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WORYTY NEAR GIETRZWAŁD, OLSZTYN LAKE DISTRICT, NE POLAND — VEGETATIONAL HISTORY AND LAKE DEVELOPMENT DURING THE LAST 12 000 YEARS

Woryty koło Gietrzwałdu na Pojezierzu Olsztyńskim — historia roślinności i rozwój jeziora w ciągu ostatnich 12 000 lat

ABSTRACT. The sediments of an overgrown lake at Woryty in the Olsztyn Lake District were studied by means of different palaeoecological methods, including chemical, mineralogical and pollen analyses, identification of *Cladocera, Rhizopoda* and *Mollusca* remains and radiocarbon dating.

On the basis of 13 local pollen zones delimited with the aid of numerical methods (computer program zonation), the vegetational history of the Woryty area is described, since the Late-Glacial climatic warming prior to the date 11 290 BP, corresponding with the Allerød chronozone, up till recent times.

Eight main stages are distinguished in the development of sedimentation basin, beginning with a mire formed on the dead-ice surface in the Late-Glacial, through the several lacustrine phases, to a swamp that developed in the youngest Holocene. Since about 5100 BP the local ecosystems have been more and more influenced by man.

INTRODUCTION

The Woryty site lies in the centre of the type subregion Olsztyn Lake District (12 b — see the map on p. 4), ca. 17 km SWW from Olsztyn, the capital of the province, and 2 km NWW from Gietrzwałd village.

A small hamlet called Woryty borders an ancient lake, now completely filled in and overgrown by mires and meadows. Since the late 1930's the surroundings of the lake have been investigated by archaeologists. The geological, pollenanalytical and other naturalistic studies initiated here in 1975 aimed to help reconstruct the natural environment of cultural groups that inhabited the area in the past. As the result of these cooperative investigations a volume of papers has been published (Woryty — an archaeological and naturalistic study of the settlement complex of Lusatian Culture, Dąbrowski (ed.) 1981).

Since the Woryty site was chosen as a reference site for the IGCP-158 project, the naturalistic studies have been continued and expanded. The present paper is a preliminary description of the development of the lake and of the surrounding vegetation starting in the earliest, Late-Glacial stages recorded in the lake sediments. The geological studies were performed by E. Stupnicka, the mineralogical analyses by M. Pawlikowski, the chemical analyses by K. Oleksynowa and her collaborators, excluding the heavy metals which were determined by A. Cieśla. The pollenanalytical and plant macrofossil studies were carried out by M. Ralska-Jasiewiczowa, diatom analyses by B. Marciniakowa, *Rhizopoda* analyses by W. Schönborn (Jena, DDR) and *Cladocera* analyses by K. Szeroczyńska; sporadically occurring *Mollusca* remains were examined by S. Alexandrowicz and S. Skompski.

The radiocarbon dates were produced by V. R. Switsur (University of Cambridge, U. K.), S. Håkansson (Lund University, Sweden) and M. Pazdur (High Politechnic School, Gliwice, Poland).

The corings were made by K. Więckowski and the Swedish colleagues from the Lund University — G. Digerfeldt and T. Persson.

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Not all of the results obtained by this multidisciplinary research will be discussed in the present report.

REGIONAL ENVIRONMENT

The Olsztyn Lake District is that part of the North Polish Lake Districts between the Vistula river and its deltaic area to the west and the depression of the Great Masurian Lakes to the east. It is a transitional zone between the influences of a maritime climate coming from the north-west and of a continental climate coming from the east. This transitional climatic position is well expressed by the large number of plant-distribution limits that occur in this area (Fig. 1). This concerns — in the first place — the western species disappearing eastwards, and boreal plants entering the area from the north-east. The best examples are *Fagus sylvatica* and associated plants such as *Acer pseudoplatanus* or *Polystichum lobatum* reaching their eastern or north-eastern distribution limit here, and *Picea abies* along with the whole group of boreal mire plants, such as *Salix lapponum*, *Chamaedaphne calyculata* or *Carex pauciflora* invading the area from the north-east (Szafer & Zarzycki 1972).

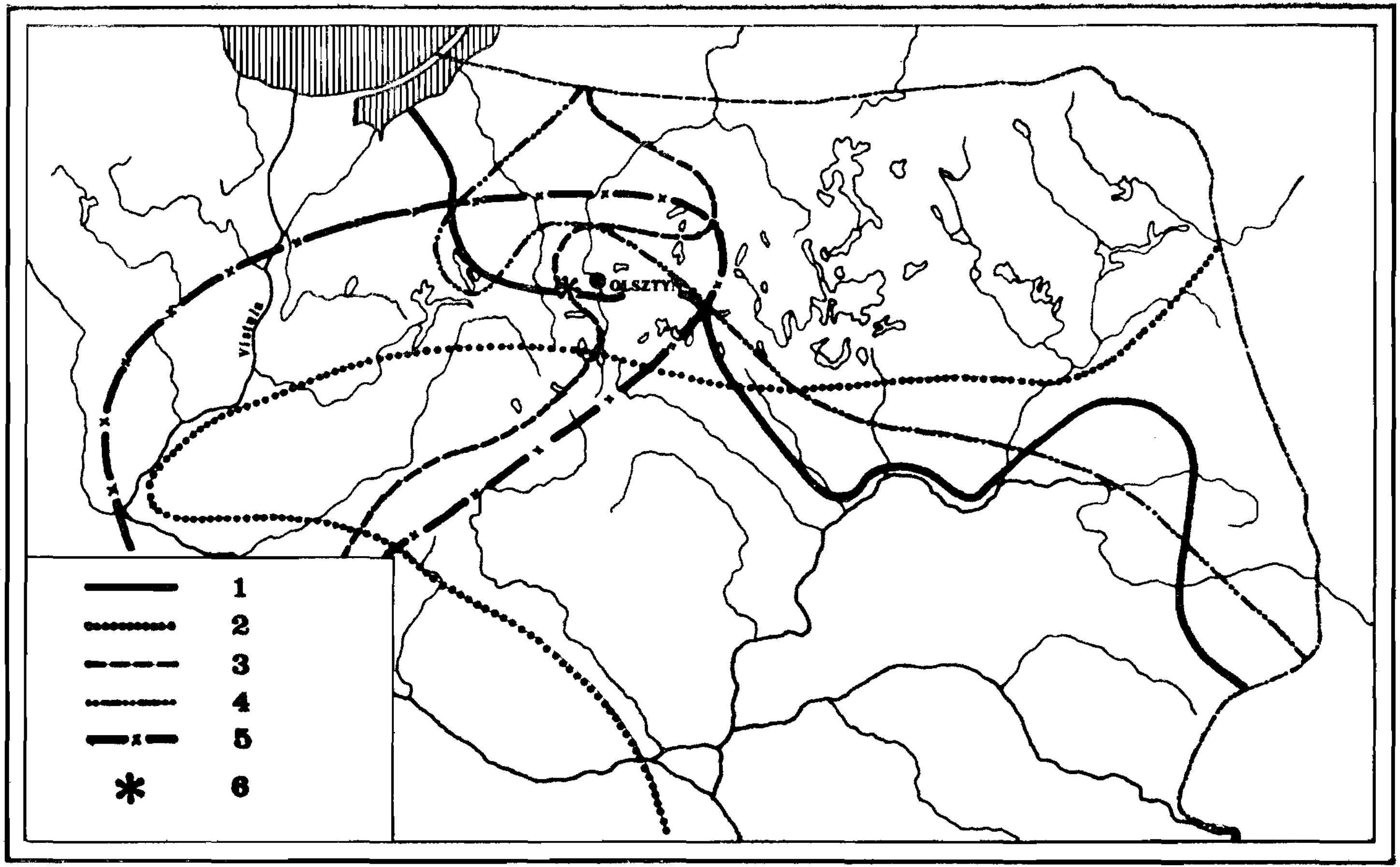

Fig. 1. Map showing the concentration of distribution limits of several tree species in the area of Olsztyn Lake District: 1 — *Picea abies*, 2 — *Taxus baccata*, 3 — *Fagus sylvatica*, 4 — *Quercus petraea*, 5 — *Acer pseudoplatanus*, (after Szafer & Zarzycki 1972) 6 — Woryty site

Topography, geology, and soils

The young morainic landscape of the Olsztyn Lake District has been formed by the Vistulian glaciation, mostly by its Poznań — and Pomeranian stages. The parallel W—E ranges of morainic hills that reach to ca. 300 m a.s.l. are dissected by perpendicular or oblique systems of numerous channel-lakes and rivers flowing to the Baltic basin.

The Quaternary drift consists of tills and sands ranging in thickness from 60 m to 200 m. It overlies older beds of Cretaceous marls and limestones or Tertiary sands and clays. The soils originate mainly from the fluvio-glacial sands and boulder clays. Typical, or leached, brown- earths are most common. The poorest soils are rusty soils often found on the tops of sandy hills; the podsolic soils and podsols on the slopes are slightly more fertile. In the depressions gley- and marsh- soils predominate.

Climate

The Olsztyn Lake District has a rather cool lowland climate. The mean January temperatures range between —2·4°C and —4°C and the mean July temperatures between 16°C and 18°C. The average annual precipitation is ca. 600 mm with its maximum during the summer. Snow cover is rather long and the growing season short (190–210 days). Westerly winds predominate, but easterly winds are also rather frequent.

Vegetation

The varied topography and diverse hydrological system provide the wide diversity of habitats for different plant communities. The most important forest communities are *Tilio-Carpinetum* occurring on rich, fresh soils and *Pino-Quercetum* on more acidic, sandy soils. In the western part of the area beech forests *(Melico-Fagetum* and *Luzulo-Fagetum)* are widespread. Damp, rich soils along the rivers and around the lakes support various types of carrs, often with abundant ash *(Circaeo-Alnetum)*, and alderwoods *(Carici elongatae-Alnetum)*. *Picea abies*, occurring as an admixture in different forest types in the NE part of area does not form any individual community here. The undrained waterlogged depressions are occupied by various bog and fen types. The natural vegetational cover of the Olsztyn Lake District has been largely destroyed and changed by man. Nowadays, the forests, including plantations, hardly cover ca. 30% of the area. The woodland management largely influences the composition of forests in favour of conifers and beech.

SITE DESCRIPTION

The overgrown lake at Woryty lies within the hilly area of less than 20 km², delimited by the rivers Pasłęka, Old Pasłęka and Giłwa, the latter flowing through the Rentyńskie channel-lake (Fig. 2). The depression of Woryty-lake,

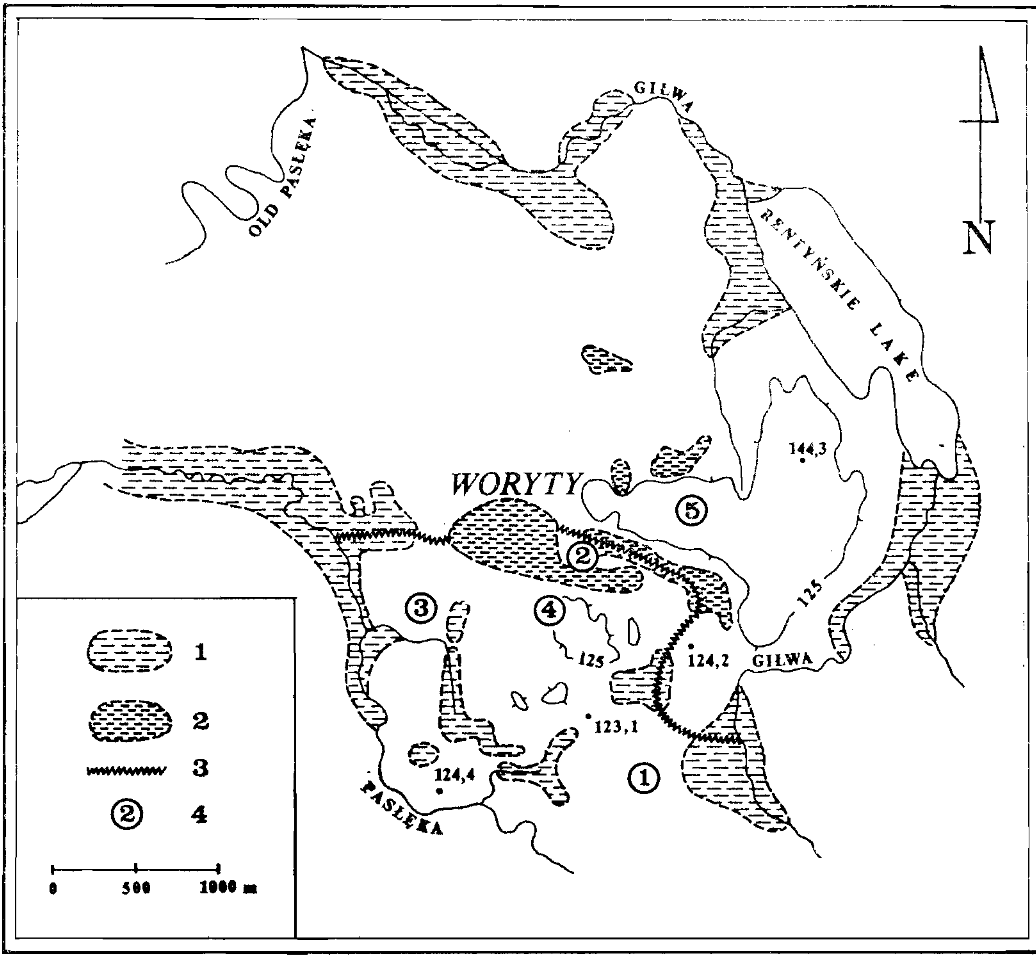

Fig. 2. Map showing the drainage system in the Woryty area: 1 — drained depressions, 2 — undrained depressions, 3 — supposed flow through the Woryty Lake ("Pragiłwa river") in the past, 4 — sites of Late Bronze Lusatian Culture

about 1·1 km long and over 30 ha in area, is surrounded by moraine hills (100–145 m a.s.l.), formed by a glacial lobe during the Pomeranian stage of the last glaciation.

The low and gentle hills to the west of the lake consist of till; the higher hills to the south-east and east are formed of coarse and medium fluvio-glacial sands. The stratified fine sands and silts exposed in the outcrops of small valleys to the north of the lake may be kame deposits (Fig. 3, Stupnicka in Dąbrowski 1981).

The ancient lake is bipartite; it is divided by a mineral bar into two uneven parts, of ca. 25 ha and 5·5 ha in areas. The bigger basin, with its recently overgrown surface at 105 m a.s.l. is connected with two small dry valleys.

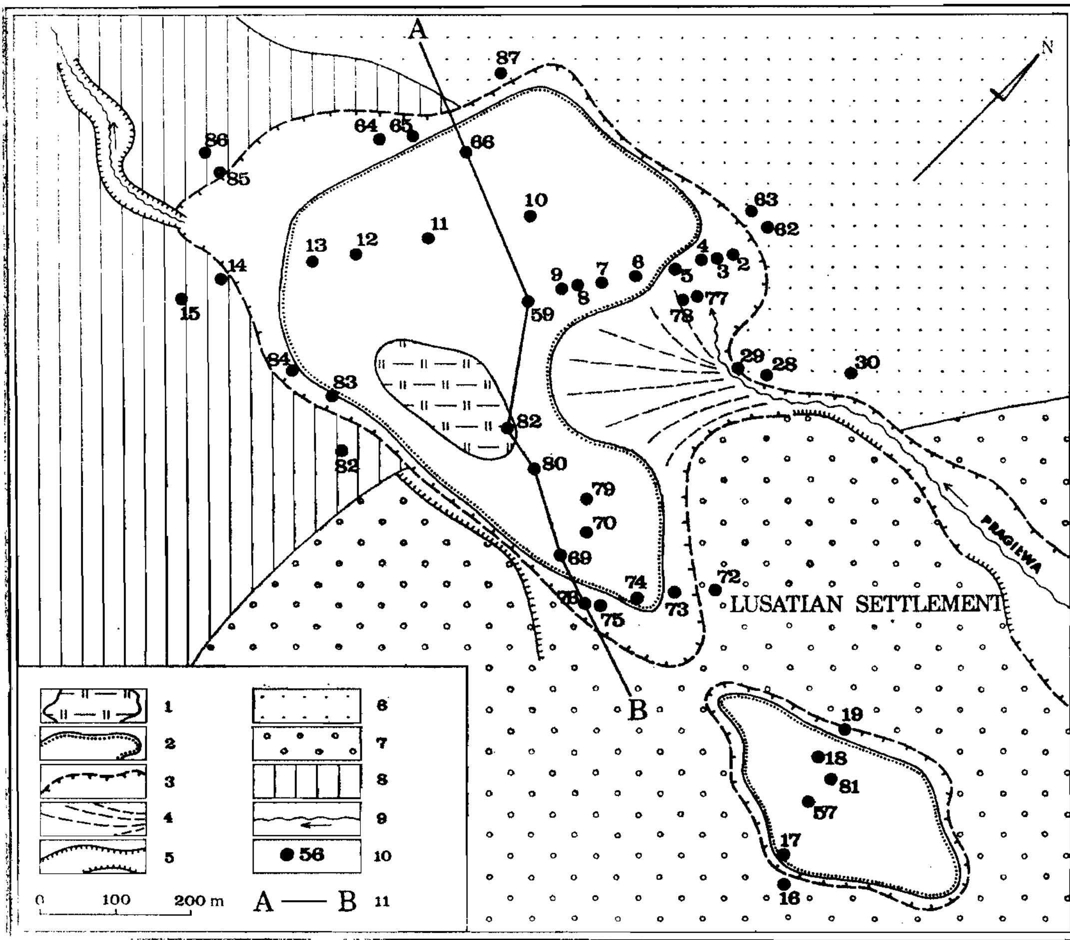

Fig. 3. Sketch map of the Woryty site showing topography, geology and location of borings: 1 — the lowest part of overgrown lake depression, covered by a reed-swamp, 2 — extent of gyttja deposits, 3 — extent of ancient lake, 4 — area of fan accumulation at the supposed inflow of "Pragiłwa river", 5 — steep escarpments on the southern side of lake depression and along the supposed outflow of "Pragiłwa river", 6 — kame silts and sands, 7 — fluvio-glacial sands and gravels, 8 — tills of Vistulian age, 9 — flow direction of unactive and periodically active streams, 10 — location of trial borings; sites 80 and 82 were cored for the paleoecological investigations, 11 — situation of borings that are used for the transect reconstruction of sediment stratigraphy shown in Fig. 4

The eastern valley is shallow and broad. Its bottom, lying at 110 m a.s.l. is buried with eolian sands. At its outlet to the lake a wide and flat alluvial fan has formed. The deep and narrow western valley is incised ca. 8–12 m into the bed, and it opens to the lake depression at 106 m a.s.l. As the eastern valley joins the lake basin with the Giłwa river and the western valley is connected to the Pasłęka river, it may be assumed that the lake had an inflow and outflow some time in the past ("Pragiłwa river" — see Fig. 2).

The recent surface of the swamp overgrowing the lacustrine sediments has been artificially drained and partly converted into damp meadows, a degraded form of *Molinietum* that is used as a pasture and intruded by many ruderal plants. In the central part of its depression there is a stand of reed-swamp dominated by *Phragmites communis*, surrounded by a belt of tall sedges *(Magnocaricion)*.

The surroundings of the site are nearly totally deforested and occupied by fields, mainly of oat, rye and potatoes. The only forest remnant nearby grows on the high bank to the south of the lake and is a mixed pine forest with oak and birch and a rich shrub understory.

Data about prehistorical settlements

According to the archaeological evidence the environs of the lake have been inhabited since the Late Neolithic. The excavations started at Woryty by German archaeologists in the 1930's (Engel 1935; Urbanek 1941) and continued during the last ten years by J. Dąbrowski and his collaborators revealed the remains of a settlement complex of Lusatian Culture (IV–VI periods of Bronze Age) consisting of 3 dwelling places, a cemetery and fishing camp (Fig. 2). In addition, a small cemetery from Roman times and some Late Neolithic (Corded Ware), Early Bronze (Trzciniec), Roman and Early Mediaeval ceramics have been found (Dąbrowski & Mogielnicka-Urban 1976 and papers quoted there; Dąbrowski 1981).

PALAEOECOLOGICAL INVESTIGATIONS

Methods

The geomorphological and stratigraphical studies were based on the surface investigations, on the examination of archaeological ditches, and on over 80 borings made in the area of the ancient lake and its close vicinity in an attempt to reconstruct the range and structure of its sediments (Figs. 3, 4[1]).

For the palaeoecological studies two cores were used, taken in 1974 and 1979 at the site where the thickest sequence of sediments was shown by trial borings, in the few meters distance from each other (profiles Woryty 80 and 82). In spite of this, they revealed quite different thickness of deposits. In the present paper the results of analyses obtained from the core Woryty 82 are mostly presented; the data from core Woryty 80 will be referred to, if necessary, for comparison or complement.

[1] Figs. 4, 5, 6, 7, and 8 under the cover.

The core Woryty 82 was taken with a 10 cm diameter Livingstone type piston sampler modified by Digerfeldt (1978, and in Berglund 1979). The 1·5 m core segments were extruded from the plastic tubes in the laboratory and sampled immediately for various analyses.

Physical and chemical analyses. The loss on ignition values were measured after ashing at 550°C. The pH determination was carried out using a pH-meter type 517, by inserting the electrode into the fresh sediment. The carbonate content was determined using the Scheibler volumetric method.

The following elements were determined:

Organic carbon — using the Tyurin's method modified by Oleksynowa (Oleksynowa et al. 1979).

Organic nitrogen — using the Kjeldahl method.

Phosphorus — using the molybdenum colorimetric (blue) method.

Total iron, manganese and magnesium — using the atomic absorbtion spectrophotometric method after digestion with concentrated HNO_3. (All these methods are described in the IGCP-158 B Guide-Book, Berglund 1979).

Mineralogical analysis was carried out by X-ray diffraction techniques using the TUR-M-62 equipment. The X-ray patterns obtained were interpreted according to the ASTM catalogue and key for determination of minerals (Michejew 1957).

Rhizopoda analysis. Air-dried samples of equal volume (1 ml) were boiled with 5% KOH and suspended in water. The whole sediment volume was examined for testae of rhizopods.

Cladocera analysis. Samples were prepared according to Frey's (1958) method described in the IGCP-158 B Guide-Book (Berglund 1979). They were treated with 10% hot HCL, 10% hot KOH, and screened through a 50 μm-mesh sieve.

Pollen analysis. Samples were taken from the core with a 1 cm^2 volumetric brass sampler. Stocmarr's (1971) *Lycopodium* tablets were added to enable pollen concentrations to be estimated. The samples were prepared by a standard procedure: KOH—HF—Erdtman's acetolysis (Faegri & Iversen 1964), stained in basic fuchsin and mounted in glycerine. Amplival-Zeiss microscope with phase-contrast was used for pollen counting.

Sediment description

The sediment lithology of both cores was described using the Troels-Smith (1955) system. Depths were measured from the recent mire surface. The description is as follows:

Woryty, core 82

Layer No.	Depth in m	Sediment description
25	0·00–0·17	soil, grey-brown, with recent roots nig 2, strf 0, elas 0, sicc 3; Th°1, Ag 2, Ga 1

24	0·17–0·25	sand, light grey, with clay and recent roots l.s. 0, nig 1–2, strf 0, elas 0, sicc 3, Th^{1}1, Ag 1, Ga 2
23	0·25–0·80	swamp peat, grey-brown, with some gyttja in the upper part l.s. 0, nig 2–3, strf 0, elas 0, sicc 2, Th^{2}4, Ld^2++, Ag/As+++
22	0·80–1·00	swamp peat, dark brown, with gyttja l.s. 0, nig 3, strf 0, elas 0, sicc 2, Th^{2}2, Ld^{2}2, Ag+
	1·00–1·20	gap in core segments
21	1·20–2·08	swamp peat, dark brown, with gyttja and some silt l.s. 0, nig 3, strf 0, elas 1, sicc 2, Th^{2}3, Ld^{2}1, Ag+++ Lc(+)
20	2·08–2·75	fine detritus gyttja, olive-brown, with calcium carbonate l.s.1, nig 2, strf 0, elas 2, sicc 2, Ld^{2}3, Lc 1, Ag ++
19	2·75–3·42	peaty gyttja, dark brown, with some silt l.s. 2, nig 3, strf 0, elas 2, sicc 2, Ld^{2}2, Sh 2, Lc+, Ag+++
18	3·42–4·03	fine detritus gyttja, olive-grey, with silt l.s. 2, nig 2, strf 1, elas 2, sicc 2, Ld^{2}3, Ag 1, Lc ++
17	4·03–4·92	sapropel-like sediment, gelatinous, dark brown with rusty shade, changing into greyish-brown on exposure to air, liberating H_2S l.s. 2, nig 3 (2), strf +, elas 1, sicc 2—1, Ld^{2}1, Sh 3, Ag+
16	4·92–5·96	detritus gyttja, grey-olive, slightly porous, with calcium carbonate; with layers of coarser detritus, or more humified (brownish) sediment l.s. 0, nig 2(3), strf 1, elas 2, sicc 2, Ld^{2}3, Lc 1, Sh+++, Dg+++, Ag++
15	5·96–6·10	fine detritus silty gyttja, olive-grey, with concretions of vivianite l.s. 1, nig 2, strf +, elas 2, sicc 2, Ld^{2}3, Ag 1, Lc ++, Lf +
14	6·10–6·21	dy-like, silty sediment, dark brown l.s. 0, nig 3, strf 0, elas 2, sicc 2, Ld^{2}1, Sh 2, Ag 1
13	6·21–6·41	fine detritus silty gyttja, grey-olive l.s. 2, nig 2, strf +, elas 2, sicc 2, Ld^{2}3, Ag 1, Lc ++
12	6·41–6·58	silt, greyish, with gyttja, sand and fine gravel l.s. 0, nig 2, strf 0, elas 0, sicc 3, Ag 2, Ld^{2}1, Ga 1, Gs +, Lc ++
11	6·58–7·01	silty gyttja, grey-olive, with some calcium carbonate; patches of partly desintegrated shells l.s.0, nig 2, strf 0, elas 1, sicc 2, Ld^{2}3, Ag 1, Lc +++, Lf +, (part. test. moll. ++)

10	7·01–7·83	fine detritus gyttja, olive-grey, with calcium carbonate l.s.0, nig 2, strf 1, elas 3, sicc 2, $Ld^2$3, Lc 1, Ag ++, Lf +
9	7·83–8·10	calcareous gyttja, dark olive, with numerous mollusc shells [7·83–7·87 m a layer of fine laminae (strf 4)] l.s.0, nig 2—3, strf 1 (4), elas 2, sicc 2, $Ld^2$2, Lc 2, (test. moll. 1)
8	8·10–8·43	calcareous gyttja, dark brown, gelatinous, very soft l.s.0, nig 3, strf 0, elas 0, sicc 1, $Ld^3$2, Lc 2, Ag+, (test. moll. +)
7	8·43–9·19	ferruginous gyttja, black, turning light beige on exposure to air, with mollusc shells [8·56–8·60 m — interbedding of coarser detritus (Dg +++); 8·60–8·68 m — layer of thin laminae (strf 4); 9·06–9·09 m — layer of sand (Ld 1, Ga 3)] l.s.0, nig 4–2, strf 2, elas 1, sicc 2, $Ld^2$3, Ag 1, Lf +++, Lc +, Ga+
6	9·19–9·42	ferruginous gyttja /silt laminae of contrast black/ grey colour, turning beige on exposure to air l.s.3, nig 3–2, strf 4, elas 2, sicc 2, $Ld^2$2, Ag 2, Lf +++, Lc+
5	9·42–9·61	ferruginous silty gyttja with calcium carbonate, black, turning beige on exposure to air, with coarse detritus and pieces of wood in the bottom part; traces of lamination more and more distinct upwards l.s.0, nig 4–2, strf 1—3, elas 3, sicc 2, $Ld^2$2, Dg 1, Lc 1, Ag+++, Lf+++, Ga+, II—III 1
4	9·61–9·86	humified peat, dark brown, with pieces of wood l.s.3, nig 3, strf 0, elas 0, sicc 3, $Th^3$3, $Ld^3$1, Ag+++, Lf++, II 1
3	9·86–10·02	sandy humified peat with gyttja, blackish-brown l.s.0, nig 3—4, strf 0, elas 0, sicc 3, $Th^3$2, $Ld^3$1, Ga 1, Lc+++, Ag+++, Lf+, I+
2	10·02–10·13	sand with humus, dark grey l.s.0, nig 2, strf 0, elas 0, sicc 3, Ga 3, Sh 1, Ag+++
1	10·13 — base not seen	outwash sand, light grey l.s. 0, nig 1, strf 0, elas 0, sicc 3, Ga 4, Ag+

Woryty, core 80

The lithology description of core 80 is given below in a simplified form:

Layer No.	Depth in m	Sediment description
21	0·00–0·10	sand with mud and plant detritus. Ga 2, Ag 1, Dh 1
20	0·10–0·50	swamp peat. Th^{2}4
19	0·50–0·70	fine detritus gyttja with peat. Ld^{2}3, Th^{2}1
18	0·70–0·80	swamp peat with gyttja. Th^{2}2, Ld^{2}2
17	0·80–1·00	peaty gyttja. Ld^{2}3, Th^{2}1
16	1·00–1·75	sapropel-like sediment (H_2S). Ld^{2}2, Sh 2
15	1·75–2·62	fine detritus gyttja with calcium carbonate. Ld^{2}3, Lc 1
14	2·62–2·77	dy?. Ld^{2}2, Sh 2, Ag+
13	2·77–3·30	fine detritus gyttja. Ld^{2}4, Ag+, Lc +
12	3·30–3·85	gelatinous, (dark brown) gyttja. Ld^{2}3, Sh 1?
11	3·85–4·35	fine detritus gyttja with calcium carbonate. Ld^{2}3, Lc 1, Ag++, Ga+
10	4·35–4·40	sand with gyttja. Ga 3, Ld^{2}1
9	4·40–4·65	dy?. Ld 1, Sh 2, Ag 1
8	4·65–4·85	fine detritus silty gyttja. Ld^{2}3, Ag 1, Lc ++
7	4·85–5·05	sandy gyttja with silt and gravel; sand content increasing downwards. Ld^{2}2(1), Ga 1(2), Ag 1, Gs++
6	5·05–5·22	silty calcareous gyttja. Ld^{2}2, Lc 1, Ag 1
5	5·22–5·75	calcareous gyttja. Ld^{2}2, Lc 2
4	5·75–5·80	ferruginous gyttja. Ld^{2}3, Ag 1, Lf +++
3	5·80–5·90	silty laminated gyttja. Ld^{2}2, Ag 2, Lc ++, Lf +
2	5·90–5·95	sandy humified peat. Th^{3}3, Ga 1
1	5·95–6·00	sand. Ga 4

Radiocarbon datings

Three series of samples from the Woryty cores have been radiocarbon dated. Datings from the Woryty core 80 made by Dr. V. R. Switsur, Cambridge, will be discussed in the next, full-data paper.

Five samples from the Woryty core 82 were dated by Dr. S. Håkansson, Lund. The results are as follows:
(*all dates based on ^{14}C half-life 5568 years)

Lab. No.	Depth in m	Type of sample	Radiocarbon age BP *
Lu-1791	9·42–9·50	wood	10 770±100
Lu-1792	9·60–9·64	wood	11 020±110
Lu-1790	9·71–9·76	peat	11 290±105
Lu-1789	9·82–9·86	wood	10 850±100
Lu-1793	9·94–10·00	sandy peat with gyttja	10 900±120

All samples were pretreated with HCl only, except for Lu-1789 which was pretreated with NaOH and HCl. The age of Lu-1789 and Lu-1793 appeared too young.

Twelve samples from the same profile 82 were dated by Dr. M. Pazdur, Gliwice. Three samples from the core section 6·65–8·86 m contained too little carbon to give reliable results. They will not be quoted here. The other nine samples have the following age:

Lab. No.	Depth in m	Type of sample	Radiocarbon age BP *
Gd-1190	1·36–1·39	swamp peat with gyttja	2080±80
Gd-1192	1·76–1·79	swamp peat with gyttja	2320±60
Gd-1191	3·16–3·19	peaty gyttja	3960±75
Gd-1193	4·06–4·09	sapropel-like sediment	5115±75
Gd-727	4·26–4·29	sapropel-like sediment	5890±90
Gd-1194	4·76–4·79	sapropel-like sediment	6465±65
Gd-731	5·86–5·89	detritus gyttja with $CaCO_3$	8045±175
Gd-1198	6·16–6·19	dy-like sediment	8440±110
Gd-802	9·20–9·30	ferruginous silty gyttja	10430±300

All samples were pretreated with HCl, the NaOH soluble fraction was not removed. The age of the lowest samples, containing little carbon, should be considered as very approximate.

Chemical and mineralogical analysis

The results of chemical, mineralogical and the most important physical analyses of sediment are plotted in Fig. 5. The diagrams are divided into stratigraphic units based on changes in the sediment composition. In order to obtain the most objective sequence of changes, the chemical and mineralogical parts of the diagram are both divided independently into 13 zones that are plotted next to each other in the middle of the diagram. However, both systems of zones appeared sufficiently similar to be described jointly.

The most important characteristics of zones are as follows:

Wch-1 (9·85–9·95 m — basal sediment not analyzed); Wm-0–1 (9·85–10·12 m) sand, sandy humified peat with gyttja: low loss on ignition, high proportion of quartz, followed by a temporary appearance of carbonates, along with a high content of Mg and an increasing proportion of organic matter.

Wch-2 (9·65–9·86 m); Wm-2 (9·70–9·80 m) humified peat: high content of organic matter and of ferrous sulphide hydrate, precipitated as hydrotroilite, no carbonates.

Wch-3 (9·40–9·65 m); Wm-3 (9·30–9·80 m) ferruginous silty gyttja: very low loss on ignition, high proportion of carbonates (mostly calcite), high content of Fe, Mn, Mg and P.

Wch-4 (8·50–9·40 m); Wm-4a, b, c (8·50–9·30 m) ferruginous silty gyttja, laminated in the lower part: low content of organic matter, temporarily increasing in the middle of zone, rather low but variable content of carbonates, not only of calcite, but also of rhodochrosite ($MnCO_3$). Very high content of Fe; in the middle part of the zone (Wm-4b) high proportion of quartz. Maximum of Mg, showing distinct negative correlation with Mn content, and less distinct one with Fe content. In the upper part (Wm-4c) maximum of rhodochrosite and the only appearance of gypsum (as secondary precipitation).

Wch-5a (7·90–8·50 m); Wm-5 (7·85–8·50 m) calcareous gyttja: very low content of organic matter and maximum of carbonates (calcite), decreasing proportion of Fe, and rising Mg, low content of Mn.

Wch-5b (7·00–7·90 m); Wm-6 (6·80–7·85 m) fine detritus gyttja with calcium carbonate: slightly higher proportion of organic matter than in Wch-5a and lower content of carbonates, but not proved by any change in the calcite pattern. The rise in mineral matter proportion shown by appearance of quartz and of clay minerals; sporadic evidence for iron minerals — gethite and hamaetite.

Wch-6,7 (6·00–7·00 m); Wm-7 (6·10–6·80 m) silty gyttja, silt with sand and gravel, silty gyttja, dy, silty gyttja: high, variable proportion of mineral matter with a maximum between 6·40–6·60 m (quartz, feldspars), reduced content of carbonates with a minimum at 6·10–6·20 m, combined with a rise in organic matter and temporary acidification of sediment (pH 6·6).

Wch-8 (4·80–6·00 m); Wm-8 (4·95–6·10 m) fine detritus gyttja with calcium carbonate: new rise in carbonate content (calcite), organic matter proportion slightly reduced, but higher than in Wch-5, 6; quartz present.

Wch-9 (4·00–4·80 m); Wm-9 (4·10–4·95 m) sapropel-like sediment (?): very high proportion of organic matter and strong acidification (lowest pH 5·09), slight rise in Fe and minimum of Mn; rise in quartz content.

Wch-10 (2·95–4·00 m); Wm-10 (3·25–4·10 m) fine detritus gyttja, peaty gyttja: rise in mineral matter, new appearance of carbonates (calcite), but in moderate amounts, and declining towards the end of Wch-10, here a maximum of Mg, organic matter content slightly reduced, more distinct decrease in Kjeldahl-N.

Wch-11 a, b (1·93–2·95 m); Wm-11 (1·95–3·25 m) peaty gyttja, fine detritus gyttja: changes in mineral content recorded earlier than changes in chemical composition, in samples corresponding to the end of Wch-10 (rise in quartz content). Generally a rise in carbonates (calcite) and higher proportion of quartz, maximum of P in Wch-11a, decreasing values of Mg, with a minimum in Wch-11b, combined with the minimum of Mn. Organic matter content and organic C — reduced.

Wch-12 (...—1·95 m); Wm-12 (...—1·95 m) silty swamp peat with gyttja: high content of organic matter, but with slightly alkaline reaction (pH > 7), low proportion of carbonates (calcite), rise in quartz content, feldspars and clay minerals present.

Wch-13a, b, c (...(1·00)—0·00 m); Wm-13a, b, c (...(1·00)—0·00 m) swamp peat, sand, soil: high content of organic matter decreasing and that of mineral matter (quartz, feldspars, clay minerals) increasing upwards, sediment very acidic (pH mostly < 5) with a temporary oscillation between 0·47 and 0·65 m towards neutral reaction (pH 7·12), connected with the appearance of carbonates (calcite) in the sediment.

Pollen analysis

Percentage pollen diagrams from the cores Woryty 80 and 82 have been divided into local pollen assemblage zones. 13 pollen assemblages zones have been distinguished, some of them with subzones. The main division into zones W-4 to W-13 suggested for the Woryty 80 pollen diagram by three numerical methods (CONSLINK, SPLITINF and SPLITLSQ) of the computer program "ZONATION" written in FORTRAN IV, developed by Gordon and Birks (1972) in the University of Cambridge, has been accepted, the only exception being the zone boundary W-12/W-13 (Fig. 6).

The pollen zones recognized here, or at least a part of them, will probably be of regional use (Figs. 6, 7) [1].

Zone W-1 (W.82, 10·12 m)

This zone contains only one pollen sample. The pollen concentration is very low. *Betula* undiff. pollen predominates (75%), *Pinus sylvestris* pollen values are 17%, and no other tree or shrub pollen types occur. The variety of herb types is small, the most important are *Gramineae*, *Cyperaceae*, and *Epilobium*, in addition *Botrychium* and *Sphagnum* spores are present.

Zone W-2 (W.82, 9·93–10·11 m)

The pollen concentration is much higher. The pollen values of *Pinus sylvestris* rise to 80% and those of *Betula* undiff. decline to 10–15%. At the base of zone there are small peaks of *Epilobium* and *Gypsophila fastigiata* type pollen and of *Botrychium* and *Selaginella selaginoides* spores. At the top of zone percentages of *Juniperus*, *Betula* cf. *nana*, *Gramineae*, *Cyperaceae*, *Artemisia*, and *Chenopodiaceae* increase, and *Phragmites* type, *Schoenoplectus* type pollen, and *Equisetum* spores appear for the first time.

Zone W-3 (W.82, 9·58–9·93 m)

The radiocarbon age of the upper boundary of zone is 11 020±110 BP. Pollen concentration is slightly higher than in W-2. Percentages of *Pinus sylvestris* are reduced to 30–40%, and *Juniperus* values rise to 28%. Within the

NAP, *Gramineae*, *Cyperaceae* incl. *Carex* type, *Artemisia* and *Chenopodiaceae* are dominant pollen types. New herb pollen taxa appear including ***Saussurea***, *Helianthemum nummularium* type, ***Rumex acetosella***, *Arctostaphylos uva-ursi* and ***Filipendula***, as well as aquatic plants such as ***Myriophyllum spicatum***, *Potamogeton* sect. ***Eupotamogeton*** and ***Hippuris vulgaris***.

Zone W-4 (W.82, 8·85–9·58 m; W.80, 5·80–6·00 m)

The pollen concentration is the lowest of all pollen zones (excl. W-1), with a minimum about the middle of zone and a slow rise in its upper part. Tree pollen values are low (***Betula*** undiff. 15–20%, ***Pinus sylvestris*** 10–15%), whereas shrub percentages are relatively high, with dominant *Juniperus* pollen (> 30%); ***Betula*** cf. *nana* reaches up to ca. 3%, and *Salix* 4%. NAP values are 30–50%. Dominant herbaceous types are the same as in W-3, but their percentages are higher. Some types are restricted to this zone (***Saxifraga oppositifolia*** type, ***Scleranthus annuus***, ***Pleurospermum***), others show their major occurrence here (***Potentilla*** type, ***Geum*** type, ***Gypsophila fastigiata*** type, ***Rumex acetosella***). In the upper part of zone ***Ranunculus trichophyllus*** type and ***Myriophyllum spicatum*** pollen have small maxima.

Zone W-5 (W.82, 8·55–8·85 m; W.80, 5·70–5·80 m)

The pollen concentration slightly rises in the upper part of zone. ***Betula*** undiff. pollen values increase to about 70%, and the *Juniperus* pollen curve gradually declines from over 20% at the base to ca. 3% at the top of zone. ***Pinus sylvestris*** percentages remain at ca. 10% or less. ***Betula*** cf. ***nana*** pollen is replaced by ***Populus*** (***P. tremula*** type) at the top of zone. A decline in NAP values is mostly caused by a reduction in *Cyperaceae* (incl. *Carex* type), ***Artemisia*** and *Chenopodiaceae* percentages. ***Helianthemum nummularium*** type pollen appears for the last time and the continuous curves of ***Filipendula*** and ***Urtica*** cf. ***dioica*** pollen begin. There are small maxima of ***Potamogeton*** sect. ***Eupotamogeton*** and ***Schoenoplectus*** type pollen, a rise in ***Phragmites*** percentages, and at the top of zone ***Typha latifolia*** pollen appears.

Zone W-6 (W.82, 6·90–8·55 m; W. 80, 5·17–5·70 m)

The zone is generally characterized by the dominance of ***Betula*** undiff. (40—55%) and ***Pinus sylvestris*** pollen (30—45%) and the consistent curve of ***Populus*** (***P. tremula*** type 2—7%). In W.82 it is divided into two subzones. with subzone boundary at 7·90 m.

Subzone *a*: Pollen concentration remains at similar values as in W-5. ***Populus*** percentages are higher than 5%, those of ***Juniperus*** ca. 4% and ***Salix*** ca. 3%. NAP values are higher than 10%, with predominant ***Gramineae***. ***Typha latifolia***, ***Phragmites*** type pollen, and ***Equisetum*** spores have small maxima, ***Nymphaea alba*** pollen appears and ***Polypodiaceae*** spores are continuously present. In the upper part of subzone (7·90–8·25 m) there are small succeeding peaks of NAP (mostly *Gramineae*, *Artemisia* and *Chenopodiaceae*), and of *Populus* and *Betula* undiff.

Subzone *b* is distinguished from the subzone *a* by a much higher pollen concentration, the declining *Betula* undiff. pollen curve, reduced pollen values of *Salix* (1%), *Populus* (2–3%), *Juniperus* (sporadic pollen), NAP (< 10%), mostly of *Gramineae* and *Cyperaceae*. The continuous curves of *Ulmus* and *Corylus* pollen begin, rising slowly near top of subzone. *Humulus* pollen appear, and the curve of *Polypodiaceae* spores is higher than in subzone *a* and includes *Dryopteris thelypteris* and *D. filix-mas* types.

Zone W-7 (W.82, 6·25–6·90 m; W.80, 4·62–5·17 m)

Pollen concentration is variable, with a minimum in the middle part of zone. The main tree pollen types are *Pinus sylvestris* and *Betula* undiff. (both > 30%). *Corylus* has pollen values rising from 7% to more than 20%. *Ulmus* pollen curve is low (< 5%), *Quercus* pollen is continuously present from the base of zone, and *Fraxinus*, *Tilia cordata,* and *Alnus* pollen from its upper part. *Salix* pollen values are ca. 1%, and those of *Populus* decline slowly to less than 0·5%. NAP are low (< 10%), with dominant *Gramineae.*

Zone W-8 (W.82, 5·30–6·25 m; W.80, 3·90–4·62 m)

The radiocarbon age of the lower boundary of zone is about 8500 BP and that of the upper boundary about 7200 BP (interpolated date). The pollen concentration is rather constant. The dominant pollen types are *Pinus* (30—40%) and *Alnus* (ca. 20%). *Betula* undiff. pollen values are lower than in W-7 (20—25%). *Corylus* pollen curve declines from about 20% at the base of zone and is consistent at ca. 10%. Percentages of *Ulmus, Tilia cordata,* and *Fraxinus* pollen rise very slowly throughout, *Viscum* and *Hedera* pollen appear for the first time. NAP values are very low (2–5%); in the upper part a small peak of *Pteridium* spores occurs.

Zone W-9 (W.82, 4·07–5·30 m; W.80, 2·90–3·90 m)

The radiocarbon age of the lower boundary of the zone is around 7200 BP, the upper boundary being dated at 5115 BP. The pollen concentration shows a depression in the middle part and a rise in the upper part of zone. The pollen values of *Pinus sylvestris* (ca. 20%) and of *Betula* undiff. (10—15%) are lower than in W-8; those of *Ulmus* and *Tilia cordata* are higher (up to ca. 10%), and the percentages of *Fraxinus* are about 5%. The values of *Corylus* pollen oscillate between 10 and 20%. *Quercus* pollen rises slowly throughout, to about 15% at the top of zone. NAP values are the lowest of all zones (< 4%), whereas *Pteridium aquilinum* and other *Polypodiaceae* spores are continuously present.

Zone W-10 (W.82, 2·72–4·07 m; W.80, 2·00–2·95 m)

The lower boundary is radiocarbon dated at 5115±75 BP, the upper boundary is around 3500 BP. Pollen concentration is very consistent, excluding a small minimum near the base of zone. Pollen values of *Pinus sylvestris* and *Betula* undiff. remain at 10–20% each, and those of *Alnus* at 20–30%, *Ulmus* pollen curve oscillates, falling to 3% near the base of zone and then rising temporarily twice in the middle and upper parts of zone. *Tilia cordata* percentages decline more gradually. There is no distinct change in *Fraxinus* and *Quercus* pollen values. *Corylus* percentages rise at the base to more than 20%, remaining around 17–23% throughout. *Fagus* and *Carpinus* pollen are continuously present, the latter rising slightly in the upper part of zone. NAP values are 30–50%, the sporadic pollen of *Plantago lanceolata*, *P. major*, *Rumex acetosella*, and cereals (*Triticum* type) appear and *Urtica dioica* values show some increase. There is also a rise of *Polypodiaceae* spore percentages in the lower part and of *Phragmites* type and *Sparganium* type pollen near the top of zone.

Zone W-11 (W.82, 1·75–2·75 m; W.80, 1·27–2·00 m)

The radiocarbon age of the lower boundary approximates 3500 BP, the upper boundary is dated at 2320±60 BP. The pollen concentration decreases throughout. *Pinus sylvestris* percentages rise to ca. 30% and those of *Betula* oscillate up to 30–35%. *Corylus* pollen values fall steeply at the base of zone to ca. 10% and later decline gradually to ca. 5%. In addition the percentages of *Ulmus*, *Tilia cordata* and *Fraxinus* decline to less than 1%, and of *Quercus* to ca. 6%. NAP values rise to 18%, with *Gramineae*, *Artemisia*, *Urtica* cf. *dioica*, *Plantago lanceolata* and *Rumex acetosella* as prominent pollen types. Cerealia pollen is sporadic and the percentages of telmatophytes increase. There is a small maximum of *Nymphaea alba* pollen.

Zone W-12 (W.82, 0·65–1·75 m; W.80, 0·52–1·27 m)

Pollen concentration is variable. The zone is generally distinguished by the *Carpinus* pollen percentages being much higher than in W-11 but variable, and the *Fagus* pollen curve being low but rising slowly throughout. The zone is divided into 3 subzones:

subzone *a* (W.82, 1·45–1·75 m; W.80, 1·07–1·27 m) is characterized by a rise in pollen concentration, the maximum of *Carpinus* pollen up to 20%, the small peaks of *Ulmus* and *Tilia cordata* pollen and a rise in the *Quercus* curve. The NAP values are very low (< 5%).

subzone *b* (W.82, 0·95–1·45 m; W.80, 0·85–1·07 m) is distinguished by a fall in pollen concentration, the minimum of all tree pollen curves mentioned in subzone *a* except for *Quercus*, and a rise in NAP pollen values with predominant *Gramineae*, *Artemisia*, *Plantago lanceolata* and *Rumex acetosella*. Within the cereals *Triticum* and *Hordeum* pollen types reappear in small amounts and *Secale cereale* has its first small peak. Cf. *Cannabis* pollen appears for the first time, and in W-80 profile a single grain of *Vitis* occurs.

subzone *c* (W.82, 0·65–0·95 m; W.80, 0·52–0·85 m) is very similar to subzone *a* in its pollen concentration and composition, with the higher *Fagus* pollen values (up to 3%) as only essential difference.

Zone W-13 (W.80, 0·00–0·65 m; W. 80, 0·00–0·52 m)

The pollen concentration declines. The pollen curves of all trees, except for *Pinus sylvestris* are very low; *Betula* pollen values also fall throughout. *Pinus* pollen values rise to 30% or more, and those of *Juniperus* to ca. 3%. NAP values are high, rising throughout to ca. 50%, and contain a wide variety of pollen types, including all the important indicators of human influence.

Cladocera analysis — Woryty, core 82

(K. Szeroczyńska)

The analysis of *Cladocera* remains from the Woryty core 82 has not been completed as yet. In the lower 5 m part of the core the interval of samples examined is 5–10 cm, but in the upper part it has been only 20–50 cm up till now.

In the analysed samples 36 species of *Cladocera,* beside the remnants of *Chironomidae*, *Megaloptera* and *Turbellaria* have been found.

The most common cladoceran taxa were *Chydoridae* (26 species) a very useful group for the interpretation of climatic changes, and *Bosminidae,* that can characterize the paleolimnological status of the lake (Goulden 1964). The species composition is typical for a rather shallow, fresh-water lake with an autochtonous *Cladocera* plankton. On the basis of species frequencies several stages of lake development have been defined, beginning with an oligotrophic lake and ending with the stage of swamp.

The variable occurrence of the deep-water species *Bosmina coregoni* and the eutrophic species *Bosmina longirostris* is interpreted in terms of changing trophic conditions; 5 periods of increased eutrophication have been found, connected either with climatic changes or with interference of man. The diagram of *Cladocera* remains has been divided into 9 zones (Fig. 8) defined as follows:

Zone 1 (ca. 10·00–9·60 m) is characterized by the maximal development of *Peracantha truncata* and *Pleuroxus trigonellus* (both stenothermic, littoral species — Frey 1958), and of littoral *Chydorus* species. The lake was shallow and the diversity of *Cladocera* low (8 species).

Zone 2 (9·60–8·90 m) is divided into two subzones, based on the appearance of a pelagic species *Bosmina coregoni.*

2a. (9·60–9·30 m): the development of “arctic” species — *Chydorus sphaericus* and *Acroperus harpae* (Pennington 1975).

2b. (9·30–8·90 m): besides the littoral “arctic” species, *Bosmina coregoni* is present that may indicate the deepening of the lake. The habitat was rather oligotrophic (Bilska & Mikulski 1979).

Zone 3 (8·90–8·00 m). This was the time of the rapid development of plankton. Several *Alona* and *Alonella* species appear in the sediment for the first time (*A. affinis, A. quadrangularis, A. rectangula, A. guttata, A. rustica*; *Alonella nana, A. rostrata, A. exigua*). The deep-water species ***Bosmina coregoni*** is replaced by the eutrophic species ***B. longirostris***, the latter showing its maximum development (29 000 individual remains/cm^3 sediment) in this zone, which may be the result of increased eutrophication. By the end of the phase the frequencies of *Bosmina longirostris* decrease.

Zone 4 (8·00–7·00 m) is characterized by the maximum of ***Bosmina coregoni***. ***B. longirostris*** is also present but in low frequencies. Between 7·80 and 7·60 m the maximum development of stenothermic species ***Alona rectangula*** and ***Alonella nana*** is recorded. These are littoral species but also occur in the pelagic zone, especially the latter (Czeczuga & Kossacka 1977). *Camptocercus rectirostris* is present in this zone and is considered to be indicative of a warm climate (Pennington 1975).

Zone 5 (7·00–6·20 m). Rather thermophilous species are dominant in the plankton. About 6·40 m there is a maximum of the stenothermic species ***Pleuroxus trigonellus***. Frequencies of ***Bosmina longirostris*** increase and those of ***Bosmina coregoni*** fall. Frequencies of littoral species ***Alona rectangula*** and ***Alonella nana*** also decrease.

Zone 6 (6·20–5·10 m) is distinguished by the development of littoral species, indicating the lowering of water level. ***Bosmina longirostris*** is increasingly dominant resulting from the eutrophication processes progressing slowly again.

(The delimination of zones from 5·00 m upwards is approximate because the intervals between the samples analysed are too wide).

Zone 7 (5·10–4·10 m)? — During this zone the conditions in the lake were rather stable, as no distinct changes among the planktonic species are observed. The number of ***Bosmina longirostris*** remains consistently rises, and littoral species ***Alona guttata*** and ***A. quadrangularia*** occur frequently.

Zone 8 (4·10–2·10 m)? — Planktonic species are abundant. Deep water species are lacking and littoral species dominate ***(Alona rectangula, A. guttata, A. quadrangularis*** and ***Chydorus globosus)***, possibly indicating a lowering of water level. Between 3·80 and 3·50 m and about 2·55 m there are rises in frequencies of ***Bosmina longirostris*** resulting possibly from increased eutrophication in response to the activities of man settled around the lake. At the depth of about 2 m the frequencies of all *Cladocera* species decline rapidly.

Zone 9 (2·10–0·00 m)? — The last maximum of ***Bosmina longirostris*** at 1·20–0·80 m indicates intensified eutrophication. The littoral species that are the only *Cladocera* species present in this zone are mostly associated with macrophytes ***(Chydorus globosus, Ch. gibbus, Alona rectangula, A. quadrangularis, A. guttata*** and ***Pleuroxus trigonellus)***. The fall in frequencies of the all planktonic fauna remains is connected with the final overgrowing of the open lake.

The investigations of *Cladocera* remains from the Woryty core 82 will be continued, especially in the upper 5 m part of the core, where the number of samples examined is not yet sufficient to give a clear picture of palaeoecological changes, of the eutrophication processes, and of the significance of human impact on the lake.

Rhizopoda analysis — Woryty, core 80

(W. Schönborn)

This preliminary comment on *Rhizopoda* remains in the sediments of Woryty ancient lake is based on results obtained from the 6 m long core 80. 40 species and two varieties of testaceous *Rhizopoda* have been recorded from this core. The most common species are shown on Fig. 9. Their constance and dominance values are generally parallel; species recorded most often usually have the highest frequencies.

The tests of genera *Arcella, Centropyxis, Paraquadrula* and *Hyalosphenia* are well preserved; the tests of *Difflugia* are much destroyed; in 13·8% of samples there occurred only indeterminable fragments of *Difflugia* tests. *Euglyphidae* were scarcely represented, though this family of *Testacea* is normally abundant in aquatic habitats. Within the genus *Centropyxis* the plant-associated species were dominant and those inhabiting the sediment were rare. The same phenomenon may be observed in recent lakes too. More than half of the recorded species had a constancy and dominance $< 3\%$. *Pontigulasia, Lesquereusia* and *Cyphoderia* were not recorded, though their presence might have been expected.

Centropyxis aerophila is usually the most abundant species in oligotrophic lakes. This is a characteristic species for this type of lakes. In the Woryty lake this taxon was found only at the depths of 4·50–4·55 m and 4·75–4·80 m. It may be supposed that the lake was oligotrophic at that time.

Paraquadrula discoides occurs to the depth of 3·90 m and again between 3·15 and 2·70 m. This is an indicator of calcareous habitat (lime-content $> 10\%$; never less than 7%).

In several samples some indicator species of dystrophic conditions appear too (*Arcella gibbosa, Trigonopyxis arcula*).

The C/N ratio > 10 is assumed to be indicative for a dy-sediment. Such a ratio occurred in many samples examined, especially in the lower part of profile, but combined with the presence of lime. The ratio may be interpreted as the result of eutrophic, or occasionally mixotrophic conditions in the lake.

Difflugia urceolata, an indicator-species of eutrophication, occurs in the upper 2 m of the profile. It appears for the first time at the onset of pollen zone W-11, along with the pollen indicators of intensive human settlement that suggest the importance of pastoral husbandry that undoubtedly influenced the lake itself.

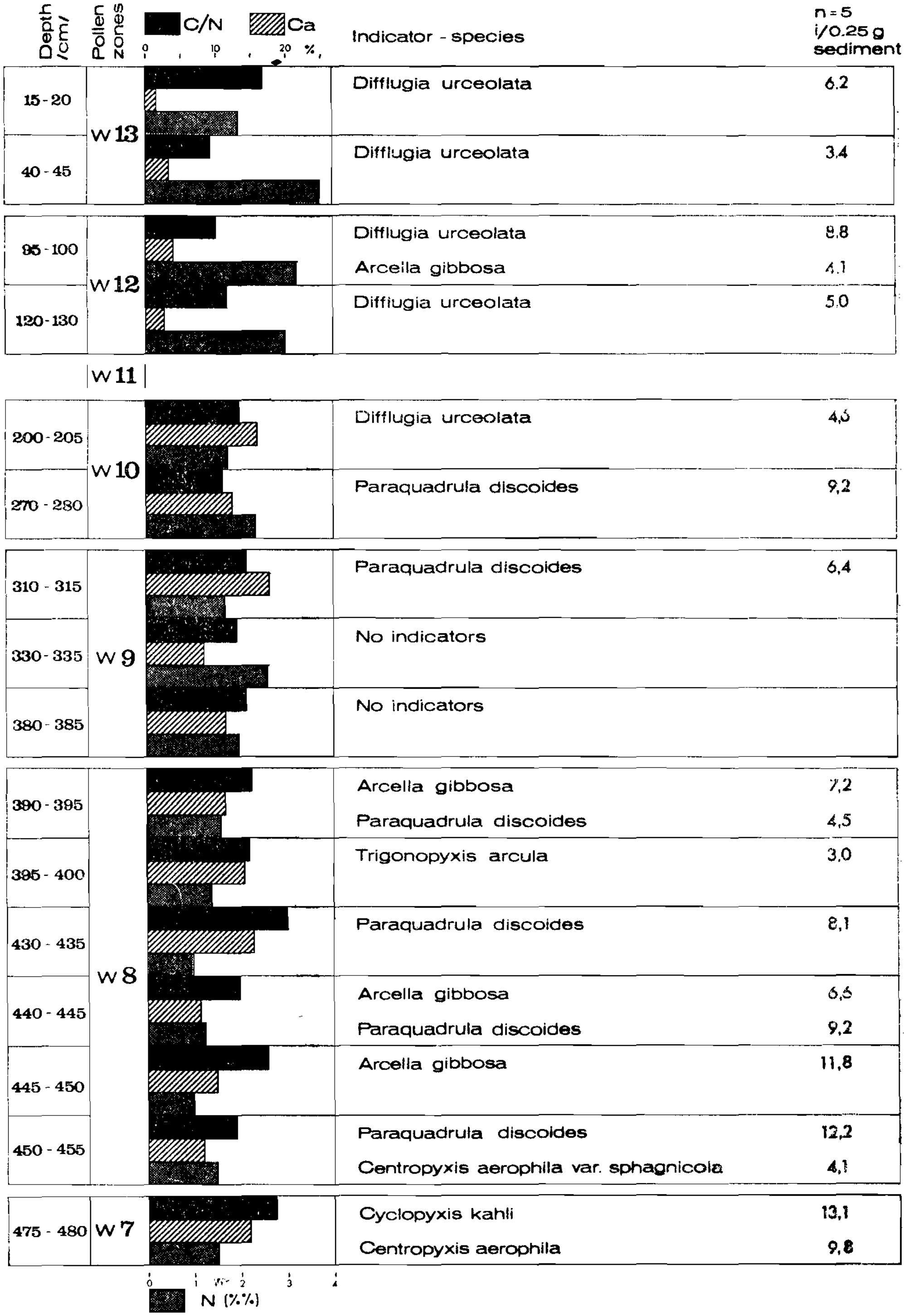

Fig. 9. Occurrence and abundance of some *Rhizopoda* indicator species, compared with the Ca and N content and C/N ratio in the Woryty profile 80

The C/N ratio and the lime content in the sediment decrease and the nitrogen content increases upwards in the profile (Fig. 9).

The topmost 20 cm section of the core shows the rapidly advancing incursion of swamp into the lake. In the peat layer accumulated at that time the moss-inhabiting species dominate among *Testacea* (*Arcella catinus, Centropyxis orbicularis, Heleoptera petricola, Assulina muscorum*, and *Corythion dubium*).

Through the whole time of accumulation of sediments examined the lake appears to have been mostly eutrophic with temporary phases of dystrophic conditions, except for an oligotrophic phase recorded below 4·75 m. The combination of a high C/N ratio with a high lime content is an interesting phenomenon, that is rather rarely recorded. Such a type of sediment has been recently found in the lakes situated within the forests in the East Europe.

VEGETATIONAL HISTORY OF THE WORYTY AREA

The development of vegetation in the area surrounding the Woryty site will briefly be discussed on the basis of the local pollen assemblage zones described, with reference to the chronostratigraphic division system of the Late Vistulian Substage and Holocene series proposed by Mangerud et al. (1974).

Zone W-1

The low pollen concentration may result from sedimentation processes rather than from a poor pollen production. The only pollen spectrum reflects an advanced stage of vegetational succession — the development of birch woodland, that was typical — as reported from the neighbouring areas (Ralska--Jasiewiczowa 1966) for the initial phase of the Allerød chronozone. The pollen values of *Pinus sylvestris* are too low to prove unquestionably its presence in situ. Herb vegetation is poorly represented. High frequencies of *Epilobium* pollen and *Botrychium* and *Sphagnum* spores reflect local phenomena, for example the colonization of fresh soil covering the buried ice block by the pioneer mire plants.

Zone W-2

Zone W-2 corresponds probably with the older part of Allerød chronozone, prior to 11 290 BP. It records the development of *Pinus sylvestris* forest in the area. The rise in pollen concentration is caused by *Pinus* pollen mainly. At the base of the zone the presence of base-rich pioneer mire vegetation near the site is still recorded. By its end the spread of open herb grassland with *Artemisia, Chenopodiaceae, Anthemis* type and with shrubs of *Juniperus* and *Ephedra* begun.

Zone W-3

The middle part of zone W-3 is dated to 11 290 BP and its end to 11 020 BP both dates corresponding to the younger part of the Allerød chronozone. It was the time of dominant open pine-birch forest with *Populus tremula* and *Larix* appearing sporadically, and with a well-developed understorey of *Juni-*

perus and *Betula nana*. The abundance of *Juniperus* pollen suggests the existence of abundant juniper shrubs within the open grassland. Damper places were occupied by tall herbs such as *Urtica dioica*, *Filipendula*, *Saussurea* and *Thalictrum*, and *Salix* shrubs.

The trend of vegetational changes towards more open communities is suggestive of a climate colder and more continental than in W-2, which conflicts with the earlier opinions about the climatic conditions in the younger part of Allerød in the lowland of Poland (Wasylikowa 1964; Ralska-Jasiewiczowa 1966).

Zone W-4

According to the radiocarbon date of 11 020 BP for its lower boundary, zone W-4 corresponds with the Younger Dryas chronozone. The very low pollen concentration is a combined result of the high sedimentation rate ranging between 2 and 5 mm per year during the middle part of zone, with laminated sediment, resulting from the intensive inwashing from the unstable shores, and the scarcity of trees in the landscape. During of the zone tree-pollen is not more than 25–30% of the total. The vegetation of that time was probably of parkland type, with well developed shrub communities of *Juniperus*, *Ephedra* on drier places and *Betula nana* and *Salix* on moister soils, and scattered groups of trees — mainly of birch and also rare pine. The well drained, rather dry habitats supported xeric grassland with abundant *Artemisia*, *Chenopodiaceae* and a variety of other plant taxa (*Gypsophila fastigiata* type, *Helianthemum nummularium* type, *Anthemis* type and others). The sandy acidic soils were occupied by poor sedge- and grass communities with *Rumex acetosella*, *Scleranthus annuus*, and dwarf shrubs such as *Empetrum nigrum* and *Arctostaphylos uva-ursi*.

Zone W-5

This zone has not been radiocarbon dated. It presumably corresponds with the initial phase of Holocene — the Early Preboreal subchronozone, — most probably with its older part. It reflects the rapid spread of birch woodland replacing the *Juniperus* and *Betula nana* shrub-communities. Grasslands with abundant *Artemisia* were still common at the beginning of zone but the variety of herbs contributing to this community is reduced. Toward the end of zone this type of vegetation was also limited in area by the developing tall herbs (*Urtica dioica, Filipendula, Thalictrum*). This may have been connected with an increasing climate humidity.

Zone W-6

The radiocarbon dates for this zone are not reliable. It presumably corresponds with the end of the Early Preboreal and the Late Preboreal subchronozones. At the beginning of zone *Pinus sylvestris* and *Populus tremula* expanded within the area of birch woodland. During the subzone W-6*a* the forests were still rather open, with *Polypodiaceae* in their understory. The shrub vegetation of *Juniperus* and *Ephedra* on drier places and of willows and tall herbs on damper soils was still common, and grasslands were widespread but with reduced species number. The small succeeding pollen maxima of herbs, mainly *Gramineae, Artemisia,* and *Chenopodiaceae*, and then of *Populus tremula* type and *Betula* recorded in the upper part of the subzone W-6*a* (7·90–8·25 m) may indicate a temporary cooling of climate, resulting in some recession in forest development. If so, this could be equivalent to the climatic oscillation recognized from different parts of Europe between ca. 10 000 and 9600 BP, and described by Behre (1967, 1978) as the Youngest Dryas phase. However, the range of changes in vegetational succession reflected here is small, so this section of zone W-6 has not been described as an individual subzone. The rise in pollen concentration in the subzone W-6*b*, combined with the rather high sedimentation rate, which, in the absence of ^{14}C dates, can only be roughly estimated at not less than 2 mm per year, may have resulted mainly from the higher pollen production, first of birch, than of pine and aspen. The forests became denser, and expanded on most of the open places, thereby reducing the juniper shrub. In the understory of willow communities on the damp lake shores, plants typical of alderwoods and riverside forests appeared, such as *Humulus lupulus, Dryopteris thelypteris*, and on drier places other ferns (*Dryopteris filix-mas* type). Towards the end of zone *Corylus* and *Ulmus* immigrated into the Woryty area.

Zone W-7

Zone W-7 with its upper boundary slightly below the radiocarbon date 8440±110 BP corresponds roughly with the Early Boreal subchronozone (9000–8500 BP). The variations in pollen concentration are due to disturbances in sedimentation processes (see p. 112). The dominant forest communities were still pine and birch forests, initially rather open, but with hazel expanding rather quickly in their understory, and forming individual shrubs in open places. The role of *Populus tremula* was gradually reduced. On more fertile, humid soils *Ulmus* expanded slowly. By the end of zone other deciduous trees — *Tilia cordata, Quercus* and perhaps also sporadically *Fraxinus*, arrived in the area, and *Alnus glutinosa* began its rapid colonization of damp lake-shores. The earlier appearance of *Quercus* pollen may have resulted from its high production due to its good dispersal.

Zone W-8

Zone W-8 (8500 — ca. 7200 BP) corresponds approximately with the Late Boreal and the lower part of the Early Atlantic subchronozones. It was the time of dominant pine forests with deciduous trees slowly expanding on more fertile soils. For the first time *Viscum* appeared in these forests. The area of birch woodlands diminished, the forests became denser and this caused the reduction in hazel flowering and in the development of herb layer. The understory of the pine forests was dominated by *Pteridium aquilinum*. The willow shrubs at the lake shores were replaced by alderwoods.

Zone W-9

This zone (ca. 7200–5000 BP) corresponds with the Middle and Late Atlantic subchronozones, including perhaps also the end of the Early Atlantic subchronozone (7200–7000 BP). At that time the mixed deciduous forests reached their maximum Holocene development in the investigated area, connected with the climatic optimum as indicated by the appearance of *Hedera* pollen. The pine forests were restricted to the poorest sandy soils and they migh thave been encroached by oak. The slow decrease in *Ulmus* and increase in *Quercus* pollen values in the upper part of zone, between 6465 and 5115 BP, along with the change in sediment suggesting a lowered water level in the lake (see p. 113), may indicate a phase of warm but drier climate. The rise in pollen concentration recorded between 5890 and 5115 BP probably results from a decreased sedimentation rate.

Zone W-10

Zone W-10 (5000 — ca. 3500 BP) corresponds with the Early and the lower part of the Middle Subboreal subchronozones. At its beginning *Ulmus* and *Tilia cordata* pollen decline, along with a temporary decrease in pollen concentration, and *Corylus* percentages rise. If we accept these changes to be the effect of Neolithic man activities, the increase in *Corylus* pollen production may be explained by the opening of the previously densely shaded deciduous forest by the cutting of elm and lime branches for cattle fodder, though there is no evidence of such activities from Poland either in the past or at present Pollen of meadow plants (*Plantago lanceolata*, *Potentilla* type, *Anthemis* type). as well as of acidophilous heliophytes (*Rumex acetosella, Melampyrum*) and nitrophilous weeds (*Chenopodiaceae*, *Plantago major*) appearing sporadically above the beginning of zone, the distinct rise in *Urtica dioica* pollen values, and finally the first pollen grains of cereals are clear evidence of man's presence near the lake. However, there is no distinct increase of either *Gramineae* or *Betula* pollen values that might have suggested more extensive forest clearances. The subsequent series of human activities is expressed by fluctuating, but in general declining, *Ulmus* and *Tilia cordata* pollen curves, and reciprocal maxima of *Corylus* pollen recording short human interference forest regeneration phases, with no clear response from other herb taxa except *Urtica* and *Artemisia*. Generally, the deciduous forest became more open, dominated by oak and with abundant hazel understory. The disturbance of the ecological equilibrium enabled *Carpinus* and *Fagus* to invade into the area.

Zone W-11

Zone W-11 (ca. 3500—2300 BP) corresponds with the upper part of the Middle and Late Subboreal chronozone. The decrease in both hazel and deciduouan tree pollen concentration and percentages related to rises in herbs iny birch pollen indicate the first extensive clearance in the forests surrounding the lake. The problems of human impact on the natural vegetation of Woryty area have already been discussed in earlier publications (Cieśla et al. 1978; Ralska-Jasiewiczowa in Dąbrowski 1981) and only the basic conclusions will be summarized here. As archaeological data show, the area was settled by people of the Late Bronze Lusatian culture. The long-lasting settlement phase reflected in the pollen diagram consisted most probably of several overlapping stages of "land occupation", not resolvable stratigraphically, connected with the continuous population, but shifting its dwelling places around the lake. These activities resulted in a considerable destruction of the forests, especially on fertile soils. The cleared grounds were used as pastures and fields. The pollen record suggests the dominance of pastoral economy.

Zone W-12

Zone W-12 corresponds roughly with the Early and Middle Subatlantic subchronozones. In the whole it may be defined as the period of mixed deciduous forests dominated by hornbeam. It consists of two phases of forest regeneration (subzones W-12*a* and W-12*c*) separated by the phase of extensive deforestation and strong cultural impact (W-12*b*).

Subzone W-12 *a*

The increase in tree pollen concentration indicates the regeneration of deciduous forest replacing fields, pastures, and pioneer *Betula* copses on the ground abandoned by man. The main contributors were *Carpinus, Quercus, Pinus* and *Alnus*; the proportions of *Corylus, Tilia cordata, Ulmus* and *Fraxinus* also rise but only slightly. This suggests that the essential change was in forest composition on fertile soils; hornbeam and oak became its main components. Poor soils were occupied, as previously, by pine and pine-oak forests.

Subzone W-12 *b*

This subzone reflects the entry of a new cultural group into the Woryty area. The series of extensive clearances expressed by the decrease in pollen concentration of all the trees was followed by the introduction, beside the pastoral economy, of a large-scale agriculture with the cultivation of all cereal types including *Secale cereale*. This record along with the pollen evidence of hemp cultivation and single find of *Vitis* pollen in the corresponding subzone of Woryty 80 profile suggest a correlation of this settlement with the time of Roman influences.

Subzone W-12 *c*

Subzone W-12 *c* reflects a new phase of forest regeneration. The composition of the regenerating deciduous forest was similar to that in subzone W-12 *a*, with dominant hornbeam but with an increasing proportion of beech.

Zone W-13

The uppermost zone records the progressive processes of land management started probably during the time of colonization by Teutonic Knights in XIIIth century and going on ever since. It led to the almost complete deforestation and formation of the cultural landscape of the Woryty area.

HISTORY OF THE LAKE

On the basis of chemical and mineralogical changes in the sediment, pollen data and *Cladocera* analysis of Woryty profile 82, complemented with data concerning the *Rhizopoda* occurrence in Woryty profile 80, 9 main stages

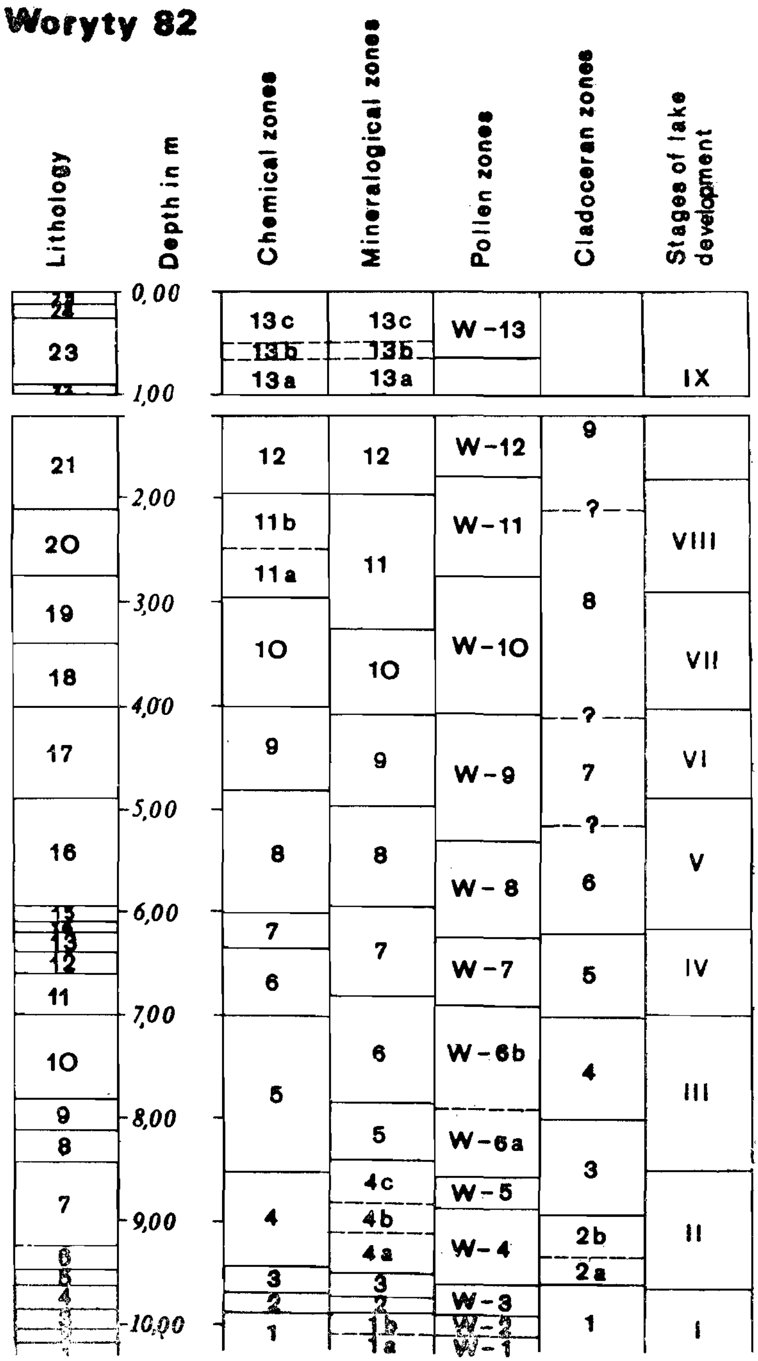

Fig. 10. Correlation of the chemical, mineralogical, pollen and cladoceran zones distinguished in the Woryty profile 82, and the inferred stages of lake development

in the lake development are distinguished (Fig. 10). Because of the limited size of this report, they are described in brief, without discussing the nature of processes that conditioned the trend of changes.

I. Pre-limnic stage (ca.10·12–9·60 m)

At the initial stage of lake formation the glacial channel was filled with an ice-block covered by inwashed sands. As a result of climatic warming the ice-melting started slowly; the sand surface was first colonized by pioneer plants (*Selaginella, Botrychium, Epilobium*) and soil formation was initiated, followed by mire development.

With the progressing ice-melting small shallow pools were formed within the mire surface and pioneer aquatic plants *Myriophyllum spicatum, Potamogeton, Hippuris vulgaris* and reedswamps, as well as littoral *Cladocera* species appeared. The combination of a high production of organic matter, of a rich supply in Fe that probably was eroded by water from the surrounding fresh soils, and of strong reducing conditions, resulted in the precipitation of hydrotroilite in the peat-like sediment formed during that time.

II. Cold-water, silted lake (ca. 9·60–8·50 m)

After a temporary phase of calcite precipitation at the transition from the temperate climatic conditions of W-3 to the colder climate of W-4 about 11 000 BP a cold-water lake was formed, with abundant silt being inwashed from the unstable shores and getting high input of Fe and Mn. The productivity of organic matter decreased and the sediment was accumulated in reducing conditions. The phase of laminated sediment formation (9·20–9·40 m), with laminae varying in minerogenic matter content, may have been the time of climatic (thermic) minimum. It was also a time of the highest rate of sediment accumulation. Then, the lake might have been temporarily stratified (Digerfeldt 1977). In the lake "arctic species" of *Cladocera* developed, *Myriophyllum spicatum* and *Ranunculus* species of subgenus *Batrachium* were common and *Cladium mariscus* appeared in its marginal zone. The phase with laminated sediments was followed by a phase with increased inwash of sand (activation of hydrological processes?) and then by a period of increased rhodochrosite precipitation (its nodules found in the sediment), perhaps with reduced inflow. This corresponds to the rapid climatic change at the onset of the Holocene (W-5) that resulted in a rich development of *Cladocera* and also of mollusca (8·56–9·00 m: *Valvata piscinalis, V. piscinalis* f. *antiqua, V. cristata, Pisidium subtruncatum, P. liliaeborgi, P. casertanum, Sphaerium corneum*) in the lake. *Potamogeton* communities grew in its deeper zone and reedswamps with *Typha latifolia* and *Schoenoplectus* type occurred around its margins.

III. Hardwater lake (ca. 8·50–6·90 m)

Coincident with the warming up of climate, the increased precipitation of calcite started in the lake synchronously with the spread of forests on the surrounding areas (W-6). The inflow ceased, the sediment deposition proceeded little disturbed, and the iron and manganese content in the sediment decreased rapidly, indicating a change from reducing to more oxidizing conditions. The lake deepened. At the beginning of this stage the eutrophic *Bosmina longirostris* attained its absolute Holocene maximum of abundance but was subsequently replaced in dominance by the deepwater *B. coregoni*, and indicators of warm climate appeared in the plankton. Among the macrophytes *Nymphaea alba,* and *Nuphar luteum* appeared. Both indicate rather a eutrophic and warm habitat. The widening of marginal zone is shown by increase of telmatophytes, and by the mollusc assemblage (8·15–8·22 m: *Physa fontinalis, Valvata cristata, V. piscinalis, Gyraulus leavis, Hippeutis complanatus, Armiger crista nautileus, Pisidium nitidum*), typical for shallow water, overgrown by macrophytes. In the younger part of this stage the input of mineral matter increased again (quartz, clay minerals), coincident with some decrease in calcite precipitation and increase in lake productivity.

IV. Disturbances of sedimentation processes and of the trophic regime (ca. 6·90–6·00 m)

The rapid input of silt and sand with gravel into the lake that might have been connected with the periodic river flow, changed the trophic regime of the lake. The production of organic matter and calcite precipitation decreased; in the corresponding section of Woryty profile 80, *Centropyxis aerophila* — an oligotrophic species of *Rhizopod,* — is recorded. This episode was followed, about 8440 BP, by a short phase of dystrophic conditions in the lake. Rather acidic (pH 6·6) sediment with a high humus content accumulated and in the Woryty profile 80 indicators of dystrophy (*Arcella gibbosa, Trigonopyxis arcula*) appeared.

V. Hardwater productive lake (ca. 6·00–4·90 m)

The time between ca. 8200 and 6600 BP was the period of increased calcite precipitation combined with a higher lake productivity than in stage III. This phenomenon might have resulted from the warm climate causing rather strong evaporation. This in turn led to the gradual lowering of water level, which is confirmed by the progressive changes in the littoral *Cladocera* species.

VI. Telmatic stage (ca. 4·90–4·00 m)

The processes described above brought about the partial overgrowing of the lake. The sediment was formed in a shallow rather stagnant water with an overproduction of organic matter and deficient in oxygen. The sulphur of authochtonous origin was bound. The sediment was acidic and no carbonates were precipitated at that time. In Woryty 80 profile a lime-indicator *Paraquadrula discoides* disappeared at that time. The overgrowing did not cover the whole lake and was not quite synchronous is its different parts. However, lowering of water level was a general tendency.

VII. First human impact on the lake (ca. 4·00–2·90 m)

At the level corresponding exactly to the *Ulmus*-fall and the appearance of first human indicators in the pollen diagram (5115 BP), the direction of changes in the lake turned. The temporary rise of water level evidenced by the accumulation of fine detritus gyttja was accompanied by rapid silting to the lake, and a reduction in lake productivity, clearly shown by the decrease in the organic nitrogen content and rise in C/N ratio (input of allochtonous organic matter poor in N — Pearsall et al. 1960; Digerfeldt 1978). At the same time some accumulation of carbonates ($MgCO_3$ involved? — rise in Mg content) started again, though to a limited extent. The increase in sedimentation rate was nearly 4-fold, compared with the rate calculated for the upper part of preceding phase (5890—5115 BP). Such phenomena are commonly observed in connection with deforestation (Manny et al. 1978; Pennington 1978). In this case the scale of anthropogenic destruction of the natural environment, as suggested by the changes in lake sediment, seems to have been greater than is suggested from the pollen-analytical evidence. In the lake littoral *Cladocera* species dominate, and in some levels ***Bosmina longirostris*** shows an increased abundance connected perhaps with eutrophication accelerated by man. In the corresponding part of Woryty 80 ***Paraquadrula discoides*** reappeared again.

VIII. Man-influenced stage of lake development (2·90–1·70 m)
The land-occupation processes in the Woryty area proceeded in steps and so their impact on the lake is recorded in the sediment. After a temporary phase of lowered water level, as evidenced by the accumulation of peaty gyttja with decreased carbonate content and increased proportion of organic matter and of quartz, a new series of more intensive human activities influenced the lake, starting from about 3500 BP (Late Bronze — Lusatian settlement). It resulted in a rise of water level, an increased loading of carbonates, and a reduction in the lake productivity. The beginning of these changes is emphasized by a very high concentration of phosphorus. In Woryty 80 ***Difflugia urceolata*** — an indicator of eutrophication appears for the first time.

IX. Final overgrowing of the lake (1·70–0·00 m)

The final overgrowing of the lake started by the end of Lusatian settlement phase and progressed synchronously with the regeneration of forests on the areas surrounding the lake. A eutrophic reed-swamp peat with oscillating limus proportion, very low content of carbonates, and slightly alkaline reaction (pH 7·2–7·5), was deposited. The content of mineral particles (quartz, feldspars, clay minerals) was variable, but generally increased upwards. It reached highest values in section corresponding to the next — Roman settlement phase. Within the 1 m top of the profile, the sediment records the highest production of organic matter and acidification of habitat. In the section 1·00–0·80 m a temporary rise of water level (high limus content in the swamp peat) is indicated, corresponding to the youngest phase of forest regeneration. Another, very short oscillation of water level, connected with the appearance of calcium carbonate in the sediment and change of reaction to neutral, is observed between 0·45 and 0·65 m. The uppermost 0·5 m section evidences a gradual decrease in the production of organic matter and an increase in sand and silt input, resulting from the total deforestation of the surrounding areas and associated soil erosion. These changes, helped by the introduction of artificial drainage system lead finally to the formation of the soil layer that stopped the growth of swamp.

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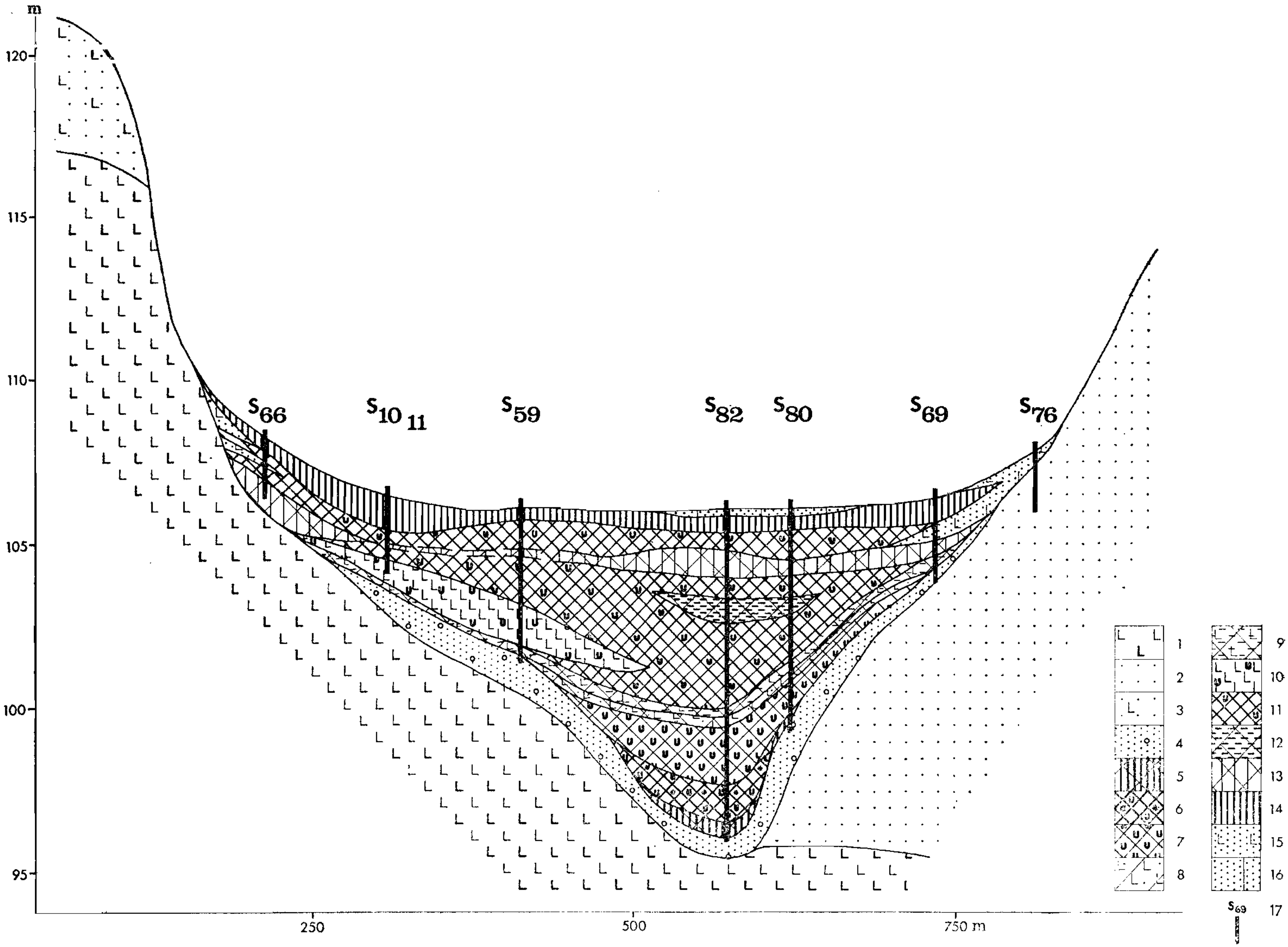

Fig. 4. Section across the Woryty site along the A—B transect shown in Fig. 3 (symbols follow Troels-Smith, 1955): 1 — glacial till, 2 — fluvio-glacial sands, 3 — kame silts and fine sands, 4 — coarse sands with gravel, 5 — basal peat, 6 — ferruginous gyttja, 7 — calcareous gyttja, 8 — sandy silt with gyttja, 9 — dy-like sediment, 10 — calcareous silt, 11 — fine detritus gyttja with variable carbonate content, 12 — sapropel-like sediment, 13 — swamp peat with gyttja, 14 — surface peat, 15 — slope land-slide material deposited in the marginal zone of lake, 16 — surface sands, 17 — position of corings, S-82 and S-80 sampled for paleoecological investigations

WORYTY 82

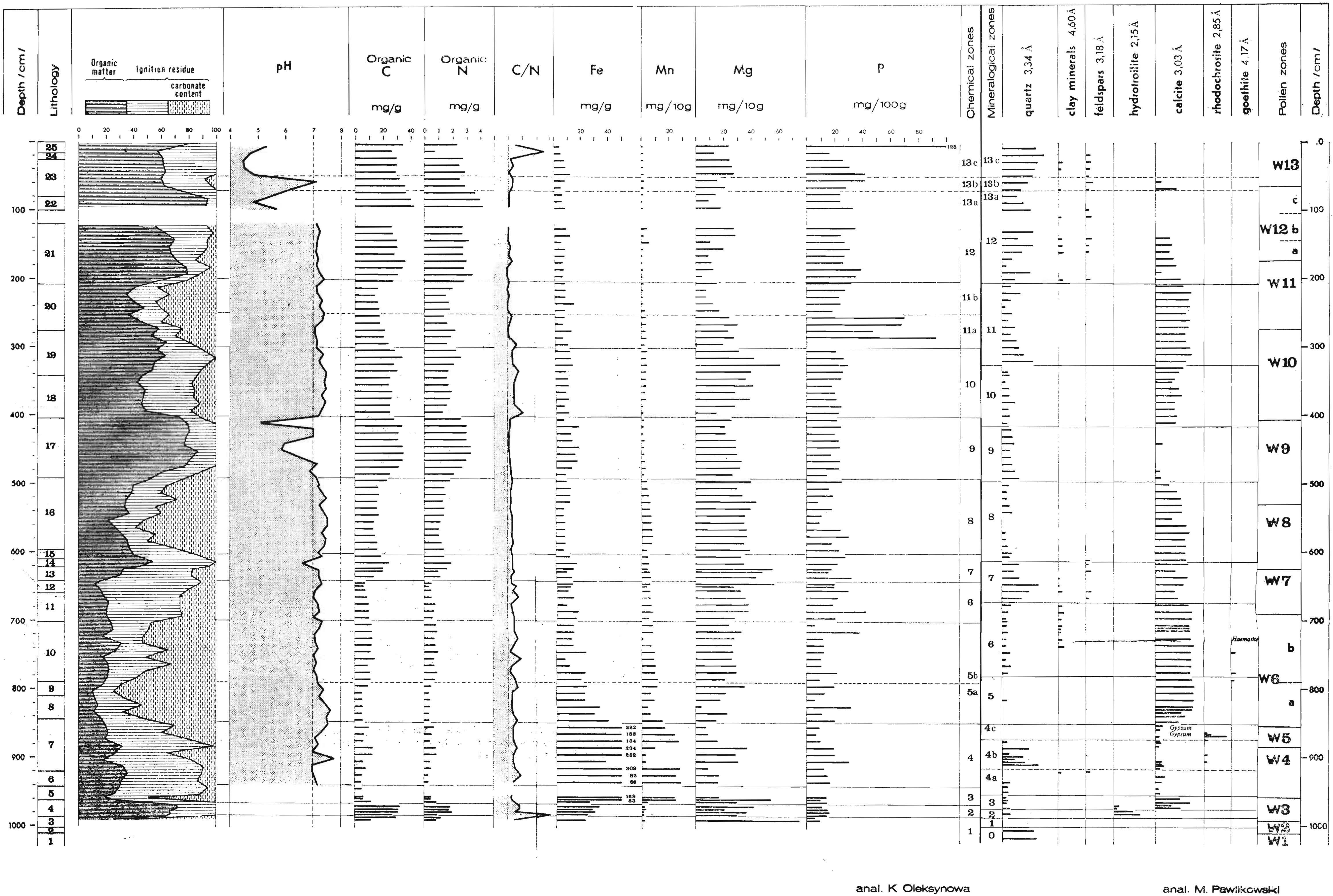

Fig. 5. Diagram showing the changes in the chemical and mineralogical composition of sediments in the Woryty profile 82. Organic matter, carbonates and elements content are calculated per dry weight. Changes in the mineral content are expressed as relative values showing changes in peak intensivity measured from the bottom of X-ray patterns. Numbers in the lithology column refer to the sediment description on p.92

WORYTY, Poland - zonation

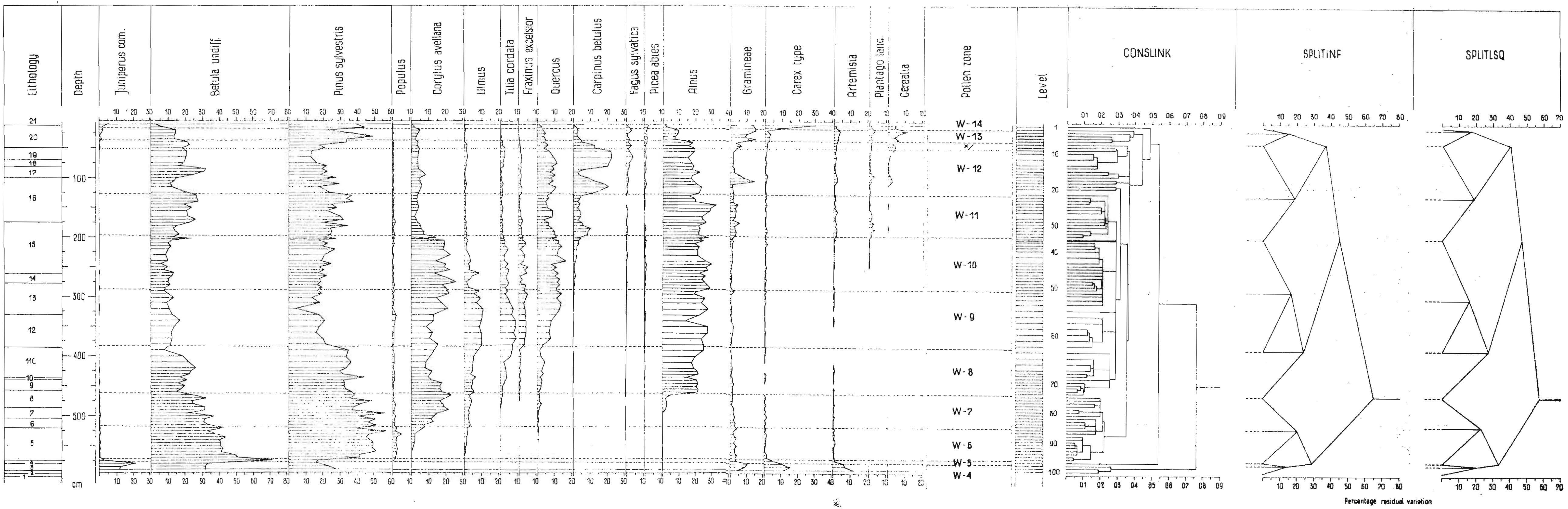

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Fig. 6. Computer diagrammatic plot of pollen data from the Woryty profile 80 used in the numerical analyses implemented by the FORTRAN IV program ZONATION. All pollen values are expressed as percentages of the total sum of pollen types shown, and are drawn to a constant scale. Dendrograms for agglomerative (CONSLINK) and divisive (SPILINF, SPLITLSQ) analyses suggesting the delimitation of pollen assemblage zones (W-4 – W-14), are shown to the left. */dotted line shows the W-12/W-13 boundary accepted instead of the boundary suggested by numerical analysis. Numbers in the lithology column refer to the sediment description on p. 95

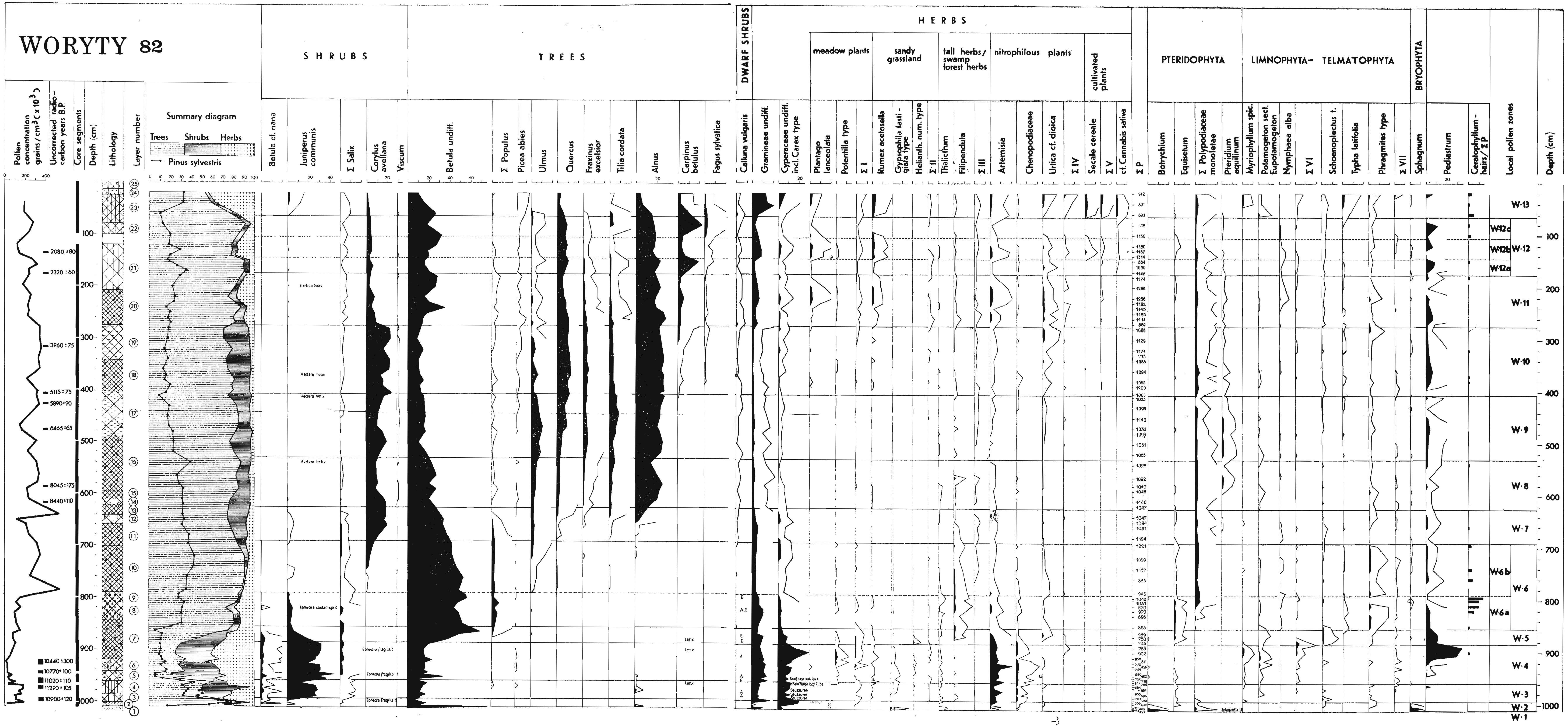

Fig. 7. Simplified percentage pollen diagram from the Woryty profile 82, selected pollen and spore taxa. Symbols used in the lithology column follow Troels-Smith (1955) system. Percentages of all tree, shrub and herb pollen taxa are calculated from the total sum, excluding *Pteridophyta, Limnophyta, Telmatophyta, Sphagnum* and *Pediastrum*, calculated from the sum Σ P + taxon. *Ceratophyllum* hairs are plotted as number of specimens per P sum. Unshaded silhouettes are exaggerated 10× scale

Σ *Salix* includes : *S. glauca* type, *S. pentandra* type, *S. polaris* type
Σ *Populus* : *P. tremula* type, *P. balsamifera* type
Σ *Polypodiaceae* monoletae: *Polypodiaceae* undiff., *Phegopteris dryopteris, Dryopteris thelypteris, D. filix-mas* type
Σ I: *Anthemis* type, *Geum* type, *Galium* type, *Ranunculus acer* type, *Rhinanthus* type, *Trifolium*
Σ II: *Jasione, Melampyrum, Plantago maritima* type, *Scleranthus annuus*
Σ III: *Humulus, Solanum dulcamara*
Σ IV: *Plantago major, Polygonum aviculare, Rumex acetosa, R. domesticus* type
Σ V: *Avena* type, *Hordeum* type, *Triticum* type, Cerealia undiff.
Σ VI: *Lemna, Myriophyllum verticillatum, Nuphar, Ranunculus trichophyllus* type, *Alisma plantago-aquatica*
Σ VII: *Cladium mariscus, Hippuris, Menyanthes, Sparganium* type, *Sagittaria*
A — *Arctostaphylos uva-ursi*
E — *Empetrum* cf. *nigrum*

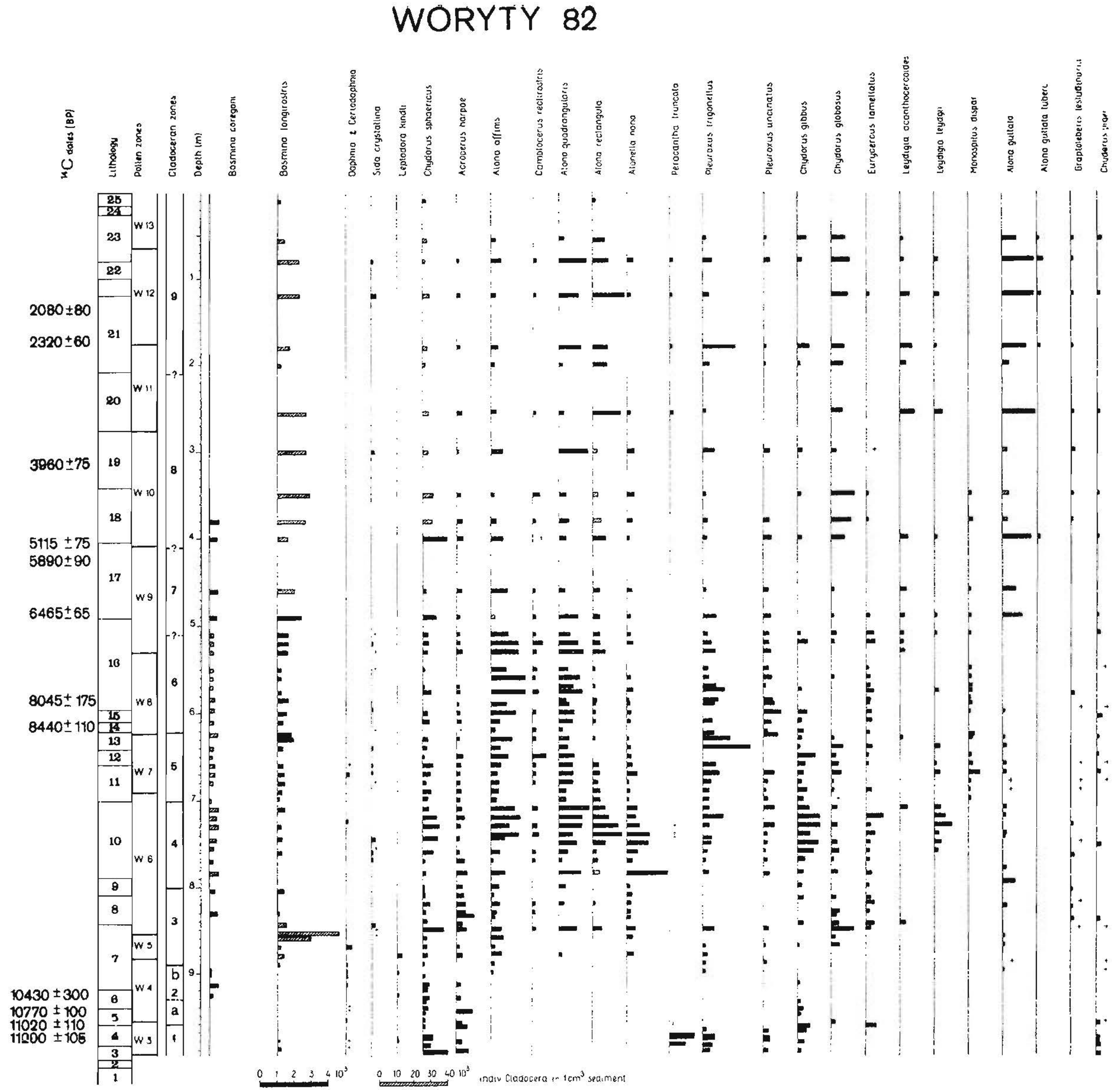

Fig. 8. *Oladocera* abundance diagram from the Woryty profile 82. Numbers in the lithology column refer to the sediment description on p. 93-95. Radiocarbon dates are given in uncorrected radiocarbon years BP