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# THE POST-GLACIAL DEVELOPMENT OF LAKE WIELKIE GACNO, NW-POLAND. THE HUMAN IMPACT ON THE NATURAL VEGETATION – RECORDED BY MEANS OF POLLEN ANALYSIS AND $^{14}$C DATING

## Postglacjalny rozwój jeziora Wielkie Gacno w NW Polsce Wpływ człowieka na roślinność naturalną — wyniki analizy pyłkowej i datowania radiowęglem

ABSTRACT. Sediments of the Lake Wielkie Gacno in the Bory Tucholskie area were studied by means of pollen analysis. Nineteen $^{14}$C dates were obtained for 8 meters long core. Pollen concentration (by the use of *Lycopodium* tablets) and pollen influx values were determined. Human influence on the natural vegetation was studied in detail and six phases of expansion of plants indicating grazing and agricultural activities of man were described. They covered the time span from the Early Neolithic (3900–3500 B.C.) to the Early Middle Ages (from 750 A.D.).

## INTRODUCTION

This study is part of a wider investigation of the Holocene landscape development in the Wielkie Gacno area of NW Poland. The investigation comprises the history of the lake itself, the regional vegetation and soil development, with particular attention being paid to human impact on the landscape development during the Late Holocene.

The palaeoecological study of Lake Wielkie Gacno is part of a Polish project dealing with the "development, productivity and functional interdependence of typical ecosystems on selected areas of Bory Tucholskie (woodland), of lake Iława and Brodnica and of the agricultural Kujawy". This project named R-III-15, is being led by professor Dr. Ryszard Bohr, Toruń, and most of the research is being performed at the Biological Institute of Toruń University. This project includes plant- and animalecological, hydrobiological and microbiological studies in addition to this present palaeoecological and -limnological investigation and the whole is intended to have practical applications, e.g. planning for tourism, industry, urbanization etc. (R-III-15-project report 1978). In connection with this task, a palaeoecological study is invaluable in solving the structure and function of the ecosystem within the landscape.

The present investigation also belongs to the International Geological Correlation Programme (IGCP) — Project No. 158, Subproject B: "Palaeohydrological changes in the temperate zone in the last 15 000 years". The object of this IGCP-project is to analyse to a high level of detail palaeoecological reference profiles which have a chronology based on accurate absolute datings from a type region, in this case NW-Poland. "The type pollen diagrams will show the regional variation in the development of the vegetation and provide a basis for an interpretation of the relation between vegetation, soil and climate development" (Berglund & Digerfeldt 1976). According to the project guide (Berglund 1979, pp. 6–7) the aim of the Subproject B is:

1. To provide palaeoecological and stratigraphical research with continental reference sites related to an absolute chronology covering the last 15 000 years.

2. To apply a variety of uniform palaeoecological methods to obtain fully accurate information on biotic and environmental conditions on the continents during the last 15 000 years.

3. To describe biotic changes in both time and space. Biotic changes refer to local ecosystems of lakes and mires as well as regional, terrestrial ecosystems of selected reference areas.

4. To describe hydrological and limnological changes in both time and space. These changes include quantitative aspects of the hydrological cycle, such as water level changes etc., as well as qualitative aspects of lake ecosystems such as nutrient status, productivity etc.

5. To describe climatic changes in both time and space and to assess their impact on biological and hydrological systems.

6. To describe human activity in both time and space and to assess its impact on biological and hydrological systems.

7. To correlate hydrological changes in lake catchment areas with conditions in fluvial environments in order to describe the total hydrological regime and its relation to climatic and human factors.

The interpretation of the limnological and environmental development of the reference area, here Lake Wielkie Gacno and its surroundings, is based on chemical and physical sediment analyses. On the basis of several microfossil and chemical analyses, Holocene settlement and landscape development can be reconstructed and valuable palaeoecological, limnological and hydrological correlations can be made between selected type regions in the temperate zone.

Wielkie Gacno is situated in a forested lowland area fulfilling the requirements of a representative lake, when thinking about the present and fossil vegetation representation in having a catchment area of radius 15–20 km. This possible regional representativeness will be tested by analyses of surface pollen spectra from 7 different lakes in the region.

The aim of this paper has been to study the changes in human activity in the area around Lake Wielkie Gacno, NW-Poland, and the influence of that on the vegetational history in the area during the last 6000 years.

## DESCRIPTION OF THE INVESTIGATION AREA

### Local geology

Lake Wielkie Gacno lies on the outwash plain of the Brda river in the northern part of the Bory Tucholskie Region, about 7 km NE of the village of Charzykowy. The area is characterized by inland dunes, which are connected with the end moraines of the Pomeranian stage, the 3rd stage of the last Baltic Glaciation (Fig. 1).

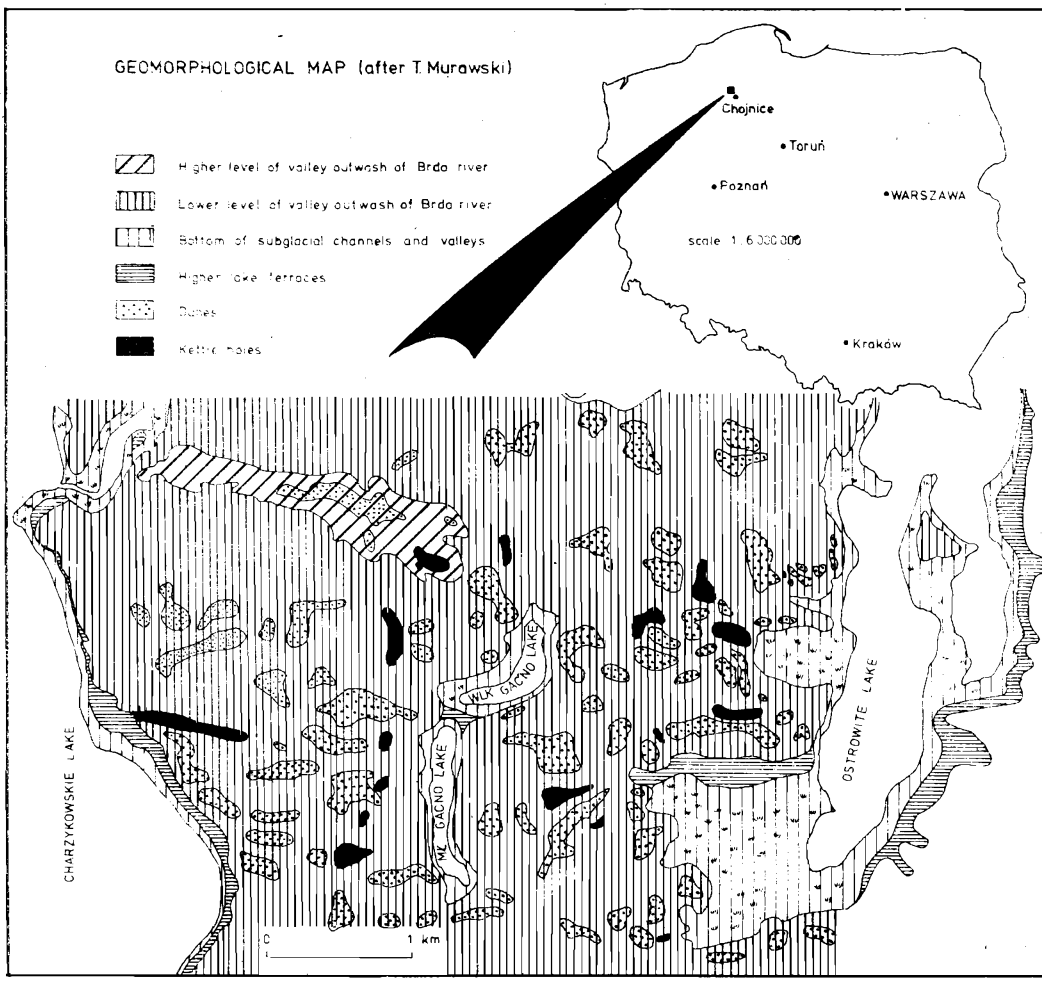


Fig. 1. Geomorphological map of the investigation area

Soils

The soils originate predominantly in deposits of glacial origin. They are mainly composed of podsols or podsolized rendzinas formed from sands. Because of the leaching of nutrients and the increasing capacity for dissolving nutrients a rapid acidification and impoverishment is going on. The raw humus layer is thin and the illuvial horizon which is of a rusty colour is very compact.

Climate

The area surrounding Lake Wielkie Gacno belongs to the lakeland climate region (after Romer 1949 in Medwecka-Kornaś 1966). The summers are quite cool and the arrival of spring is delayed due to the great number of lakes. The lakeland climate region lies within an annual isotherm of +6·5°C, the mean January temperature is —3°C and that of July +17·5°C. The annual rainfall is ca. 600–650 mm and the length of the growing season about 190–200 days (Narodowy Atlas Polski 1978).

Vegetation

The area belongs to the West-Pomeranian Transition Belt (after Szafer and Pawłowski in Szafer 1966). The forests have an anthropogenic origin and the dominant forest community on sandy soils is *Pineto-Vaccinietum*. On the shores of the lakes and between dunes in waterlogged places there are some fragments of *Alnus* — communities. In general, forests are poor in species, the higher parts of the dunes, especially, are extremely poor in species, the so-called *Cladonia* — pine woods.

Lake Wielkie Gacno

The Wielkie Gacno lake is part of a glacial channel complex on the lower level of the proto-valley of the Brda river. This glacial channel contains two lakes: Małe Gacno and Wielkie Gacno (Fig. 1). Wielkie Gacno is an oligotrophic, so-called Lobelia lake. This kind of lake with *Lobelia dortmanna* and *Isoëtes* communities occurs almost exclusively in Pomerania to the west of the Vistula river (Pawłowski *et al.* 1966). The lake area is 13·1 ha and the maximum water depth, in the nort-eastern part, is 6·1 m, in most parts the water depth ranges between 3 and 4 m.

Stratigraphy

Organic fine detritus gyttja forms the bottom in all parts of the lake. The maximum thickness of the Holocene sediment, which is found in the north-eastern part of the lake, reaches 8 m. Mostly the thickness ranges from 3 to 6 m. Two deep areas are found which are separated by a threshold area with a sediment thickness of only 0·2 m. The gyttja also contains several very thin sand layers, which can be observed only by *X*-ray analysis. These may indicate a stronger erosion from the surrounding area of the lake and in this way give evidence of the diverse phases of human activity (e.g. Vuorela 1976). In the deeper parts of the lake the gyttja is underlain by sand, and at the shores by clay gyttja, which reaches a thickness of 70 cm, and is shown to be of Late-glacial age.

## METHODS

The working methods follow closely the recommendations in the IGCP-Guide (Berglund 1979; Digerfeldt 1979).

A sediment core of eight metres was taken partly with a Livingstone sampler with a tube diameter of 100 mm (from 1 m to 8 m), and partly with a Digerfeldt–Lettevall sampler (the uppermost metre) (Digerfeldt & Lettevall 1969). The water depth at the site of the profile was 5·05 m.

The samples for pollen analysis were taken at every 5 cm and the preparation follows largely the Faegri & Iversen (1964) KOH-acetolysis method.

About 3000 AP pollen grains were counted from each sample.

Absolute pollen determinations were made according to the method described by Stockmarr (1971). 3 *Lycopodium* tablets were added to 1 $cm^3$ gyttja. Pollen influx values (pollen $\times$ $cm^{-2}$ $\times$ $yr^{-1}$) were determined according to the formula:

$$\text{Pollen concentration (grains} \times \text{cm}^{-3}) \times \text{the sediment deposition rate (cm} \times \text{yr}^{-1})$$

Pollen concentration values were counted according to the formula:

$$\text{Pollen concentration} = \frac{\text{number of spores added in tabl.}}{\text{No. of spores counted in preparation}} \times \frac{\text{No. of fossil pollen counted}}{\text{sample volume (cm}^3)} \text{grains} \times \text{cm}^{-3}$$

In the main pollen diagram follows the model originally used by Berglund (1969). All species are presented as percentages of the total pollen sum (AP + NAP), excl. *Filicales* and aquatic elements.

Both the percentages and the pollen influx diagram in this paper cover only the upper part of the whole main profile. In the text several species and genera *(Populus, Epilobium, Melampyrum, Centaurea cyanus, Linum, Fagopyrum, Vicia, Urtica, Chenopodiaceae* and *Umbelliferae)* are mentioned which are not illustrated in the diagrams presented. These finds are important even though the pollen types occur only sporadically or in low frequencies. In general, however, for various practical reasons they will only be presented in the complete pollen diagram used in a discussion of the vegetation history of the area (in prep.).

The time resolution of each pollen spectrum corresponds to 12–15 years except for the uppermost metre (taken with the Digerfeldt–Lettevall sampler) where each spectrum is from a subsample of a mixed 5 cm thick sediment column so that the time resolution is ca. 60 years. This explains the smoother curves in the upper part of the pollen diagram.

Biostratigraphically the diagram is zoned into pollen assemblage zones and pollen assemblage subzones. The boundaries are drawn in accordance with the discussion of Birks (1973, pp. 273 and 281), but are, however, named only by the characterizing tree species. The pollen assemblage zones demonstrate the immigration and succession of the tree species (Figs. 2* and 3).

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Fig. 2 is under the cover.

| DEPTH, m | DESIGNATION OF THE P.A.Z. | POLLEN ASSEMBLAGE ZONES | POLLEN ASSEMBLAGE SUBZONES | $^{14}C$-DATES B.P. | CHRONOZONES | |
|---|---|---|---|---|---|---|
| | WG 8 | PINUS | | 780 ± 50 | SUBATLANTIC | Late |
| 5,5 | WG 7 7:3 | PINUS-BETULA-ALNUS-CARPINUS-FAGUS | Pinus-Quercus | 1220 ± 50 | | Late |
| 6,0 | 7:2 | | Quercus | 1790 ± 50 | | Middle |
| 6,5 | 7:1 | | Quercus-Picea | 2250 ± 50 | | Middle / Early |
| 7,0 | WG 6 6:2 | PINUS-BETULA-ALNUS-CARPINUS | Quercus-Picea | 2650 ± 55 | SUBATLANTIC / SUBBOREAL | Early / Late |
| 7,5–8,0 | 6:1 | | Quercus-Ulmus-Picea-Corylus | 3320 ± 55; 3740 ± 55 | SUBBOREAL | Late / Middle |
| 8,5 | WG5 5:2 | PINUS-BETULA-QUERCUS-CORYLUS-ALNUS | Ulmus-Fraxinus | 4230 ± 60 | | Early |
| 9,0–9,5 | 5:1 | | Ulmus-Tilia-Fraxinus | 4810 ± 60; 5130 ± 60; 5430 ± 65 | SUBBOREAL / ATLANTIC | Early / Late |
| 10,0–11,0 | WG 4 4:2 | PINUS-BETULA-CORYLUS-ALNUS-ULMUS | Quercus-Tilia-Fraxinus | 5950 ± 65; 6590 ± 70 | ATLANTIC | Late / Middle |
| | 4:1 | | Quercus-Tilia | 7160 ± 75 | | Middle / Early |
| 11,5–12,0 | WG 3 3:2 | PINUS-BETULA-CORYLUS-ALNUS | Quercus-Ulmus | 8120 ± 85 | | Early |
| 12,5 | 3:1 | | Ulmus-Quercus | 8350 ± 85 | BOREAL | Late / Early |
| | WG 2 2:2 | PINUS-BETULA-CORYLUS | Ulmus-Alnus | 8830 ± 85 | | Early |
| | 2:1 | | Ulmus | 9280 ± 90 | PRE-BOREAL | Late |
| 13,0 | WG1 | PINUS BETULA | | 9870 ± 90 | | Early |

Fig. 3. The regional pollen assemblage zones and subzones related to chronostratigraphy

A complete description of the Holocene pollen assemblage zones will be given in connection with the study of the vegetation history (in prep.).

The chronostratigraphical zonation of the pollen diagram is based on the

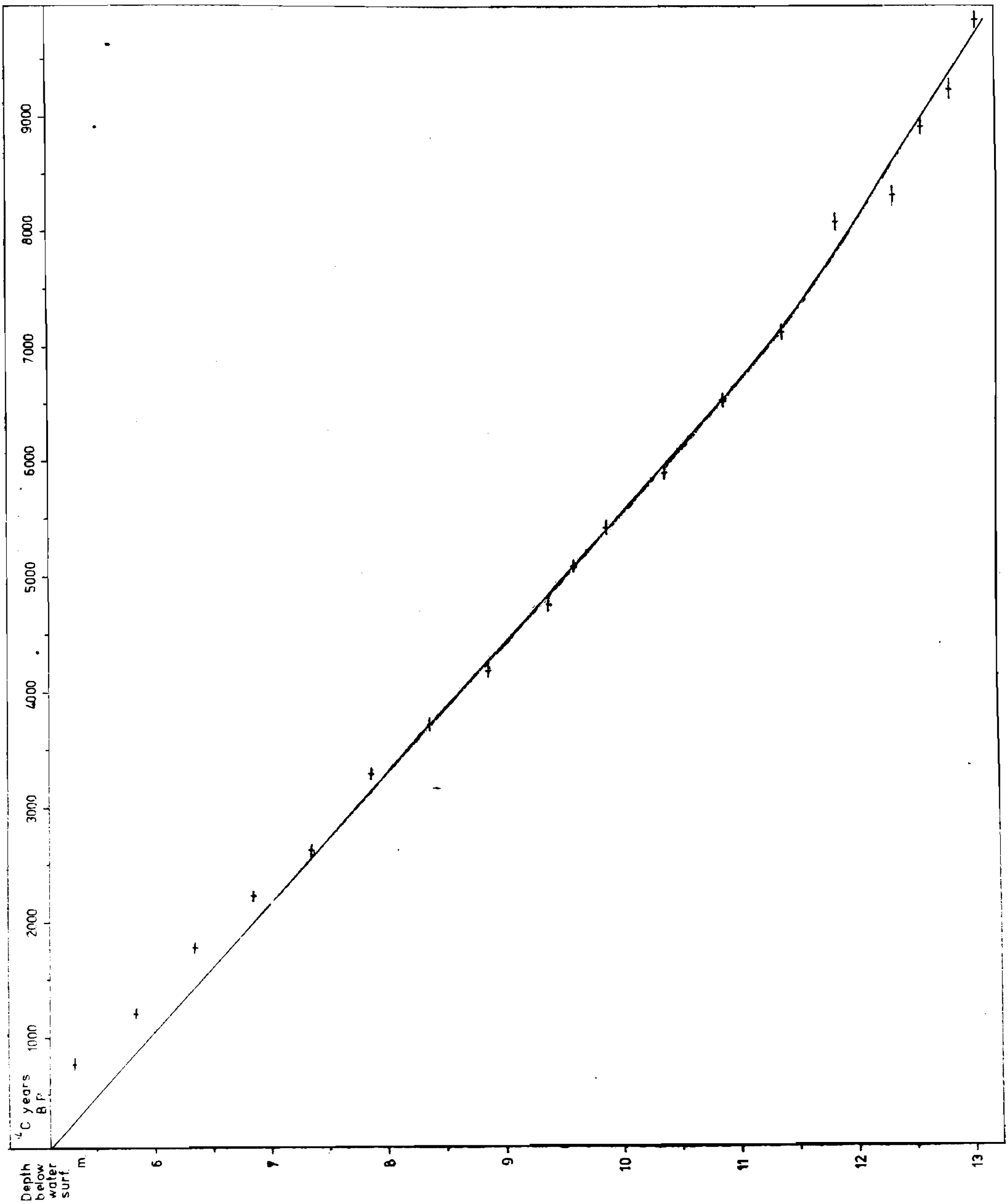


Fig. 4. $^{14}C$ dates from Lake Wielkie Gacno plotted against sediment depth (only the upper part of the main profile is presented)

$^{14}C$ dates and follows the chronozone system proposed by Mangerud *et al.* (1974). 19 radiocarbon datings are available from the main profile.

The radiocarbon datings from the upper part of the diagram are thought to be in error, the youngest one showing the greatest deviation being ca 500 years too old. This phenomen commences at the same time as the first traces of human cultivation appear (the problem is discussed by Olsson 1974; Huttunen and Tolonen 1977; Tolonen 1978).

The $^{14}C$ dates are used to give a radiocarbon time-scale to the diagram and for determining the rate of sediment deposition, necessary for the calculation of pollen influx values. In Fig. 4 the $^{14}C$ dates are plotted against sediment depth and the deposition curve is constructed graphically. The sediment deposition rate seems to have been quite even during the whole of the natural development of the lake varying between 0·63 mm $\times$ $yr^{-1}$ and 0·85 mm $\times$ $yr^{-1}$.

The archaeological time-scale used in the pollen diagram was originally constructed by Jażdżewski (1965) for northern Poland. With some corrections, it is approved by archaeologists who are working within the investigation area (Dr. G. Wilke, pers. comm.).

## LOCAL ANTHROPOGENOUS PHASES

Human impact on the landscape is traced in the pollen diagram by the occurrence of anthropochores and apophytes (terminology after Simmons 1910; Linkola 1916 and Ahti & Hämet-Ahti 1971) and by disturbance in the forest ecosystems. Using primarily the frequency changes of the anthropochores and apophytes, it has been possible to identify six expansion phases in the human landscape (cf. Königsson 1968, Berglund 1969), (Figs. 5, 6 and 7, which are under the cover).

Phase 1. (3900–3500 B.C.)

The appearance of the first pollen grains of *Plantago lanceolata* and increasing values of *Plantago major*, *Artemisia* and *Chenopodiaceae* must be considered as a result of human activity. The regular finds of *Calluna* and *Juniperus* may indicate grazing. In terms of the forest vegetation an opening of the tree canopy is assumed, in that *Betula*, *Corylus* and *Populus*, as light demanding species, have a slight maximum while *Pinus* values are low. As evidence of fire some *Vicia* pollen are found together with the increasing values of *Pteridium* (e.g. Berglund 1966; Görnsson 1977).

Archaeologically this phase corresponds to the middle part of the Early Neolithic.

Phase 2. (3150–2650 B.C.)

The first Cerealea pollen was found at the 9·5 m depth level coincident with the *Ulmus* decline. The surface pattering of the grain was like that of *Triticum*, but the pollen itself was so corroded and split that a precise identification was impossible. This level is $^{14}C$ dated to 3180 B.C. *Plantago lanceolata* increases somewhat later together with *Rumex*, *Urtica*, *Artemisia* and *Umbelliferae*. The first *Triticum* pollen are observed at the 9·15 m depth level and in addition to *Triticum* a pollen grain of *Hordeum* is also found.

In the middle part of the period *Pinus* decreases by about 20% while *Betula*, *Corylus* and *Alnus* (the latter only in influx terms) are increasing slightly. This, together with high percentages of *Pteridium* and the occurrence of *Vicia* — type pollen provide evidence of slash-and-burn cultivation.

The maximum of *Calluna* in the earlier part of the period and higher values of *Juniperus* in the later part can be considered as an evidence of grazing. In addition to grazing, actual agriculture has been practised during this period in the neighbourhood of the lake. This is shown by the presence of Cerealea pollen together with the pollen of plants which are considered as followers of man and indicators of cultivation. If Cerealea pollen are found alone, then the long-distance transport of these pollen must be considered.

Archaeologically this phase 2 corresponds to the Middle Neolithic.

Phase 3. (2000–1500 B.C.)

The lower part of this phase is characterized by a clear and sudden increase in *Carpinus* and thus a change in composition of the forest. The pollen of *Picea* are found in such frequencies that one can suppose that spruce appeared locally. Soon after the *Carpinus* expansion an increase in human activity is seen in the form of grazing activity in the district. Both the percentage and influx values of tree pollen are high but there is also a distinct increase in human indicators: *Artemisia* and *Cannabaceae*, *Chenopodiaceae* and *Rumex*, and the Cerealea curve is rising.

In the middle and later part of this period *Carpinus* and *Quercus* values are decreasing. *Picea* has a brief maximum but also decreases later. *Betula* and *Corylus* are increasing, and at the same time pollen grains of *Epilobium* and *Vicia*-type are found, while the *Pteridium* curve shows a maximum. *Populus* and *Melampyrum* benefited from the more open forests.

Archaeologically this period may be correlated with the transition Late Neolithic/Bronze Age as well as with the early Bronze Age.

Phase 4. (800–4500 B.C.)

In the later Bronze Age *Ulmus*, *Tilia* and *Fraxinus* decline dramatically, *Carpinus* decreases, and at the same time there is an increase in *Pteridium*, *Gramineae*, *Plantago lanceolata* and *Rumex* as evidence of forest clearance. This forest clearance is followed by a short but intensive phase of human expansion with increased values of *Triticum* and *Secale* pollen. Together with high values for the indicators of human interference one pollen grain of *Linum* is found for the first time.

From an archaeological point of view this period may be correlated with the late Bronze Age and the Hallstatt C- and D- as well as the earlier part of the La Tène period.

Phase 5. A.D. (50–400)

*Carpinus* is decreasing while the influx values of *Betula*, *Alnus* and *Quercus* are high and slightly increasing. *Gramineae* and *Calluna* show a maximum and all grazing indicators are well presented. Cerealea, which besides *Triticum* also includes a large number of *Secale* pollen, has a distinctly marked increase.

Some single pollen grains of *Centaurea cyanus* are observed. In the later part of the period the curve for *Carpinus* begins to rise, reaching its peak at the 6·2 m depth level, only to fall to very low values in the following and final phase.

This phase corresponds archaeologically to the middle and later part of the Roman period and the beginning of the Migration period.

Phase 6. (A.D. 750–)

In fixing the lower boundary of this stage one can observe the importance of the pollen influx diagram in connection with studies of landscape changes and human activity. The dramatic drop in the influx values of all AP species is hardly visible in the pollen percentage diagram.

Throughout this period the landscape is more open and the proportions of herbs and grasses are increasing. NAP reaches a maximum and among them weeds show a marked increase. Besides Cerealea, *Fagopyrum* is also found in such amounts that it may have grown in the close vicinity of the lake.

Archaeologically the beginning of this last phase corresponds to the middle part of the Early Medieval Age.

As is generally known the landscape has been changing from one of cultivated arable land to grazed woodlands and open pastures with Juniperus and heaths. The last enormous expansion of *Pinus* is caused by plantations of about 200 years ago. In the surface sample Cerealea is found in its highest frequencies although no cultivation is practised in the surroundings of the lake. This is possibly because the uppermost pollen spectrum does not correspond to the present-day vegetation but rather to that of the beginning of this century.

## DISCUSSION AND CONCLUSIONS

On the basis of the pollen diagram it is difficult to say if there has been any human activity in the Wielkie Gacno region before 3900 B.C. Throughout the whole of the Holocene the pollen spectra have been dominated by *Pinus*, and small-scale clearances caused by hunters and gatherers would obviously have had only a slight effect on the total pollen composition.

During the Atlantic chronozone, before human activity had caused any widescale changes in the natural vegetation, the forest was composed of deciduous, broad-leaved trees. Several species of different plant communities were competative and demanded fertile soils.

During the early and middle part of the Neolithic I pollen grains indicating pasture occur simultaneously with a slight reduction in the nemoral broad-leaved forest. On the basis of the pollen finds of both apophytes and anthropochores such as *Plantago lanceolata*, *Juniperus*, *Plantago major*, *Artemisia* and *Chenopodiaceae* the opening of the forest is presumed to have been caused by man rather than forest fire. These Late Atlantic changes in vegetation may have been caused by tribes belonging to the Danubian culture, who, it is assumed, already practised some animal husbundary.

The first expansion phase (3900–3500 B.C.) has a pollen-analytical character similar to the earliest landnam phase in Denmark, sometimes called A-Landnam (Troels-Smith 1953, 1961 Berglund 1969). It is, however, more than 500 years earlier in the Wielkie Gacno area. Possibly this early phase can be correlated with the first introduction of stock-raising. Small areas were cleared to provide grazing land in the forest. There are no proofs of agriculture during this phase.

Just after the *Ulmus* decline (about 3200 B.C.) in the later part of Late Atlantic chronozone a marked minimum of *Quercus* is observed simultaneous with a distinct increase in pollen grains of hemerophilous plants, indicating increased human activity with pasturing and stock-raising. Somewhat after that, about 2800 B.C. the first identifiable pollen grains of Cerealea have been found. (The very first Cerealea pollen is found at the same level as the *Ulmus* decline.) These Cerealea pollen are identified to *Triticum* sp. and one to *Hordeum*-type.

This part of the Tuchola pine forest is poor in archaeological investigations, but at the Neolithic dwelling site of Chełmża, near Toruń, *Triticum*, *Secale* and *Hordeum* are all found as macroscopic plant remains (Klichowska 1972). Close to Lake Charzykowskie, on its western shore, there is a Neolithic grave field, and scattered finds of Neolithic age have also been found south of Lake Charzykowskie (Dr. G. Wilke, pers. comm.).

The evidence of the Cerealea and *Plantago lanceolata* finds in the Wielkie Gacno — pollen diagram suggests that these neolithic people practised farming at the beginning of the Early Sub-boreal chronozone, archaeologically corresponding to the Neolithic II. The percentage pollen diagram shows that this phase is comparable with the B-Landnam (Iversen 1941) characterized by a minimum of *Ulmus* and *Quercus*, a simultaneous increase in the values of human indicators such as *Plantago lanceolata*, and quite high values of *Betula*. In the pollen influx diagram the minimum of the AP species is more distinctive and their increasing values in the later part of the period can be seen more clearly than in the percentage diagram.

Many different interpretations have been presented concerning the *Ulmus* decline, was it caused by human interference or by a change in climatic conditions. A lot of these suggestions have been treated in discussion by Göransson (1977). In the pollen diagram from Wielkie Gacno one cannot see any clear connections between the *Ulmus* decline and human activity. Before the decline human influence is quite strong in the form of grazing causing a reduction of the broad-leaved trees. This is observed in decreasing values of the other QM-species: *Quercus*, *Tilia* and *Fraxinus*, *Ulmus* first declines somewhat later. Slightly after the *Ulmus* decline human activity increases markedly, pollen finds indicate arable land and pastures. The *Ulmus* reduction is possibly caused by edaphic and climatic changes leading to a situation which was immediately utilized by man.

Around the Late Neolithic/Bronze Age boundary, in the Middle Sub-boreal, chronozone (2000–1500 B.C.) the next expansion phase is observed. The forest community has been developing into a form corresponding to that of the present *Querco-Carpinetum* association. AP values decrease slightly in percentage terms, but the influx values show a distinct increase. However, in both diagrams the curve for *Carpinus* falls. *Carpinus* has been shown to be very sensitive to human activity and decreases simultaneously with the colonization phases (Ralska-Jasiewiczowa 1964, 1977). Probably this period was one of a more local character, and the traces of an enlargement of the area under pasture land and stock-raising together with the cultivation of *Triticum*, *Hordeum* and probably also *Secale*, the pollen of which are found in the sediment, originated from the activity of people living directly in the neighbourhood of the lake.

The landscape was more open because of forest clearance caused partly by fire and partly by the use of leaf-fodder. The dominance of Pinus pollen is possibly due to long-distance transport.

The increase in the clearance of fields for cultivation is also reflected in the amount of mineral material washed into the lake basin, which can be observed in the loss-on-ignition curve as well as in the increasing values of *Isoëtes*. It has been shown in England (Pennington 1977) that *Isoëtes* can not tolerate increased silting in the sediment and the amount of *Isoëtes* spores decreases simultaneously with an increase in mineral matter. On the other hand Göransson (1977) has evidence for a connection between the maximum of the *Isoëtes* and *Pteridium* curves. *Pteridium* is an indicator of forest fire which usually causes stronger erosion from the surrounding area into the lake. In the Wielkie Gacno profile the curve for *Isoëtes* closely follows that of the mineral matter in the sediment.

The more open landscape seems to have provided suitable conditions for the spread of *Picea* into the area. Spruce, however, decreases as soon as the other more competative tree species begin to regenerate.

During the middle part of the Bronze Age there was a slight standstill in the degree of human influence. The pollen evidence indicates an open *Querco-Carpinetum* forest with grazing. Human activity is observed throughout the period, but not as strongly as in the earlier part of the Bronze Age.

In the Late Sub-boreal chronozone which, archaeologically, corresponds to the later Bronze Age and the Hallstatt period, *Carpinus* has a new minimum, which is followed by an increase in pollen grains indicating grazing and an enlargement of the area of arable land. There is an intensive expansion phase, dated to 800–450 B.C. with a large number of Cerealea pollen. As evidence of a more advanced agriculture one pollen grain of *Linum* is found. According to Helback (1960) *Linum* was brought from Russia through the Baltic to Central Europe. The seeds of flax have been found at Biskupin together with finds of the Lusatian culture, corresponding to the Late Bronze Age and the Hallstatt period (Kozłowska 1966, Klichowska 1972).

The archaeological information from the Charzykowskie lake district indicates that the shores of the lake were rapidly and densely colonized, about 650–125 B.C., by people belonging to the Lusatian culture (Dr. G. Wilke, pers. comm.).

Simultaneous with the Cerealea maximum *Picea* is found in such large quantities that it was probably growing at that time in the Wielkie Gacno district. It has generally been held that *Picea* did not occur in the Tuchola pine-forest during the Holocene or it has, at least been very uncommon (e.g. Środoń 1967). One fragment of *Picea* excelsa twig has, however, been found in a soil sample from archaeological excavations at Odry, not so far from Wielkie Gacno (Klichowska 1969). This settlement site was in existence during the La Tène-period (La Tène: 400–0 B.C. — in the Wielkie Gacno region 500–100 B.C.). It is obvious that here also prehistoric man encouraged the advance of spruce with his clearance activities. Vera Markgraf has evidence from Switzerland, of how *Picea*, as a less sensitive tree species, came to dominance after forest clearances (Markgraf 1970).

*Picea* has a distinct decline slightly after the beginning of forest regeneration. *Carpinus* reaches its maximum around the boundary Early/Middle Sub-atlantic chronozone, and *Quercus* is also increasing. The *Querco-Carpinetum*-like forest community seems to have reached its climax at this time. The pollen diagram shows that cultural development has been continuous, but slight. It is perhaps worth mentioning that at Odry traces of ploughing and slash-and-burn farming have been found from this time (Kmieciński 1968).

During the Roman period (A.D. 50–400) *Carpinus* has a distinct minimum, during which Cerealea has two peaks, around A.D. 100 and 350. Simultaneous with the increasing proportions of *Triticum* and *Secale*-type pollen single *Centaurea cyanus* pollen are found which show that *Secale* was cultivated in the neigbourhood.

It has been emphasized by Lange (1971) that at that time in Poland *Secale* cereale was cultivated in as large amounts as *Hordeum vulgare* with *Triticum aestivum* taking third place in importance. When comparing Poland with Central Europe one can deduce that *Secale* must have moved from the east through Poland to Central Europe.

From an archaeological point of view the period between A.D. 100 and A.D. 350 is quite poor in finds from the area around Lake Charzykowskie, but two grave fields originate from this period. In spite of the poor archaeological factors the presence of man is clearly seen in the pollen-analytical evidence, especially in the increasing NAP influx-values.

Clearance has taken place in the supposed *Querco-Carpinetum* forest, and the opening of the forest is indicated by an increase of the curves of heaths, *Gramineae* and hemerophilous plants. A new slight *Picea*-expansion is noticeable.

The Roman period is followed by a regeneration phase lasting A.D. 500–750. The signs of settlement disappear almost completely. *Pinus* decreases and a dense broad-leaved forest dominates.

At the level of 6·2 m depth, dated to ca. A.D. 750, a sudden change in the landscape can be seen in the pollen diagram. Among the NAP scarcely any change can be noticed but the curves of all the AP-species show a distinct reduction. It should be mentioned that this reduction is only seen in the pollen influx diagram. Forest clearances often cause such a kind of alteration in pollen diagrams and changes in forest vegetation of this nature are usually explained in terms of political and economical reasons. That is, however, impossible because all the human indicators pollen also decrease. One possible explanation for this curious phenomenon may be a sudden short-time increase in the rate of sedimentation, which is difficult to prove because of the lack of closer radiocarbon datings. This problem will be discussed in more detail in connection with the investigations of water-level changes in Lake Wielkie Gacno (in prep.).

Archaeologically this corresponds to the Early Medieval Age.

Following this, at the level of 6 m depth, dated to ca. A.D. 975, can be seen a distinct increase in human influence, especially in terms of the agricultural indicators: cereals, among which *Secale* is dominant, *Fagopyrum* and *Cannabaceae*.

About A.D. 1300 the picture of the landscape changes slightly. Grazing elements become more common and the forest turns into a community resembling *Pineto-Quercetum*. During the Sub-atlantic chronozone, when the temperature remained fairly constant and precipitation was quite high, soil conditions must have changed rapidly. Soil leaching which had already begun in the Sub-boreal chronozone continued. Valuable substances from the uppermost layers were washed downwards and the soils became less fertile and poorer in nutrients (e.g. Berglund 1969).

Some smaller fluctuations in Cerealea- and human indicator-curves are seen in the uppermost part of the diagram.

In the later part of the 18th century and at the beginning of the 19th century the last forest clearance occurred, the enormous *Pinus* expansion after this clearance is caused by plantations of this tree (pers. comm. in Toruń).


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## REFERENCES

Ahti & Hämet-Ahti L. 1971. Hemerophilous flora of the Kuusamo district, north-eastern Finland, and the adjacent part of Karelia, and its origin. Ann. Bot. Fenn., 8: 1–91.

Berglund B. E. 1966. Late-Quaternary vegetation in eastern Blekinge, south-eastern Sweden. A pollen analytical study. II. Post-Glacial time. Opera Bot., 12 (1): 1–190.

— 1969. Vegetation and human influence in south Scandinavia during prehistoric time. Oikos, suppl., 12: 9–28.

— 1979. Presentation of research program, methods and organization of work. In: Palaeohydrological changes in the temperate zone in the last 15 000 years. Subproject B. Lake and mire environments. Project guide (ed. B. E. Berglund), I: 5–10, II: 133–168. LUNBDS/(NBGK-3001).

Berglund B. E. & Digerfeldt G. 1976. Environmental changes during the Holocene — a geological correlation project on a Nordic basis. Newsl. Stratigr., 5 (1): 80–85.

Birks H. J. B. 1973. Past and present vegetation of the Isle of Skye. A palaeoecological study. Cambridge University Press.

Digerfeldt G. 1979. Guideline for lake investigations. In: Palaeohydrological changes in the temperate zone in the last 15 000 years. Subproject B. Lake and mire environments. Project guide (ed. B. E. Berglund), I: 31–48. LUNBDS/(NBGK-3001).

Digerfeldt G. & Lettevall U. 1969. A new type of sediment sampler. Geol. För. Förh., 91 (3): 399–406.

Faegri K. & Iversen J. 1964. Texbook of pollen analysis. Munksgaard, Copenhagen.

Göransson H. 1977. Flandrian vegetational history of southern Östergötland. LUNBDS/(NBGK-1003).

Helbaek H. 1960. Notes on the evolution and history of *Linum*. Kuml. 1959: 103–129.

Huttunen P. & Tolonen K. 1977. Human influence in the history of lake Lovojärvi, S. Finland. Finskt Museum 1975: 68–117.

Jażdżewski K. 1965. Poland. Ancient Peoples and Places, 45, London.

Klichowska M. 1969. Zawartość próbki z wykopalisk w Odrach, pow. Chojnice, z 1962 roku (summary: Content of a sample from the 1962 excavations at Odry, district of Chojnice). Spraw. Archeol., 21: 419.

— 1972. Rośliny naczyniowe w znaleziskach kulturowych Polski północno-zachodniej (summary: Vascular plants in archaeological excavations of NW Poland from the Neolithic to the early Middle Ages). Pozn. Tow. Przyj. Nauk, Prace Kom. Biol., 35 (2): 1–73.

Kmieciński J. 1968. Odry, cmentarzysko kurhanowe z okresu rzymskiego w powiecie chojnickim. Acta Archaeol. Lodz., 15: 1–193.

Kozłowska A. 1966. The role of cultivated plants in the historical development of material culture in Poland. In: The vegetation of Poland (ed. W. Szafer), pp. 594–639. Pergamon Press, PWN Warszawa.

Königsson L.-K. 1968. The Holocene history of the Great Alvar of Öland. Acta Phytogeogr. Suec., 55: 1–171.

Lange E. 1971. Botanische Beiträge zur mitteleuropäischen Siedlungsgeschichte. Schriften zur Ur- und Frühgeschichte, 27: 1–142.

Linkola K. 1916. Studien über den Einfluss der Kultur auf die Flora in den Gegenden nördlich von Ladogasee. I. Allgemeiner Teil. Diss. Acta Soc. Fauna Flora Fenn., 45: 1–429.

Mangerud J., Andersen S. T., Berglund B. E. & Donner J. J. 1974. Quaternary stratigraphy of Norden, a proposal for terminology and classification. Boreas, 3: 109–128.

Markgraf V. 1970. Palaeohistory of the spruce in Switzerland. Nature, 228 (5628): 249–251.

Medwecka-Kornaś A. 1966. Factors affecting the geographical distribution of plants in Poland. In: The vegetation of Poland (ed. W. Szafer), pp. 21–96. Pergamon Press, PWN Warszawa.

Olsson I. 1974. Some problems in connection with the evaluation of $^{14}C$ dates. Geol. För. Förh., 96: 311–320.

Pawłowski B., Medwecka-Kornaś A. & Kornaś J. 1966. Review of terrestial and fresh-water plant communities. In: The vegetation of Poland (ed. W. Szafer), pp. 241–534. Pergamon Press, PWN Warszawa.

Pennington W. 1977. The Late Devensian flora and vegetation of Britain. Phil. Trans. R. Soc. London, B, 280: 247–271.

Ralska-Jasiewiczowa M. 1964. Correlation between the Holocene history of the *Carpinus betulus* and prehistoric settlement in north Poland. Acta Soc. Bot. Polon., 33 (2): 461–468.

— 1977. Impact of the prehistoric man on natural vegetation in pollen diagrams from different regions of Poland. Folia Quaternaria, 49: 75–91.

Simmons H. 1910. Om hemerofila växter. Bot. Not., 1910: 137–155.

Stockmarr J. 1971. Tablets with spores used in absolute analysis. Pollen et Spores, 13 (4): 615–621.

Szafer W. 1966. Foundations of a geobotanical division of Poland. In: The vegetation of Poland (ed. W. Szafer), pp. 640–653. Pergamon Press, PWN Warszawa.

Środoń A. 1967. Świerk pospolity w czwartorzędzie Polski (summary: The common spruce in the Quaternary of Poland). Acta Palaeob., 8 (2): 1–59.

Tolonen M. 1978. Palaeoecology of laminated sediments in Lake Ahvenainen, S. Finland. I. Pollen and charcoal analyses and their relation to human impact. Ann. Bot. Fennici, 15: 177–208.

Troels-Smith J. 1953. Erteböllekultur — Bondekultur. Resultater af de sidste 10 aars undersögelser i Aamosen, Vestsjaelland. Aarb. Nord. Oldkynd. 5–62. Copenhagen.

— 1961. Probleme in Zusammenhang mit Europas ältester Bauernkultur in naturwissenschaftlicher Beleuchtung. Bericht über den V Intern. Kongr. für vor- und Frühgeschichte Hamburg 1958: 825–832. Berlin.

Vuorela I. 1976. An instance of slash-and-burn cultivation in southern Finland investigated by pollen analysis of a mineral soil. Memor. Soc. Fauna Flora Fennica, 52: 29–46.

Maps. Geomorphological map. After T. Murawski. Manuscript in archivum of the Department of Physiography, Pol. Acad. Sci., Toruń. Narodowy Atlas Polski. Warszawa 1978.

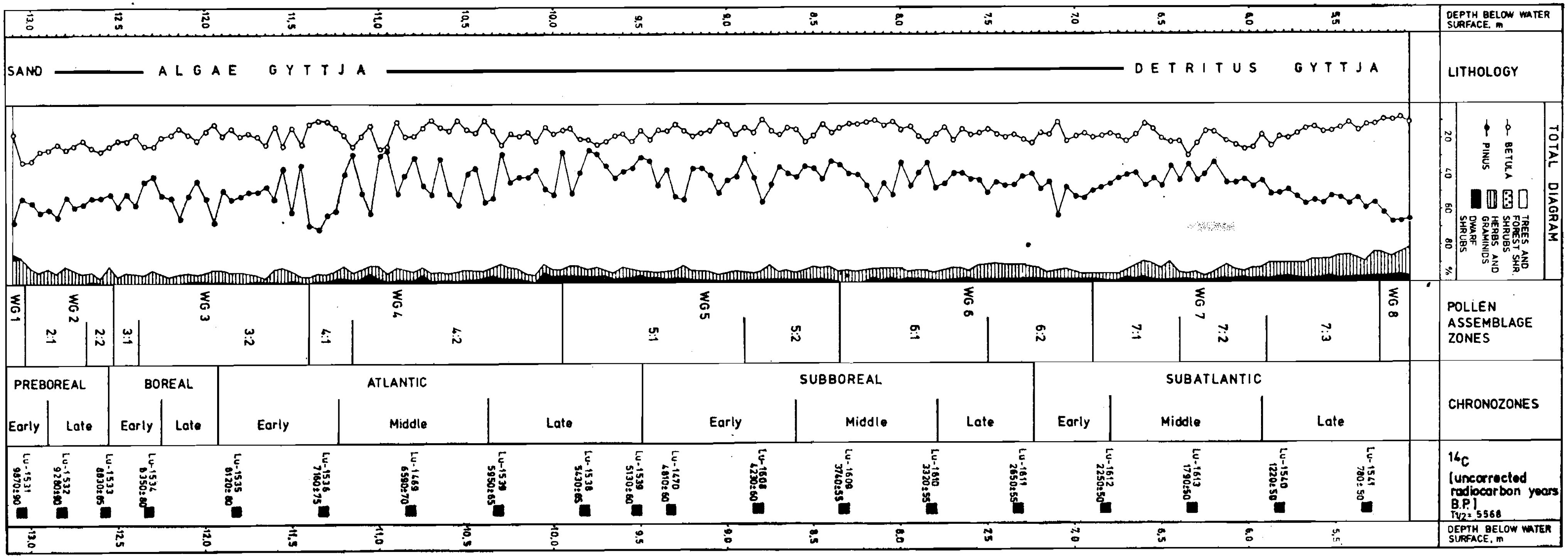


Fig. 2. Total pollen diagram from Lake Wielkie Gacno showing the main features in the Post-glacial vegetation development. The terrestric spermatophytes form the basic sum

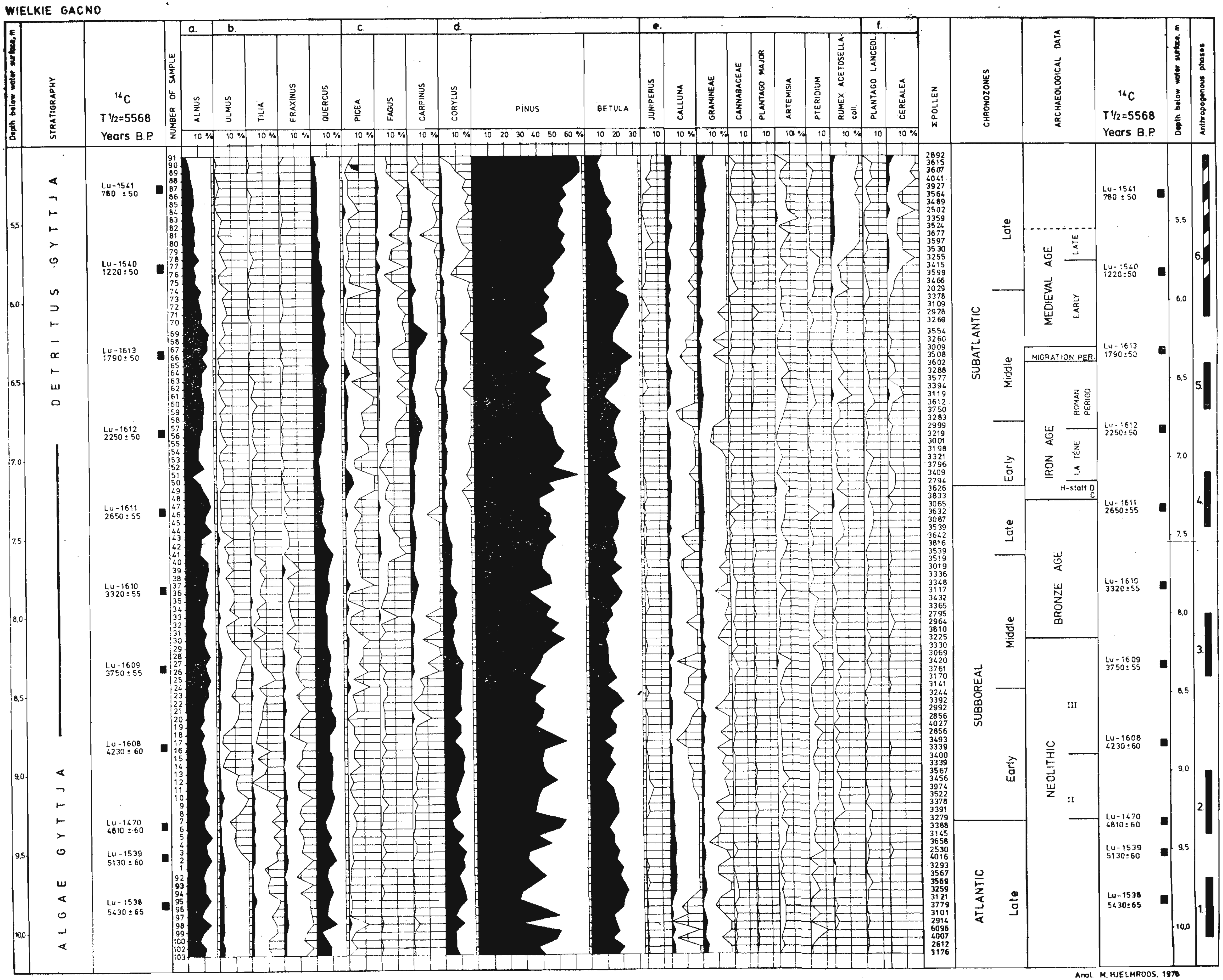


Fig. 5. Simplified pollen percentage diagram representing the uppermost part of the Lake Wielkie Gacno main profile. The plants have been grouped in the following way: a — trees of rather moist soils; b — high competitive and shade-tolerant trees; c — trees of the same ecological group but immigrating during late Holocene; d — low-competitive and lightdemanding trees; e — shrubs, herbs and graminids favoured by man (apophytes); f — herb and graminids introduced by man (anthropochores). The terrestric spermatophytes form the basic sum

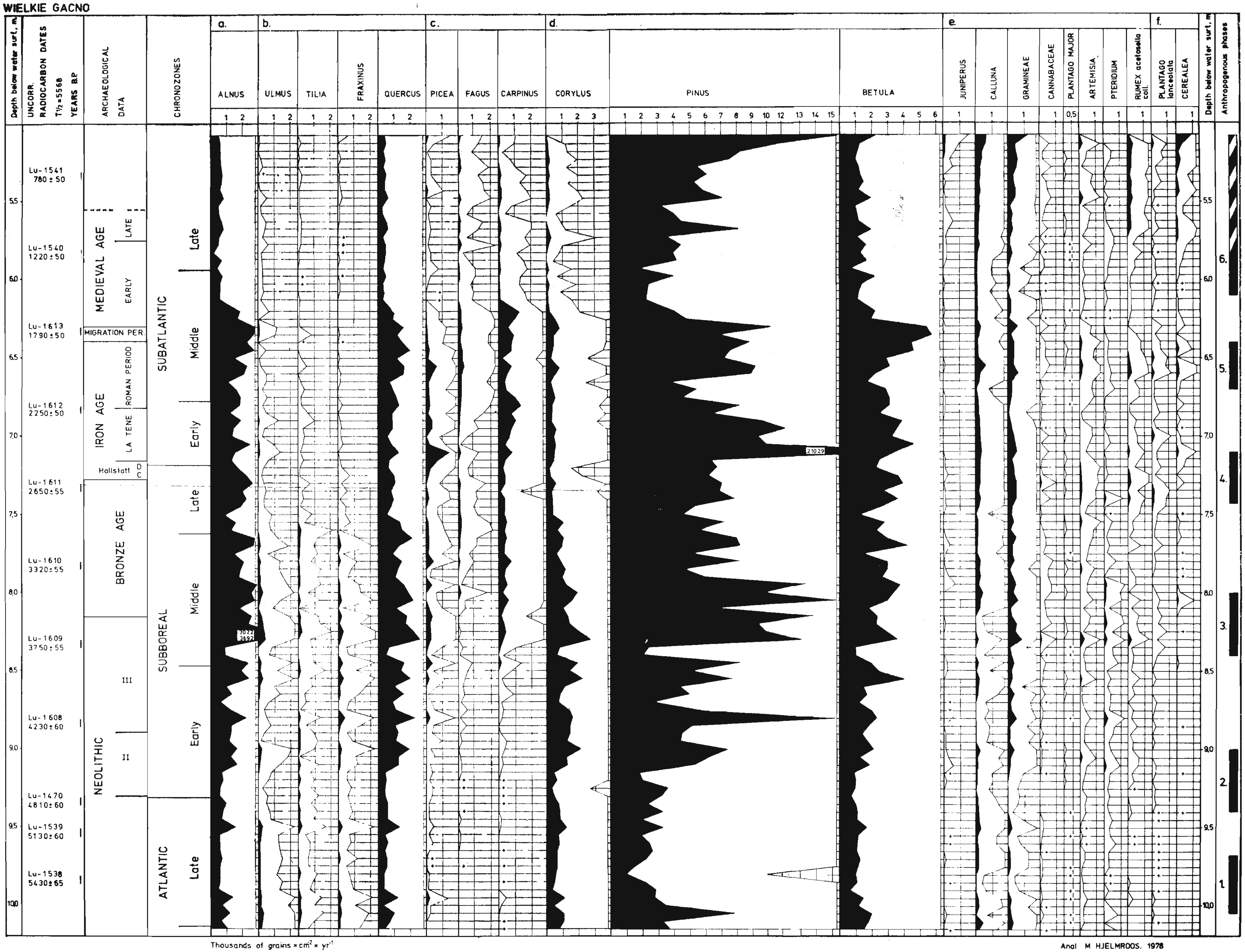


Fig. 6. Simplified pollen influx diagram representing the uppermost part of Lake Wielkie Gacno main profile. The grouping is the same as in the percentage diagram

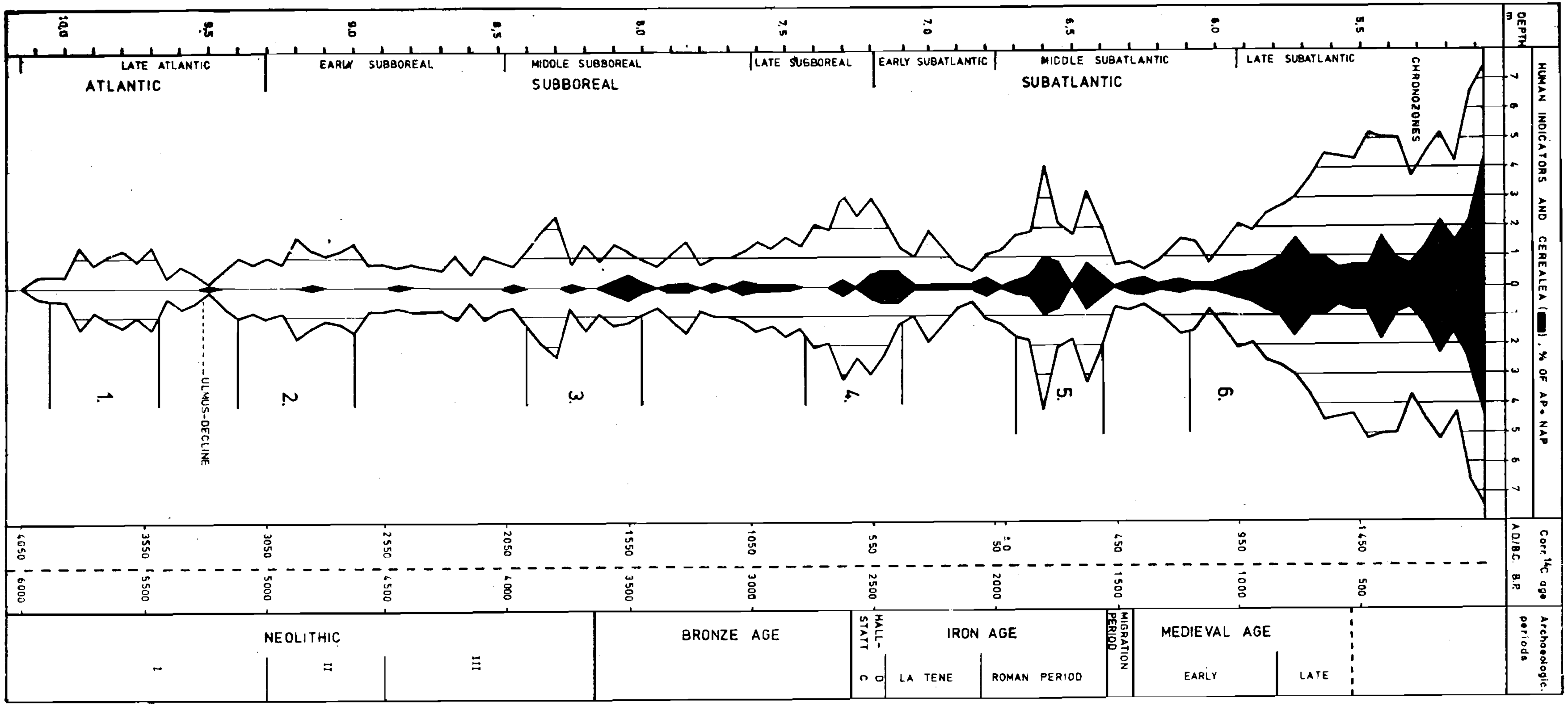


Fig. 7. Survey pollen diagram illustrating the human influence on the vegetation in Lake Wielkie Gacno area. Human indicators: *Artemisia*, *Cannabaceae*, *Centaurea cyanus*, *Fagopyrum Linum*, *Plantago major*, *P. lanceolata* and *Rumex acetosella* coll