowski (1957), Churska (1958, 1969) and Mrózek (1958). The development of settlement has been studied by Kwiatkowska (1963) and the climate by Wójcik and Wójcikowa (1973). A summing up of the existing information on the geological structure of the area is the geological map published by Churski et al. (1978). The pollen diagrams of the Late-Glacial and Holocene sediments have been published by Oszast (1957) and Kępczyński (1960). Kępczyński (1960, 1965) have been conducted also geobotanical studies, while Grześkowiak (MS) have been carried out archaeological investigations.

The first palaeoecological analyses of the bottom sediments of Lake Steklin were done by Author as a complement to the studies on the development of the lake channel carried out by Dr. Z. Churska. In February 1978, by the kindness of Dr. K. Więckowski, a full profile of lacustrine sediments was taken in the central part of the lake as material for study within the IGCP programme. Due to high $CaCO_3$ content in the profile radiocarbon dating was impossible and the only dating comes from the peat layer in the bottom of the profile. For supplementary C^{14} datings another profile was taken directly from the peatbog in the western part of the lake channel; this is now being studied.

On the material from the first coring the following analyses have been made: molluscs by Dr. I. Dmoch, fish remains by Dr. B. Wilczyńska, fruit scales and fruits of birch by Dr. U. Boińska, and diatoms by Dr. B. Marciniak.

Nitrogen and organic carbon contents have been determined at the Institute of Biology; pH, water content, wet density, loss on ignition and $CaCO_3$ content have been studied in the Institute of Geography.

A full report on the analysis of the material from the reference site, according to the rules set by "Project Guide" (Berglund 1979), will be published at a later date.

THE CONTEMPORARY NATURAL ENVIRONMENT

Description of the palaeoecological region

The Dobrzyń Moraine Plateau District distinguished by Szafer and Pawłowski (1973) in the geobotanical division of Poland includes in fact the Drwęca Valley and the Chełmno Moraine Plateau as well as the Dobrzyń Moraine Plateau, hence the name used by these authors is inaccurate. It could rather be termed the Chełmno-Dobrzyń Lake District in accordance with the physical and geographical division proposed by Kondracki (1978).

A characteristic feature of this area is the young glacial relief developed mostly during the Poznań Stage of the Last Glaciation (Vistulian). Within the Chełmno and Dobrzyń Moraine Plateau there is the definite preponderance of flat and undulant moraine plains made up of till and sandy-till deposits. During the longer halts of the inland ice there developed zones of end moraines built of till and fluvioglacial deposits, belonging to the Poznań Stage and its recession phases: the Kuyavian and Krayna Phases, distinguished by Galon (1961). During those phases the sandy outwash developed plains, the largest of which is the Dobrzyń outwash. Of great importance in those lake districts are the dead ice moraines, kames, eskers, and subglacial channels with the lakes which fill them up (Niewiarowski 1973). In the Drwęca Valley which separates the two moraine plateaux there occur vast sandy and gravel terraces and a sandy-silty or peaty flood-plain that is often waterlogged. Numerous kettle depressions filled up with peats and slime occur over the whole area.

The vegetation cover of the region has been largely changed by human management. Most of the land now is under crop, and forests occur only in outwash plains, river terraces and on the slopes of channels and valleys. The dominant forest species is now the pine *(Pinus sylvestris)*. Other common species in forest communities are: oak *(Quercus robur)* and birches *(Betula pendula* and *B. pubescens)*. Other deciduous tree species form but a small percentage in the forest communities.

The boundaries of the natural ranges of *Fagus sylvatica*, *Sorbus torminalis* and *Betula humilis* run through the Chełmno-Dobrzyń Lake District. The scattered stands of *Larix polonica*, *Picea abies* and *Taxus baccata* are here beyond their natural range (Kępczyński 1973).

Description of the reference area

a. Topography, geology, soil, climate

As mentioned above the Lake Steklin lies in the south-western part of the Dobrzyń Lake District, at a small distance from the Vistula valley. It is situated west of the road T-81, 23 km from Toruń towards Lipno. The south margin of the lake is bordered by the grounds of the village Steklin, on the north there are the localities Steklinek, Steklinek Nowy and Hornówek. The lake surface is about 20 m below the surrounding flat and undulating moraine plateau. West and south of the lake, along the edge of the moraine plateau and over the Vistula river terraces spread a vast dune field. The moraine plateau near the channel is built of till and very often of sandy till. The upper till layer is underlain by several more till layers interbedded by fluvioglacial and fluvial deposits. The total thickness of the Quaternary deposits ranges from 40 to 60 m. The Quaternary is underlain by Pliocene deposits (mainly clays) and Miocene deposits (mainly sands and fine silts of the browncoal formation).

The soils show close links with the lithology. In the eastern part of the lake district podzolic soils prevail developed chiefly on outwash sands and locally on sandy till. In the southern and north-western part of the area there occur varieties of brown soils, and locally grey-brown podzolic soils developed on moraine deposits. Lake Steklin is situated within the compass of brown and grey-brown soils developed over sandy-loamy and loamy deposits (Prusinkiewicz & Regel 1973).

The Dobrzyń Lake District lies in the temperate climate zone, intermediary between oceanic and continental climate. Data on the precipitation in the environs of Lake Steklin come from the measuring station at Czernikowo, whereas the data on temperature were obtained from the meteorological station in Toruń. Considering the difference in altitude between these two points

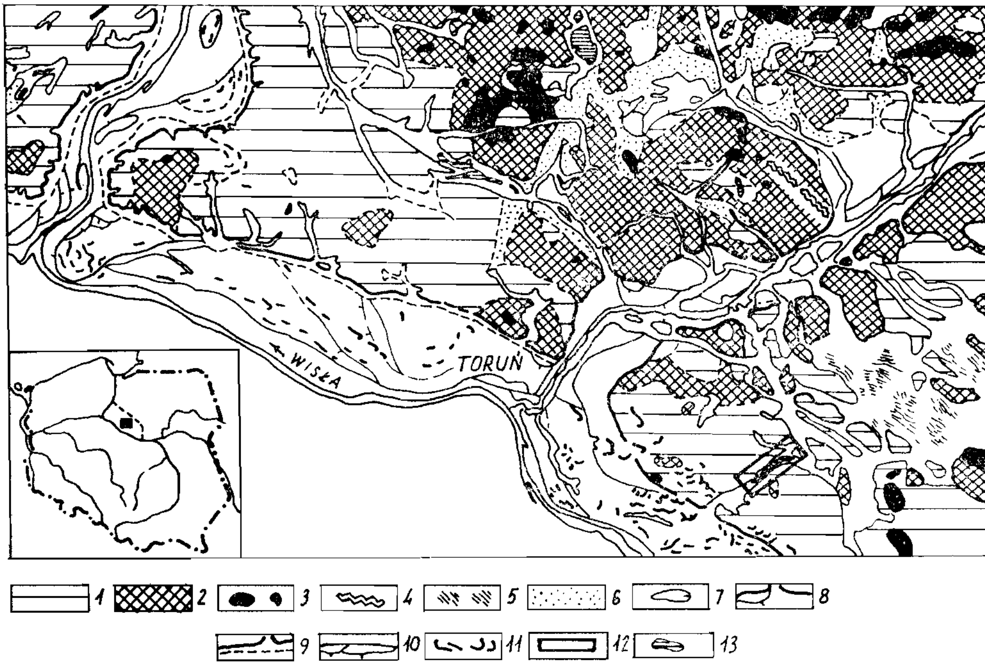

Fig. 1. Geomorphological map of the environs of the Lake Steklin (after Galon and Roszko 1953): 1 — flat moraine plateau, 2 — undulant moraine plateau, 3 — moraine hummocks and hills, 4 — eskers, 5 — drumlins, 6 — outwash plains, 7 — major depressions without outflow, 8 — edges of moraine plateau, 9 — zone of denudation, 10 — edges of river terraces, 11 — dunes, 12 — Lake Steklin, 13 — lakes

(environs of Lake Steklin 92 m a.s.l., Toruń 69 m a.s.l.), the data should be regarded as approximate.

The basic climate features can be characterized by the following parameters: the mean annual temperature in the 20 years period (1951–70) is 7·4°C, the mean January temperature for that period being —3·2°C, and the mean July temperature 18·0°C. The mean length of the growing season is 214 days.

The mean annual precipitation for the period 1965–69 at Czernikowo is 539 mm, out of which 324 mm falls on the growing season IV–IX. The highest mean monthly precipitation were recorded in July — 66 mm, the lowest in February and March — 27 mm. The prevailing winds during the year are those blowing from the west.

b. Present vegetation

The steep slopes of the lake basin do not favour the development of aquatic and reedswamp vegetation. Only the western and southern part of the channel, which is considerably shallower, present favourable conditions for the development of these species.

The belts of characteristic lake vegetation have developed along the lake shores. However, due to the rapid bottom sinking, the total width of the three vegetation belts — submerged plants, floating leaf plants and reedswamp plants — reaches a maximum of 4 m. The belts consist of rather loosely arranged vegetation patches.

In the belt of submerged plants the most frequent species are: *Ceratophyllum demersum*, *Myriophyllum verticillatum* and *Elodea canadensis*. Stands of *Nymphaeidae* are composed of *Nuphar luteum*. In the third belt species characteristic of the class *Phragmitetea* occur. In shallow places side by side with reedswamps species members of the class *Alnetea glutinosae* grow; such as *Dryopteris thelypteris*, *Solanum dulcamara*, *Lycopus europaeus*, *Salix cinerea* and *Ribes nigrum*. Between the western end of the lake und the road patches of wet alderwood have developed with a tree layer composed of *Alnus glutinosa*.

Among patches of reedswamp plants and of species of the class *Potametea*, along the shores as well as in the small pools occurring in the filled up part of the channel there occur patches of pleustonic plants made up of *Lemna minor*, *L. trisulca*, *L. gibba*, *Spirodela polyrrhiza* and sporadical *Hydrocharis morsus-ranae* and *Stratiotes aloides*.

Over the slopes of the channel and on elevated places in its western and southern portion anthropogenic communities of pastures and meadows have developed, whose specific compositions is dominated by species of the class *Molinio-Arrhenatheretea*. Species of that class also penetrate into patches of reedswamps and wet alderwood.

Fragments of channel slopes and numerous side valleys have become occupied by tree and shrub communities dominated by species characteristic of the class *Querco-Fagetea*. The herb layer in those patches depends on the man impact. Where the trees and shrubs do not grow very densely herbaceous species of different syntaxonomic classes have become mixed together, but there is a predominance of species of the class *Molinio-Arrhenatheretea*. On the other hand, on channel slopes reaching sometimes more than 40° gradient and on steep slopes of side valleys, where trees and shrubs grow more densely, many species characteristic of *Tilio-Carpinetum* forests have survived in the herb layer. These species are no doubt relics of alluvial forests and oak-hornbeam forests which are natural in this region. They have survived only in places which are inaccessible for farming and grazing.

In the flora of the lake and its immediate surroundings, besides species natural to the area, also kenophytes are found, such as *Elodea canadensis*, *Acorus calamus*, *Acer negundo*, *Robinia pseudacacia*.

c. Archaeological and historical data and present-day state of land use

Archaeological sources testifying to the presence and activity of man in the Dobrzyń Lake District are rather poor. They are derived mainly from rescue investigations. On the grounds of these data it has been found that the oldest traces of man date from the Late Palaeolithic and are represented by findings of the Świderian Culture (Late Magdalenian). From the Mesolithic (8000–4500 BC) only fragmentary findings have survived to testify to the presence of man in the area in question. Considerably more traces come from the Neolithic (4500–1700 BC). Among the findings objects referred to the Linear Pottery, the Funnel Beaker, the Globular Amphorae and the String Pottery Cultures were represented. Records of the first three periods of the Bronze Age (1700—1450—1200—100 BC) are very scarce, whereas ample pottery material coming chiefly from graves are referred to the following two periods (1000—800—650 BC) and represent the Lusatian Culture including also the Hallstatt period (650—400 BC). The younger part of the latter period is marked by the arrival of the population of the Pomeranian Culture. The large number of graves of the Pomeranian Culture (40 found so far) is evidence of intensive colonization of the area by people of that culture. The culture transformations in the end phases of La Téne (400 BC to 0) and in the Roman period (0 to 375 AD) resulted in the development of the Burrow Grave Culture reported from 16 sites in the Lake District.

In the archaeological material available there is a complete lack of data referring to the Migration period (375—570 AD). In the early Middle Ages (VII to mid-XIII cent.) colonization becomes quite important, as evidenced by relics of strongholds, open settlements and burial grounds.

The historic times, and in particular the late Middle Ages, were marked by an intensive development of a settlement, which was linked with considerable deforestation of the area. The people then occupied in the first place lands along streams and around lakes and on the flat and undulant moraine plateau (Kwiatkowska 1963).

Another period of considerable deforestation of the area followed in the XVIII and XIX centuries as a result of increased demand for grain and of the construction of iron and glass-works. The Dobrzyń Lake District, 2500 km² in area, has a population of ca. 190 000, which gives an average density of 80 persons/km². 70·9% of the area is arable land, 17·6% — forests, the remaining 11·5% — waste and urbanized land. The largest part of the arable land is under grain — 57% (rye — 33·9%, wheat — 10·1%, barley — 9·0%, oats — 4·0%), fodder crops including maize — 17·9% and potatoes — 17·5%. The rest of the arable land is under industrial plants and pulse crops. Economically the Dobrzyń Lake District is a farming and industrial area. The mainly food and metal industry employs only about 6000 people.

Description of the lake

Lake Steklin lies in the south-western part of the catchment area of the stream Gnilszczyzna, a left-bank tributary of the Drwęca. It is connected also by a permanent stream with a smaller lake, Wygoda, and fills part of a subglacial channel, which opens westwards into the Vistula Valley at the terrace level 66—68 m a.s.l. The inclination of the channel slopes is considerable (in places it exceeds 40°) and averages 20°. The lake has no shore beach, only in some places there are fragments of flattened slopes. On the slopes there are fragments of two terraces: a lower one 4 m above the water surface level and a higher one at 10 m above the surface level. The water surface has been assessed at 73·3 m a.s.l.

The lake follows the shape of the channel it fills, which makes that being only 340 m in maximum width, it reaches now 5000 m in length. The shoreline, which shows little diversity, reaches 10 750 m in length and the water surface occupies an area of 112·3 ha. The channel cuts deep into the surrounding moraine plateau (92-94 m a.s.l.) reaching down to 55·2 m a.s.l. in the deepest place of the lake (maximum lake depth 18·5 m). The bottom of the lake is trough-like without steps or hollows.

PALAEOECOLOGICAL STUDIES

Methods

The bottom deposits of Lake Steklin (thickness — 940 cm) were sampled with a piston corer (Więckowski 1961) in the western part of the lake (Fig. 2) from a water depth of 750 cm.

Material for palynological, macrofossil and physical analyses was taken from the core at 10 cm intervals; only when taking samples for organic carbon and nitrogen determination no regular intervals were kept. Before starting a palynological analysis, calcareous gyttja was treated with 10% HCl and 10% KOH, silica was removed with hydrofluoric acid; all samples were prepared by Erdtman's method and stained with basic fuchsin. An average of 1000 AP was counted from each level. Due to very low frequency in the silt from 920 cm depth it was possible to count only 92 AP. The percentage values were calculated from the pollen sum including trees, shrubs (AP) and herbaceous plants (NAP). The sum did not include pollen of aquatic plants and spores. The results have been presented in a diagram showing silhouettes of all trees and of the most important shrubs and herbaceous plants.

For macrofossil analysis 15 g of deposit were used, which after boiling in water was scoured on a double-bottom sieve with mesh diameters of 0·5 and 0·2 mm. Identified animal and plant fossils have been presented in Figs. 4 and 5.

Stratigraphy of the lake deposits

The sediments have been described according to the system proposed by Troels-Smith (1955). The depth of the profile starts from the top of the lake deposit, whose composition and physical properties have been presented in Table 1.

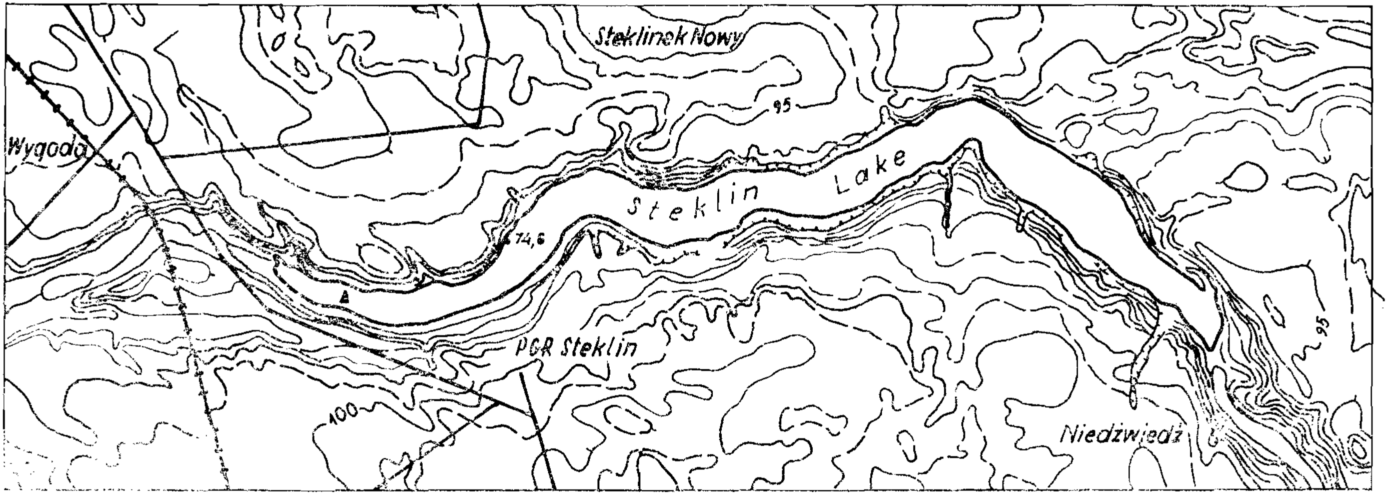

Fig. 2. Topographic sketch of the environs of Lake Steklin. 1 — Sampling site

Physical and chemical analyses

The deposit placed in plastic containers was transported to the laboratory, where it was analysed. The fresh sediment was weighed in order to determine its wet density. For pH measurements 150 ml of boiled distilled water was poured on to each 60-g sample and after 18 hours the measurement was taken on a potentiometer. The water content was obtained by drying the samples to constant weight at 105°C; the loss on ignition was assessed after ashing

Table 1

Depth (cm)	Layer No.	Description
0–860	6	Calcareus gyttja, grey to black-grey nig 2, strf 2, elas 1, sicc 2; Lc 4, Dg +
860–910	5	Gyttja with clay, black-grey nig 2, strf 0, elas +, sicc 2; Lc 3, As 1
910–915	4	Lake marl with mollusc shells, light grey nig 2, strf 2, elas 0, sicc 2; Lc 4, Ag +, Ga +
915–920	3	Silt with plant detritus, nearly black nig 3, strf 0, elas 0, sicc 2; As 2, Dl 1, $Th^4$1
920–930	2	Fine-grained and medium-grained sands with silt and organic matter nig 1, strf 0, elas 0, sicc 2; Ga 4, As/Ag +
930–940		Fine-grained sands with medium-grained sands, well sorted nig 1, strf 0, elas 0, sicc 2; Ga 4

the material in a muffle furnace at 550°C. Calcium carbonate was determined by Scheibler's method, nitrogen by Kjedahl's, and organic carbon by Tiurin's method. The results have been presented in a graph (Fig. 6 under the cover).

The wet density in the whole deposit shows very little variation. The water content is inversely proportional to dry weight. In the bottom layers dry weight shows higher values, and towards the top water content rises. With the ageing of the lake the organic matter content grows; this no doubt is linked with the progressing eutrophication of the lake. Another evidence of the changing trophic conditions is the ratio of organic carbon to nitrogen, which, starting from zone 4, is diminishing. The lowest nutrient supply occurred in the periods represented by the deposits of zones 1 and 4. $CaCO_3$ content in the deposit shows high values in the whole profile, except for the bottom section, rarely falling below 60%. The large amounts of calcium carbonate stimulate the reaction of the deposit, which is weakly alkaline and varies from pH = 7·4 to pH=7·9.

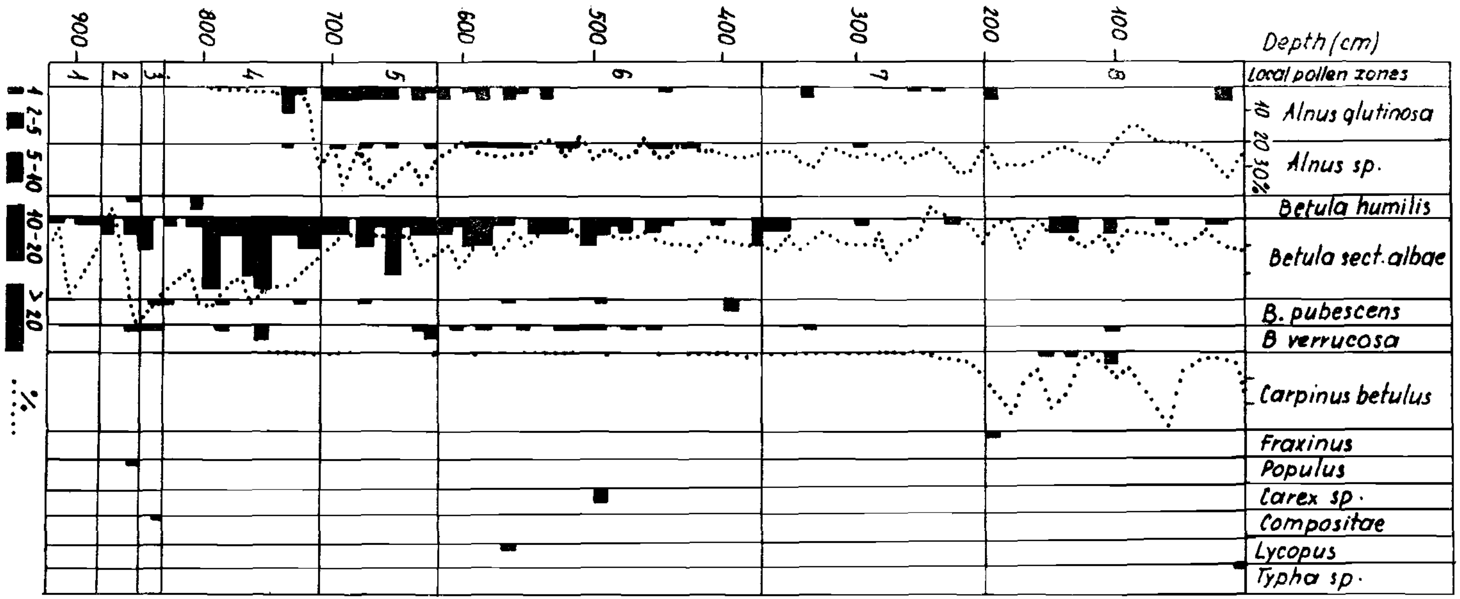

Fig. 4. Plant-macrofossil diagram from the Lake Steklin. 1-20 — number of specimens in a sample, ... the curves for percentage values of pollen grains

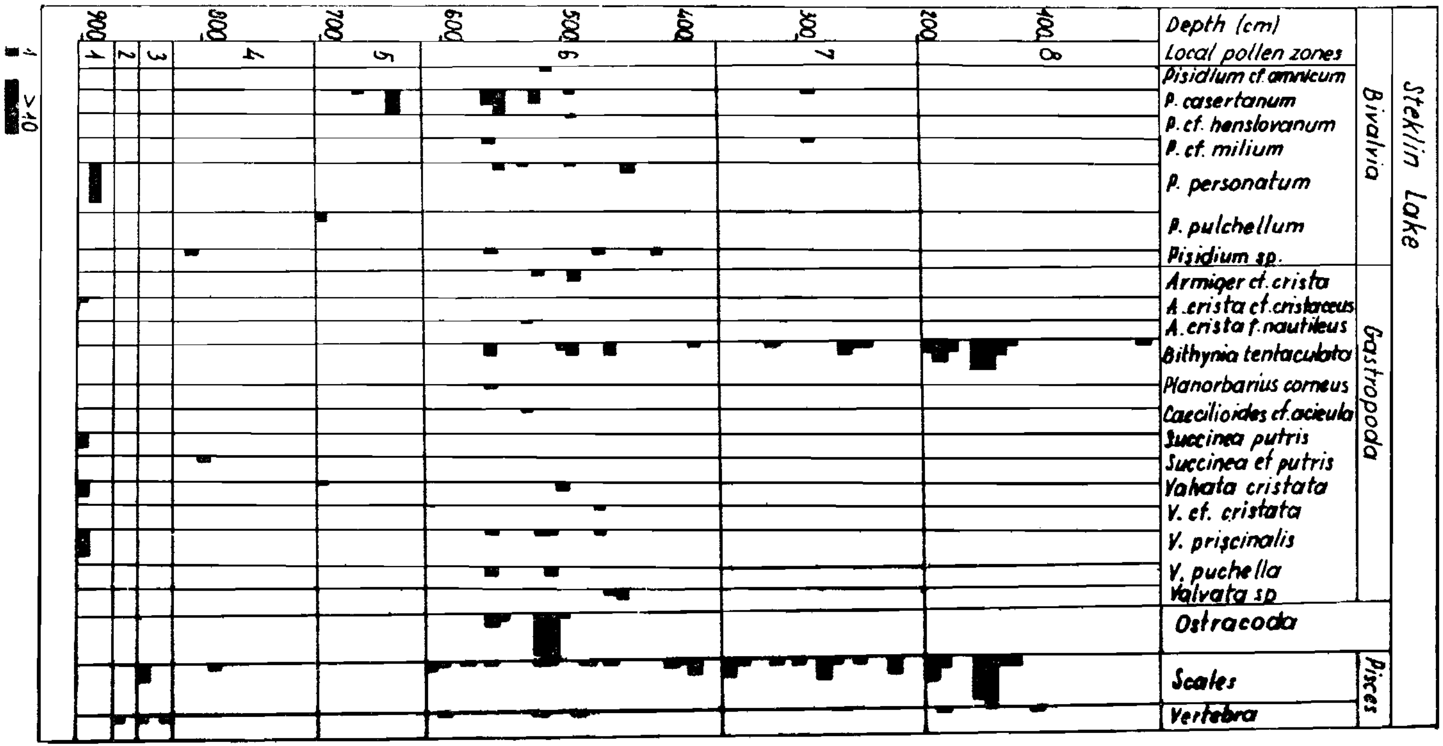

Fig. 5. Animal-macrofossil diagram from the sediments of Lake Steklin. 1,10 — number of specimens in a sample

The comparatively mild changes of the parameters in question point to the stability of the lake environment.

Pollen analysis — division of the diagram into local pollen assemblage zones (Fig. 3 under the cover)

In the pollen diagram of the Lake Steklin eight local pollen zones have been distinguished, two of which have been further subdivided into subzones.

Zone St 1 — is a period characterized in the diagram by an increase in frequency of *Pinus* and *Betula* pollen with simultaneous decrease in *Juniperus* and NAP values.

Subzone St 1a — increase in *Pinus* pollen values with simultaneous slight decrease of *Betula* and comparatively high percentage values of *Juniperus* (11 %) and *Salix* (6 %) pollen. In the earlier part of the period a maximum of NAP (34 %) is recorded, with *Artemisia, Chenopodiaceae* and *Cyperaceae* pollen prevailing. Also pollen grains of *Hippophaë* and spores of *Selaginella selaginoides* are observed.

Subzone St 1b — further rise of *Pinus* (58 %) and *Betula* pollen (28 %) curves with simultaneous decline in NAP values (minimum 8·2 %). The boundary between zone 1 and 2 is placed at a rapid fall of the *Betula* pollen curve with another increase in *Juniperus* and NAP values.

Zone St 2 — continuous fall of the *Betula* pollen curve, which reaches its minimum (6·4 %) in the middle part of zone. At the same time there is an increase in the pollen values of species of open habitats, i.e. of *Juniperus* (8·4 %), and above all of herbs — *Artemisia, Cyperaceae, Chenopodiaceae* — which in this part of the diagram reach their maxima. A rise in frequency of *Pinus* pollen is also noted.

The boundary between zones 2 and 3 is placed at a considerable rise of the *Betula* pollen curve with simultaneous reduction in *Pinus, Juniperus* and NAP values.

Zone St 3 — absolute maximum for the whole diagram is reached by *Betula* pollen (53 %), while *Pinus* and *Salix* pollen curves fall. No pollen grains of *Populus* are found in the spectra. Among herbaceous pollen taxa *Artemisia* and *Cyperaceae* values decline and of *Chenopodiaceae* disappear.

The boundary between zones 3 and 4 is placed where *Pinus* pollen rises again in value, the *Betula* pollen curve falls, and *Ulmus, Alnus* and *Corylus* pollen appear.

Zone St 4 — the pollen spectra of this zone are dominated by *Pinus, Betula* and *Corylus*. The *Pinus* and *Betula* pollen curves decline, the *Corylus* curve rises gradually. A regular occurrence of *Ulmus* and *Alnus* pollen is noted.

The boundary with zone 5 is placed at the rise in the *Alnus* and *Quercus* pollen curves and the beginning of the *Tilia* curve.

Zone St 5 — the *Pinus* pollen curve decrease systematically. *Corylus* pollen occurs regularly in values of several percentage, *Alnus* pollen shows absolute domination (37 %), while *Quercetum mixtum* is dominated by *Quercus*. *Ulmus* pollen reaches a lower frequency, and the values of *Tilia* pollen do not exceed 1 %.

The rise of the *Tilia* pollen curve and the fall in *Quercus* and *Betula* percentages mark out the beginning of zone 6.

Zone St 6 — the pollen curves of *Pinus*, *Betula* and *Alnus* show more or less constant values. *Quercetum mixtum* is dominated by *Quercus* and *Tilia*, lower percentage values are shown by *Ulmus* and *Fraxinus*. *Picea* and *Acer* pollen is sporadic. *Carpinus* pollen, till then sporadic, towards the end of zone form a continuous curve with a maximum of 1·2 %.

The boundary with zone 7 is placed at a fall in *Ulmus*, *Quercus* and *Carpinus* pollen values.

Zone St 7 — in the percentage pollen composition of zone 7, *Pinus* and *Betula* occur in similar values as in the preceding zone. *Quercus* increases in frequency, and in the *Ulmus* curve there are two peaks of 2·6 % and 1·8 %. In the younger part of the zone there is a fall in the pollen values of *Pinus*, *Betula* and *Ulmus*. An increased frequency of *Carpinus*, *Fagus* and *Corylus* pollen is observed. A decline of the *Corylus* pollen curve to 5·2 % and a rapid rise of the *Carpinus* pollen curve mark out the beginning of zone 8.

Zone St 8 — the most characteristic species for the distinction and further subdivision of zone 8 is *Carpinus*. Four pollen maxima of that species (15 %, 27 %, 21·9 % and 23·7 %) are noted permitting the distinction of 6 subzones. The successive falls in frequency of *Carpinus* pollen are accompanied by rises in the *Betula* and NAP curves, especially in *Cyperaceae*, *Gramineae* and synanthropic species. Besides *Carpinus*, also *Fagus* pollen reaches its absolute maximum (1·3 %) in zone 8.

Macrofossil analysis

In the profile studied macrofossils occur in small quantities. This is probably due to the fact that the profile was taken from the central deep part of the lake, as well as to the adverse effect of the steeply sloping banks of lake basin on the development of organic and particularly plant life in the littoral zone. To illustrate the relationship between the occurrence of macrofossils and the pollen values percentage curves of *Alnus*, *Betula* and *Carpinus* pollen have been marked on the macrofossil diagram (Fig. 4).

Among plant remains the birch fruit scales and fruits are most numerously represented. Birches, both arboreal and shrub species were present in the lake surroundings as early as in the Late-Glacial. It seems noteworthy that scales and fruits of *Alnus* occur already in zone 4, before the culmination of its pollen curve in zone 5. Scattered hornbeam nuts were found only in the zone 8.

Among animal remains the most numerous are molluscs, whose presence in zone 1 is evidence of the existence of the lake already at that time. 6 species of bivalves *(Bivalvia)* and 10 species of snails *(Gastropoda)* have been found in the profile. They are fairly common species, found nowadays in shallow and calm stagnant waters, except *Caecilioides* cf. *acicula,* which lives deep in the ground under stones, and whose shells are often transported by water. The greatest diversity of species is found in the deposit of zone 6. In that zone *Ostracoda* remains have also been found.

Ktenoidal scales of fishes, characteristic of *Perciformes,* and scattered vertebrae of fishes have been preserved in the deposit. The vertebrae have been extracted from the deposit of zone 2, whereas the largest number of fish remains have been found in zones 6, 7, and 8.

THE HISTORY OF THE CHANGES IN NATURAL ENVIRONMENT

The history of regional changes

Zone St 1. The pollen curves of both trees and herbaceous plants in zone 1 indicates that the lake surroundings were occupied by arboreal vegetation. It can be presumed that the plant cover at the beginning of zone 1 (11 630± 110 BP) was a thin birch-pine forest. Part of the area was occupied by shrubs with *Juniperus, Hippophaë* and communities of heliophilous herbaceous plants. The most numerous were species of the family *Chenopodiaceae* as well as *Artemisia, Helianthemum* and *Polygonum bistorta/viviparum.* The younger part of zone 1 was characterized by a closer growth of the forest, whose important constituent were birch-trees. Less frequent was *Populus.* The presence of pollen grains of *Oxyria digyna,* an Arctic-Alpine plant, whose occurrence in Poland is now confined to the highest parts of the Carpathians, is evidence of its formerly wider range. *Sphagnum* spores found in the zone point to the development of peat in the marginal parts of lake. Aquatic vegetation is not represented; pollen grains of *Typha latifolia* are evidence of the occurrence of littoral vegetation.

Zone St 2. The changes in the species composition in this zone point to a cooling of the climate. The tree stands became thinner, and the vegetation cover resembled a park tundra. The macrofossils reveal the occurrence of arboreal birches, which probably found favourable development conditions on the slopes of the Lake Steklin channel. *Juniperus* increases in frequency, *Salix, Populus* and *Betula humilis* are also present. From among aquatic plants, *Potamogeton, Sparganium* and *Nuphar* are found.

Zone St 3. In the vegetation cover of the older part of zone 3 compared with that of the preceding zone a considerable increase in the role of birches is observed while *Pinus, Salix, Juniperus* and NAP decrease in frequency. This indicates that the canopy became closer, contributing to the disappearance of a number of heliophilous herbaceous and shrub species. The environs of Lake Steklin were dominated by birch-pine forests in which, besides *Pinus sylvestris* grew *Betula pendula* and *B. pubescens*, and in the herb layer grasses occurred. The clearings and forest edges were overgrown by *Compositae — Aster* type, *Umbelliferae*, *Calluna*, *Empetrum* and plants persisting from the preceding zones: *Artemisia, Chenopodiaceae, Filipendula, Labiatae, Stachys* type. Shrubs of *Betula humilis* and *Salix* occurred on moister substratum and *Cyperaceae, Phragmites, Polypodiaceae* grew in submerged habitats. In the younger part of the zone a fall in the *Betula* and *Salix* pollen curves is correlated with a slight rise in *Pinus* pollen and NAP. At that time the first pollen of *Alnus* and *Corylus* appeared.

Zone St 4. In the zone 4 we observe a continuous slight decrease in *Pinus sylvestris*, *Betula pendula* and *B. pubescens* frequencies but they still dominate in the vegetation cover. It is correlated with the appearance of small amounts of pollen of species with higher climatic requirements. In the tree layer *Ulmus* and *Alnus* occur regularly. Pollen grains of *Populus*, *Quercus*, *Tilia* and *Picea* are noted sporadically. In the shrub layer *Corylus* systematically increases in importance, and *Juniperus* is also found. Like in the preceding zone, the area is dominated by birch-pine forests, in whose herb layer *Gramineae, Polypodiaceae, Melampyrum* occur. On forest edges and in thinly grown places *Artemisia, Caryophyllaceae, Campanula, Calluna* survived. In lower situated places with moist substratum patches of communities of the riverside forest type developed with *Ulmus, Populus, Alnus, Salix, Humulus* and *Urtica*. In fertile habitats fragmentarily deciduous tree stands composed of *Quercus* and *Ulmus* developed, and *Anemone*, *Pulmonaria* and *Rubiaceae* could grow in their ground flora. On the lake shores, between the reedswamp belt and the willow-alder brushwood, grew *Rumex acetosa, Filipendula, Labiatae, Mentha* type, *Lysimachia nummularia*, *Caltha* type, *Ranunculus* and *Dryopteris thelypteris*. In the lake aquatic vegetation belts developed, made up of the following species: *Nymphaea, Nuphar, Myriophyllum spicatum, Batrachium, Phragmites* and *Sparganium*. The presence of *Sphagnum* spores points to the local development of peat.

Zone St 5. The tendency observed in zone 4 is still continuing. There is a further slow decrease in importance of the hitherto dominating *Pinus* and *Betula*. They are superseded chiefly by *Alnus*, which reaches in this zone its absolute pollen maximum and by *Quercus*, whose curve oscillates between the values of 3 and 7%. *Ulmus* increases in value compared with the preceding period. There is also a regular occurrence, though in small numbers, of *Tilia*, *Fraxinus* and *Picea*. *Salix* occurs only sporadically. *Corylus* occurs throughout the zone reaching values from 5 to 11%. Compared with zone 4, NAP values decrease. The area occupied by pine-birch forests, though decreasing, is still considerable, and *Quercus* appears in their composition. There occur pure pine stands with *Linnea borealis* in their herb layer. The presence of *Calluna* points to the local thinning of the forests or to the existence in their proximity of open herb communities of the heath type. Riverside forests, growing in moist habitats and therefore situated in the channel, become more important. In submerged places, which were scarce due to the rather steep slopes of the channel, there occurred patches of wet alderwood with dominating *Alnus*. Considerably larger areas were occupied by communities of alder and ash-elm riverside forests. *Populus* grew in similar sites. In the herb layer of riverside forests occurred: *Circaea*, *Labiatae-Stachys* type, *Humulus, Urtica, Anemone* type, *Scrophularia*. On fertile brown soils there developed, besides riverside forests, also forests of the *Querco-Carpinetum* type with *Quercus*, *Tilia* and *Ulmus*. In the undergrowth *Corylus* occurred; this species, however, probably penetrated also into the mixed forests and formed pure hazel communities on the steep slopes of the channel resembling those which can be seen now near the village of Steklinek. In open grounds near woodland areas meadow communities developed with various species of *Ranunculus*, *Caltha* type, *Bellis* type, *Polygonum bistorta/viviparum*, *Filipendula* and *Thalictrum*. In the lake along its shores there developed aquatic vegetation with *Potamogeton*, *Batrachium* and *Nymphaea*, like in the preceding zone. In warm shallows *Utricularia* found good development conditions. In reedswamp communities *Typha latifolia*, *Sparganium*, *Rumex* sect. *Lapathum* occurred and probably species of the families *Umbelliferae* and *Cyperaceae*. In all types of plant communities the family *Gramineae* was represented.

Zone St 6. Only *Pinus, Betula* and NAP show similar values to those in the preceding zone. On the other hand, definite changes are seen in the pollen curves of thermophilous deciduous trees. *Tilia*, which in the zone 5 did not reach even 1%, increases to 7%. *Quercus*, *Ulmus* and *Fraxinus* reach also higher values. New species of deciduous trees appear: *Acer*, *Carpinus* and *Fagus*. Another evidence of a warming up of climate is the presence of *Viscum* and *Hedera*. *Picea* continues at about the same level as in zone 5. *Salix*, *Alnus* and *Populus* — species of moist habitats — increase their proportions in the composition of the forests. Compared with the forest cover of the preceding zone, there is a marked increase in *Pteridium* values, what is probably linked with a wider spread of mixed forests. In sandy habitats dry pine forests developed, with *Lycopodium clavatum* and. *L. tristachyum* in the herb layer. In the lake *Nuphar* appeared.

Zone St 7. In this zone the curves of *Quercus, Tilia, Alnus* and NAP are fairly regular. The percentage values of other species show certain oscillations, whose coincidence with NAP values point to the influence of external factors, viz. human interference. At the turn of zones 6/7 there is a rather rapid decrease in the frequencies of *Ulmus, Fraxinus, Carpinus* and *Corylus* pollen. Also the percentages of *Gramineae* fall while that of *Artemisia* rise. Such a coincidence of decreasing curves of a number of forest species can be related to the presence of Neolithic man in the area, a surmise confirmed by archaeological finds. Man at that time was engaged in pastoral economy using natural pastures, i. e. most frequently forests; this contributed to the destruction of seedlings and new growths and to the thinning down of the vegetation. Human presence was probably responsible for the occurrence of *Plantago maior* pollen, the presence of *Urtica*, growing on grazing-land, and the increase in the role of *Artemisia*, whose species spread over areas devastated by animals. The new fall of the *Ulmus* pollen curve is correlated with the beginning of the nearly continuous curves of *Plantago lanceolata* and *Rumex acetosella* pollen. In the younger part of this zone, which with hige probability could be related to the 3rd and 4th period of the Bronze Age-the Lusatian Culture population intensified agriculture and developed stock, raising using extensive pastures. They obtained new land at the expense of forests, which is reflected in the decrease in the pollen values of *Betula* and *Pinus* and in the increase of NAP, chiefly of *Gramineae, Rumex acetosa, R. acetosella* and *Urtica*.

Zone St 8. The curves of the most part of pollen taxa in the zone 8 show a number of fluctuations. There are culminations of some species correlated with minima of others. A comparatively stable course is seen only in the pollen curves of *Quercus* and *Corylus*. *Ulmus, Fraxinus* and *Picea* pollen decrease in value compared with zone 7. The most considerable increase occur in *Carpinus* and *Fagus* pollen values; the latter for the first time shows a continuous curve. On the grounds of the very clear changes in percentage values of *Carpinus*, connected with the changes in pollen frequencies of other species both arboreal and herbaceous, the zone has been subdivided into 6 smaller units. The vegetation of these units points to its close links with phases of human settlement and management.

Subzone *a* — begins with a rapid increase in *Carpinus* pollen values,whose first maximum occurs towards the end of the zone. The maximum percentage values of that species clearly coincide with a marked decrease in the pollen frequencies of *Tilia, Quercus, Betula, Pinus* and NAP. The rich development of *Carpinus*, a species growing in close stands, has a limiting effect on the development of heliophilous species. During the *Carpinus* maximum there is a slight increase in the values of *Fraxinus*, *Picea* and *Salix* pollen, which occur in moist habitats avoided by *Carpinus*.

Subzone *b* — *Carpinus* pollen values decrease, those of *Tilia*, *Quercus*, *Betula* and *Pinus* increase, and so does the NAP frequencies, especially as regards *Gramineae, Cyperaceae, Artemisia, Plantago lanceolata, Cerealia, Secale cereale* and *Ranunculus*. Such proportions of the particular species may be related to settlement development, and in particular to the deforestation of land for cultivation. The felling of hornbeam, occupying fertile soils, was reflected in an increased frequency of pioneer birches, and only later of the other species. The changes noted in this subzone are probably due to the economic development in the Hallstatt period revealed by archaeological sources in the Dobrzyń Lake District.

Subzone *c* — *Carpinus* pollen rises again in importance, while all the other species except *Fraxinus* show falling pollen curves. There is another stop in the development of agriculture. *Carpinus* encroaches on former farmland and begins to restrict the development of heliophilous species. Subzone *c* may be dated to the Middle La Těne period.

Subzone *d* — is characterized by a successive minimum of the *Carpinus* pollen values associated with changes in the frequencies of other species, like those in subzone *b*. There is an increase in the importance of apophytes and antropochors, which coincides with the revival of agriculture noted towards the end of the La Téne period and during the Roman period.

Subzone *e* — here occurs the last maximum of *Carpinus* in zone 8 and the NAP curve shows low values. With great probability these changes can be related to the Migration period and to the older phase of the Early Middle Ages, from both of which there are no evidence available of human presence in the Dobrzyń Lake District.

Subzone *f* — reflects the intensive development of settlement during the Middle Ages. The large areas covered by forests till then have been occupied for farming. Man gains better lands formerly occupied by deciduous forest communities. In the younger part of subzone *f* only pioneer birches and alders, growing in waterlogged habitats, show slightly higher values. Herbaceous species in this subzone reach their pollen maxima of 18 and 16%. Cereals and *Rumex acetosella* reach their absolute maxima.

CONCLUSIONS

The oldest organic deposits in the profile have been dated to 11 630±110 BP. On the grounds of palynological studies the profile has been divided into 8 local pollen zones. The two oldest ones correspond to the Late-Glacial: zone 1 — Alleröd, zone 2 — Younger Dryas. The other come from the Holocene and correspond: zone 3 to the Pre-Boreal period, zone 4 to the Boreal period, zones 5 and 6 to the Atlantic period, zone 7 to the Sub-Boreal period and zone 8 to the Sub-Atlantic period.

Arboreal vegetation was present in the area under study ever since the Alleröd, only in the Younger Dryas it became park tundra. The presence of fertile soils in the environs of Lake Steklin was favourable to a good development, and therefore to a dense growth of pine-birch forests at the beginning of the Holocene. This was the cause of a rather poor development of hazel, which in zone 4 was not very abundant. Propitious edaphic conditions enabled forest communities with lime and oak to survive until zone 8 (Sub-Atlantic period).

The first traces of man have been found in zone 7 (Sub-Boreal period), and intensive human activity is observed in zone 8. The earliest traces of the occurrence of plants related to the open water have been found in zone 1. The succession of aquatic vegetation in the lake started in zone 2.

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REFERENCES

Berglund B. E. (ed.) 1979. Palaeohydrological changes in the temperate zone in the last 15 000 years. Subproj. B. Lake and mire environments. Project Guide. 1 and 2. LUNBDS (NBGK—3001): 1–140; LUNBDS (NBGK—3002): 1–340.

Churska Z. 1958. Wybrane zagadnienia hydrograficzne na arkuszu Czernikowo. Dokument. Geogr., 6: 153—163.

— 1969. Fazy rozwoju wydmy w Czernikowie-Witowężu (summary: Evolutionary phases of dune situated at Czernikowo-Witowąż). Inst. Geol. Prace, 75: 181–207.

Churski Z., Kotarbiński J., Liberacki M., Niewiarowski W., & Wójcik C. 1978. Mapa geologiczna 1:200 000, arkusz Brodnica, wersja A i B.

Galon R. 1961. Morphology of the Noteć—Warta (or Toruń—Eberswalde) ice marginal Streamway. Inst. Geogr. Prace, 29: 1–129.

Galon R. & Roszkówna L. 1953. Przeglądowa mapa geomorfologiczna woj. bydgoskiego. Przegl. Geogr., 5, 3.

Grześkowiak J. 1980. Dzieje najdawniejsze. In: Monografia Ziemi Dobrzyńskiej, MS.

Kępczyński K. 1960. Zespoły roślinne jezior Skępskich i otaczających je łąk (summary: Plant groups of the Lake District of Skępe and the surrounding peat-bogs). Studia Soc. Sci. Tor., 6: 1–244.

— 1965. Szata roślinna Wysoczyzny Dobrzyńskiej (Zusammenfassung: Die Pflanzenwelt des Diluvialplateau's von Dobrzyń). Toruń.

— 1973. Szata roślinna doliny dolnej i środkowej Drwęcy i terenów do niej przyległych (summary: Vegetation cover in middle and lower reaches of the Drwęca Valley and adjoining regions). Acta Univ. Nicolai Copernici, Geogr., 9 (31): 123–158.

Kondracki J. 1978. Geografia fizyczna Polski, PWN, Warszawa.

Kwiatkowska E. 1963. Osadnictwo wiejskie Ziemi Dobrzyńskiej w świetle planów z XVIII i XIX w. i jego przemiany pod wpływem uwłaszczenia i parcelacji (summary: The country colonization of the country of Dobrzyń in the light of plans of the XVIII and XIX century, and its changes under the influence of enfranchisement and parcellation). Stud. Soc. Sci. Tor., 4 (3): 1–89.

Mrózek W. 1958. Wydmy Kotliny Toruńsko-Bydgoskiej. In: Wydmy śródlądowe Polski, 2: 1–59.

Niewiarowski W. 1957. Wybrane zagadnienia z badań geomorfologicznych na arkuszu Mazowsze-mapy 1:25 000. Dokument. Geogr., 3: 24–37.

— 1973. Rzeźba terenu i budowa geologiczna doliny dolnej Drwęcy i jej otoczenia (w granicach woj. bydgoskiego) i ich wpływ na zagrożenie erozją wodną gleb (summary: Relief and geological structure of Drwęca valley and its surroundings (within Bydgoszcz Voivodeship) and their effect upon the danger of water soil erosion). Acta Univ. Nicolai Copernici, Geogr., 9 (31): 39–62.

Oszast J. 1957. Historia klimatu i flory Ziemi Dobrzyńskiej w późnym glacjale i holocenie (summary: History of the climate and flora of the Dobrzyń Region, northern Poland, in the Late-Glacial and Holocene). Inst. Geol. Biul., 118: 179–232.

Prusinkiewicz Z. & Regel S. 1973. Mapa gleb woj. bydgoskiego, skala 1:300 000.

Szafer W. & Pawłowski B. 1973. Geobotaniczny podział Polski — mapa. In: Szata roślinna Polski, 2, PWN, Warszawa.

Troels-Smith J. 1955. Characterization of unconsolidated sediments. Danm. Geol. Unter., IV, 3, 10: 1–73.

Więckowski K. 1961. Improved vertical core sampler for collecting the bottom sediments monoliths. Bull. Acad. Pol. Sci., 9 (2): 129–133.

Wójcik G. & Wójcikowa A. 1973. Uwagi o klimacie dorzecza dolnej Drwęcy oraz o niektórych aspektach mikroklimatu doliny Drwęcy (summary: Notes on the climate in the lower part of the basin of the Drwęca River and on some aspects of the microclimate in the Drwęca River valley). Acta Univ. Nicolai Copernici, Geogr., 9 (31): 87–122.

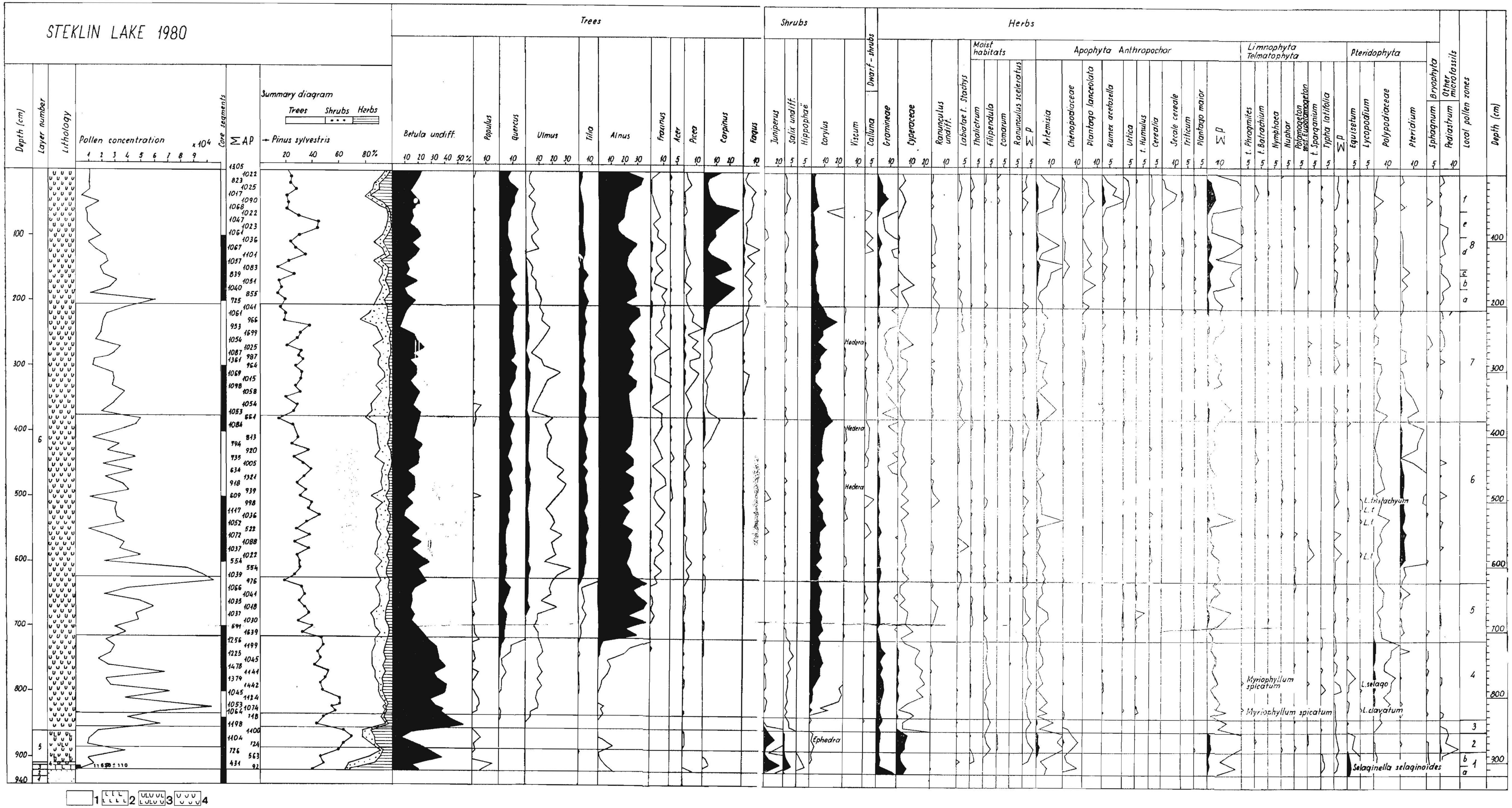

Fig. 3. Pollen diagram from the **Lake Steklin**: 1 — Fine- and medium-grained sands, 2 — Silt with plant detritus, 3 — Gyttja with clay, 4 — Calcareous gyttja

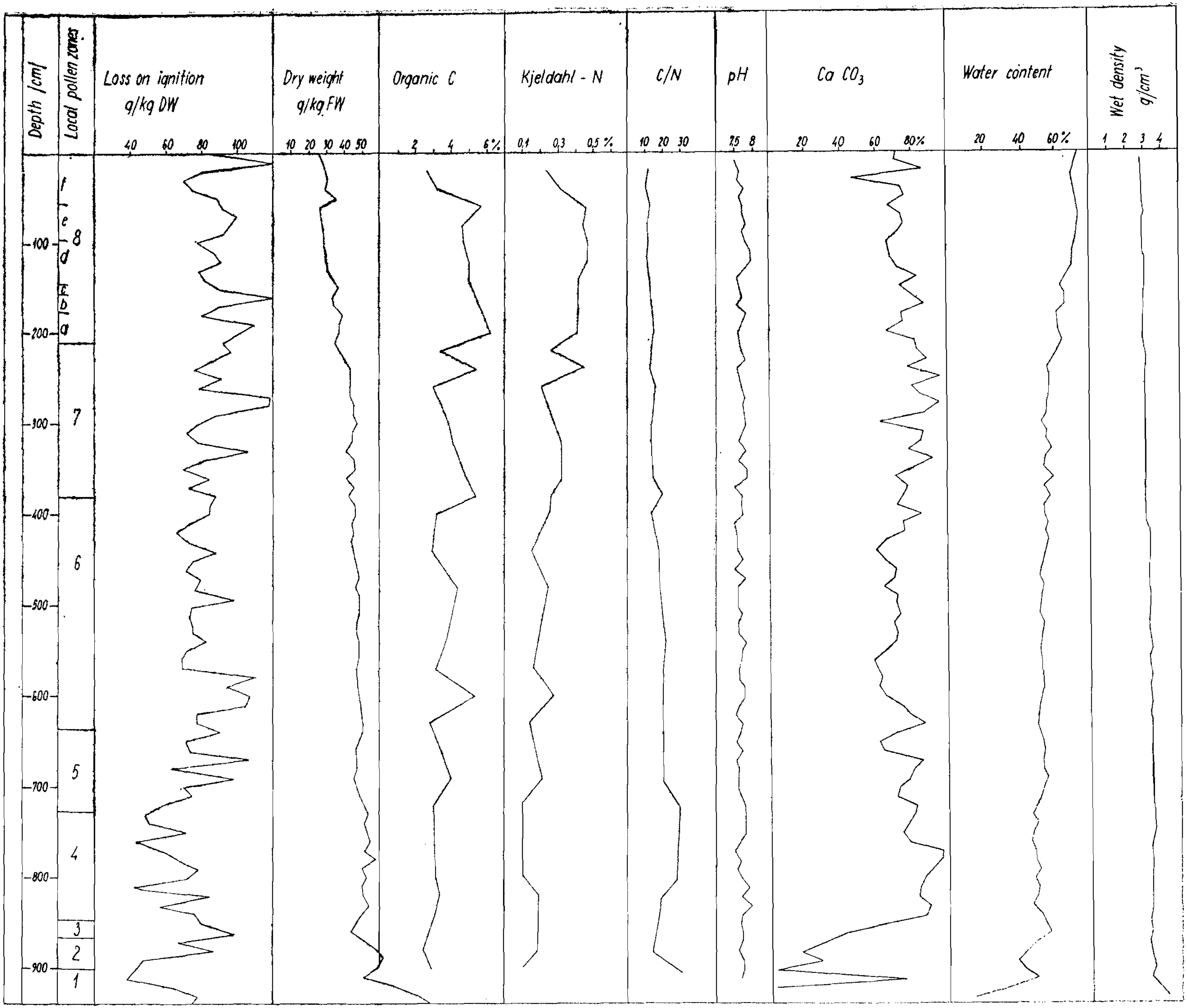

Fig. 6. Results of physical and chemical analyses