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LATE GLACIAL AND HOLOCENE PALAEOECOLOGICAL CONDITIONS AND CHANGES OF VEGETATION COVER UNDER EARLY FARMING ACTIVITY IN THE SOUTH KUJAWY REGION (CENTRAL POLAND)

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Late Glacial and Holocene palaeoecological conditions and changes of vegetation cover under early farming activity in the south Kujawy region (Central Poland)

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ABSTRACT. The Late Glacial and Holocene vegetation development in the environs of the Osłonki region is reconstructed through pollen analysis. The Late Glacial sediments include the chronozones from part of the Bølling to the Younger Dryas. The Holocene section, even though the record of plant succession is not continuous, starts with the Preboreal, followed by part of the Boreal, and then includes the decline of the Atlantic, part of the Subboreal and only a few fragments of the Subatlantic. On the basis of pollen analysis, early Neolithic farming in the Osłonki region is described. Pollen data combined with archaeological evidence and radiocarbon dating permit the recognition and characterization of human influence on the local plant cover by settlers of the Linear Pottery culture, Lengyel culture, and Globular Amphorae culture. Numerical analysis helps to correlate the palynologically investigated material. Pollen percentage maps for the taxa distribution of *Juniperus communis* at the Younger Dryas chronozone and Cerealia undiff., Poaceae, *Juniperus communis*, *Quercus*, *Pinus sylvestris* and *Artemisia* at the younger part of Atlantic chronozone are plotted for the Kujawy region.

KEY WORDS: pollen analysis, numerical analysis, pollen percentage maps, Late Glacial, Holocene, Linear Pottery culture, Lengyel culture, Poland.

CONTENTS

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INTRODUCTION

The history of the Kujawy area was, and remains, the subject of great interest because since early Neolithic time this region has been intensively used for agriculture due to its fertile soils. Earlier Mesolithic people also penetrated this area. The Kujawy region has become one of the most important areas studied by archaeologists since the 1930s (Jażdżewski 1938, Cofta-Broniewska & Kośko 1982, 2002, Grygiel 1986, 2004, Czerniak 1994, Grygiel & Bogucki 1997). However, there have been no complete studies on the Late Glacial and the Holocene vegetational history of this area, due to the lack of any thick, continuous series of biogenic sediments suitable for pollen analysis. Until now only sediments of the Late Glacial, (Makohonienko et al. 1998), Holocene (Milecka 2000, Noryśkiewicz 2002) and some episodic deposits of the youngest Holocene (Dąbrowski 1971, Milecka 1998) have been found and investigated palynologically. The nearest sites with biogenic sediments that have been completely studied with respect to the vegetation development since the end of the last glaciation to the youngest Holocene and dated radiocarbon are situated in the Wielkopolska region and in the Wisła valley. Although these locations are relatively close to the Kujawy area, they represent different natural geographical regions.

The south-eastern part of the Kujawy, in the region of Brześć Kujawski, was one of the archaeological areas intensively studied. In the Osłonki (Fig. 1) settlement, in the immediate vicinity of the well-recognized large settlement of the Lengyel culture (Grygiel & Bogucki 1997, Grygiel 2004), thick series of biogenic sediments suitable for the pollen analyses have been found. They represent a time interval from the Bølling interstadial to the Mid-Holocene. The analysis of these materials has enabled studies on the vegetation development to be completed. This vegetation development was first influenced only by natural factors and later also by anthropogenic factors in the south of the Kujawy. Due to these factors it was also possible to investigate the influence of some forms of prehistoric economy on the vegetation.

Fig. 1. Map of Central Europe showing locations of Osłonki, Lake Gościąż, and Pleszów

The main objective of the work presented below was to recognize the stages of vegetational development in the Kujawy region after the last glacial period as well as to explain when the vegetation of the southern Kujawy area lost its primary character; whether it happened as a result of the development of agricultural cultures or whether it took place earlier as a result of the activity of hunter-gatherers. It was also essential to define the influence of the Neolithic settlements on further transformations of vegetation in the study area.

A secondary aim was also to present the stages of vegetation development in the Kujawy area during the time period studied against a background of the analogous processes in the neighbouring natural geographical regions that had been the subject of detailed palaeobotanical studies. An attempt has been made to detect the events of regional and local character and to explain the causes of their similarities and differences. The next goal was to define to what extent traces of human activity during the early Neolithic have been reflected in the pollen record from the point of view of comparison of their quantity and quality in relation to the archaeological remains of the Linear Pottery culture and Lengyel culture in the immediate vicinity of the basins of the biogenic accumulation. A further aim was to collate and supplement the botanical interpretations using results from numerical analyses.

The results of the palynological investigations obtained hitherto in the area of Osłonki (Nalepka et al. 1998, Nalepka 1999, 2004a,b, 2005, Nowaczyk et al. 2002, Gąsiorowski & Nalepka 2004, Nowaczyk & Nalepka 2005) have been compiled together with the parallel archaeological research and studies on biotic and abiotic elements. Apart from the sporomorphs including pollen grains and plant spores presented in this study, the materials studied from the biogenic sediments also include other plant microfossils (diatoms), animal microfossils in the form of cladoceran remains (Gąsiorowski & Nalepka 2004, Gąsiorowski 2005 and in prep.), and macrofossils such as mollusc shells (Alexandrowicz 2005 and in prep.). The composition of the biogenic sediments with respect to organic matter and calcium carbonate contents has been also studied (Nowaczyk in prep.). Part of the collected material has been already worked out and those results have been published. In this paper unpublished results being in preparation for publication are used thanks to the permission by the authors, too. The description of numerical analysis (Walanus & Nalepka in prep.) created to used in this monograph has also been published. The materials for the analyses have been obtained from two areas of deposition: from the area adjacent to the archaeological settlement and from the biogenic sediments in depressions situated in close vicinity of the archaeological sites. The macroscopic plant remains (Bieniek 2002, 2003), human bones (Krenz-Niedbała 2000), fish bones (Makowiecki 2003), and animal bones have been collected directly from the settlements. The local geomorphology has been worked out (Nowaczyk in prep.) and the types of soils have been described (Grygiel 2004).

RESEARCH AREA

The Osłonki site (52°37′N, 18°48′E) is situated in the south-eastern part of the Kujawy Lake District (Kondracki 1994) in the Kujawy-Pomorze province (Fig. 2). It is a flat landscape lying at the altitude of ca. 90 m a.s.l., in which level ground-moraine hills are extensive, with rare kame fields as well as wide areas of proglacial stream valley drainage (Gilewska 1991a,b, Kondracki 1994). This area is situated within the zone of the Vistulian. Some kilometres to the north and the north-east from Osłonki is the Bachorza valley and south

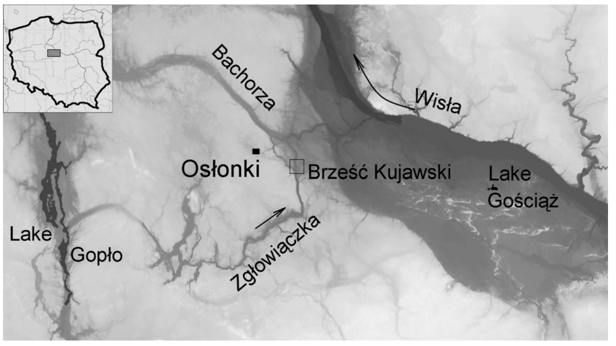


Fig. 2. Location of the Osłonki area in the south Kujawy region

of Osłonki the Zgłowiączka river (the left-bank tributary of the Noteć), which flows in a S-N direction. The transformed glacial channel joins these two valleys.

The cover of this area is formed of till and in some sites of sand with gravel of glacial origin (Kozarski 1991). Black soils occur there, formed from moraine clay or dust deposits, and less frequently from sand. The black soils occupy the largest expanses in the area of Osłonki, the brown-earth soils cover a relatively small area and the sand even less (Prusinkiewicz & Bednarek 1991). The soils of the Kujawy area have been presented in the literature in various ways according to accepted classifications and with some degree of generalization in maps. For example, according to the map of Polish soils (Gleby Polski, Atlas Rzeczypospolitej Polskiej 1993) the area of Osłonki is situated on the lessivés soils. However, the detailed soil map of the Osłonki and Brześć Kujawski areas, elaborated recently by Marosik (in Grygiel 2004) has confirmed that in the area of Osłonki there are typical black soils surrounded by degraded black and grey soils which are also a form of degraded black soils (Grygiel 2004). All these soils are very fertile. The brown-earth soils and podzols also occur in the neighbourhood and form a varied mosaic. The brown-earth soils (typical as well as leached and acidic) occur in a form of islands, often as a subsidiary of the black. The podzol and pseudo-podzol soils occur in areas devoid of running water. There are also the hydromorphic soils (muddy-peat, peat, boggy-peat, and boggy soils) but they occur only along narrow belts of a few reservoirs and rivers.

The potential natural vegetation consists of oak-hornbeam forests of an oak-lime-hornbeam type, of a central-European type [*Galio sylvatici-Carpinetum*] with *Quercus robur* and partly *Fagus sylvatica* (Matuszkiewicz 2002). Based on the map by Matuszkiewicz et al. (1995) it can be suggested that in the immediate vicinity of the Osłonki area, the central-European oak-lime-hornbeam forests of the Kujawy variety of a poor series may have been growing. Among them the lowland, wetland alder wood, and ash–alder type forests of the wet habitats, periodically becoming marshy, and the continental mixed forests, could have formed very small islands. Also the central-European oak-lime-hornbeam forests of the Kujawy variety of the fertile series occurred a short distance from those of the poor series.

At present, this area is completely anthropogenically transformed. The majority of the areas are used for agricultural purposes, mainly as ploughed fields, with wheat (*Triticum*), sweet beet-root (*Beta vulgaris*) and potatoe (*Solanum*) cultivation. To a smaller degree some parts are used as pasture and the remaining areas have been used for built-up areas. Wasteland occupies only small parts of the area.

The study area lies in a central part of the Kujawy climatic region, characterized by a mean July temperature of 18°C, January temperature of –2.5°C and a mean annual temperature of 8°C. The summer lasts here 95 days on average, the winter about 80 days and a snow cover exists for about 70 days. The Kujawy region belongs to areas with the lowest amount of precipitation in Poland (which probably results from its situation within the rain shadow due to the presence of moraines in the north). The mean amount of precipitation is about 500 mm per year (Okołowicz & Martyn 1983).

The sites archaeologically explored are located in the Osłonki, Miechowice and Konary villages. The site at Konary lies about 1 km north-west of Osłonki and the Miechowice site about 500 m to the north-east (Fig. 3).

Geomorphological observations in the area of the archaeological excavations were made by Paweł Marosik MSc. (unpublished report, archives of Archaeological and Ethnographical Museum, Łódź) in 1992 and 1993. Then, biogenic sediments were found, reaching down to 4 m below the depression surface, filling a small depression adjacent to the south of the explored archaeological settlement. At the bottom part of these sediments brown peat was found, which was radiocarbon dated to the

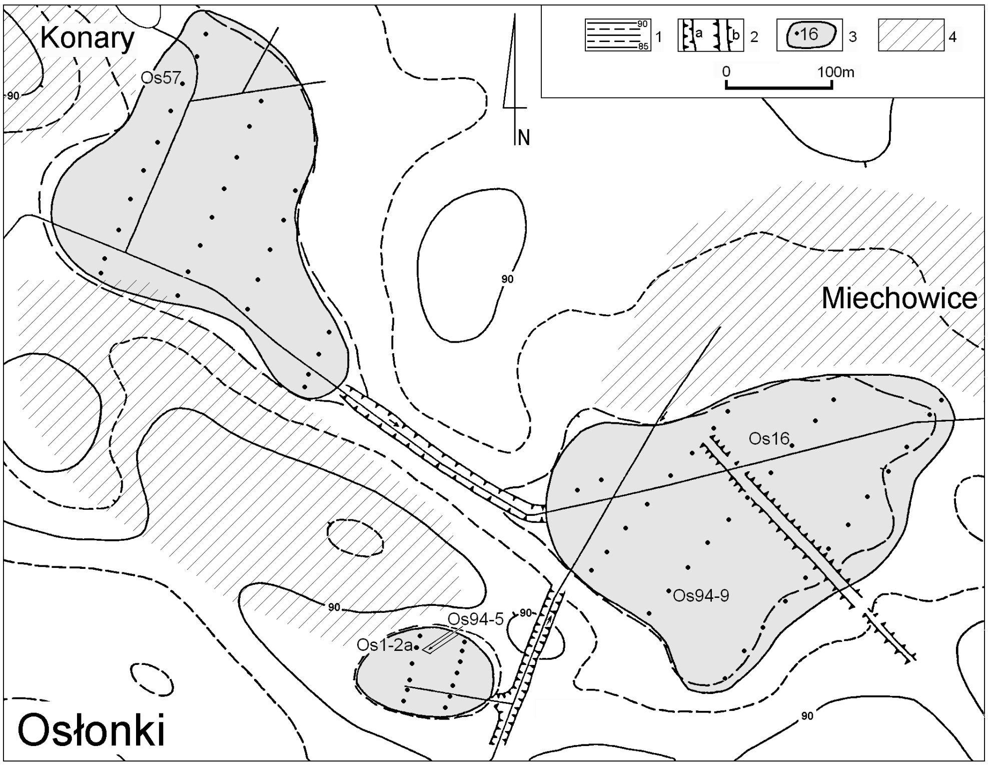


Fig. 3. Location of the investigated profiles in the basins in the Osłonki area. **1** – contour lines at 1.25 m intervals, **2a** – ditches, **2b** – banks, **3** – numbers of investigated profiles in the basins, **4** – archaeological sites (after Nowaczyk et al. 2002, modified)

Boreal chronozone (7920 ± 170 ^{14}C BP). The succeeding investigations were carried out between 1994 and 1999 by Bolesław Nowaczyk and Dorota Nalepka. More than 100 probe drillings were made, which provided data for the detailed geomorphologic description of the Osłonki region. During these investigations another two basins filled with biogenic sediments were identified, lying north-west and north-east of the archaeological site at Osłonki (Nowaczyk et al. 2002). The archaeological site 1 in Osłonki (Fig. 3) is situated on a small (ca. 90 m a.s.l) and a narrow (100–200 m) rise. It is bordered from the north by a shallow valley running in a west-east direction, which joins the valley of the Bachorza channel (Fig. 2). In this valley, two flat-bottomed basins filled with biogenic sediments are present (Nowaczyk et al. 2002). The north-western basin (named later as a western basin) of a longer axis ca. 380 m in the western part has a width of ca. 300 m, whereas in the east it is ca. 80 m wide. The Os 57 profile from its north-western part has been the subject of a detailed appraisal. The north-eastern basin (named later as an eastern basin) is ca. 380 m in length and up to 250 m width, and from its southern part the profile Os 94-9 has been palynologically analysed, and from the eastern part preliminary analysis of the Os 16 profile has been performed. A small, oval depression (named later as the southern basin), of ca. 130 m in length along the W–E long axis, is situated south of the site. Two profiles from this basin (Os 1-2a and Os 94-5) have been analysed palynologically. Both of these landscape forms, the relicts of the Vistulian, have dried out due to drainage ditches and were used for pasture. At the beginning of the twenty first century the peat in the southern basin were exploited for gardening purposes and a small fish pond has been established.

A detailed description of the geomorphological investigations will be presented in a separate paper (Nowaczyk in prep.).

ARCHAEOLOGICAL BACKGROUND

Since the earliest Neolithic time, the fertile soils of the Kujawy Lake District have been an area of agriculture settlement. Archaeological investigations carried out for many years in the area of Brześć Kujawski (Jażdżewski 1938, Grygiel 1986, Bogucki & Grygiel 1993, Grygiel & Bogucki 2005) have resulted in the discovery of two periods of early Neolithic settlement. The older, dated to ca. 5400 and

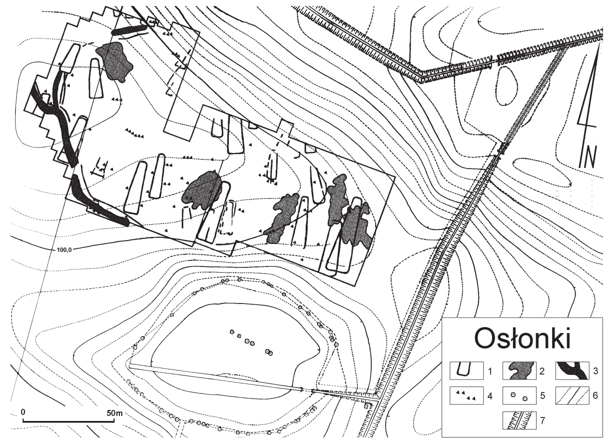


Fig. 4. Plan of the Neolithic settlement at the Osłonki site 1. Area excavated in 1994. **1** – outlines of trapezoidal long-houses, **2** – clay-extraction pits, **3** – fortification system, **4** – burials, **5** – trees, **6** – contour lines at 0.25 m sites intervals, **7** – ditches (after Grygiel & Bogucki 1997, modified)

4900 cal BC was related to the Linear Pottery culture, while the younger one from ca. 4400 to 4000 cal BC was related to the Lengyel culture. The archaeological site at Osłonki, as well as at Brześć Kujawski, which was studied earlier, have both provided much data about the life of the early agricultural communities that, in the middle of the sixth century BC, reached the area of southern Kujawy via paths along the Wisła, Odra, and Noteć rivers. The fertile black soils, with a thick humus layer, were the main reason that this area was favoured by farmers. Studies have shown that their economy was based on cereal cultivation (wheat and barley) and animal husbandry (cattle, pig, goat/sheep) but food supply was also supplemented by wild plants and wild animals. Not only were wild animals hunted (bear, deer, beaver, small fur-bearing animals, aquatic birds) and fish caught, but tortoises and mussels were also consumed (Grygiel & Bogucki 1997, Grygiel 2004).

The investigations of settlement in the area of Osłonki and Brześć Kujawski have provided much information about the formation of agricultural societies in the Polish Lowlands, as this area is situated along a dividing line connected with the introduction of agriculture in this part of Europe. South of this line the agriculture economy was introduced through colonization by groups of people coming from south-central Europe, whereas north of this line the agricultural economy was adopted by the local people. Grygiel and Bogucki (1997) suggested that the area of Osłonki might have played the role of transmitting an agricultural economy to hunter-gatherer societies.

The archaeological excavation at Osłonki (Fig. 4), carried out since 1989 (Grygiel & Bogucki 1997, Grygiel 2004), has resulted in the recovery of very rich remains of a settlement inhabited continuously for several centuries by the farmers of Lengyel culture. Over the area of more than 15 000 m^2 (1.5 ha) several dozen trapezoidal long-houses (usually 35–30 m in length), and numerous traces of clay-pits were uncovered, as well as fragments of a fortification surrounding the settlement (found for the first time in this part of Europe) and more than 80 richly equipped graves. The fortification system consisted of an earth embankment, a palisade and a 2 m deep moat (Grygiel 1986) that enclosed the inhabited area from the west. The settlement was also protected by a natural defensive system formed by lakes situated in the glacial channel from the north and east and the small peat bog from the south.

The graves were always situated within the settlement, close to the homesteads, and contained skeletons of one or more people. They were equipped with tools made of bone, antler, flint, stone, shell, and copper. Many graves, dating from the flourishing times of the settlement, very often contained valuable and refined jewellery made of some of the oldest, central-European copper, as well as shells and animal bones (Bogucki 1996, Grygiel & Bogucki 1997). Moreover, within the area of the settlement many artefacts have been found such as pottery and stone tools, as well as animal bones and horns, fish bones, and burnt macroscopic plant remains. Anthropological studies of the skeletons (Krenz-Niedbała 2000) have revealed that the Lengyel people from Osłonki did not differ genetically from the other Neolithic groups, though some differences between them existed. Probably this resulted from their south-European origin (Krenz-Niedbała after Wierciński 1989). According to the latter, the society of the Lengyel culture reacted to food limitation and infections, in consequences of the agriculture economy connected with their settled mode of life.

Based on radiocarbon dating, it has been estimated that the maximal development of the settlements occurred in the calendar years of 4300–4050 BC (Grygiel & Bogucki 1997) and according to the newest calibration to 4700–4200 cal BC (Grygiel 2004). It has been ascertained that during these 500 years a four-phase building structure was applied. At the site of Osłonki there are no archaeological traces of a culture older than the Lengyel one, but there are some remains of younger stages of settlements corresponding to the late Neolithic Globular Amphorae culture, the Bronze Age, and the Roman period. Traces of the oldest Neolithic Linear Pottery culture have been found in the sites of Miechowice and Konary (Grygiel 2002, 2004) lying about 0.5 km and 1 km, respectively, from Osłonki. The rich and widespread remains of this settlement have been studied at Brześć Kujawski, lying about 10 km to the east (Grygiel 1986).

The results of the archaeological investigations dealing with the settlements of the Linear Pottery culture are extensively presented in the monograph of Grygiel (2004), which begins a series of volumes, showing the results of many years of complex archaeological investigations concerning the particular Neolithic cultures in the area of south-eastern Kujawy.

STATE OF PALAEOBOTANICAL RESEARCH ON THE LATE QUATERNARY VEGETATIONAL HISTORY IN THE AREA OF KUJAWY AND ITS VICINITY

Two palynologically investigated sites lying near the Osłonki region are Lake Gopło and Lake Gościąż. Both lakes contain sediments that were deposited during the Late Glacial and Holocene. The bottom sediments of Lake Gopło, which is situated about 10 km west of the Kujawy Lake District, were the subject of pollen analysis (Jankowska 1980), and although they cover the vegetational history from the last glacial retreat, they were not dated with absolute methods. Moreover, Lake Gopło belongs to a geographically different region i.e. the Wielkopolska region (Kondracki 1994). The bottom sediments of Lake Gościąż (Ralska-Jasiewiczowa et al. 1998), situated in the Wisła valley, 20 km east of the Kujawy Lake District, serve as a model (i.e. reference) site, to which many events in the pollen diagrams from the area of Central Poland can be related, but they can be applied only to regional phenomena. Other sites, also palynologically investigated, are situated further to the west: Lake Biskupin (Noryśkiewicz 1995) and the numerous sites of the Wielkopolska area (Tobolski 1991, 1998), to the north the Bory Tucholskie (Hjelmroos 1981, Hjelmroos-Ericsson 1982, Miotk-Szpiganowicz 1992, Milecka 1998, Noryśkiewicz 2002), and to the north-east in the Dobrzyń-Chełmno region, the bottom sediments of Lake Steklin (Noryśkiewicz 1987). Most of the mentioned sites have been studied in detail within the framework of the IGCP Project 158A and 158B. The results have been published in separate papers, and they have been also included in the summaries describing the development of vegetation in Poland during the youngest Quaternary, published in 1989 in Acta Palaeobotanica 29/2 (Ralska-Jasiewiczowa ed., 1989), and in the volume describing the vegetational changes in Europe during that time (Ralska-Jasiewiczowa & Latałowa 1996). The general trends of plant change during the youngest Quaternary have also been compiled in a new edition of isopollen maps (Ralska-Jasiewiczowa et al. eds, 2004). The results of the studies from the sites lying in the closest vicinity of the Osłonki area, i.e. from Rybiny (Milecka 1998) as well as from the sites in Bożejewice (Makohonienko et al. 1998) and Sławsko (Milecka 2000) have also been used in the present paper. Detailed references to the individual sites are found on page 75.

MATERIAL AND METHODS

Sampling of sediments in the Osłonki region began in 1993. The terrain examined initially encompassed the close vicinity of the archaeological site at Osłonki 1; then the radius of examination was expanded to cover the vicinity of the neighbouring settlements of Miechowice and Konary. Almost one hundred cores (Fig. 3) were taken during a few seasons. Cores were taken using a Więckowski-type corer; Russian cores were also taken as well as samples from the wall of a trench.

Five cores were selected for palaeoecological examination. Three of them (Os 1-2a, Os 94-5, Os 94-9) were subjected to complete pollen analysis, and two others (Os 16 and Os 57) were used for auxiliary investigations. The lithology of the Os 1-2a, Os 16, and Os 57 profiles was briefly described in the field, and profiles Os 94-5 and Os 94-9 received more detailed description in the laboratory. The sediments have been described on the basis of a system developed by Troels-Smith (1955, see also Tobolski 2000). Symbols used in the lithology columns of the diagrams also follow Troels-Smith (1955). Colours of sediments were described using a table by Munsell (1954). A detailed description of lithology is provided in separate tables (Tabs 1–5).

LITHOLOGICAL DESCRIPTION OF THE INVESTIGATED PROFILES

Two profiles (Os 1-2a and Os 94-5) were collected from a southern basin (Fig. 3), drained in the twentieth century. The basin was a small (130 × 100 m) oval depression adjacent to the archaeological site of Osłonki 1 (Grygiel 2004) to the north-west. In 2003 this basin was destroyed by the excavation of all organic sediments for garden soil and transformed into a fish pond. The preliminary history of past vegetation near this basin has been described by Nalepka (2004a,b).

Table 1. Lithological description of the Osłonki Os 1-2a profile. The depths are measured from the field point at 0.15 m below present surface level

Obtained segments [cm]	Description of sediment according to Troels-Smith (1955)
0–32	Clay with recent plant roots, sand and shells of molluscs. Nig.4, elas.0, sicc.3, strf.0, lim.sup.0, As 2, Ag 1, Sh 1, Th+, Ga+, [part.test.moll.+]
100–108	Clay with recent plant roots and shells of molluscs. Nig.4, elas.0, sicc.3, strf.0, lim.sup.0, As 2, Ag 1, Sh 1, Th+, [part.test.moll.+]
108–118	Peaty mud with recent plant roots and shells of molluscs (transitory level). Nig.3, elas.0, sicc.2, strf.0, lim.sup.?, Ag 2, Th 1, Sh 1, [test moll.+, part.test.moll.+]
118–151	Sandy clay with fragments of plant roots and shells of molluscs. Nig.3, elas.0, sicc.2, strf.0, lim.sup.?, As/Ag 2, Ga 1, Sh 1, Th+, [part.test.moll.+]
151–153	Clay. Nig.3, elas.0, sicc.2, strf.0, lim.sup.?, As/Ag 3, Sh 1
200–221	Clay (2.17–2.21 m destroyed) Nig.3, elas.0, sicc.3, strf.0, lim.sup.?, As/Ag 3, Sh 1
221–260	Peaty mud. Nig.4, elas.0, sicc.2, strf.0, lim.sup.?, As/Ag 2, Sh 1, Ga 1, Th+
270–300	Silty gyttja with small admixture of sand, small fragments of herb tissues and shells of molluscs. Nig.2, elas.0, sicc.2, strf.0, lim.sup.?, $Ld^2$2, Th 1, $Sh^1$1, As/Ag+, Ga+, Dl+, [part.test.moll.+]
300–325	Peat. Nig.3, elas.?, sicc.2, strf.0, lim.sup.0, Th 4
350–380	Peat. Nig.3, elas.?, sicc.2, strf.0, diagonal lim.sup.0, Th4
410–437	Peat. Nig.3, elas.?, sicc.2, strf.0, lim.sup.0, Th 4
437–446	Silty peaty mud. Nig.3, elas.0, sicc.2, strf.0, lim.sup.?, As/Ag 3, Th 1
446–486	Sandy clay. Nig. 2, sicc.2, elas. 0, strf. 0, lim.sup.?, As/Ag 3, Ga 1

Table 2. Lithological description of the Osłonki Os 94-5 profile. The depths are measured from the field point at 0.38 m below present surface level

[cm]	Description of sediment according to Troels-Smith (1955)
0–13	Clay with recent plant roots, sand and shells of molluscs. Nig.3, elas.0, sicc.3, strf.0, lim.sup.0, col. 10YR 3/1, As 2, Ag 1, Sh 1, Th+, [part.test.moll.+]
13–28	Clay with recent plant roots, sand and shells of molluscs and pices of clay, sand and small pebbles. Nig.3, elas.0, sicc.2, strf.0, lim.sup.0, col. 10YR 4/2, Ag 2, Th 1, Sh 1, Ga+, Gg(min.)+, [test moll.+, part.test.moll.+]
28–37	Clay with black humus. Nig.2, elas.0, sicc.2, strf.0, lim.sup.1, col. 2.5Y 2/0, As 3, Sh 1
37–52	Humus with plant roots and shells of molluscs. Clay is present as small lences. Nig.4, elas.0, sicc.2.5, strf.0, lim.sup.2, col. 2.5Y 2/0, Sh 4, Th+, Ga+, As/Ag+, [part.test.moll.+]
52–100	Clay with humus with plant roots and shells of molluscs. Nig.3, elas.0, sicc.2, strf.0, lim.sup.1, col. 10YR 2/1, As/Ag 3, Sh 1, Th+, Ga+, [test.moll.+, part.test.moll.+]
100–130	Sandy clay with plant roots and shells of molluscs. Nig.3, elas.0, sicc.2, strf.0, lim.sup.2, col. 10YR 3/2, As/Ag 2, Ga 1, Sh 1, Th+, [part.test.moll.+]
130–138	Sand with clay. Nig.3, elas.0, sicc.2, strf.0, lim.sup.3, col. 10YR 3/2, Ga 2, As/Ag 2
138–238	Peaty mud with sand, plant roots and shells of molluscs. Upper part: Nig.4, elas.0, sicc.2, strf.0, lim.sup.2, col. 2.5Y 2/0, As/Ag 3, Sh 1, Th^1+, [part.test.moll.+]. Bottom part: Nig.3, elas.0, sicc.2, strf.0, lim.sup.1, col. 10YR 3/1, As/Ag 2, Sh 1, Ga, Th+, [part.test.moll.+]
238–242	Peaty mud with sand, plant roots and shells of molluscs and anthrax. Nig.2, elas.0, sicc.2, strf.0, lim.sup.2, col. 10YR 4/4, As/Ag 2, Th 1, Dh 1, Ga+, [part.test.moll.+, test.moll.+], anth.
242–283	Gyttja slightly sandy with plant roots and shells of molluscs. Nig.2, elas.0, sicc.2, strf.0, lim.sup.0, col 2.5Y 4/4 up to 2.5 Y 3/2, $Ld^2$2, Th 1, Sh 1, As/Ag+, Ga+, Dl+, [part.test.moll.+]
283–291	Clay with small amount of sand, and shells of molluscs. Nig.1, elas.0, sicc.2, strf.0, lim.sup.2, col. 7.5YR 5/0, Ag 4, As+, Ga+, [part.test.moll.+]
291–298	Peat (mostly *Sphagnum*). Nig.3, elas.?, sicc.2, strf.2, lim.sup.3, col. 5YR 3/4, Th 2, $Tb_{(Sphag)}$1, Dh 1, As/Ag+, Dg+
298–325	Peaty mud slightly clayey. Nig.3, elas.0, sicc.2, strf.0, lim.sup.2, col. 10YR 4/2, Ag 2, As 2, Dg+, Th+, Ga+
from 325	Sandy clay. Nig. 2, sicc.2, elas. 0, strf. 0, lim.sup.?, col. 5Y 4/1, As/Ag 3, Ga 1

After several reconnaissance borings in 1992 and 1993, one sediment core Os 1-2a (Tab. 1) was collected by means of a piston corer constructed by Więckowski, similar to a Livingstone corer. The diameter of the core was 8 cm.

The second profile Os 94-5 was taken from the same southern basin (Fig. 3). It was collected from the wall of a trench 25 m long, 1.5 m wide and up to 4 m deep (Fig. 5). The trench was carried from the closest edge of the basin adjacent to the archaeological settlement of Osłonki 1 into the deepest part of the basin, in a south-east direction. The core was taken as monoliths in metal boxes measuring 25 × 8 × 5 cm (Fig. 6).

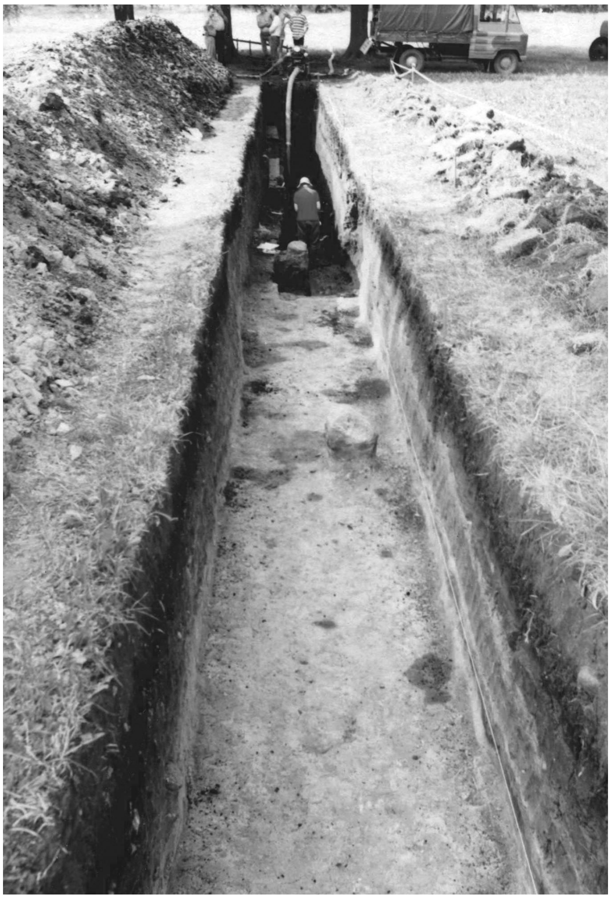


Fig. 5. The view of the trench in the southern basin in Osłonki at the deepest wall direction (photo W. Pohorecki)

Having a wall in the trench available (Fig. 7) that provided complete information about the investigated sediment from the archaeological site to the deepest part of the basin, complete cores were taken and detailed observations of the lithological levels and the boundaries between them were also carried out (Tab. 2).

First of all in the southern basin levels of sediments were thought that might be a continuation of any levels in the lithological profiles within the archaeological settlement Osłonki site 1. These levels should include some archaeological artefacts like pottery fragments, bones, tools, or layers of charcoal or other traces of ancient settlers. Unfortunately, there was a lack of such levels. However, it was discovered why the cores taken by the Więckowski corer were incomplete. The lack of parts of core was due to the presence of thin sandy layers, which cut the organic layers. At these mineral layers, the cores were broken during the fieldwork.

The next three profiles were taken from two basins situated north-west and north-east of the southern basin (Fig. 3). Both basins are situated in a shallow valley, running from west to east, about 150 m north of the archaeological site. After several reconnaissance borings in 1993 and 1994 (Nowaczyk in prep.), the profiles were taken using 8 cm, 5 cm, and 3 cm – diameter Russian corers.

Fig. 6. North-western corner of the trench in the southern basin in Osłonki with boxes pushed into the wall to take the sediment of the Os 94-5 profile (photo W. Pohorecki)

The profile Os 94-9 was taken from the deepest part of the eastern basin (Tab. 3). The profile Os 16 (Tab. 4) was taken from the north-eastern edge of the same basin, in close proximity to the early Neolithic archaeological site at Miechowice 4 (Linear Pottery culture and Lengyel culture). The last core Os 57 (Tab. 5) was collected from the north-west edge of the western basin, close to the Lengyel settlement at Konary.

Table 3. Lithological description of the Osłonki Os 94-9 profile. 0.00 m level of described sediments = the surface

cm	Description of sediment according to Troels-Smith (1955)	
0–41	Recent soil with fragments of herb tissues and shells of molluscs. Nig.3, elas.0, sicc.3, strf.0, lim.sup.4, col. 5YR 3/2, As 2, Th^{1}1, Sh 1, [part.test.moll.+]	
41–67	Clay with recent plant roots, tissues of herbs and shells of molluscs. Nig.4, elas.0, sicc.3, strf.0, lim.sup.1, col. 5YR 2/1, As 3, Th^{2}1, Ag+, [part.test.moll.+]	
67–110	Peat with plant roots, tissues of herbs and shells of molluscs. Nig.4, elas.1, sicc.2, strf.0, lim.sup.0, col. 5YR 3/2, Th^{1}3, As(Ag?)1, [part.test.moll.+, test.moll.+]	
110–138	Detritus gyttja with tissues of herbs. Transitory level between peat and gyttja. Nig.3, elas.1, sicc.2, strf.0, lim.sup.1, col. 10YR 3/1, Ld^{3}3, Th^{2}1, Ag+, Dh+, [part.test.moll.+, test.moll.+]	
138–150	Gyttja lighter brown	Gyttja slightly laminated, with plant roots, and shells of molluscs. Nig.2, elas.1, sicc.2, strf.1, lim.sup.1, col. 10YR 4/2, Ld^{2}3, Th^{1}1, Dh+, As+, [part.test.moll+, test.moll.+]
150–158	Gyttja darker brown	
158–167	Gyttja lighter brown	
167–177	Gyttja darker brown	
177–185	Gyttja lighter brown	
185–195	Gyttja darker brown	
195–200	Gyttja lighter brown	
200–212	Gyttja darker brown	
212–223	Detritus gyttja with plant roots, tissues of herbs and shells of molluscs. Nig.3, elas.1, sicc.2, strf.0, lim.sup.0, col. 10YR 3/2, Ld^{3}3, Th^{1}1, Dh+, [part.test.moll.+, test.moll.+]	
223–231	Peat with plant roots, tissues of herbs and shells of molluscs. Nig.4, elas.1, sicc.2, strf.0, lim.sup.1, col. 2.5Y 2/0, Th^{2}3, Sh 1, Dh+, [test.moll.+, part.test.moll.+]	
231–244	Clay/gyttja. Nig.2, elas.0, sicc.2, strf.0, lim.sup.2, col. 5YR 4/1, As 3, Ld^{2}1, Th^{2}+, Dh+, [part.test.moll.+]	
244–255	Detritus gyttja with plant roots, tissues of herbs and shells of molluscs. Nig.2, elas.1, sicc.2, strf.0, lim.sup.2, col. 5YR 3/2, Ld^{2}4, Th+, Dh+, As+ [test.moll.+, part.test.moll.+]	
255–260	Gyttja with shells of molluscs. Nig.3, elas.1, sicc.2, strf.0, lim.sup.0, col. 10YR 3/1, Ld^{3}3, As/Ag 1, Th+, Dh+	
260–274	Gyttja with plant roots and shells of molluscs. Nig.3, elas.1, sicc.2, strf.0, lim.sup.2, col. 10YR 4/2, Ld^{2}3, As/Ag 1, Th+, Dh+, [part.test.moll.+]	
274–292	Gyttja with shells of molluscs. Nig.2, elas.1, sicc.2, strf.0, lim.sup.1, col. 5Y 5/2, Ld^{1}3, As/Ag 1, Dh+, Th+, [part.test.moll.+]	
292–307	Gyttja with plant roots, tissues of herbs and shells of molluscs. Nig.3, elas.0, sicc.2, strf.0, lim.sup.1, col. 10YR 3/1, Ld^{2}3, As/Ag 1, Th+, Dh+ [test.moll.+, part.test.moll.+]	
307–311	Gyttja lighter brown lim.sup.1	Gyttja lighter brown as 2.74–2.92 m, Gyttja blackish as 2.92–3.07 m; strf. 1
311–318	Gyttja darker brown lim.sup.1	
318–332	Gyttja lighter brown lim.sup.0	
332–335	Gyttja blackish lim.sup.1	
335–343	Gyttja lighter brown lim.sup.2,	
343–345	Gyttja blackish lim.sup.3	
345–350	Gyttja lighter brown lim.sup.2	
350–351	Gyttja blackish lim.sup.1	
351–545	Gyttja with shells of molluscs. Nig.3, elas.1, sicc.2, strf.1, lim.sup.1, col 5 Y 4/2, Ld^{2}4, As/Ag+ [test.moll.+, part.test.moll.+]	
545–809	Silty gyttja with shells of molluscs. Nig.4, elas.1, sicc.2, strf.0, lim.sup.0, col. 5Y 2/1, Ld^{4} 3, As/Ag 1, Th+, Dh+ [part.test.moll+, test.moll.+]	
809–822	Gyttja with shells of molluscs. Nig.3, elas.1, sicc.2, strf.+?, lim.sup.0, col. 5Y 2/1, Ld^{4} 3, As/Ag 1, Th+, Dh+ [part.test.moll+, test.moll.+]	
822–850	Sand. Nig.2, elas.0, sicc.2., strf.0, lim.sup.1, col. 2.5Y 6/0, Ga4	
850–861	Silty peat strongly decomposed. Nig.3, elas. 0, sicc.2, strf.0, lim.sup.1, col. 2.5Y 5/0, Th3, Th+, As/Ag1	
861–900	Silty sand with pebbles up to 0.5 cm of diameter. Nig.3, elas.0, sicc.2, strf.0, lim.sup.1, col. 2.5Y 5/0, Ga3, Gg1, As/Ag+	

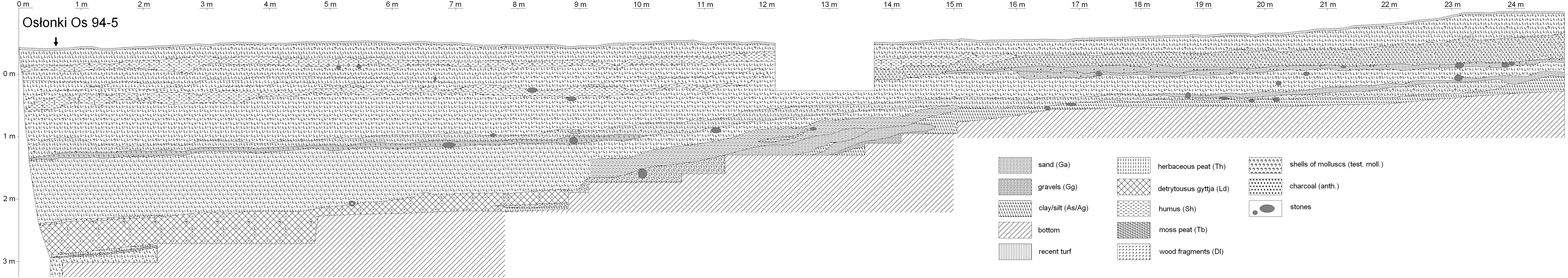


Fig. 7. North-western wall of the trench in the southern basin in Osłonki. Arrow indicates the profile Os 94-5 taken for the palynological analysis

Table 4. Lithological description of the Osłonki Os 16 profile. 0.00 m level of described sediments = the surface

cm	Description of sediment according to Troels-Smith (1955)
0–25	Recent soil with fragments of herb tissues, roots and shells of molluscs. Nig.3, elas.0, sicc.3, strf.0, lim.sup.4, col. 5YR 3/2, As 2, $Th^1$1, Sh 1, [part.test.moll.+]
25–59	Clay with recent plant roots, tissues of herbs and shells of molluscs. Nig.4, elas.0, sicc.3, strf.0, lim.sup.1, col. 5YR 2/1, As 3, $Th^2$1, Ag+, [part.test.moll.+]
59–70	Gyttja. Nig.3, elas.0, sicc.2, strf.0, lim.sup.1, Lc3, As/Ag 1, Th+, [part. test.moll.+]
70–127	Silty detritus gyttja with recent plant tissues of herbs. Nig.2, elas.0, sicc.2, strf.0, lim.sup.1, Lc3, As/Ag 1, Th+, [part.test.moll.+]
127–150	Silty gyttja with tissues of herbs and shells of molluscs. Nig.1, elas.1, sicc.2, strf.0, lim.sup.2, Lc4, Th+, [part.test.moll.+]
150–152	Reworked level
152–170	Silty gyttja with tissues of herbs and shells of molluscs. Nig.3, elas.1, sicc.2, strf.0, lim.sup.2, Lc4, Th+, [part.test.moll.+]
170–283	Silty gyttja with tissues of herbs and shells of molluscs. Nig.1 (from 2.60 cm nig.2), elas.1, sicc.2, strf.0, lim.sup.2, Lc4, Th+, As/Ag+, [part.test.moll.+]
283–370	Silty peat strongly decomposed or silty detritus gyttja. Nig.4, elas.2, sicc.2, strf.0, lim.sup.0, Th/Ld4, Th+, As/Ag+, [part.test.moll.+]
370–381	Gyttja? Nig.3, elas.1, sicc.0, strf.0, lim.sup.1, Ld4, Th+
381–400	Sand with pebbles up to 2 cm of diameter. Nig.2, elas.0, sicc.2, strf.0, lim.sup.1, Ga3, Gg1, Th+

Table 5. Lithological description of the Osłonki Os 57 profile. 0.00 m level of described sediments = 0.15 m below the surface

cm	Description of sediment according to Troels-Smith (1955)
0–60	Clay with sand, recent plant roots, tissues of herbs and shells of molluscs. Nig.4, elas.0, sicc.3, strf.0, lim.sup.1, col. 5YR 2/1, As 3, $Th^2$1, Ag+, [part.test.moll.+]
60–143	Clay with small amount of plant tissues. Nig.4, elas.1, sicc.2, strf.0, lim.sup.1, As4, Th+, [part.test.moll.+]
143–263	Gyttja with small amount of shells of molluscs. Nig.2, elas.1, sicc.2, strf.0, lim.sup.1, col. 5Y 5/2, $Ld^1$3, As/Ag 1, Dh+, Th+, [part.test.moll.+]
263–395	Detritus gyttja with small amount of shells of molluscs. Nig.3, elas. 1, sicc.2, strf.0, col. 10YR 3/2, Ld 4 [part.test.moll.+]
395–400	Transitory from gyttja to peaty mud. Nig.3, col. 5Y 5/2
400–411	Silt. Nig.2, elas.0, sicc.2. strf. 0, lim.sup.1, col. 5Y 4/3, Ag 4
411–450	Sand slightly silty. Nig.2, elas.0, sicc.3, strf.0, lim.sup.1, col. 5Y 4/1, Ga 4, As/Ag+

RADIOCARBON DATING

Fourteen radiocarbon determinations are available from three profiles at the Osłonki site. Seven radiocarbon determinations were obtained from the profiles Os 1-2a and Os 94-5, and from the preliminary boring Os 2/93 (Tab. 6). These samples consisted of peaty mud, but the amount of organic matter was very small. All these samples were dated in the Radiochemical Laboratory of the Museum of Archaeology and Ethnography in Łódź, using conventional techniques.

The next six determinations, obtained from the profile Os 94-9 in the eastern basin, have been made by the Poznań Radiocarbon Laboratory, using the AMS technique to date selected plant macrofossils. These samples were composed of macroscopic remains of fruits, seeds and charred fragments of plants. These remains were selected after dilution of a few cm^3 of sediments. The recovered macrofossils were very sparse, and moreover almost all of them were damaged. Identification of these remains was possible using the macrofossil reference collection in the Palaeobotanical Department, W. Szafer Institute of Botany, Polish Academy of Sciences. Several levels of the core, composed of silty gyttja with fragments of molluscs shells, did not contain any organic macroremains suitable for radiocarbon dating. One additional sample from Os 94-9 contained too small amount of carbon for dating. In the next sections ^{14}C data are presented as conventional ^{14}C dates (in ^{14}C BP) and in brackets the 68% and 95% ranges of calibrated age are denoted, as BC1 and as BC2, respectively. This notation follows the convention used in the archaeological monograph by Grygiel (2004).

Table 6. Radiocarbon dates obtained from profiles at Osłonki site. The 68% and 95% ranges of the calibrated age are shown, as BC1 and as BC2, respectevely.

Profile	Depth [cm]	Lab. no.	Date ^{14}C BP	Age cal BC		Description of dated material
				BC1 68%	BC2 95%	
Os_{1-2a}	306–311	Lod-1180	10 470 ± 90	10 750–10 200	10 900–10 000	peat
Os_{1-2a}	291–295	Lod-1181	6730 ± 70	5700–5560	5750–5500	peaty mud
Os_{1-2a}	212–217	Lod-1179	4260 ± 60	2920–2720	3020–2640	peaty mud
Os_{94-5} bis	291–297	Lod-1178	8900 ± 80	8190–7890	8250–7750	peat
Os_{94-5}	279–283	Lod-1177	6670 ± 70	5660–5520	5710–5480	gyttja
Os_{94-5}	256–260	Lod-1176	6470 ± 70	5490–5360	5600–5310	peaty mud
Os_{94-9}	443	Poz-837	8190 ± 80	7350–7100	7470–7030	fruit and seed plant remains: *Carex*, Poaceae, cf. *Ceratophyllum*, scale of *Betula*, unidentified piece of needle, charcoal
Os_{94-9}	433	Poz-1174	8870 ± 70	8170–7860	8230–7740	fruit and seed plant remains: *Betula*, unidentified fragments of scales and piece of wood
Os_{94-9}	413 and 408	Poz-1172	9010 ± 50	8270–8060	8290–7970	fruit and seed plant remains: *Urtica dioica*, *Carex*, *Betula*
Os_{94-9}	403	Poz-0	> 0			fruit and seed plant remains: *Carex rostrata/vesicaria*, *Betula*, unidentified pieces of wood
Os_{94-9}	344	Poz-836	8440 ± 150	7610–7260	7900–7050	fruit and seed plant remains: *Urtica dioica*, *Typha*, Poaceae, *Chenopodium*, unidentified scale, charcoal
Os_{94-9}	221	Poz-839	5790 ± 40	4700–4570	4470–4530	fruit and seed plant remains: Poaceae, *Rumex*, *Carex*, Cyperaceae, cf. Caryophyllaceae, *Urtica*, *Cicuta*, *Chenopodium*, charcoal
Os_{94-9}	135	Poz-840	3110 ± 35	1415–1320	1470–1260	fruit and seed plant remains: *Rumex*, *Chenopodium*, *Typha*, *Urtica*, *cf. Potentilla*, fragment of *Pinus*, unidentified fruit fragment
Os 2/93*	420	Lod-581	7920 ± 170	7060–6610	7350–6450	brown peat

* Trzeciak & Borowiec (1996)

LABORATORY TREATMENT OF MATERIAL FOR POLLEN ANALYSIS

The sampling intervals were 1.2 up to 5.0 cm. The samples for pollen analysis were prepared by standard procedures. Each sample of 1 cm^3 was treated by Erdtman acetolysis (Faegri et al. 1989), together with a known number of indicator spores of *Lycopodium* (Stockmarr 1971). Mineral components were removed by boiling in 10% KOH, decantation and boiling in hydrofluoric acid. The material was then mounted in glycerin. Sporomorphs were counted on at least 2 slides for each sample. Between 310 to 1700 AP pollen grains were counted for each sample with the exception of a few basal samples and from mineral levels, in which some tens of AP pollen grains and hundreds of spores were counted only. Finally for palynological interpretation 244 spectra were used and 191 taxa have been determined. Almost 100 samples were discarded because they included very low amounts of sporomorphs or the sporomorphs were very badly preserved. About 20 spectra did not include any sporomorphs at all. The pollen sum of trees, shrubs and herbs, excluding aquatic and swamp plants and spores, was used as the basis for calculating the percentages. For counting sporomorphs, drawing the diagrams and maps, and implementing numerical analysis, the POLPAL computer programs were used (Walanus & Nalepka 1999, 2004, Nalepka & Walanus 2003a).

DESCRIPTION OF LOCAL POLLEN ASSEMBLAGE ZONES

The pollen diagrams (Figs 8–17) are divided into local pollen assemblage zones (L PAZ) in the sense of Birks (1979, 1986) and Janczyk-Kopikowa (1987) on the basis of visual analysis of individual pollen curves supported by numerical analysis (ConSLink, PCA). In addition to the L PAZ, anthropogenic phases were distinguished in order to illustrate man-made changes. The description of local pollen assemblage zones is presented in Tables 7–11.

Fig. 8. Percentage pollen diagram of the Osłonki profile Os 1-2a

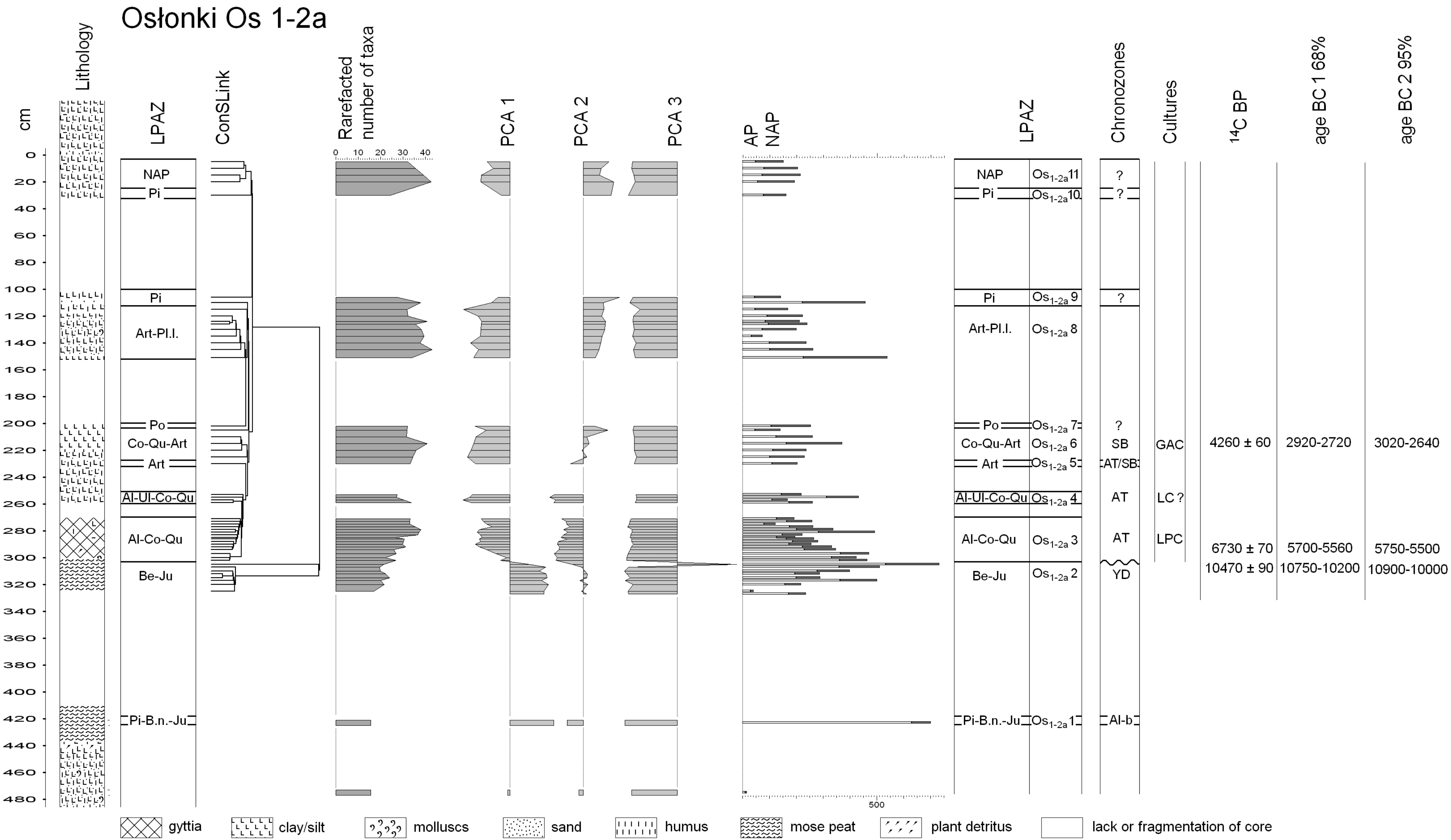


Fig. 9. Concentration and numerical analysis diagrams of the Osłonki profile Os 1-2a

Table 7. Osłonki Os 1-2a. Description of local pollen assemblage zones (L PAZ) (Figs 8, 9)

L PAZ	Name of L PAZ	Depth [cm]	Description of pollen spectra
		475	Spectrum excluded from interpretation due to the high values of rebedded pollen grains (*Alnus*, *Corylus avellana*, *Quercus*, *Fagus sylvatica*, *Carpinus betulus*) and corroded sporomorphs (22.6%).
$Os_{1\text{-}2a}$ 1	*Pinus-Betula nana-Juniperus*	423	Only one spectrum included. Maximum frequency of *Pinus sylvestris* (50.4%) pollen and high frequency of *Betula* (36.3%). The presence of *Betula nana*-t. (1.6%). Low frequency of *Salix polaris*-t., *Juniperus communis*, and *Artemisia*. Corroded sporomorphs are at relatively low values. Upper limit: not known due to damage of the core. Numerical analysis (ConSLink) separates this spectrum from the lower and upper spectra.
$Os_{1\text{-}2a}$ 2	*Betula-Juniperus*	303–325	Maximum of *Pinus sylvestris* (22.4–38.8%) pollen grains. The highest frequency reached by *Juniperus communis* (max. 6.8%), *Betula nana*-t. (max. 4.9%), and *Salix* (max. 3.8%). *Hippophaë rhamnoides*, *Salix polaris*-t., *Pinus cembra*-t., *Populus*, *Larix,* and *Artemisia* are present and single spores of *Selaginella selaginoides*. High frequency of Cyperaceae. Upper limit: disappearance of *Betula nana*-t. and *Salix polaris*-t., decrease of *Juniperus*, *Salix*, and Cyperaceae, appearance of *Alnus*, *Ulmus*, *Corylus avellana*, *Quercus*. Numerical analyses (PCA and ConSLink) confirmed this boundary.
$Os_{1\text{-}2a}$ 3	*Alnus-Corylus-Quercus*	271–303	High frequency of *Quercus* (2.9–12.5%), *Corylus avellana* (3.0–8.0%), *Alnus* (5.1–9.5%), *Ulmus* (0.3–3.9%), presence of *Fraxinus excelsior* and *Tilia cordata*-t. Pollen of *Artemisia* (1.0–3.1%) is continuously present. The curves of Poaceae and sporomorphs of reedswamp taxa rise, relatively high value reaches of *Pteridium aquilinum* (0.7–3.2%) curve. In the middle part of this zone Poaceae increase, and pollen of cereals (*Triticum*-t., *Hordeum*-t., and Cerealia undiff.) and weeds (*Spergula arvensis*-t., *Polygonum persicaria*-t., and *Ranunculus arvensis*) appear. The *Ulmus* curve declines. The upper limit not known due to damage of the core. Numerical analysis (ConSLink) confirms joining these spectra into one L PAZ.
$Os_{1\text{-}2a}$ 4	*Alnus-Ulmus-Corylus-Quercus*	253–257	The highest frequency of *Quercus* (10.2–14.8%) and *Alnus* (11.3–15.1%) pollen, the rise of *Corylus avellana* (7.4–10.2%) and *Ulmus* (1.4–6.2%) curves. Pollen of *Fraxinus excelsior*, *Tilia cordata*-t., *Triticum*-t., Cerealia undiff., Poaceae, and *Pteridium aquilinum* are continuously present. The upper limit not known due to damage of sporomorphs. Numerical analysis (ConSLink) confirms joining these spectra into one L PAZ and suggests its close correlation with the previous L PAZ.
$Os_{1\text{-}2a}$ 5	*Artemisia*	230	One only spectrum included. Higher frequency of *Artemisia* (6.4%) and Poaceae pollen and corroded sporomorphs (17.9%). Lower frequency of mesophilous trees pollen: *Alnus*, *Quercus*, *Tilia cordata*-t., *Fraxinus excelsior*, and *Corylus avellana*. The upper limit: the decline of *Ulmus*, slight decline of *Artemisia* and increase of Poaceae. Numerical analysis (ConSLink) confirms joining these spectra into one L PAZ and suggests close correlation with the previous L PAZ.
$Os_{1\text{-}2a}$ 6	*Corylus-Quercus-Atremisia*	204–228	Reappearance of *Juniperus communis* (0.0–0.2–3.6%) pollen. Low frequency of *Alnus* (3.7–7.4%), *Corylus avellana* (1.0–6.6%), and *Quercus* (2.0–7.2%), distinct drop of *Ulmus*, *Fraxinus excelsior*, and *Tilia cordata*-t., temporary rise of *Artemisia*, appearance of *Plantago lanceolata* and *Rumex acetosella* (low, but continuous curves). The highest frequency of *Filipendula*. In the upper spectra the temporary decrease of *Juniperus communis*, *Alnus*, *Corylus avellana*, *Quercus*, *Fraxinus excelsior*, Chenopodiaceae, *Artemisia*, and *Plantago lanceolata*, temporary disappearance of *Ulmus*, reappearance of *Hordeum*-t. pollen grains and increase of corroded sporomorphs. In the highest spectrum the appearance of the first pollen grains of *Cannabis*, *Secale cereale*, and *Centaurea cyanus*. Numerical analysis (ConSLink) confirms joining these spectra into one L PAZ and suggests the relation with the previous L PAZ.
$Os_{1\text{-}2a}$ 7	Poaceae	202	Only one spectrum included. High frequency of Poaceae (28.2%), although lower than in older the level. Numerical analysis (ConSLink) joins this spectrum with the upper spectra, but there are hiatuses between them (damage of core).

Table 7. Continued

L PAZ	Name of L PAZ	Depth [cm]	Description of pollen spectra
$Os_{1\text{-}2a}$ 8	*Artemisia-Plantago lanceolata*	115–151	Maximum of *Artemisia* (4.8–11.2%) and *Plantago lanceolata* (0.9–6.3%) pollen, high frequency of Chenopodiaceae (1.2–2.7%), *Plantago major* (0.2–1.4%), *Plantago major/media* (0.2–1.8%), *Rumex acetosella* (0.0–0.5–1.6%), *Rumex acetosa/acetosella* (0.4–1.5%), Poaceae (20.3–24.2%), and *Pteridium aquilinum* (0.0–0.5–up to 1.6%). Low curves of *Alnus*, *Corylus avellana,* and *Quercus*, the lowest of *Pinus sylvestris* (5.1%) in one spectrum. In the lower spectra the single pollen grains of *Fagus sylvatica*, low curve of *Carpinus betulus* which gradual decreases, while *Plantago lanceolata* rises. The upper limit: increase of *Pinus sylvestris*, decrease of *Alnus*, *Corylus avellana*, *Quercus*, Chenopodiaceae, *Plantago lanceolata*, and *Pteridium aquilinum*, *Ulmus* curve is discontinuous. Numerical analysis (ConSLink) confirms clearly the marked upper limit.
$Os_{1\text{-}2a}$ 9	*Pinus*	106–110	Two spectra included. High frequency of *Pinus sylvestris* (24.2–36.1%) and Cyperaceae (9.3–29.1%), very low frequency of *Betula* (1.4–5.7%). Pollen curves of *Alnus*, *Corylus avellana*, *Quercus*, *Artemisia*, *Plantago lanceolata* decrease. The lack of *Ulmus* pollen. The upper limit not known due to the presence of hiatus. Numerical analysis (ConSLink) suggests the similarity to the upper spectra, lying above the hiatus.
$Os_{1\text{-}2a}$ 10	*Pinus*	30	Only one spectrum included. The dominance of *Pinus sylvestris* (38.0%) pollen. The upper limit not known due to the presence of hiatus. Numerical analysis (ConSLink) suggests the similarity to the lower spectra, lying below the hiatus.
$Os_{1\text{-}2a}$ 11	NAP	5–15	The maximum values of Poaceae (26.4–39.2%), the repeated rise of *Juniperus communis* (0.8–3.1%), slight increase of *Quercus* (2.3–5.1%), presence of Cerealia undiff. Numerical analysis (ConSLink) confirms joining these spectra into one L PAZ.

Table 8. Osłonki Os 94-5. Description of local pollen assemblage zones (L PAZ) (Figs 10, 11)

L PAZ	Name of L PAZ	Depth [cm]	Description of pollen spectra
$Os_{94\text{-}5}$ 1	*Pinus-Artemisia*	318–324	Two spectra included. The dominance of *Pinus sylvestris* (35.9–36.3%), relatively high frequency of *Betula* (23.6–26.6%). High *Juniperus communis* (4.5–4.7%), *Salix* (2.5–2.9%), *Artemisia* (2.7–3.5%), and *Urtica dioica*-t. (0.6–1.4%) curves. The presence of *Betula nana*-t., *Salix polaris*-t., *Pinus cembra*-t., and *Populus*, appearance of *Larix* pollen grains. Rebedded sporomorphs are characterized as the low curve. The single pollen grains of *Alnus* and *Quercus*, recognized here as rebedded too. The upper limit: the drop of *Pinus sylvestris*, increase of *Betula nana*-t. and *Juniperus communis*. Numerical analyses (ConSLink and PCA) confirm this boundary.
$Os_{94\text{-}5}$ 2	*Betula nana-Juniperus-Artemisia*	299–312	Maximum value of *Juniperus communis* (7.0–8.7%) and *Betula nana*-t. (2.9–4.8%), increase of *Betula* (25.2–39.5%) curve, presence of *Hippophaë rhamnoides*, *Salix polaris*-t., *Pinus cembra*-t., and *Populus*. Relatively high frequency of *Artemisia* (1.9–3.3%) pollen. The continuous although low curve of rebedded sporomorphs. The presence of single grains of *Alnus*, *Corylus avellana*, and *Quercus* and recognized here as rebedded too. The high frequencies of hyphae fragments. The upper limit: the drop of *Betula nana*-t., *Salix polaris*-t., *Juniperus communis*, *Salix*, *Artemisia*, and Poaceae. Numerical analyses (ConSLink and PCA) separate this spectrum from the lower and upper spectra.
$Os_{94\text{-}5}$ 3	*Pinus*	295	Only one spectrum included. Higher frequency of *Betula* (38.4%), in comparison with *Pinus sylvestris* (32.7%). Decrease of *Betula nana*-t. (0.4%), *Salix polaris*-t. (0.1%), *Juniperus communis* (0.9%), *Salix* (0.7%), *Artemisia* (0.7%), and Poaceae (2.8%). Increase of Cyperaceae and pollen frequency of local taxa (*Potamogeton* sect. *Eupotamogeton*, *Myriophyllum spicatum*, *Typha latifolia*, *Sparganium*-t.). The appearance of *Nymphaea alba*, *Nymphaea candida*, and *Utricularia*. The upper limit: not known due to the presence of hiatus. Numerical analyses (ConSLink and PCA) confirm joining these spectra into one L PAZ.

Table 8. Continued

L PAZ	Name of L PAZ	Depth [cm]	Description of pollen spectra
$Os_{94\text{-}5}$ 4	*Alnus–Corylus-Quercus*	240–281	Dominance of mesophilous trees pollen: *Quercus* (7.8–14.2%), *Alnus* (6.5–15.4%), *Corylus avellana* (3.3–9.1%), *Ulmus* (1.4–3.1%), presence of *Fraxinus excelsior* and *Tilia cordata*-t. as well *Artemisia* and *Filipendula*. Temporary increase of *Juniperus communis* and *Rumex acetosella*. Presence of cereals (Cerealia undiff., *Triticum*-t., *Hordeum*-t.) and weeds (*Spergula arvensis*-t. and *Ranunculus arvensis*). Temporary increase of Indeterminable: corroded. The upper limit: not known due to the presence of hiatus. Numerical analysis (ConSLink) confirms joining these spectra into one L PAZ.
$Os_{94\text{-}5}$ 5	*Artemisia-Filipendula*	191	Only one spectrum included. High frequency of Poaceae (22.1%), *Artemisia* (3.9%), and *Filipendula* (1.4%) as well corroded sporomorphs. Presence of cereals (Cerealia undiff., *Triticum*-t., *Hordeum*-t.) and *Plantago lanceolata*. Slight decrease of *Alnus*, *Ulmus*, *Quercus*, and *Corylus avellana*. The high frequency of corroded sporomorphs. The upper limit: not known due to the presence of hiatus. Numerical analysis (ConSLink) suggests the similarity to the lower spectra, lying below the hiatus.
$Os_{94\text{-}5}$ 6	*Artemisia-Plantago lanceolata*	131–137	Two spectra included. The highest frequency of *Artemisia* (3.7–6.3%) and *Plantago lanceolata* (3.5–6.0%), high frequency of *Urtica dioica*-t. (1.1–1.6%) and corroded (17.7–25.2%). Presence of Cerealia undiff. and *Hordeum*-t. Increase of *Pinus sylvestris*, decrease of *Alnus*, *Ulmus,* and *Corylus avellana* as well as a slight increase of *Quercus* curve.

Table 9. Osłonki Os 94-9. Description of local pollen assemblage zones (L PAZ) (Figs 12, 13)

L PAZ	Name of L PAZ	Depth [cm]	Description of pollen spectra
$Os_{94\text{-}9}$ 1	NAP- *Betula nana*	851–860	The high frequency of NAP (36.2–30.3%), increases of *Betula nana*-t. (1.0–6.3%) and *Betula* (10.2–29.5%), decrease of *Pinus sylvestris* (42.9–21.6%). The appearance of *Hippophaë rhamnoides*, presence of *Juniperus communis*, *Pinus cembra*-t., *Salix*, as well as *Alnus*, *Corylus avellana*, *Quercus*, *Fagus sylvatica*, *Vitis*, recognized here as rebedded. The upper limit: not known due to the presence of hiatus. Numerical analysis (ConSLink) separates these spectra from all other spectra in the whole diagram.
$Os_{94\text{-}9}$ 2	*Pinus*	820–823	The high frequency of *Betula nana*-t. (3.9–5.2%). Increase of *Pinus sylvestris* (34.7–46.3%). Presence of *Hippophaë rhamnoides* (0.2%), *Juniperus communis* (0.8–0.9%), *Salix* (1.9–2.0%), and *Salix polaris*-t. as well as rebedded *Alnus*, *Corylus avellana*, *Quercus*. Decrease of corroded sporomorphs. The upper limit: rise of *Salix*, *Hippophaë rhamnoides*, *Juniperus communis*, and considerable decreases of *Pinus sylvestris* curve. Numerical analyses (ConSLink and PCA) confirm joining these spectra into one L PAZ.
$Os_{94\text{-}9}$ 3	*Betula nana-Hippophaë-Juniperus*	810	Only one spectrum included. The maximum value of *Hippophaë rhamnoides* (3.3%), *Salix* (8.0%), the first maximum of *Juniperus communis* (3.5%). The high frequency of *Betula nana*-t. (5.8%) is continuously present. The presence of *Larix* and rebedded *Alnus*, *Quercus*, *Fraxinus excelsior*. The upper limit: drop of *Hippophaë rhamnoides*, *Juniperus communis*, *Salix*, Poaceae. Numerical analysis (ConSLink) suggests the similarity to the lower spectra.
$Os_{94\text{-}9}$ 4	*Betula nana-Pinus cembra*	763–801	*Pinus sylvestris* (30.9–51.6%) and *Betula* (24.9–47.5%) on similar level. *Betula* curve fluctuates. High frequency of *Betula nana*-t. (0.5–8.6%), presence of *Juniperus communis* although discontinuous curve. Continuous and relatively high curves of *Pinus cembra*-t. and *Populus*. Rebedded pollen grains: *Alnus*, *Quercus*, *Corylus avellana*, *Ulmus* are present. Slight increase of *Artemisia*. Presence of corroded sporomorphs. High frequency of charcoal in some spectra. The upper limit: drop of *Betula nana*-t. Numerical analyses (ConSLink and PCA) confirm joining these spectra into one L PAZ.
$Os_{94\text{-}9}$ 5	*Pinus-Betula nana*	720–748	Temporary increase of *Pinus sylvestris* (43.2–64.5%), the opposite of *Betula* (15.0–31.7%). Slight decrease of *Betula nana*-t. (5.0–0.6%). *Juniperus communis* and *Artemisia* curves low but continuous. Presence of *Salix polaris*-t., *Pinus cembra*-t., *Populus*, *Larix*. Disappearance of rebedded sporomorphs. Discontinuous presence of charcoal. The upper limit: drop of *Pinus sylvestris*, *Betula nana*-t. curves, rise of *Betula*. Numerical analyses (ConSLink and PCA) confirm joining these spectra into one L PAZ.

Table 9. Continued

L PAZ	Name of L PAZ	Depth [cm]	Description of pollen spectra
$Os_{94\text{-}9}$ 6	*Betula nana-Juniperus-Artemisia*	603–710	The rise up to maximum of *Juniperus communis* (0.9–7.5%), the maximum frequency of *Artemisia* (1.0–6.5%), high frequency of *Betula nana*-t. (0.1–4.7%), and Cyperaceae (3.8–13.6%), relatively high Chenopodiaceae (0.2–0.9%). *Salix polaris*-t. curves low, but almost continuous. Presence of *Pinus cembra*-t., *Larix*, *Populus*. Single pollen grains of *Hippophaë rhamnoides* and rebedded sporomorphs. Gradual decrease of *Pinus sylvestris*, low value of *Betula*. High frequency of NAP. The upper limit: drop of *Betula nana*-t., *Juniperus communis*, *Artemisia*, Chenopodiaceae, and NAP curves. Numerical analyses (ConSLink and PCA) confirm joining these spectra into one L PAZ.
$Os_{94\text{-}9}$ 7	*Betula-Filipendula*	572–597	The rise up to maximum of *Betula* (32.4–64.1%), decrease of *Pinus sylvestris* (44.0–21.1%). Disappearance of *Hippophaë rhamnoides* and *Salix polaris*-t. Decrease of Chenopodiaceae (0.4–0.0%) and *Artemisia* (2.1–0.1–0.0%). The upper limit: drop of *Betula*, *Betula nana*-t., and *Juniperus communis*. Numerical analyses (ConSLink and PCA) confirm joining these spectra into one L PAZ.
$Os_{94\text{-}9}$ 8	*Ulmus-Filipendula*	513–567	Relatively high frequency of *Filipendula* (0.3–1.9%). Low and continuous *Ulmus* curve (0.2–1.0%). Increase of *Pinus sylvestris* (21.1–51.0%). Disappearance of *Betula nana*-t., significant drop of *Juniperus communis* (1.7–0.0–0.5%) and Cyperaceae (11.6–1.1%). In the upper part appearance of *Corylus avellana*, *Quercus,* and *Fraxinus excelsior* pollen grains. Appearance of charcoal. The upper limit: increase of *Quercus*. Numerical analyses (ConSLink and PCA) confirm joining these spectra into one L PAZ.
$Os_{94\text{-}9}$ 9	*Ulmus-Corylus*	348–508	Gradual increase of *Corylus avellana* (2.4–11.4%). Low and continuous curve of *Ulmus* (0.7–2.3%). *Filipendula* curve still on relatively high level (0.1–1.7%). In the upper part rise of *Quercus* (0.0–5.8%), *Alnus* (0.0–2.3%), and *Fraxinus excelsior* (0.1–1.0%) as well as charcoal. The upper limit: significant decrease of AP curve. Numerical analyses (ConSLink and PCA) confirm joining these spectra into one L PAZ.
$Os_{94\text{-}9}$ 10	*Alnus-Corylus-Quercus*	245–344	High frequency of *Alnus* (0.5–12.3%), *Corylus avellana* (3.1–14.3%), *Quercus* (5.7–12.7%), *Ulmus* (0.2–3.5%), *Fraxinus excelsior* (0.1–1.4%), and *Tilia cordata*-t. (0.1–0.6%). Higher frequency of *Artemisia* (0.5–1.9%). Low frequency of *Betula* (8.5–24.2%), gradual decrease of *Pinus sylvestris* (50.2–14.9%). Appearance of Cerealia undiff., *Triticum*-t., *Hordeum*-t. single pollen grains. The rise of *Urtica dioica*-t. (0.1–5.1%), particulary in the lower part. Presence of charcoal. The upper limit: not known due to the presence of hiatus. Numerical analysis (ConSLink) suggests the similarity to the upper spectra.
$Os_{94\text{-}9}$ 11	*Alnus-Ulmus-Corylus-Quercus*	140–221	The maximum of *Quercus* (11.1–22.8%), *Alnus* (6.6–14.2%), *Corylus avellana* (4.3–13.1%), *Ulmus* (1.8–5.4%), *Fraxinus excelsior* (0.3–3.3%), and *Tilia cordata*-t. (0.2–1.5%). Slight rise of *Artemisia* (0.6–2.4%). Low and discontinuous curves of Cerealia undiff. (0.0–0.9%), *Triticum*-t. (0.0–0.3%), *Hordeum*-t. (0.0–0.5%). Continuous presence of *Pteridium aquilinum* (0.1–1.0%). Appearance of first pollen grains of *Carpinus betulus*. Relatively high frequency of charcoal. The upper limit: drop of *Alnus*, *Ulmus*, *Corylus avellana*, *Quercus,* and significant rise of corroded sporomorphs. Numerical analyses (ConSLink and PCA) confirm joining these spectra into one L PAZ.
$Os_{94\text{-}9}$ 12	*Carpinus*-NAP	112–136	Gradual increase of *Carpinus betulus* (1.7–3.8%), *Artemisia* (0.7–1.6%), and Poaceae (15.4–24.6%). *Plantago lanceolata* as single pollen grains (0.0–0.3%), but almost continuous. In the lower part significant rise of Chenopodiaceae (2.1–14.3%) and corroded sporomorphs (6.6–23.9%) and increase of Cyperaceae (4.8–10.5%). Low and continuous curve of Cerealia undiff. (0.1–0.5%). The very high requency of charcoal. The upper limit: drop of AP excluding *Pinus sylvestris*, increase of Poaceae and corroded sporomorphs. Numerical analyses (ConSLink and PCA) confirm joining these spectra into one L PAZ.
$Os_{94\text{-}9}$ 13	Poaceae?	108	Only one spectrum included. Spectrum not interpreted due to the rapid rise of corroded sporpmorphs (18.9%), Poaceae (38.4%), and low value of AP (46.0%). The relatively high frequency of *Plantago lanceolata* (1.3%). Presence of charcoal. Numerical analysis (ConSLink) separates this spectrum from all the others.

Fig. 10. Percentage pollen diagram of the Osłonki profile Os 94-5

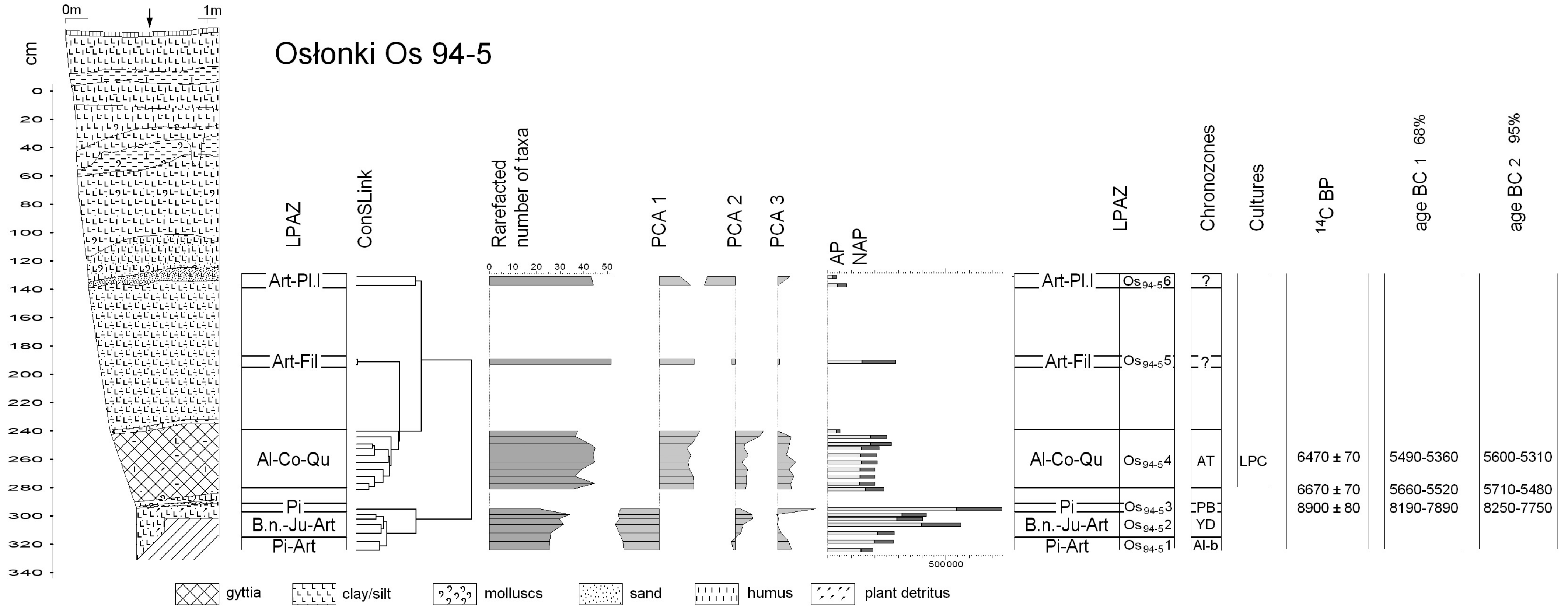


Fig. 11. Concentration and numerical analysis diagrams of the Osłonki profile Os 94-5

Fig. 12. Percentage pollen diagram of the Osłonki profile Os 94-9

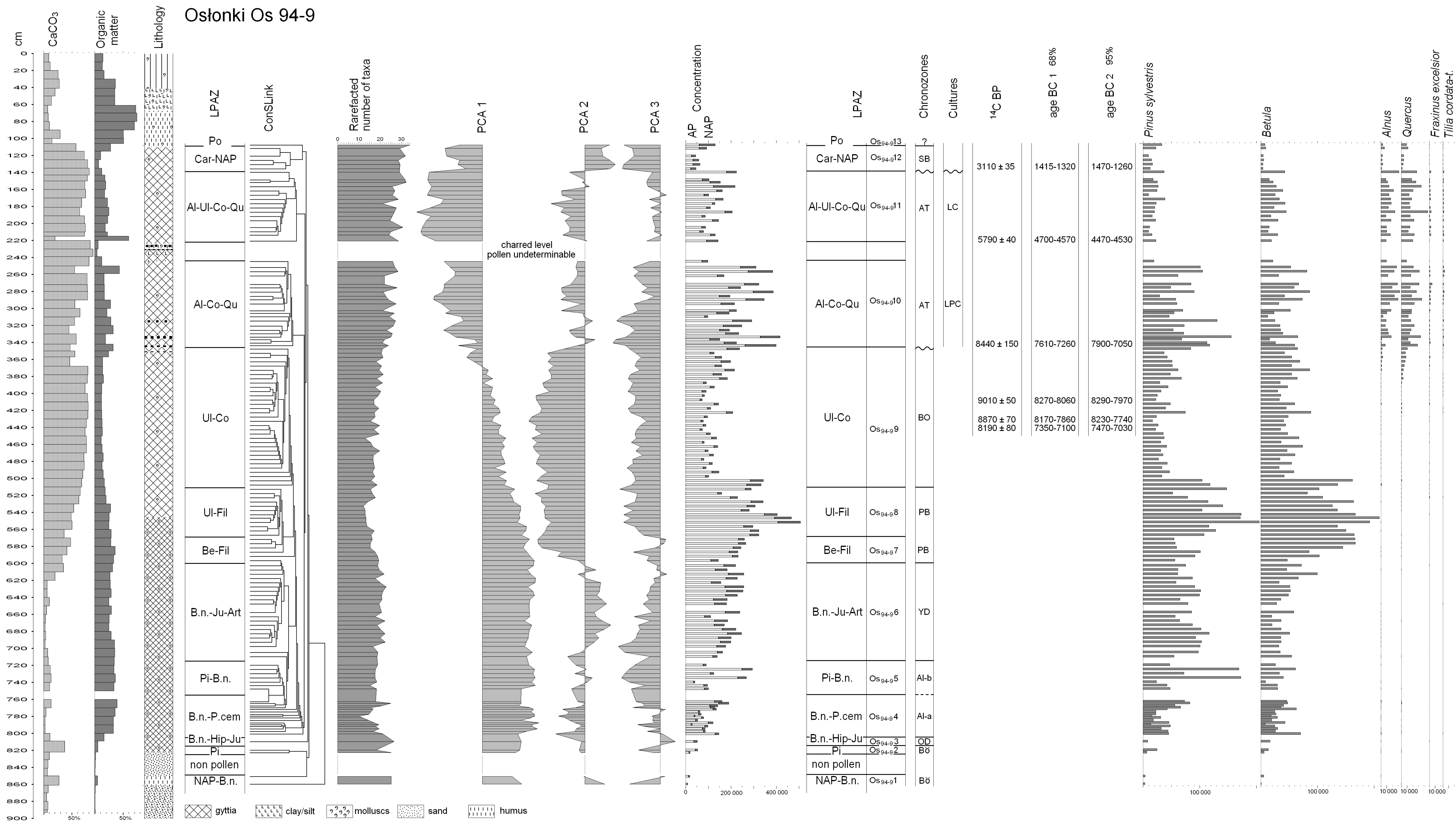


Fig. 13. Concentration and numerical analysis diagrams of the Osłonki profile Os 94-9

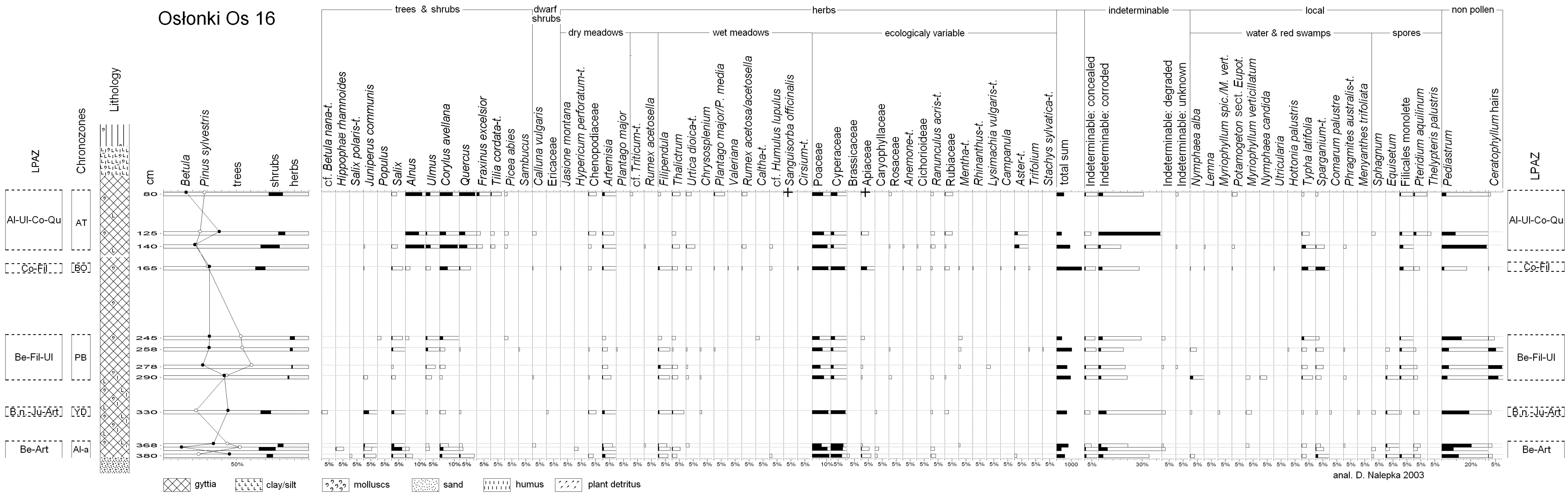


Fig. 14. Percentage pollen diagram of the Osłonki profile Os 16

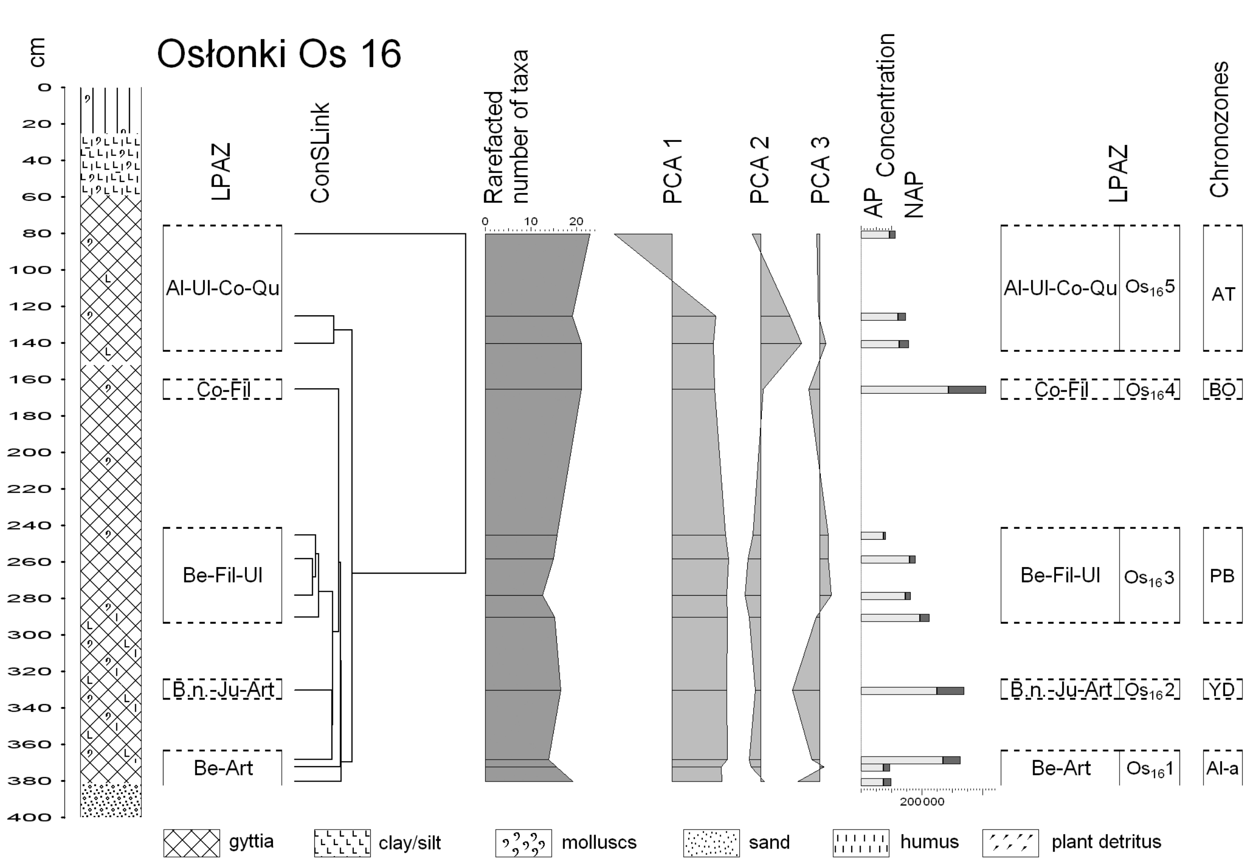


Fig. 15. Concentration and numerical analysis diagrams of the Osłonki profile Os 16

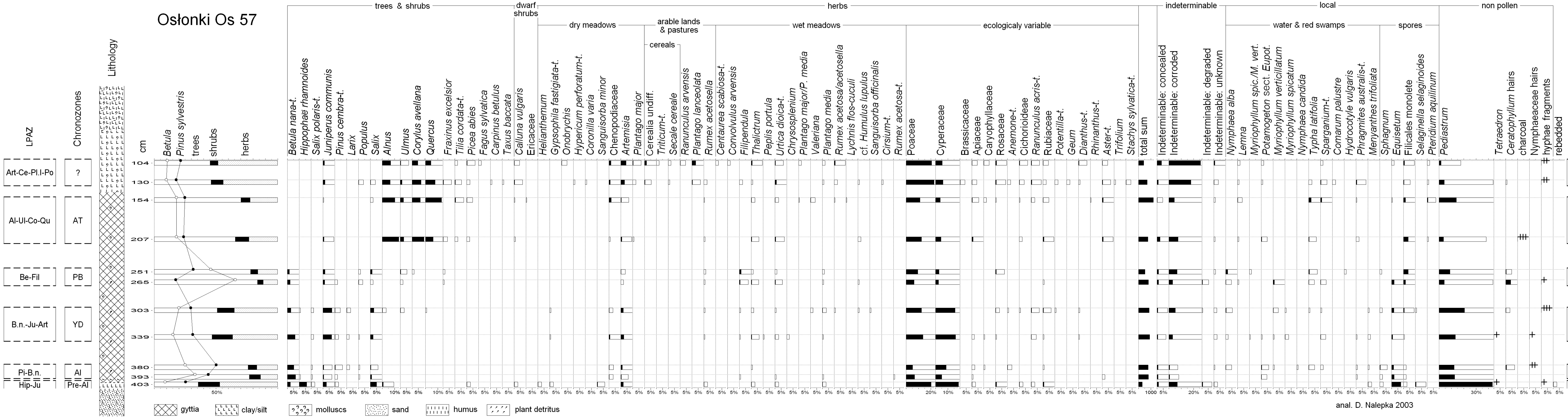


Fig. 16. Percentage pollen diagram of the Osłonki profile Os 57

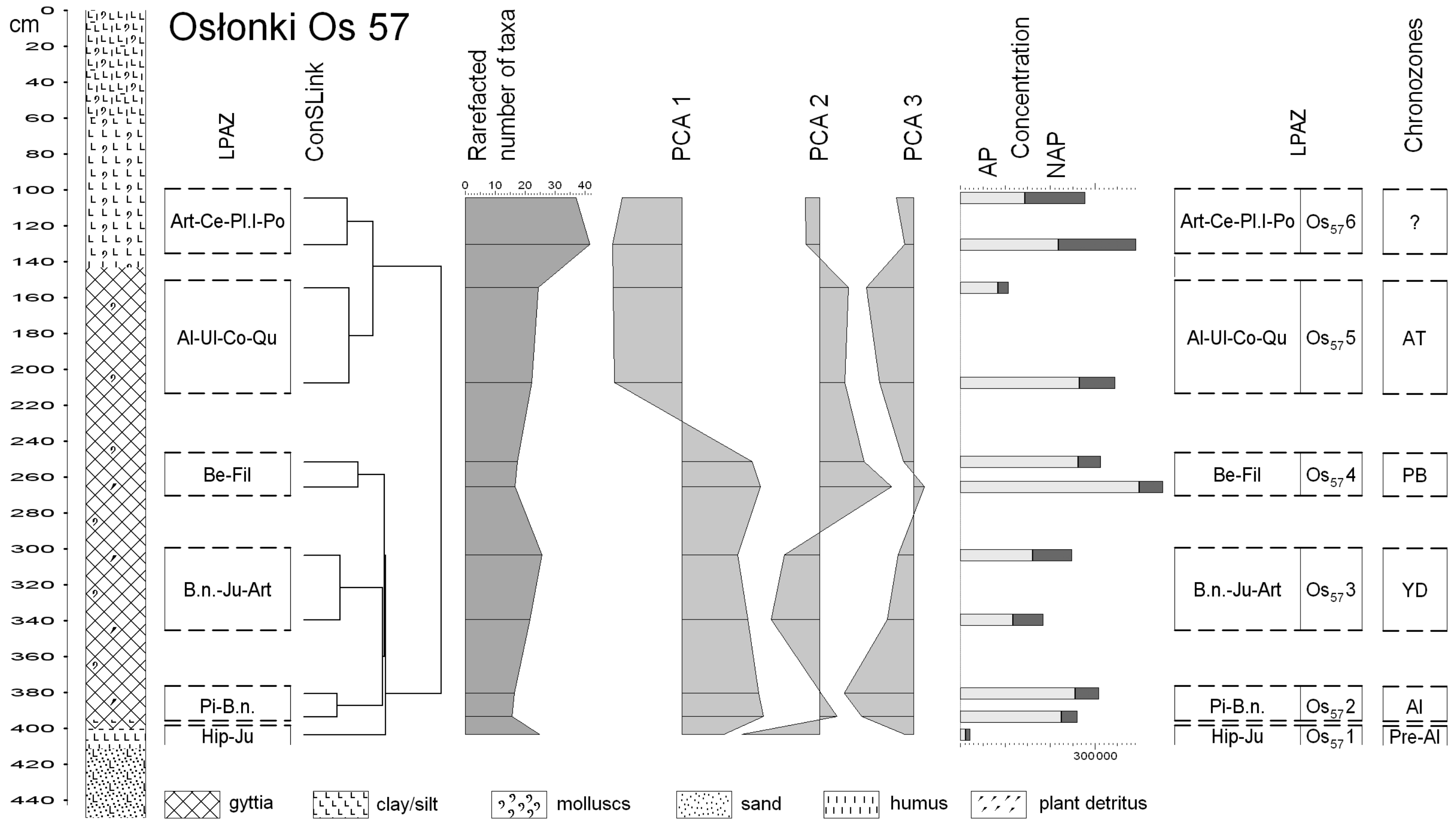


Fig. 17. Concentration and numerical analysis diagrams of the Osłonki profile Os 57

Table 10. Osłonki Os 16. Description of local pollen assemblage zones (L PAZ) (Figs 14, 15)

L PAZ	Name of L PAZ	Depth [cm]	Description of pollen spectra
Os_{16} 1	*Betula-Artemisia*	368–380	The dominance of *Betula* (24.2–52.6%), relatively high frequency of *Artemisia* (1.1–2.3%), presence of *Hippophaë rhamnoides* (0.6%), *Juniperus communis* (0.6–1.0%). The maximum of *Salix* (1.2–7.5%), corroded sporomorphs (2.0–6.5%) and pollen grains recognized here as rebedded: *Alnus*, *Ulmus*, *Corylus avellana*, *Quercus*.
Os_{16} 2	*Betula nana-Juniperus-Artemisia*	330	Only one spectrum included. The dominance of *Pinus sylvestris* (44.3%), relatively high *Juniperus communis* (3.9%) curve, high frequency of *Artemisia* (1.8%). Curve of *Filipendula* continuous although low. Small decrease of corroded (5.6%) and rebedded sporomorphs. *Betula nana*-t. presents only in this single spectrum.
Os_{16} 3	*Betula-Filipendula-Ulmus*	245–290	The dominance of *Betula* (43.4–60.5%). Curve of *Filipendula* continuous although low (0.3–1.8%). In the lower part *Juniperus communis* pollen disappeared. Low value of *Ulmus* (0.4–1.5%). Presence of *Alnus* pollen grains (0.3%). Increase of *Corylus avellana* (0.2–2.3%), decrease of *Artemisia* (0.6–0.3%).
Os_{16} 4	*Corylus-Filipendula*	165	Only one spectrum included. Small frequency of *Alnus* (0.3%) and *Quercus* (0.8%). High frequency of *Corylus avellana* (5.7%), *Filipendula* (1.2%), *Sparganium*-t. (6.5%), and *Typha latifolia* (4.6%).
Os_{16} 5	*Alnus-Ulmus-Corylus-Quercus*	80–140	Higher frequency of *Pinus sylvestris* (15.7–38.4%) and *Betula* (22.4–28.1%). High frequency of *Alnus* (9.3–13.1%), *Corylus avellana* (4.4–12.3%), *Quercus* (4.1–11.1%), *Ulmus* (1.1–3.4%). Increase of *Fraxinus excelsior* (0.3–1.9%) and *Tilia cordata*-t. (0.3–0.8%). In the upper part the presence of a single pollen grain of *Triticum*-t. In the spectrum at 125 cm the highest frequency of corroded sporomorphs (42.9%).

Table 11. Osłonki Os 57. Description of local pollen assemblage zones (L PAZ) (Figs 16, 17)

L PAZ	Name of L PAZ	Depth [cm]	Description of pollen spectra
Os_{57} 1	*Hippophaë-Juniperus*	403	Only one spectrum included. The highest frequency of *Hippophaë rhamnoides* (6.1%), high frequency of *Juniperus communis* (2.9%) and *Salix* (5.2%), as well as corroded sporomorphs (12.9%), Cyperaceae (18.7%) and Poaceae (20.3%). Presence of *Betula nana*-t. (2.6%).
Os_{57} 2	*Pinus-Betula nana*	380–393	Two spectra included. The dominance of *Pinus sylvestris* (43.8–50.1%), high frequency of *Betula nana*-t. (5.3–6.7%), presence of *Pinus cembra*-t. (0.2–0.6%) and single pollen grains of *Larix*. Decrease of *Juniperus communis* (0.8–0.7%), Cyperaceae (5.1–8.8%), Poaceae (5.4–7.0%), and corroded sporomorphs (0.9–1.0%), slight decrease of *Artemisia*.
Os_{57} 3	*Betula nana-Juniperus-Artemisia*	303–339	Two spectra included. The highest frequency of *Juniperus communis* (7.2–7.3%), *Salix* (2.6–3.2%), and *Betula nana*-t. (3.1–6.5%). Presence of *Pinus cembra*-t., *Larix,* and *Salix polaris*-t. Increase of *Artemisia* (2.2–2.6%) and Chenopodiaceae (0.3–1.1%). High frequency of Cyperaceae (16.1–16.3) and Poaceae (12.7–13.7%). Single pollen grains of *Alnus*, *Quercus*, and *Ulmus* recognized as rebedded.
Os_{57} 4	*Betula-Filipendula*	251–265	Two spectra included. The maximum of *Betula* (48.5–65.6%), the highest frequency of *Filipendula* (0.7–1.7%) and *Populus* (0.2–0.4%). Gradual decrease of *Betula nana*-t. (2.5–1.9%), *Juniperus communis* (1.6–1.9%), Cyperaceae, temporary decreases of *Artemisia*, disappearance of *Pinus cembra*-t. The appearance and increase of *Ulmus* and *Corylus avellana*.
Os_{57} 5	*Alnus-Ulmus-Corylus-Quercus*	154–207	Two spectra included. The dominance of *Alnus* (10.4–13.7%), *Corylus avellana* (6.9–9.8%), *Quercus* (6.5–13.1%). The presence of *Tilia cordata*-t. (0.3–0.7%). Increase of Chenopodiaceae (0.1–2.0%) and *Juniperus communis* (0.1–0.9%).
Os_{57} 6	*Artemisia-Cerealia-Plantago lanceolata*-Poaceae	104–130	Two spectra included. The relatively high frequency of *Alnus* (6.7–6.9%), *Corylus avellana* (4.8–7.5%), *Quercus* (4.6–8.0%). Gradual decrease of *Ulmus* (1.7–0.7%) and *Tilia cordata*-t. The rise of *Artemisia*. Appearance of Cerealia undiff., *Plantago lanceolata*, and single pollen grains of weeds. The maximum of corroded sporomorphs.

DEVELOPMENT OF VEGETATION IN THE AREA OF OSŁONKI

Development of the vegetation in the Osłonki area has been characterized after correlation of the local pollen assemblage zones (Tab. 12, Fig. 18), distinguished at all five sites. Based on the available radiocarbon datings they are presented in the periods treated as chronozones in accordance with the convention proposed by Mangerud et al. (1974).

The chronology of events has been described on the basis of the following profiles: Os 94-9, Os 1-2a, and Os 94-5. The data from Os 16 (Figs 14, 15) and Os 57 (Figs 16, 17) have been used only as supplementary ones (because

Table 12. Local pollen assemblage zones (L PAZ), chronoznes and ^{14}C data from all profiles from the Osłonki region. * – not in accordance with palynological dating. BØ – Bølling, OD – Older Dryas, Al – Allerød, YD – Younger Dryas, PB – Preboreal, BO – Boreal, AT – Atlantic, SB – Subboreal.

L PAZ	Name of L PAZ		Depth [cm]	Chronozone	^{14}C BP
		Osłonki Os 1-2a			
$Os_{1\text{-}2a}$ 1	*Pinus-Betula nana-Juniperus*	*Pi-Bn-Ju*	423	Al-b	
$Os_{1\text{-}2a}$ 2	*Betula-Juniperus*	*Be-Ju*	303–325	YD	10470
$Os_{1\text{-}2a}$ 3	*Alnus-Corylus-Quercus*	*Al-Co-Qu*	271–303	AT	6730*
$Os_{1\text{-}2a}$ 4	*Alnus-Ulmus-Corylus-Quercus*	*Al-Ul-Co-Qu*	253–257	AT	
$Os_{1\text{-}2a}$ 5	*Artemisia*	*Art*	230	AT/SB	
$Os_{1\text{-}2a}$ 6	*Corylus-Quercus-Atremisi*a	*Co-Qu-Art*	204–228	SB	4260
$Os_{1\text{-}2a}$ 7	Poaceae	Po	202	?	
$Os_{1\text{-}2a}$ 8	*Artemisia-Plantago lanceolata*	*Art-Pl.l*	115–151	?	
$Os_{1\text{-}2a}$ 9	*Pinus*	*Pi*	106–110	?	
$Os_{1\text{-}2a}$ 10	*Pinus*	*Pi*	30	?	
$Os_{1\text{-}2a}$ 11	NAP	NAP	5–15	?	
		Osłonki Os 94-5			
$Os_{94\text{-}5}$ 1	*Pinus-Artemisia*	*Pi-Art*	318–324	Al-b	
$Os_{94\text{-}5}$ 2	*Betula nana-Juniperus-Artemisia*	*Bn-Ju-Art*	299–312	YD	
$Os_{94\text{-}5}$ 3	*Pinus*	*Pi*	295	PB	8900
$Os_{94\text{-}5}$ 4	*Alnus-Corylus-Quercus*	*Al-Co-Qu*	240–281	AT	6670*, 6470*
$Os_{94\text{-}5}$ 5	*Artemisia-Filipendula*	*Art-Fil*	191	?	
$Os_{94\text{-}5}$ 6	*Artemisia-Plantago lanceolata*	*Art-Pl.l*	131–137	?	
		Osłonki Os 94-9			
$Os_{94\text{-}9}$ 1	NAP-*Betula nana*	NAP-*Bn*	851–860	BØ	
		hiatus			
$Os_{94\text{-}9}$ 2	*Pinus*	*Pi*	820–823	BØ	
$Os_{94\text{-}9}$ 3	*Betula nana-Hippophaë-Juniperus*	*Bn-Hi-Ju*	810	OD	
$Os_{94\text{-}9}$ 4	*Betula nana-Pinus cembra*	*Bn-Pc*	763–801	Al-a	
$Os_{94\text{-}9}$ 5	*Pinus-Betula nana*	*Pi-Bn*	720–748	Al-b	
$Os_{94\text{-}9}$ 6	*Betula nana-Juniperus-Artemisia*	*Bn-Ju-Art*	603–710	YD	
$Os_{94\text{-}9}$ 7	*Betula-Filipendula*	*Be-Fil*	572–597	PB	
$Os_{94\text{-}9}$ 8	*Ulmus-Filipendula*	*Ul-Fil*	513–567	PB	
$Os_{94\text{-}9}$ 9	*Ulmus-Corylus*	*Ul-Co*	348–508	BO	8190*, 8870*, 9010*
$Os_{94\text{-}9}$ 10	*Alnus-Corylus-Quercus*	*Al-Co-Qu*	245–344	AT	8440*
		hiatus			
$Os_{94\text{-}9}$ 11	*Alnus-Ulmus-Corylus-Quercus*	*Al-Ul-Co-Qu*	140–221	AT	5790
$Os_{94\text{-}9}$ 12	*Carpinus*-NAP	*Car*-NAP	112–136	SB	3110
$Os_{94\text{-}9}$ 13	Poaceae?	Po?	108	?	
		Osłonki Os 16			
Os_{16} 1	*Betula-Artemisia*	*Be-Art*	368–380	Al-a	
Os_{16} 2	*Betula nana-Juniperus-Artemisia*	*Bn-Ju-Art*	330	YD	
Os_{16} 3	*Betula-Filipendula-Ulmus*	*Be-Fil-Ul*	245–290	PB	
Os_{16} 4	*Corylus-Filipendula*	*Co-Fil*	165	BO	
Os_{16} 5	*Alnus-Ulmus-Corylus-Quercus*	*Al-Ul-Co-Qu*	80–140	AT	
		Osłonki Os 57			
Os_{57} 1	*Hippophaë-Juniperus*	*Hi-Ju*	403	Pre-Al	
Os_{57} 2	*Pinus-Betula nana*	*Pi-Bn*	380–393	Al	
Os_{57} 3	*Betula nana-Juniperus-Artemisia*	*Bn-Ju-Art*	303–339	YD	
Os_{57} 4	*Betula-Filipendula*	*Be-Fil*	251–265	PB	
Os_{57} 5	*Alnus-Ulmus-Corylus-Quercus*	*Al-Ul-Co-Qu*	154–207	AT	
Os_{57} 6	*Artemisia*-Cerealia-*Plantago lanceolata*-Poaceae	*Art-Cer-Pl.l*-Po	104–130	?	

palynological research has shown considerable gaps in these sequences), and the analysed zones were correlated with those of the basic diagrams.

In the Late Glacial, lake basins developed as a result of processes connected with glacial retreat such as the melting of buried ice blocks left in glacial channels and less frequently of the ice blocks laying outside the channels. Flat surfaces of such blocks were covered with material from the moraines. On these surfaces as a result of progressive warming of the climate, increased moisture provided favourable conditions for the development of pioneer plant communities. In the course of ice melting, those plants became gradually flooded, and become totally submerged. Finally, after melting had been completed the lake was formed and the remains of the plants formed an organic layer at the bottom of the lake (Nowaczyk 1986, Kozarski 1991, Starkel ed. 1991).

In the area of Osłonki, traces of the buried ice blocks have been found at two sites – in the post-glacial channel and in one site outside the

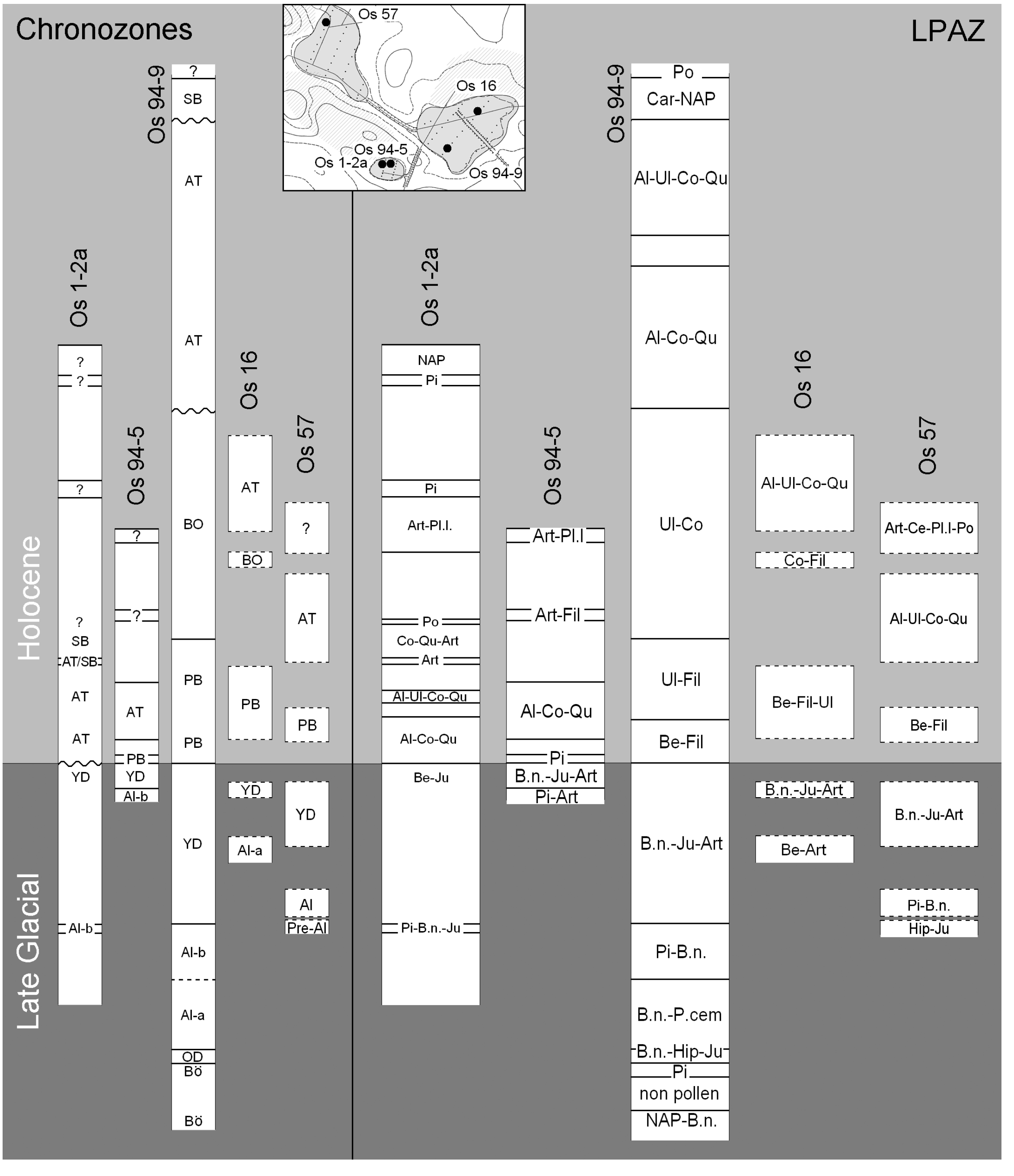


Fig. 18. Correlation of chronozones and local pollen assemblage zones (LPAZ) of all profiles in the Osłonki region. The abbreviations of the pollen zones and the chronozones are explained in Table 12.

channel (Fig. 3). The studied basins with the biogenic accumulation originated from these ice blocks. The oldest organic deposits have been found at the place of the melting ice blocks lying in the eastern part of the glacial channel in the profile of borehole 9 (Os 94-9) at the depth of 852 cm. The pollen spectrum from this horizon, included in the $Os_{94\text{-}9}$1 NAP-*Bn* L PAZ, has been palynologically dated to the Bølling interstadial. The deepest organic horizons at the place of melting of the buried ice block in the western part of the channel have been dated to the pre-Allerød (Os_{57}1 L PAZ). The deepest layers derived from the ice block lying outside the channel in the southern part of the studied area appeared to be younger. These horizons have been palynologically dated to the Allerød chronozone ($Os_{94\text{-}5}$1 *Pi-Art* L PAZ and $Os_{1\text{-}2a}$1 *Pi-Bn-Ju* L PAZ).

Older organic deposits, dated to the Oldest Dryas, have been found outside the study area, about 30 km to the east in the bottom sediments of the Tobyłka Bay of Lake Gościąż (Ralska-Jasiewiczowa et al. 1998) as well as to the north-west in the bottom biogenic sediments of the fossil lake in Bożejewice (Makohonienko et al. 1998), and to the west in the bottom sediments of Lake Gopło (Jankowska 1980). The younger organic sediments accumulating since the Older Dryas, have been studied in the profile of the Potrzymiech Peninsula in the central part of Lake Gopło (Molewski & Noryśkiewicz 2000). For Bożejewice and Potrzymiech sites see page 75. The sediments accumulating since the Allerød have been studied in the profile from Lake Gościąż (Ralska-Jasiewiczowa et al. eds, 1998).

LATE GLACIAL

Bølling

$Os_{94\text{-}9}$ 1 NAP-*Betula nana* L PAZ, $Os_{94\text{-}9}$ 2 *Pinus* L PAZ

The very low frequency of sporomorphs in the blackish-grey, clayey and badly decomposed organic layer (peat?) that includes the local pollen zone described here (Figs 12, 13), makes estimation of the participation of each component of the vegetation cover difficult. Based on the available data (Fig. 12) it can be concluded that during the period discussed, in the vicinity of the investigated site, there was an open landscape of a tundra characterized by developing patches of herbaceous plants and shrubs. Nevertheless, isolated trees were probably present.

In wet habitats, willows (*Salix*) grew and in the developing patches of tundra, thickets of dwarf birch (*Betula nana*) occurred. It is likely that within these communities plants of the Ericaceae family were also present, similarly as in the neighbouring areas, for example in the vicinity of Bożejewice (Makohonienko et al. 1998), Potrzymiech (Molewski & Noryśkiewicz 2000), Lake Gopło (Jankowska 1980) and Lake Gościąż (Ralska-Jasiewiczowa et al. 1998). However, the presence of Ericaceae pollen only in the oldest spectrum (Fig. 12) should be viewed with considerable caution. These pollen grains may have been washed out from the older sediments, which is supported by the presence of redeposited (rebedded) pollen grains of trees with high thermal requirements (*Quercus*, *Picea abies*, *Fagus sylvatica*, *Vitis*). Contamination by younger material during core extraction can be excluded as ericaceous pollen occurs very rarely in the higher part of the core.

Sparganium and/or *Typha latifolia* grew in damper habitats where water melting from the block of ice could have stagnated and formed temporary floodwaters. At this time *Typha latifolia* was still rare, but the presence of its single pollen grains (< 0.1%) has already been at a few sites in central and northern Poland. Its earliest appearance was recorded from the bottom sediments of Lake Mikołajki (Ralska-Jasiewiczowa 1966) and later records dated to the Bølling were obtained at a few sites including Stary Cieszyn (Noryśkiewicz et al. 2000, 2002), Lake Gościąż (Ralska-Jasiewiczowa et al. 1998), Rośle (Krajewski & Balwierz 1984), Bełchatów (Balwierz & Goździk 1997), Niechorze (Ralska-Jasiewiczowa & Rzętkowska 1987), and Witów (Wasylikowa 1964). *Typha latifolia* spread throughout the whole of Poland not earlier than during the Allerød, which can be seen on the isopollen maps for the 11 500 ^{14}C BP horizon (Ralska-Jasiewiczowa et al. 2004a). This taxon formed a component of the reedswamp belt around lakes. The presence of *Typha latifolia* pollen may indicate that the mean July temperatures during this period were not lower than 13°–14°C (Paus 1992) or even 14°–15°C (Wasylikowa 1964, Isarin & Bohncke 1999). Perhaps aquatic plants appeared already at that time, which is suggested by the presence of one pollen grain of *Nymphaea alba* indicating favourable climatic conditions, although a single pollen grain is a weak evidence of this. *Nymphaea alba*, which in Scandinavia grows south of the July isotherm of 15°C (Borówko-Dłużakowa & Janczyk-Kopikowa 1989), may indicate that such temperatures occurred, as suggested by the presence of *Typha latifolia* (see above). In the Late Glacial, at sites situated near the Osłonki area, the development of aquatic plants has been documented by the presence of sporomorphs and macroscopic remains of these plants in the analysed sediments. At Bożejewice, situated north-west of Osłonki, macroscopic remains of aquatic plants, mainly Charophyceae and *Potamogeton filiformis*, although very poorly represented, have been already noted in the zones dated to the Oldest Dryas (Makohonienko et al. 1998). In the bottom sediments of Lake Gopło, located west of Osłonki, at the end of the Oldest Dryas, pollen grains of *Myriophyllum spicatum* and *M. verticillatum* were found (Jankowska 1980). In the profile collected from the lake deposits in Potrzymiech, which at present occurs on the peat plains at the bottom of the Lake Gopło valley, pollen of aquatic plants has been recorded from the oldest zones dated to the Bølling. Similarly dated layers containing macrofossils of *Potamogeton* and *Ceratophyllum* have been noted in the bottom sediments of Lake Gościąż (Ralska-Jasiewiczowa et al. 1998), situated to the east, though farther from the region of Osłonki. Thus, it may be assumed with a high probability that during the Bølling chronozone at Osłonki there already existed conditions favourable for the development of aquatic plants.

The communities of herbaceous plants which developed in habitats of various soil moisture, apart from those already mentioned, included *Filipendula*, *Thalictrum*, grasses (Poaceae) and plants of the following families: Apiaceae, Cyperaceae, Rosaceae, Caryophyllaceae, as well as cryptogamic plants: horsetail (*Equisetum*) and ferns (Filicales monolete). Among the light-demanding herbaceous plants preferring dry habitats, the following were growing: *Artemisia*, Chenopodiaceae, *Helianthemum*, and shrubs of *Juniperus communis* and *Hippophaë rhamnoides* in similar habitats. Cold-resistant *Pinus cembra* could be growing as scattered specimens, based on rare *Pinus cembra*-type pollen grains presence in the sediment. The presence of an arborescent birch (*Betula*) and pine (*Pinus sylvestris*) has been also noted.

The sequence of interpreted events is broken in the lithological profile by a layer of clayey sand, about 30 cm thick, which does not contain sporomorphs. This layer could have been deposited by aeolian processes, which were rather rare during the Bølling chronozone (Nowaczyk 1986), and it could have been a result of one episode of very strong winds (Nowaczyk in prep.). In the following local pollen zone ($Os_{94\text{-}9}$2 *Pi* L PAZ), also included in the Bølling chronozone (Fig. 12), pollen of *Salix polaris* type suggested its presence, indicating arctic willow low mats. In the stagnant flood waters which were developing further into a small and shallow lake (Nowaczyk in prep.), *Nymphaea alba* and *Ceratophyllum* grew. At its bottom, clayey, dark, olive-grey gyttja accumulated, in which mollusc shells were also deposited.

In the dry sites of the studied area, scattered specimens of the light-demanding and cold-resistant larch (*Larix*) grew. In various habitats, from dry to wet, new plants appeared, mainly light-demanding taxa represented by pollen grains of *Gypsophila*, *Helianthemum nummularium*, *H. oelandicum* type, *Peplis*, *Rumex acetosa/acetosella*, *Caltha* type, *Saxifraga oppositifolia* type, Cichorioideae, Rubiaceae, *Ranunculus acris*, *Anemone*, *Menyanthes*, and spores of *Selaginella selaginoides*. However, it is likely that they were already present earlier in the study area, but their pollen was not found due to poor preservation of the sporomorphs and their very low frequency in the spectra.

When comparing the vegetation in the area of Osłonki with vegetation in the neighbouring areas, an assumption can be made that during the Bølling chronozone pine and birch were already growing in this part of Poland, forming stands of park-type or open forests. This cannot be unequivocally stated, as in the four oldest spectra containing the sporomorphs, separated by the sterile mineral deposit, the picture may be considerably deformed. However, the presence of macroscopic remains of cf. *Betula pubescens* in the bottom sediments of nearby Lake Gościąż (Ralska-Jasiewiczowa et al. 1998) representing the support may prove this assumption.

This reconstructed vegetation in both local pollen zones supports the assumption that the investigated site was located in the ecotonal area near the polar forest boundary.

The considerable amount of damaged sporomorphs (Indeterminable: corroded and degraded) reworked from older sediments (rebedded) indicates that during the discussed period vegetation did not form a complete cover. The very low amount of reworked sporomorphs may also imply that the palynological material was intensively damaged in the natural conditions. Only some sporomorphs were sufficiently well preserved to be determined as rebedded. The rest displayed a much worse state of preservation and were included in Indeterminable: corroded and degraded. The study area was undergoing intensive transformations under the influence of atmospheric factors such as wind and precipitation in the form of both rain and snow. The presence of barren sandy surfaces of ablation origin, about 40 cm thick (Nowaczyk in prep.), on which deflation and solifluction took place, resulted in both the deposition of mineral particles in the water basin (clayey gyttja) and the partial or entire destruction of the sporomorphs, resulting in a fragmented picture of the past vegetation interpreted from the bottom part of the diagram.

Older Dryas

$Os_{94\text{-}9}$ 3 *Betula nana-Hippophaë-Juniperus* L PAZ

During the Older Dryas chronozone (Figs 12, 13) the melting of the buried ice blocks was probably set back due to harsher climatic conditions. This assumption is based on a comparison with neighbouring areas, for example with the Bory Tucholskie, ca. 100 km north of the studied area, where ice wedges, radiocarbon-dated to this period, prove an occurrence of permafrost lasting many years (Nowaczyk in prep.). Climate deterioration was reflected in changes of vegetation. In the landscape there was a decrease in pine and birch, which were probably rare and forming open stands, and the cold resistant larch (*Larix*) were growing as the scattered specimens. More favourable conditions became prevalent for the development of light-demanding plants, both herbaceous (NAP) and shrubs. They caused *Juniperus communis* stands to develop well and *Hippophaë rhamnoides* to grow in great abundance in the study area.

The wet habitats were favourable for willows development, where their thickets became increasingly dense. The stands of dwarf birch (*Betula nana*) were still developing. The communities of herbaceous plants (not only light-demanding) became enriched with new taxa from ecologically various habitats such as *Potentilla*. Ferns and horsetails had favourable conditions to produce spores and thus to continue their development. At the wet shores of the shallow lake *Menyanthes trifoliata* and *Phragmites australis* appeared.

At the bottom of the basin, black clayey gyttja was accumulating, displaying a slight increase in organic matter and the presence of the fragments of mollusc shells.

In divisions of pollen diagrams covering the Late Glacial, the Older Dryas stadial is either distinguished or not distinguished (Starkel 1991). When it is not distinguished, the earlier (Bølling) and the later (Allerød) interstadials are linked into one complex. The possibility of finding the Older Dryas is expected first in areas, where vegetation cover was influenced by a drier continental climate and not wet oceanic climate (van Geel & Kolstrup 1978). If that stadial had been distinguished and moreover it has been dated, it turned out that it lasted around 200 radiocarbon years (12 000–11 800 ^{14}C BP), i.e. it was relatively short. This is the second reason for the Older Dryas being hard to observe in the analysed profiles. The problem of distinguishing Bølling and Allerød interstadials and the Older Dryas stadial was discussed by de Klerk (2004). It is difficult to characterize more precisely this period in the region of Osłonki because its interpretation is based on only one pollen spectrum (the Os 94-9 profile). In the analysed deposits from Lake Gopło (Jankowska 1980) and Potrzymiech (Molewski & Noryśkiewicz 2000) this period has been distinguished on the basis of similar pollen curves based on more spectra, but these sites are situated in a slightly different geographic area. An additional difficulty results from the fact that not all the researchers distinguish the Older Dryas chronozone, applying other criteria to their pollen diagram classification. The Bożejewice site (Makohonienko et al. 1998) is such an example where the authors combined the earlier and later chronozones into one Bølling /Allerød complex.

In spite of the very limited data based on one pollen spectrum, it may be assumed that vegetation developed in a similar manner as at the sites neighbouring the Osłonki area to the west (Lake Gopło, Potrzymiech). East of Osłonki in the Wisła valley, in the region of Lake Gościąż, during this period *Hippophaë rhamnoides* and *Juniperus communis* thickets were scarcer, which may be explained as a result of the drier and perhaps more continental climate (van Geel & Kolstrup 1978).

The oscillations in the pollen percentages of *Hippophaë rhamnoides* are difficult to correlate and interpret in the context of regional changes of climatic conditions in the particular stadials and interstadials of the Late Glacial. The values of its pollen at one site may even reach a high value, for example in Chojna, in north-western Poland, where in the Bølling these values exceed 30% (Krupiński 1988, 1991) or in Rośle in the Łódź Upland they are even up to 36% (Krajewski & Balwierz 1984). During the same period at neighbouring sites its values are much lower, usually about 1%. However, its highest values are always recorded from the pre-Allerød period, for example in the Oldest Dryas in the Bory Tucholskie in Mukrz (Noryśkiewicz 2002), in the Oldest Dryas and in the Bølling in the Wielkopolska region in Imiołki (Tobolski 1998) and in the Łódź Upland in Rośle (Krajewski & Balwierz 1984) and Witów (Wasylikowa 1964, 2001), and prior to the Bølling in the Wisła valley at the site of Gościąż (Ralska-Jasiewiczowa et al. 1998). Thus, it seems that the presence of *Hippophaë rhamnoides* may be characterized only locally, accepting that the best time for its development occurred prior to the Allerød. Such a picture is also reflected in the isopollen maps for this taxon (Krupiński et al. 2004).

Allerød

Allerød – a

$\mathbf{Os_{94\text{-}9}}$ 4 *Betula nana-Pinus cembra* L PAZ

During this period the progressive process of thawing of buried ice blocks (Nowaczyk in prep.) indicates an amelioration in the climatic conditions. Thawing of the ice block in the glacial channel, from which the profile Os 94-9 was taken, caused the depth of the lake to increase. At the bottom of the lake, gyttja clay (to a small extent) accumulated. In that sediment the sporomorphs displayed better preservation than those from the previous period, thus reflecting the composition of the pollen rain more reliably. In this part of the profile (Figs 12, 13), gyttja was characterized by a black colour, which may point to the deficiency of oxygen during its deposition, similarly as in the profile from Bożejewice (Makohonienko et al. 1998). Shells of molluscs were continuously deposited in this gyttja.

The responce to the amelioration in climatic conditions was the development of populations in this area of open birch and pine forests. However, a part of the studied area was still occupied by light-demanding herbaceous plants, shrubs (among which *Ephedra* appeared), and cold-resistant trees, including stone pine (*Pinus cembra*), aspen (*Populus*), and larch (*Larix*).

In the zone under discussion, the relatively high pollen values of stone pine (*Pinus cembra*) (up to 1%, and in one spectrum > 2%), forming almost a continuous curve, are characteristic (Fig. 12). In central and northern Poland, apart from the Osłonki profile, its pollen has been identified only in a few profiles from the sites of Wolbrom (Latałowa & Nalepka 1987), Aleksandrów (Balwierz pers. com.) and Woryty (Pawlikowski et al. 1982), in the lakes of Kwiecko (Madeja 2003), Mukrz (Noryśkiewicz 2002), and Miłki (Wacnik et al. 2001, Wacnik 2003) as well as Niechorze (Ralska-Jasiewiczowa & Rzętkowska 1987). Wacnik (2003) has assumed that in north-eastern Poland, pollen of *Pinus cembra* occurring in the oldest Late Glacial spectra derives from Tertiary redeposition (*Pinus cembra*/*haploxylon*), and its later records might have been blown from the south of Poland where stone pine was growing in situ. Perhaps the most northern position of stone pine growth was in the Silesian-Kraków Upland in the area of Wolbrom, because on the point pollen map, at the 12 500 ^{14}C BP horizon the value of its pollen is 5.3% (Obidowicz et al. 2004). However, it should be remembered that in the original publication *Pinus cembra* in Wolbrom was determined as *Pinus haploxylon* (Latałowa & Nalepka 1987).

Further to the north, in Central Poland, in Aleksandrów (Balwierz pers. com.), only a single pollen of stone pine has been noted in one of the oldest spectra. At the other sites these values are also low (Obidowicz et al. 2004). It might seem that the almost continuous pollen curve, as well as values reaching up to 1%, point to the presence of this tree in the close vicinity of Osłonki. However, this cannot be unequivocally stated, for in the Os 94-9 profile, in the same local pollen zone (Allerød -a), redeposited pollen grains of warmth-loving trees (*Alnus*, *Ulmus*, *Corylus avellana*, *Quercus*) are still recorded (Fig. 12). Maybe some of the stone pine pollen grains belong to those redeposited (*Pinus haploxylon* type?), but some might have been blown from sites south of Kujawy. It was a period when in the study area open birch and pine forests was developing but woodless areas also existed. Pollen of stone pine could therefore have been transported over great distances with no problem.

Similarly, an almost continuous curve, although of lower values, is formed by poplar pollen (*Populus*). With no doubt its pollen can be interpreted as coming from aspen growing in situ. Aspen is a non-demanding tree that belongs to the earliest colonizers of open areas. Its pollen is not adapted to being transported over long distances, thus even its small amount in the profile confirms its presence in the local vicinity. However, its small amount at the majority of sites in Poland is noted in the pollen spectra dated to the Allerød chronozone.

A single grain of larch pollen (*Larix*) may also indicate the presence of this tree in the neighbourhood of the studied site, because its pollen also shows no obvious adaptation to long-distance transport.

Tundra with dwarf birch and arctic willow (*Salix polaris*) was still developing in the wet habitats. In the stagnant water of the lake there were already richer plants, represented by those rooted in the muddy bottom, including *Nymphaea alba*, *Nuphar lutea*, *Myriophyllum spicatum*/*verticillatum*, *Ceratophyllum*, and *Potamogeton* (sect. *Eupotamogeton*). They indicate that it was a shallow basin quite abundant in nutrients (Nowaczyk in prep.). Some parts of the water surface were covered with *Lemna*. Plant communities formed a kind of mosaic and overlapped with each other. In the littoral sectors where the basin was shallow (from a few cm to 1.5 m) and the water could have periodically dried up, marshy and reedswamp communities developed. Besides *Typha latifolia*, *Sparganium*, *Phragmites australis, Equisetum*, and Cyperaceae as well as *Menyanthes trifoliata* and *Comarum palustre* could have been growing there. In these habitats the conditions were also favourable for *Pediastrum*, whose presence may be indicative of an increase in the lake trophic status (Milecka 1997, Jankovská & Komárek 2000, Komárek & Jankovská 2000).

Similar conclusions concerning the character of the lake basin result from the malacological analyses (Alexandrowicz in prep.). They indicate that during this period it was a shallow basin with a muddy bottom, periodically drying up. It is very likely that mineral matter, permanently present in the lake bottom sediments, could have been derived mainly from these periodically dried up banks. Such conditions in the lake itself were very good for aquatic and marsh plants, whereas they appeared to be unfavourable for molluscs, which were very poorly developing there. The malacological analyses also indicate that this basin was surrounded by wet meadows, episodic flood plains, and open meadow habitats (Alexandrowicz in prep.), which were populated by the plants characterized above on the basis of the pollen analysis.

During this period the open areas with no vegetation shrank into the areas periodically flooded/dried up in the shoreline belt of the basin. These areas were still a source of pre-Quaternary sporomorphs included in the mineral sediment eroded into the basin. This process also caused damage to the contemporaneous sporomorphs and was responsible for the fluctuations in their number in the bottom sediments. A very significant fall in pollen concentration of *Pinus sylvestris*, *Betula*, Cyperaceae, and Poaceae at the depth of 790 or 788 cm and 740 cm (Fig. 13) might have also been caused by a short-lived water outflow following heavy and long-lasting rains or from thawing after snowy winters (Nowaczyk in prep.). Nevertheless, the distinct development of aquatic plants, a decrease in the number of corroded and redeposited sporomorphs, as well as an almost complete lack of degraded sporomorphs indicate an increasing density of plant cover in the adjacent areas. Based on this, as well as on the fact that during this period an increase in blue-green algae of the *Tetraedron* was noted in the sediments of Lake Gościąż (Ralska-Jasiewiczowa 2000), a progressing warming of climate can be concluded.

The development of vegetation in the area of Lake Gopło displays a very similar character (Jankowska 1980, Molewski & Noryśkiewicz 2000, Makohonienko pers. com.) and occurred in a typical manner for this part of Poland and Europe (Ralska-Jasiewiczowa & Latałowa 1996).

Allerød – b

$Os_{94\text{-}9}$ 5 *Pinus-Betula nana* L PAZ; $Os_{1\text{-}2a}$ 1 *Pinus-Betula nana-Juniperus* L PAZ; $Os_{94\text{-}5}$ 1 *Pinus-Artemisia* L PAZ

From this time on, the interpretation of the palynological diagrams (Figs 8–11) from two profiles (Os 1-2a and Os 94-5) from the southern basin, situated a few hundred metres to the south-west of the eastern basin (Fig. 3), has provided additional data regarding the character of the vegetational development. The appearance of the southern open water also resulted from the melting of a block of buried ice, thus being similar in its origin to the previously described lake, but in a slightly different geomorphologic situation, as that block was lying outside the glacial channel (Nowaczyk in prep.).

In dry areas the landscape became dominated by pine, forming open pine forests with an admixture of tree birch (*Betula*). Birch trees could have been more numerous in sites where the forest was relatively thin or at the forest edges. Some scarce *Pinus cembra*, *Larix*, and *Populus* could have also been growing there. Birch trees may have formed a lower forest layer in a similar way as in Bożejewice, characterized by Makohonienko et al. (1998). The polar forest boundary had already shifted to the north of the study site. *Juniperus communis* was still present in the treeless areas with much insolation, though these areas were smaller than previous ones. *Ephedra* shrubs (pollen of *Ephedra fragilis* type) also inhabited dry and open sites.

In the reduced open spaces, the communities of herbaceous plants growing in various habitats still had good conditions for their development. The members of these communities were represented by Poaceae and *Artemisia*, whith various plants as the Ranunculaceae, Caryophyllaceae, Apiaceae, Rubiaceae, Asteraceae, Rosaceae, and *Filipendula*. Apart from the above, other herbaceous plants appeared such as *Pleurospermum*, *Mentha*, and the fern *Thelypteris palustris*.

In wet habitats around the basins conditions for the development of both willow thickets (*Salix*) as well as patches of tundra plants with arctic willows (*Salix polaris*) and dwarf birch (*Betula nana*) still persisted, although they were not as abundant as before. The wet areas still provided favourable conditions for the development of communities of marshy and reedswamp herbaceous plants with Cyperaceae, *Sparganium* or *Typha*, and *Menyanthes trifoliata* among which peat moss (*Sphagnum*) were growing. Shallow hollows with stagnant water may have been overgrown with *Lemna*. In the shallow water algae of the *Pediastrum* genus were also growing.

At the end of the period *Nymphaea alba* might have required improved conditions for its development (Fig. 12). Aquatic plant communities of a present day *Myriophyllo-Nupharetum*-type, which started to develop in the previous period were already present. In modern times such plants are typical of European eutrophic lakes with low transparency and small or moderate amounts of humic substances (Szafer & Zarzycki 1972). Thus, it may be assumed that it was, shallow lake (Nowaczyk in prep.) with eutrophic water. Such ecological conditions were still unfavourable for the development of molluscs, as indicated by the unchanged fauna compared to the previous period (Alexandrowicz in prep.).

The variable concentration of sporomorphs in the Os 94-9 profile (Fig. 13), particularly in the middle part of this period, may still have been a result of local processes connected with the removal or displacement of part of the sediment. Overfilling of the hollow and water overflowing outwards the depression area as a consequence of torrential rains might have caused removal. Another explanation suggests that sudden thaws, which resulted not from major climatic changes but from such extreme phenomena were important (Nowaczyk in prep.). Such an interpretation is supported by the considerable numbers of indeterminable sporomorphs (corroded and concealed) in the sediment.

The pattern of the pollen curves, showing the expansion of pine forests with an admixture of birch is similar to diagrams from neighbouring sites (Jankowska 1980, Ralska-Jasiewiczowa & Latałowa 1986, Ralska-Jasiewiczowa et al. 1998, Molewski & Noryśkiewicz 2000, Makohonienko pers. com.). This similarity enables some biostratigraphic correlations to be made. Thus, the discussed fragment of the diagram (Fig. 12) can be correlated with the younger (later) phase of Allerød (Al-b), i.e. with the pine phase.

Younger Dryas

$\mathbf{Os_{94\text{-}9}}$ 6 *Betula nana-Juniperus-Artemisia* L PAZ; $\mathbf{Os_{1\text{-}2a}}$ 2 *Betula-Juniperus* L PAZ; $\mathbf{Os_{94\text{-}5}}$ 2 *Betula nana-Juniperus-Artemisia* L PAZ

In the older part of this period, the melting of the buried ice blocks was nearing the end. The lakes that originated from this melting in the area of Osłonki were not deep, and as stated by Nowaczyk (in prep.), the water depth in the deepest place of the eastern basin reached about 6.5 m.

During this period unfavourable thermal conditions caused the gradual opening of the landscape. Light-demanding herbaceous plants and shrubs dominated again (Figs 8, 10, 12). There was a successive decrease in the participation of pine (*Pinus sylvestris*), which was gradually eliminated to a few stands and at the end of this period could have been scattered. The limited participation of woody birches persisted until the younger part of this period. In the expanding open areas, larch (*Larix*) and poplar (*Populus*) were growing. The following question returns again whether stone pine could have been really growing in the area of Osłonki or whether its pollen was blown from the south and/or was redeposited from older sediments. This problem has been already discussed in the description of the older part of the Allerød. In the analysed section the well-preserved grains of *Pinus cembra*-type pollen generally exclude their origin being from redeposition, despite the fact that the supply of mineral matter from the shores still took place, although it was gradually decreasing. It seems to be more likely that its pollen could have been blown from areas in the south. The nearest documented site of stone pine was at Wolbrom in the Silesian-Kraków Upland (Latałowa & Nalepka 1987). During the Younger Dryas stone pine pollen could have been even more easily transported over longer distances than in the Allerød chronozone, when the landscape was dominated by the open birch-pine and pine forests. Moreover, in the Younger Dryas there was again more stone pine pollen than in the earlier period (Obidowicz et al. 2004) as a consequence of the deterioration of climatic conditions.

Hippophaë rhamnoides appeared again, but it was probably very scattered due to the presence of other plants that were more competitive in occupying the area. Single pollen grains of this shrub have also been found in Bożejewice (Makohonienko et al. 1998). However, during this period juniper (*Juniperus communis*) had optimal conditions for its extensive development (probably the most favourable since the last glaciation) and it could have formed dense stands in dry habitats.

Differences in juniper distribution in the Younger Dryas have been already considered by Noryśkiewicz (Molewski & Noryśkiewicz 2000). In this period in the area of Biskupin, juniper communities dominated (max. 14.8% pollen), whereas in the area of Lake Gopło they were poorer, as indicated by low percentage values. Next to Lake Gopło in the north, in Bożejewice the maximum values reach 2.4% (Makohonienko pers. com.), while in the central part of Lake Gopło they are about 1% (Jankowska 1980), and in Potrzymiech 0.8% (Molewski & Noryśkiewicz 2000). Again, its amount is higher east of Gopło in the area of Osłonki (Os 1-2a max 6.8%, Os 94-5 max 8.7%, Os 94-9 max 7.5%), and still further to the east in the Wisła valley at Gościąż it is up to 10% (Ralska-Jasiewiczowa et al. 1998). The lower values in the profiles from Tobyłka (2–4%) result from the local character of this site in relation to the deepest part of Lake Gościąż (Ralska-Jasiewiczowa et al. 1998). Such a phenomenon in the Biskupin region has been explained by the differences resulting from varied surface topography, for example by the existence of dry elevations in the bottom of the channel in the form of kame ridges and mounds, which were favourable for the development of shrub communities that formed a natural "filter" for transported pollen grains of herbaceous plants, and on the other hand by the fact that the Gopło area was flat and open (Molewski & Noryśkiewicz 2000). The area of Osłonki and the Biskupin region are situated slightly higher than the sites in the glacial channel of Lake Gopło at 80 m a.s.l. In the area of Osłonki the differences in relief range from 86 to 94 m a.s.l. (Nowaczyk 2005), while the Wisła valley is a flat area, lying at about 60 m a.s.l., and covered with sandy soils (Lake

Gościąż) which are very favourable for juniper. For further discussion, see also page 77.

The significant development of herbaceous plants indicates the presence of edaphically differentiated sites, which could have been populated by them. The composition of varied communities of herbaceous plants in dry habitats, dominating larger and larger areas, included the following: *Artemisia*, Chenopodiaceae, *Helianthemum*, Poaceae, *Galium*, as well as *Ranunculus acris* type, Rosaceae, and *Pteridium aquilinum*. Particularly light-demanding herbaceous plants such as *Gypsophila*, *Dryas*, *Helianthemum*, *H. nummularium*, *Sedum*, *Onobrychis* (xerothermic communities?), and *Epilobium* (its pollen for the first time was noted in the diagram, Fig. 12), appeared again.

In wet habitats, tundra with dwarf birch (*Betula nana*) and arctic willow low mats (*Salix polaris*) was still well developed. In this period *Selaginella selaginoides* found ideal conditions for its development here. The willow thickets also developed well and in the wet habitats there were favourable conditions for the occurrence of herbaceous plants, including *Filipendula*, *Thalictrum*, *Urtica*, *Caltha*, *Sanguisorba officinalis*, and *Rumex acetosa/acetosella*, as well as (for the first time recorded in the pollen spectra), *Solanum dulcamara*, *Humulus lupulus*, *Epilobium*, *Sagina*, and *Lysimachia*.

On the shores around the ponds stands of Cyperaceae, *Typha latifolia*, *Sparganium*, *Phragmites australis*, and *Menyanthes trifoliata* formed part of the reedswamp belt. In wet habitats, peatmoss (*Sphagnum*) grew. Colonies of *Pediastrum* and *Tetraedron* also developed in the wet sites that were periodically flooded or in the permanent shallow hollows. Some habitats may have temporarily dried up which is shown by the considerable participation of hyphae fragments in the studied spectra of the profile from the southern basin (Figs 8, 10). They were still a source of mineral matter and sporomorphs redeposited from older periods. However, the decreasing participation of the mineral fraction and the disappearance of redeposited sporomorphs indicate that despite the worse climatic conditions almost the entire area was covered with plants, and only such temporarily dried-up shores of basins could remains without a plant cover for some time.

The amount of organic matter (Fig. 13) maintained a relatively stable level (about 20%). The stagnant waters were, however, not clear waters. On the bottom of the basins *Nymphaea alba*, *Potamogeton* (sect. *Eupotamogeton*), *Nuphar lutea*, and *Myriophyllum verticillatum* were present, indicating further development of aquatic communities of the present day type *Myriophyllo-Nupharetum*. However, abundant *Myriophyllum spicatum* is very sensitive to shade and non clear water and is a component of a pioneer community of mineral habitats in quite shallow waters (Matuszkiewicz 2001). Thus, it may be assumed that a mosaic of habitats was developing depending on distance from the shoreline towards the deeper parts of the lake basin. The water surface was partly covered with *Lemna*. Despite deterioration of climatic conditions the communities of aquatic plants were developing well without any obstacles, perhaps even better than in the Allerød interstadial. Aquatic plants do not react quickly to climatic cooling as the temperatures in the water basins change more slowly than in the surrounding area, and thus the favourable local conditions for the development of more demanding plants could be prolonged (Iversen 1954, Wasylikowa 1964, Tobolski 1976).

For the moment it has been possible to characterize the local conditions within the eastern basin not only on the basis of the preserved plant microfossils (Nalepka et al. 1998, Gąsiorowski & Nalepka 2004) and the macroscopic remains of molluscs (Alexandrowicz in prep.) but also on the interpretation of the results of the cladoceran analysis (Gąsiorowski & Nalepka 2004, Gąsiorowski in prep.).

The initial presence of rare cladoceran species in the lower part of the discussed local pollen zone, characterizes the basin as a small lake of a low trophy and low pH. Slightly higher up, including the central part of the Younger Dryas, the presence of many new species in various habitats indicates that in this period the small lake had a well-formed zone of open water and a littoral area (Gąsiorowski & Nalepka 2004). Macrophytes, i.e. plants submerged in water, were intensively developing. Also present were the exposed, non-overgrown fragments of the basin floor. This is in accordance with the palynological interpretation in showing that in the littoral zone aquatic and marshy plants were growing and that their participation decreased towards the open waters. However, for molluscs the conditions were not favourable, the same as in the preceding period (Allerød). They were still living mainly in the shallow parts of the basin with a muddy bottom (Alexandrowicz in prep.).

This picture suggests that the changes which must have occurred in the landscape were due to the deterioration of climatic conditions. Additional, non-palynological indication of those changes in the Younger Dryas is given by a considerable decrease in the calcium carbonate content in core Os 94-9 (Fig. 13), as at Bożejewice (Makohonienko et al. 1998), where a break in sedimentation of $CaCO_3$ occurred in that period.

Towards the close of the Younger Dryas there was a significant decrease in the participation of the floristic elements indicating the cold period (*Betula nana*, *Juniperus communis*, and *Artemisia*), and the amount of *Betula* pollen shows an increasing tendency (Fig. 12). Similarly, in the upper part of this pollen zone in Os 94-9 changes in the cladoceran composition have been noticed, reflecting changes in the aquatic environment (Gąsiorowski & Nalepka 2004, Gąsiorowski in prep.). At the same level changes in the mollusc assemblages were marked. A quite rich development of molluscan assemblages indicates a considerable improvement in conditions within the shallow basin (Alexandrowicz in prep.). Also here in the upper part in gyttja, the amount of calcium carbonate increased quite rapidly (Fig. 13), indicating progressive warming.

On the basis of similarities to the regional features in the other pollen diagrams from this part of Poland (Ralska-Jasiewiczowa & Latałowa 1996), this biostratigraphically described zone can be correlated with the Younger Dryas stadial. The only radiocarbon date obtained from the studied cores (from the Os 1-2a profile), 10 470$\pm$ 90 ^{14}C BP (10 750–10 200 BC1 and 10 900–10 000 BC2), supports this correlation. Its identification in the pollen diagram Os 94-5 and Os 94-9 is distinctly confirmed by the ConSLink analysis (Figs 11–13).

HOLOCENE

The older part of the Preboreal chronozone

Os$_{94\text{-}9}$ 7 *Betula-Filipendula* L PAZ; Os$_{94\text{-}5}$ 3 *Pinus* L PAZ

In the early phase of the Preboreal chronozone (Figs 10–13) the areas previously populated by light-demanding plants started to diminish and their habitats became occupied by birch forests. Birch reacted quickly to the climatic warming, which is reflected in its increasing participation to the highest percentage values in the whole diagram (Fig. 12) and high pollen concentration (Fig. 13), along with fluctuating concentration of *Pinus sylvestris* pollen (even with a tendency to fall). A similar occupation of the area by forests whose main component was birch, was described at Bożejewice by Makohonienko (Makohonienko et al. 1998) and at Lake Gopło by Jankowska (1980), whereas in the vicinity of Lake Gościąż the main element of the forests was pine. This probably resulted from trees occupying different soil substrata in the Kujawy region. Lake Gościąż is situated on sand in the Wisła valley (Ralska-Jasiewiczowa et al. eds, 1998), on which pine develops better than birch.

In open areas, where tree cover was still sparse with a park-type character or in the forest gaps or at the forest edges, aspen (*Populus tremula*) and rare larch trees (*Larix*) were still growing. Not far from the studied site the earliest elms (*Ulmus*) could have been growing. These probably migrated from the south-east (Ralska-Jasiewiczowa 1983, Zachowicz et al. 2004). Forests were overgrowing large areas, therby limiting the areas of the dry habitats occupied until then by light-demanding herbaceous plants such as *Artemisia* and Chenopodiaceae and shrubs of *Juniperus communis*, whose stands probably underwent considerable reduction. In the wet, woodless areas or along the forest edges, tall-herb communities with *Filipendula*, *Urtica*, and *Ophioglossum* were still present. At the same time communities with Cyperaceae and Poaceae were losing their significance, which may have been partly connected with the marked reduction of tundra habitats. This is show by the considerable decrease in *Betula nana* type and *Salix polaris* type pollen (Fig. 12).

The aquatic plants were still developing well. In consequence, the shallowing of the basin, which had already started earlier, continued due to natural succession. In this zone the first maximum of the microscopic remains of *Ceratophyllum* sp. is visible in the diagram (Fig. 12). This plant is insensitive to shade and to very low water transparency. It may develop in stagnant water under a cover of other communities (Matuszkiewicz 2001), deeper than water lily, down to 3 m (Faliński 2000). Also in this zone there appeared a small amount of the pollen of *Nymphaea candida*. At present this plant usually occupies shallow basins significantly poor in nutrients (Matuszkiewicz 2001). Thus, the fall of *Myriophyllum spicatum* pollen and the development of *Ceratophyllum* sp., *Nymphaea alba* and *N. candida* provide evidence for the basin shallowing due to a natural succession. However, the presence of *M. verticillatum* pollen indicates also the occurrence of such areas where the water was deeper. Perhaps these aquatic plant communities still formed a kind of interwining mosaic.

The beginning of this stabilized period in the basin history, being gradually overgrown by aquatic plants, is also reflected by the structure of the cladocera assemblages (Gąsiorowski & Nalepka 2004, Gąsiorowski in prep.). Similar conclusions result from the analysis of the molluscan remains comprising the whole Preboreal chronozone, i.e. *Be-Fil* and *Ul-Fil* both L PAZ's). In the early Holocene a stable lake basin was formed, with stable ecological conditions with abundant vegetation and supporting a rich assemblage of molluscs (Alexandrowicz in prep.).

This zone reflects an amelioration of climatic conditions due to a rise in temperature. This warming resulted in the final disappearance of the arctic tundra communities and in the development of forests. At first birch and birch-pine forests developed, as the mesophilous trees had not reached the study area due to their slower biologic responses. Thus, this zone in the pollen diagram can be biostratigraphically correlated with the beginning of the Holocene, i.e. with the Preboreal chronozone. The investigations of annually laminated sediments from Lake Gościąż have shown that the warming at the Late Glacial/Holocene boundary was very striking and quick. The mean annual temperature increased by 5°C, and this took place during about 70 years (Ralska-Jasiewiczowa et al. eds, 1998).

The younger part of the Preboreal chronozone

$Os_{94\text{-}9}$ 8 *Ulmus-Filipendula* L PAZ

During this time the final disappearance of tundra communities with *Betula nana* took place (Figs 12, 13) and the minimum of Cyperaceae occurrence might have been connected with that process. Pine-birch and birch-pine forests dominated the landscape. Elm (*Ulmus*), which had already reached the study area (Zachowicz et al. 2004), could have formed a small component within these forests. The presence of *Populus* pollen (Fig. 12) indicates that there may still have existed open woodless areas, but they were not very widespread which is proved by the fall in Chenopodiaceae and *Artemisia* pollen and by the very small amount of *Juniperus communis* pollen. Hazel (*Corylus avellana*) spread into these areas and its significant development started at the end of this period. Also in this area the first oak trees (*Quercus*) appeared from the north-west direction, in accordance with isopollen maps (Milecka et al. 2004). Elm and oak may have occupied the area through the colonization of wet sites next to the willow thickets. Perhaps these lowlands provided an easier migration route than through the dry upland habitats.

At the end of this period bracken (*Pteridium aquilinum*) was growing within the undergrowth of the pine and mixed forests. Among the herbaceous plants in the wet clearings, and perhaps also at the edges of forests, tall-herb communities with *Filipendula*, *Thalictrum*, *Urtica*, and *Solanum dulcamara* were still present. The willow thickets, developing in wet habitats, occupied smaller areas than in the preceding period. It is likely that poplar (*Populus*) was also one of their components, forming communities similar to the present wetland willow–poplar forests (*Salici-Populetum*). These thickets were adjacent to the richly developing belt of reeds, which is indicated by the increasing participation of *Typha latifolia* and *Sparganium* type pollen in the diagram (Fig. 12). *Pteridium aquilinum* spores appeared in the diagram simultaneously with both the end of the occurrence of *Equisetum* and the decrease in the amount of organic matter (i.e. at the boundary between this L PAZ and the preceding one).

The lake was already considerably shallow, which is indicated by the almost complete disappearance of pollen of *Myriophyllum*. Next, *Nymphaeion* communities began to develop by a natural succession (Matuszkiewicz 2001). The continued significant presence of *Nymphaea alba* pollen (Fig. 12) also indicates that the water was more shallow and eutrophic. Today this plant is a component of the water-lily association *Nupharo–Nymphaetum albae*, which due to the very high biomass production plays the main role in the succeeding stages of the basin becoming shallower and more overgrown (Matuszkiewicz 2001). The presence of *Nymphaea candida* pollen confirms that the lake basin became considerably shallower but was impoverished in nutrients (Matuszkiewicz op. cit.). The ecological conditions of the lake were still very favourable for molluscs, permitting the development of rich molluscean populations. They also indicate the same as the plants, namely that it was a stable lake basin with a rich vegetation, colonised by an increasingly abundant assemblage of snails (Alexandrowicz in prep.). Cladocera also point to a stable period in the lake history, being gradually overgrown by the aquatic plants (Gąsiorowski in prep.).

During this period, it can be seen that fundamental transformations in vegetation were taking place. The open spaces diminished, and the ground was covered with rather scattered forests in which small gaps were frequent. The communities of arctic plants disappeared completely and mesophilous deciduous trees, requiring a mild climate, started their expansion. At the very end of this period, lime (*Tilia*) and ash (*Fraxinus excelsior*) have a weak but unstable presence in the pollen rain, suggesting that they had reached the study area from neighbouring regions.

At the shore of the overgrown lake basin, a short episode of drying up could have occured, which is reflected in the plant development. It is indicated by an increase in the percentages of corroded and other indeterminable sporomorphs in one spectrum. At the same time, better conditions for the development of reeds began. Already slightly earlier, the amount of aquatic plants decreased and *Equisetum* disappeared.

There is a high concentration of pollen of all trees, particularly in the lower part of discussed zone (Fig. 13). It is a transitory period showing the development of new but still unstable plant communities.

The ^{14}C date of 8900 ± 80 BP (8190–7890 BC1 and 8250–7750 BC2) from the southern basin in $Os_{94\text{-}5}$ 3 *Pi* L PAZ (Fig. 10) is slightly too young with its position at the late part of the Preboreal chronozone, whereas the pollen spectra indicate the beginning of this period. Higher up in the core a clay layer occurs devoid of sporomorphs and the levels lying above it have been palynologically dated to the Atlantic chronozone. Perhaps this date is slightly too young with its position at the late part of the Preboreal, whereas the pollen spectra suggest the beginning of this period.

B o r e a l c h r o n o z o n e
(upper boundary destroyed)

$Os_{94\text{-}9}$ 9 *Ulmus-Corylus* L PAZ

The boundary between the local pollen zones, corresponding to the Preboreal/Boreal transition, is not distinct in the pollen diagram (Figs 12, 13).

During the Boreal chronozone, birch and birch-pine forests were still developing in the study area. In the neighbouring areas to the east (Lake Gościąż – Ralska-Jasiewiczowa et al. 1998) and to the west (Lake Gopło – Jankowska 1980, Bożejewice – Makohonienko et al. 1989) the participation of birch decreased and the role of pine increased, which may be explained by a changing water balance (increasing water deficit). According to the isopollen maps for *Betula* (Ralska-Jasiewiczowa et al. 2004b) however, at the 9000 ^{14}C BP time interval *Betula* pollen approaches higher values in the belt from Suwałki to the Wielkopolska area (excluding the Baltic coast). At the 8500 ^{14}C BP horizon birch pollen percentages are already similar to its value in the Polish Lowlands, and the amount of pine in the Boreal horizons is similar to the Polish Lowlands (Latałowa et al. 2004b). Thus, it can be assumed that locally in the area of Osłonki the amount of birch was higher than pine. In the forests with birch dominance, occupying more fertile habitats (Ralska-Jasiewiczowa et al. 1998) elm was slowly spreading as an admixture in a small amount. In the Kujawy area until 8500 ^{14}C BP its participation was lower than in the adjacent areas of the Polish Lowlands (Zachowicz et al. 2004). In the lower layer of the forest shrubs, *Viburnum opulus* occurred. *Corylus avellana* was also gradually gaining better conditions, indicating – in a similar manner to *Ulmus* – the amelioration of climate. Hazel was expanding rapidly and probably replacing open patches of pinewood at the dry edges of the forests and in the meadows. Here, there were still conditions for the development of light-demanding plants, a such as *Helianthemum* and *Sedum* as well as *Juni-*

perus communis and *Populus*. Juniper already had a reduced participation in the vegetation in the preceding zone, reacting negatively to the amelioration of climate. Poplar trees were also gradually decreasing as a result of the reduction of open spaces, at least at the beginning of this period. It is likely that its original habitats were colonised by *Corylus avellana*. As in the Preboreal chronozone, tall-herb communities were growing along wet edges of the forests. Among them *Filipendula* and *Humulus* were occurring. In wet habitats, closer to the water thickets of willow (*Salix*) were growing.

The shoreline of the lake basin was probably differentiated, and in its various bays and at the sites close to the open water, the aquatic and rush plants alternated as a mosaic. Also in the belt of reeds, marsh fern (*Thelypteris palustris*) and reeds (*Phragmites australis*) were growing. Their presence, as well as the disappearance of *Nymphaea alba* in the open water, indicates an advanced stage of succession with some parts of the lake becoming shallower. The presence of various communities of cladocera and mollusca suggests that it was still a small, stable lake basin in which aquatic plants developed well. Species of cladocera living there indicate that in some parts of the basin the water was clear and poor in nutrients, with a well-developed association of aquatic plants, gradually encroaching onto the area of the whole lake (Gąsiorowski in prep.). Determined subfossil remains of molluscs also indicate (continuation of the phase formed already at the beginning of PB) the stability of the lake with rich vegetation and populated by abundant assemblages of snails that were increasingly richer in species and specimens (Alexandrowicz in prep.). However, some cladoceran species preferring higher fertility and lower pH (pH 5.0–6.5) were also present in the lake (Gąsiorowski in prep.).

At present, a succession in eutrophic habitats that develops in such a manner leads to the development of alder wood-type communities (Tomaszewicz 1979). Perhaps, during the Boreal the first alder (*Alnus*) encroached onto such habitats, but they were not in sufficient amount as indicated by the low percentages of *Alnus* pollen and they were not able to form alder woods. In the area of Osłonki, *Alnus* manifested its stronger presence later, most likely not before the Atlantic chronozone. This suggestion results from the analysis of the isopollen maps (Szczepanek et al. 2004), as in the analysed profiles there are no segments dated to the late Boreal chronozone as well as at the late and middle Atlantic chronozone. Throughout the whole Kujawy region, as is shown by these maps, the lower values of the *Alnus* pollen, in comparison with the adjacent areas, continued until the later part of the Atlantic chronozone till 5500 ^{14}C BP time horizon. In the isopollen maps constructed by Ralska-Jasiewiczowa (1983), this trend was not noted. A wider discussion concerning the expansion of alder was presented basing on the analysis of laminated sediments at Lake Gościąż by Ralska-Jasiewiczowa et al. (1998).

Since the middle part of the described period, the wet communities could have comprised oak (*Quercus*) and also slightly later some ash (*Fraxinus excelsior*). Oak and ash were on the route of migration, from west to east, which is in accordance with the picture obtained from the new edition of isopollen maps (Milecka et al. 2004, Tobolski & Nalepka 2004). Elm and ash trees with a small admixture of oak may have formed the first patches of elm-ash wetland forests in wetter habitats situated at slightly lower elevations.

At the end of this period there were already deciduous forests in fertile habitats, in which oak, lime, elm, and ash trees were growing, with hazel in the understory, as well as birch coppices. It is likely that on the poorer, sandy soils small patches of communities similar to the present day coniferous or pine–oak forests were developing. It cannot be excluded that there were only isolated stands or even scattered specimens of pine, and that the major part of the pollen of this tree may have resulted from far distance transport blown from far away. Around the studied site in Osłonki there are few soils on which pine could have competed with deciduous trees. However, due to the increasing density of the deciduous tree crowns it is possible that distant transport of pollen of wind-pollinated plants decreased. Despite the dominance of the forests, there were also woodless areas at the edges of thickets or along the shoreline of the water basins as well as on natural meadows. In such dry sites communities of hazel and light-demanding herbaceous plants were developing with *Helianthemum*, *Plantago media*, *Rumex acetosella*, *Anthericum*, and *Artemisia*. In wet habitats *Lychnis flos-cuculi*, *Ranunculus acris*, and *Urtica dioica* started to grow, and *Humulus*, *Filipendula*, *Valeriana*, and *Rumex* continued to be present.

At the top of *Ul-Co* L PAZ a further decrease in water depth is observed, which is confirmed by the rapid increase in the amounts of *Pediastrum* cenobia. The water occupied less and less area, which is shown by rare pollen grains of *Nuphar lutea*, and the water surface was partly coated with duckweed (*Lemna*). In the neighbourhood, the reed belt was well developed. The low amount of corroded sporomorphs suggests that the vegetation formed a dense cover. No local traces of extreme events causing deforestation or drying up are recorded. Nevertheless, the cladoceran reflects considerable changes in the species composition (Gąsiorowski & Nalepka 2004). A disappearance of several species characteristic of oligotrophic waters indicates a significant increase in the trophic status of the basin. On the other hand, cosmopolitan species developed (neutral to many environmental factors) or those preferring high trophy, which corresponds with a decrease in the $CaCO_3$ amount in the core (Fig. 13). It is likely that this cladoceran composition is an effect of sediment mixing at the Boreal/Atlantic chronozones boundary.

The picture derived from the analysis of spectra from 353 and 348 cm (Fig. 12), i.e. just at the top of *Ul-Co* L PAZ (corresponding to the Boreal) is very difficult to compare with the picture of past vegetation resulting from the isopollen maps (Ralska-Jasiewiczowa et al. eds, 2004). Based on ^{14}C dates from the southern basin, ranging between 6700 and 6400 ^{14}C BP, and the archaeological dating, an attempt has been made to compare it with the isopollen maps ranging between 7000 and 6000 ^{14}C BP. The analysis of the pollen diagram indicates the dominance of deciduous forests by trees characteristic of the Holocene climatic optimum. The insignificant participation of plants of open spaces could dates this zone to the Atlantic chronozone. The similar palynological picture illustrated in the pollen diagram from Lake Gościąż has been dated as older than 5600 ^{14}C BP (or 4400 cal BC).

The uppermost part of the profile Os 94-9 is destroyed and mixed with the lowest layers of the succeeding zone. At the Bożejewice site of deposits dated to the younger part of the Boreal and the older part of the Atlantic chronozones are also lacking (Makohonienko pers. com.). The author has drawn this conclusion based on a comparison with data derived from research at the neighbouring sites in Pakość (Noryśkiewicz pers. com.) and Lake Gopło (Jankowska 1980).

The younger part of the Atlantic chronozone

$\mathbf{Os_{94\text{-}9}}$ 10 ***Alnus-Corylus-Quercus*** **L PAZ;** $\mathbf{Os_{1\text{-}2a}}$ 3 ***Alnus-Corylus-Quercus*** **L PAZ;** $\mathbf{Os_{94\text{-}5}}$ 4 ***Alnus-Corylus-Quercus*** **L PAZ**

This zone (Figs 8–13) can be biostratigraphically correlated with the younger segment of the Atlantic chronozone, which is also identified by radiocarbon dates. The ^{14}C date 6730 ± 70 BP (5700–5560 BC1 and 5750–5500 BC2) from the Os 1-2a profile, and the dates 6670 ± 70 BP (5660–5520 BC1 and 5710–5480 BC2), and 6470 ± 70 BP (5490–5360 BC1 and 5600–5310 BC2) from the Os 94-5 profile correspond with the younger part of the Atlantic chronozone. The determinations of radiocarbon age (Tab. 6) have been performed on material where the first grains of cereal pollen are recorded (Os 94-5, Fig. 10) or immediately before their appearance (Os 1-2a, Fig. 8). Thus, these dates relate to the period when the people of the Linear Pottery culture inhabited the surroundings of Osłonki and Brześć Kujawski (Grygiel 1986, 2004). The AMS date 8440 ± 150 ^{14}C BP is evidently older than this period, and was performed on displaced and burnt sediment (which may be connected with the appearance of the Linear Pottery culture).

In this period, the landscape was dominated by mixed deciduous forests, which consisted of *Quercus*, *Tilia*, *Ulmus* and *Fraxinus excelsior*, with *Corylus avellana* in the lower layer and in the patches of forest gaps, as well as *Alnus*, without a distinct dominance of one of them. In the forest understorey shade-tolerating herbaceous plants were growing, for example of the *Anemone* type pollen group. Pine trees grew in small amounts and perhaps formed pine-oak forests with bracken (*Pteridium aquilinum*) developing in the understorey. At present, bracken is a natural component of the understorey in *Pino-Quercetum* and *Quercetum robori* vegetation (Zarzycki et al. 2002), and becomes more abundant after fires. *Pteridium aquilinum* may have been quite abundant in patches that experienced burning

(Figs 8, 10, 12). The constant presence of charcoal dust, recorded practically in almost every spectrum of this L PAZ (Fig. 12) also confirms the occurrence of fires. It can be assumed with a high probability, that the fires had an anthropogenic origin. Pine, as a pioneer tree, could have developed in sites deforested by man during the first stages of plant succession. The question arises whether the pine-oak forests could have had suitable habitats for their development and longer maintenance, or whether deciduous forests rapidly replaced them. It is likely that only scattered pines grew or if they were more abundant humans, due to the valuable wood, immediately cut down almost every pine tree. As a result more demanding deciduous trees may have rapidly inhabited former pine stands.

Very low percentage values of *Betula* pollen in this time suggests that seedlings and suckers could have been eaten by goats/sheep and that is why these trees did not reach their maturity and thus could not have been able to produce pollen. Almost every habitat is suitable enough for the development of birch.

In the treeless areas various communities of herbaceous plants developed. Grasses (Poaceae) were frequent, if not the main the component. In wet and fresh meadows and in the thickets at the forest edges, apart from grasses, the following plants could have grown: *Cirsium*, *Sagina*, *Humulus lupulus*, *Solanum dulcamara*, *Thalictum*, *Filipendula*, *Valeriana*, *Lychnis flos-cuculi*, *Ranunculus acris*, *Trifolium pratense*, and *Potentilla*. In dry swards the following may have occurred: *Jasione montana*, *Plantago media*, *Coronilla varia*, *Anthericum*, *Campanula*, *Hypericum perforatum*, and *Sedum*.

Herbaceous plants requiring a high amount of nitrogen in the soil such as *Plantago major* and *Urtica* found good conditions for their development around the study site. *Urtica* – a natural component of wetland forests – develops particularly abundantly in conditions of increased light and on soils enriched in nitrogen. Here, together with plantain (*Plantago major*), it was a component of the ruderal flora. All kinds of transition from wet to dry thickets and from wet to dry meadows/swards are present, which might be caused by human activity. This part of the pollen diagram, comprising the development of the mixed deciduous forests of the climatic optimum, also includes an appearance of the first significant indicators of the agricultural activity of man. This indicates that the area was inhabited by settled human communities (Nalepka et al. 1998, Gąsiorowski & Nalepka 2004, Nalepka 2004a,b). The appearance of indicators of cereal (Cerealia undiff.) cultivation with wheat (*Triticum* type) and barley (*Hordeum* type), and weeds (*Spergula arvensis*, *Ranunculus arvensis*, and *Scleranthus annuus*) indicates that during this period cultivated fields existed in close vicinity of the basin. Some species of Chenopodiaceae, *Melampyrum*, *Plantago lanceolata*, and *Rumex acetosella* could have grown on fallow land. In the areas occupied by people and in their immediate vicinity, ruderal plants were abundant, developing on sites among houses, paths, surroundings of refuse dumps and latrines; these include *Urtica*, *Artemisia*, Chenopodiaceae and *Plantago major*. Additional, indirect proof of the presence of human settlements, apart from the increasing amount of pollen of ruderal plants and cereals, is also the presence of sand intercalations within the gyttja in this part of the core, which indicates the temporary occurrence of surfaces devoid of vegetation cover (Nowaczyk et al. 2002).

The reeds around the eastern basin did not show significant changes, whereas in all three diagrams *Phragmites australis* is more distinctly marked as the main component (Figs 8, 10, 12). Along the wet shores of the southern basin, alder (*Alnus*) was growing, willow thickets were developing, and reeds with members of the family Cyperaceae, *Typha latifolia*, *Sparganium* or/and *Typha angustifolia*, *Phragmites australis*, as well as *Menyanthes trifoliata* and *Cladium mariscus* were also developing. An occurrence of stagnant water is marked by the presence of *Myriophyllum spicatum*, and *M. verticillatum*. A further progressive decrease in the depth of the basin is shown by the rapid growth of cenobia of *Pediastrum*. Its presence may also indicate an increase in trophic status caused by the presence of man. The water surface shrank, occupying less space than previously, which is pointed by the infrequent grains of *Nuphar lutea* pollen. It could have been also covered with *Lemna*. The belt of reeds nearby developed well. The composition of cladocera confirms a continuity of the eutrophication process of the eastern basin (Gąsiorowski & Nalepka 2004). Most likely, in the described

L PAZ the eutrophication reached its highest intensity. The basin changed from oligotrophic to eutrophic, and its colour and pH increased. The changes in the physico-chemical conditions caused some modification in the composition of aquatic plants, which is reflected by the temporary appearance of a range of cladocera species associated with macrophytes.

Apart from the geomorphological interpretation (Nowaczyk in prep.), the analysis of the fish bones gathered from the early Neolithic archaeological settlements provide additional showing that some sections of the lake basin in the area of Osłonki were quite shallow (Makowiecki 2003). The results of this analysis provided more details of the picture of the environment in the studied area. From the list of fish species, characteristic of the shallow eutrophic water basin is a tench-pike (*Tinca tinca – Esox lucius*) type, indicating that such waters must have existed within the reach of activity of the early Neolithic settlers. Today, the depth of such water basins usually does not exceed 6 m. A littoral zone is very wide and its slope is gradual. The bottom surfaces are often covered with a thick layer of mud of organic origin. The remains of asps (*Aspius aspius*), which is more a river than a lake fish, roaming long distances indicate the existence of water connections between the Wisła river in the east and the Noteć with Lake Gopło in the west. The presence of the European pond tortoise suggests the existence of shallow-water basins with an extensive zone of wet meadows and maybe also some bogs.

At the top of the zone the number of corroded sporomorphs increase and above there is a clay layer devoid of pollen, succeeded by a layer of burnt peat, with indeterminable – due to very severe damage – sporomorphs. It breaks the continuity of the record of the vegetation history around the study site.

$Os_{94\text{-}9}$ 11 *Alnus-Ulmus-Corylus-Quercus* L PAZ; $Os_{1\text{-}2a}$ 4 *Alnus-Ulmus-Corylus-Quercus* L PAZ

This zone (Figs 8, 9, 12, 13), depicts the time when diverse mesic deciduous forests still dominated with a slight local increase in human influence on the vegetation. The character of the forest communities did not undergo particular changes in comparison with the preceding period (Os 94-9/221–140 cm, Fig. 12). There were still the optimal conditions for the development of deciduous forests with *Quercus*, *Ulmus*, *Fraxinus excelsior*, *Tilia*, *Viscum*, as well as *Alnus*. These forests still displayed as primary structure despite local human interference. The presence of forest gaps and the traces of fires are confirmed by the development of bracken (*Pteridium aquilinum*). A stable curve of *Corylus avellana* (Fig. 12) allows the assumption that hazel formed an understory within the thinned (anthropogenically cleared?) parts of the forests and may have even formed communities which at present do not have an equivalent in the modern vegetation. It overgrew the exposed areas prior to being replaced by trees as a result of shading of its habitats by the tree crowns. Alternatively man may have again disturbed it. The presence of forest gaps is also indicated by a higher participation of poplar (*Populus*) pollen. Poplar again found more habitats where it could grow to maturity and produce pollen. The open sites, naturally or anthropogenically cleared, were occupied by *Juniperus communis* shrubs and by herbaceous plant communities. Heather (*Calluna*) was also more abundant. Still present were areas suitable for the development of various communities of herbaceous plants such as wet thickets, wet or dry meadows, and sandy sites. Cultivated fields were also an element of the landscape.

The first appearance of hornbeam (*Carpinus betulus*) in the area of Osłonki was marked by the presence of its single pollen grains in the pollen assemblage.

The wet and moist sites were very favourable for the development of alder forests and willow thickets. *Calystegia sepium*, *Valeriana*, *Urtica*, and *Humulus lupulus* could have been growing in them. The basin was relatively shallow and the surface of the water was covered in places with duckweed (*Lemna*). The shore areas were overgrown by reeds. It may be assumed that humans could have locally influenced the shape of the shorelines by trampling, throwing rubbish into the water basin, or digging ditches to connect the natural basins (e.g. the protecting moat in Osłonki).

The cladoceran assemblage (138–221 cm), distinguished above a gap in the fossil record, indicates a partial return to a lower trophic level of the basin waters (the re-appearance of the small amount of *Acropeus harpae*, *Alonella* *nana*, and *Eurycercus lamellatus*), though it was still a eutrophic site. Periodically some species indicating distinct water contamination (*Leydigia acanthocercoides* and *Leydigia leydigi*) appeared (Gąsiorowski & Nalepka 2004).

Atlantic or Subboreal chronozone

$Os_{1\text{-}2a}$ 5 *Artemisia* L PAZ

The vegetation cover was still formed by the mesic, mixed deciduous forests but due to the distinct human presence their area was gradually becoming reduced. This is indicated by the higher amount of *Artemisia* pollen (Fig. 8).

The older part of the Subboreal chronozone

$Os_{1\text{-}2a}$ 6 *Corylus-Quercus-Artemisia* L PAZ; $Os_{94\text{-}5}$ 5 *Artemisia-Filipendula* L PAZ

The forested areas around the studied site became reduced, although the structure of the tree stands had not undergone changes (Figs 8–11). The open spaces were occupied by herbaceous plant communities with grasses, ruderal plants in the settlements and in their vicinity, cereals on the cultivated fields, and *Rumex* and *Plantago* in the pastures and fallow lands. This zone can be biostratigraphically correlated with the Subboreal chronozone. From the two interpretations concerning the age of the analysed segment proposed by Nalepka (Nalepka et al. 1998), at present the second interpretation has been accepted, which is confirmed by the radiocarbon date of 4260 ± 60 ^{14}C BP (2920–2720 BC1 and 3020–2640 BC2) from the middle part of the zone (Fig. 10), indicating the Subboreal chronozone. The increased participation of *Artemisia* and Poaceae, as well as a reduction in the deciduous trees, would be in agreement with the archaeological evidence of the presence of the Globular Amphorae culture settlements in the immediate vicinity of the southern site.

The younger part of the Subboreal chronozone

$Os_{94\text{-}9}$ 12 *Carpinus*-NAP L PAZ

The area occupied by mixed deciduous forests characteristic of the climatic optimum, became reduced, whereas the areas re-colonised by herbaceous plant communities increased. Within the tree stands, hornbeam (*Carpinus betulus*) was significant, but the considerable amount of damaged sporomorphs indicates disturbances within the studied deposit leading to an inability to characterize the vegetation in the discussed period. The Cladocera remains, while displaying considerable variety of species, do not show the abundance of any particular species (Gąsiorowski & Nalepka 2004). This indicates that the disappearance of the lake basin must have been rapid without an intermediate stage, as observed in some other fossil basins from elsewhere in Poland (Szeroczyńska & Gąsiorowski 2002).

In the open areas grasses played an important role, which is proved by their increased amount in the diagram, whereas the other herbaceous plants, particularly those which were the components of the alder forests, wet thickets and meadows, almost disappeared, indicating that the local areas fragmentarily dried out. The reeds also became partly dry around the remains of the shallow-water basin. Duckweed (*Lemna*) cover decreased but in the water the aquatic plants *Myriophyllum* and *Potamogeton* were present.

The description of the vegetation of this period cannot be compared with the picture resulting from the isopollen maps (Ralska-Jasiewiczowa et al. 2004c) due to the local maximum of *Carpinus betulus* pollen in the Wielkopolska area, which obscures the local changes in the neighbouring areas. In the diagram from Osłonki, pollen percentages of *Carpinus betulus* and other trees are low. This may indicate an age of the younger phase of the Subboreal chronozone and not its beginning. In such a case, it should be accepted that the fall in the *Carpinus betulus* curve indicates a settlement phase (Ralska-Jasiewiczowa 1964) and not a break in settlement. However, the settlement phase cannot be seen here as there are no anthropogenic indicators, while there is a considerable frequency of corroded sporomorphs. This zone occurred above the hiatus of an unknown thickness, which has been palynologically documented. The radiocarbon dating from the bottom of this sediment (3110 ± 35 ^{14}C BP, i.e. 1415 BC1 and 1470–1260 BC2) corresponds with the younger part of the Subboreal chronozone. Archeologically, this date indicates the Bronze Age.

Parts of the Subatlantic chronozone

More precise palynological dating of these zones has not been possible due to the lack of materials in the profiles that are suitable for analysis.

Os$_{1\text{-}2a}$ 7 Poaceae L PAZ, Os$_{1\text{-}2a}$ 8 *Artemisia-Plantago lanceolata* L PAZ; Os$_{94\text{-}5}$ 6 *Artemisia-Plantago lanceolata* L PAZ

An open landscape dominated and forests occupied only small areas in which the amount of deciduous trees was declining, while the participation of pine trees increased (Figs 8–11). Juniper shrubs and a range of herbaceous plant communities occupied open areas. A high degree of deforestation, as well as the presence of synanthropic plants, indicates that human activities were carried out on large parts of the area. Distribution of juniper and sorrel (*Rumex*) growing on the poor soils may point to impoverishment of some habitats. In open areas agricultural activity (land cultivation and animal breeding) was performed, and the significant increase in the amount of indicators of ruderal habitats such as *Artemisia*, *Urtica*, *Plantago major*, and *P. major*/*P. media* proves the existence of permanent sites of habitation, trodden paths, and waste accumulations (the nitrophilous nettle *Urtica*). An increase in participation of *Plantago lanceolata* indicates an expansion of pasture and fallow land (Behre 1981). A considerable amount of corroded sporomorphs may by indirect proof of intensive human activity. The mineral material from the area lacking of vegetation was washed into the southern water basin together with contained sporomorphs, which became decomposed in the oxygenated environment and mechanically damaged during transport.

The water level rose in the southern basin in which *Potamogeton* and algae of the *Pediastrum* developed better, and *Sphagnum* again found more favourable conditions. The interpretation of these changes is based only on pollen analysis, as the analysis of subfossil cladoceran and mollusc remains has not yet been performed.

A very low participation of *Pinus sylvestris* pollen in one of the topmost spectra (Fig. 8) cannot be explained by climatic or anthropogenic causes. Even the complete felling of pine in the southern Kujawy area could not have caused such a low amount of pollen in the sediment, as pollen from long-distance transport, for example from the Wisła valley, should still have reached this area, the more so as the landscape was deforested during this time. Thus a destruction of sporomorphs in later times seems to be a more probable explanation. It is likely that this is an effect of drying up of the upper parts of the sediments due to drainage work performed in these areas in the twentieth century. A significant increase in the amount of corroded sporomorphs occurring simultaneously with the *Pinus sylvestris* pollen minimum is an additional argument for the later drying out of the deposit.

Os$_{1\text{-}2a}$ 9 *Pinus* L PAZ, Os$_{1\text{-}2a}$ 10 *Pinus* L PAZ, Os$_{1\text{-}2a}$ 11 NAP L PAZ

The landscape was open and herbaceous plants dominated (Figs 8, 9), among which grasses (Poaceae) were the most abundant, whereas the presence of ruderal plants represented by *Artemisia* was much smaller. The agricultural activity increased both as cereal cultivation as well as animal pasturage, which is suggested by the presence of *Plantago lanceolata*. The increased participation of *Juniperus communis* pollen indicates the occurrence of waste and overgrown areas on impoverished soils. In the shallow, incompletely overgrown water body of small area *Potamogeton* was growing, and the shorelines were overgrown by reeds with *Sparganium* and *Typha latifolia*. A few oak, poplar, alder, and willow were growing, and here was a marked but temporary regeneration of *Pinus sylvestris*.

ECONOMIC ACTIVITY OF MAN REFLECTED IN POLLEN DIAGRAMS FROM THE SOUTHERN AND EASTERN BASINS IN THE OSŁONKI REGION

Between 7000 and 5000 years ago, farming villages were established in Poland and other parts of Central Europe. The understanding of the earliest European farming is important since it represents the first instance of domesticated plants and animals outside their native region. The Kujawy region, populated in the early Neolithic time, is almost lacking any biogenic sediments. The presence of a few organic layers, deposited in the younger Atlantic, which filled some small basins in the Osłonki region has offered a special opportunity to analyse the relationships between pollen data and the specific conditions of an archaeological site. When based only on palynological results the palaeoecological interpretation of the pollen diagrams encounters many difficulties in the interpretation of events in a human context. Then, palynological characterization of Neolithic cultures in the analysed material was possible due to radiocarbon dating and correlations with the results of archaeological studies carried out in the region of Osłonki.

EARLY NEOLITHIC

The first evidence of human activity in the region of Osłonki may be seen in the upper part of *Ul-Co* L PAZ in the Os 94-9 profile from the southern basin (Fig. 12). It was a time when open pine-birch forests grew in the study area, hazel shrubs spread abundantly, and elm, ash, and oak became more and more abundant components of the mixed forests. Willow shrub developed on moist habitats on which alder gradually arrived. Lakes in the process of natural succession were being overgrown with aquatic plants and reeds and became more shallow.

In the profile (Os 94-9) from the eastern basin, the content of charcoal at 388 cm depth (Fig. 19) increased considerably, the percentage of corroded sporomorphs increased too, and degraded sporomorphs and single pollen grains of *Plantago major* and *Populus* pollen occurred (though these latter once after a gap following a more frequent occurrence). An increase in charcoal is evidence of fires, which possibly took place in the vicinity of the site or increased in intensity. *Populus* pollen is not adapted to long transport, and therefore its presence in the sediment indicates that the tree may have been growing near the site. *Plantago major* is a herbaceous plant which usually grows along paths in trodden sites. Higher up, at the 368 cm depth, the percentages of charcoal and corroded sporomorphs increase again, and in the upper spectrum (363 cm) an increased percentage of *Pteridium aquilinum* (which develops more readily on patches of burnt ground) spores is noted.

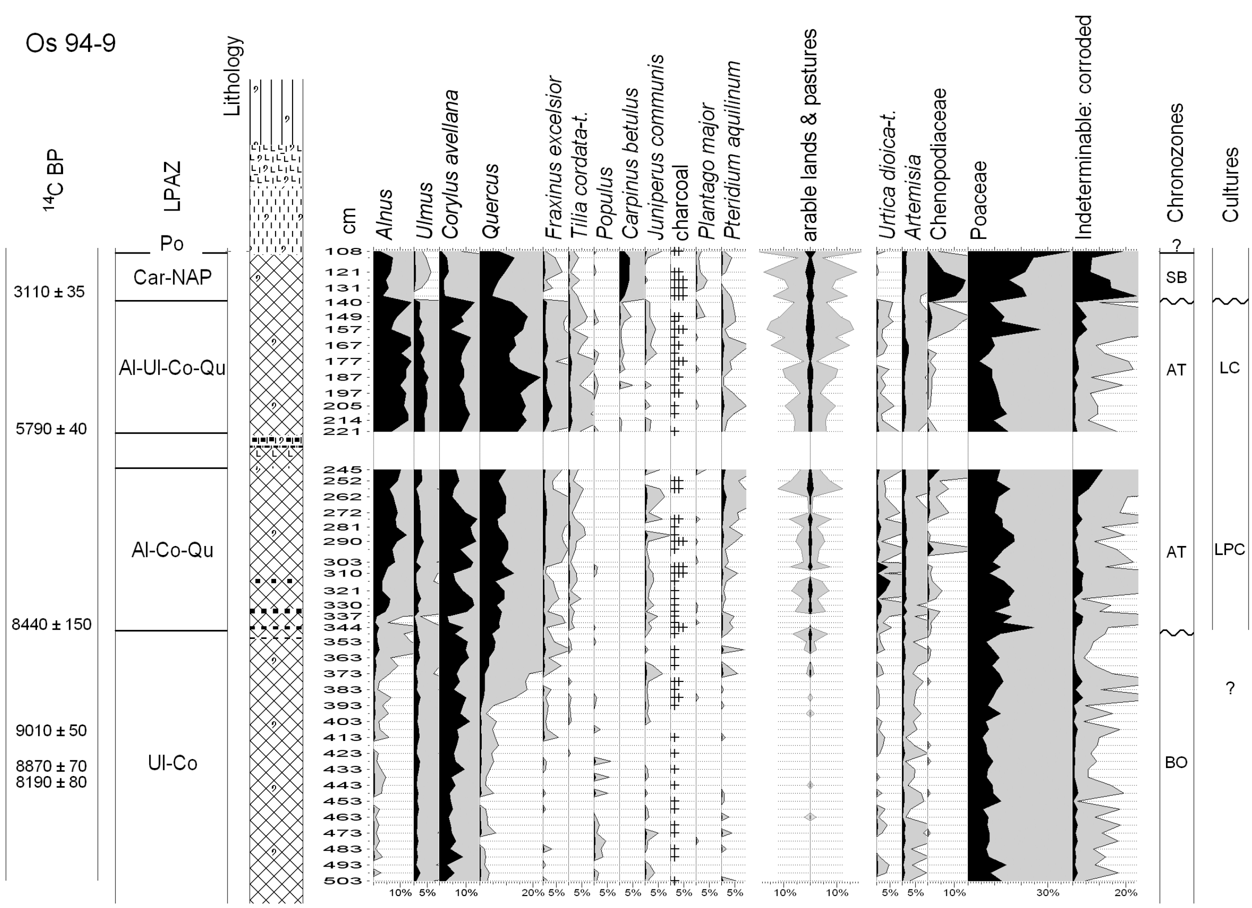


Fig. 19. Selected percentage curves of pollen taxa indicating the climatic optimum and the beginning of agricultural activities in the Os 94-9 profile from the eastern basin

The appearance of sporomorphs of the above taxa, together with the increased amount of charcoal may indicate an opening of small areas caused by fires near the studied basins. At the same time, it may indicate episodic human penetration of the Osłonki region in the Boreal chronozone. It cannot be excluded, based on archaeological (Cofta-Broniewska & Kośko 1982) and palynological evidence (e.g. Ralska-Jasiewiczowa & van Geel 1989), that in the vicinity of the Wisła valley Mesolithic tribes were present, and episodic penetration of southern Kujawy by hunters and gatherers was possible. Based on archaeological studies, no trace of Mesolithic people has been found in the investigated region (Grygiel 2004). But the landscape, which changed completely (into agriculture and a housing infrastructure) between the Neolithic period and the present day, significantly limits the possibilities of finding any Mesolithic artefacts that are rare by nature. Attributing these changes in vegetation cover to natural factors like trampling of paths by animals seems to be less likely, as palynological indicators of openings co-exist with the increased quantity of charcoal in the same spectrum. This could indicate the use of fire by man, for example, to flush out wild animals.

In the two highest spectra (from 353 and 348 cm depth) of the same local pollen assemblage zone $Os_{94\text{-}9}$ *Ul-Co* from the eastern basin, the first pollen indicators of farming activity are recorded, as single grains of *Spergula arvensis* type weed pollen. These two pollen spectra were obtained from a disturbed profile section, and they contained sporomorphs taken from the upper layers, in which the other palynological indicators of agriculture were already present. *Spergula arvensis* is now a common plant, which grows on sandy soils, fallow lands, and roadsides (Matuszkiewicz 2001). This is an archaeophyte occurring in weed assemblages (Zając 1979, 1984), primarily of summer cereals and root crops, but also in winter cereals and fallow lands. It can also occur as a component of footpaths and ruderal communities (Behre 1981). Zarzycki et al. (2002) include *Spergula arvensis* in the following assemblages: *Aperion spicae-venti*, *Arnoseridenion minimae* and *Panico-Setarion*. These data indicate that *Spergula arvensis* type pollen, of small size (30.0–37.5 μm), and features difficult to observe (Beug 2004), has a low chance of being found in biogenic sediments, as this plant does not usually grow in the vicinity of lakes or peat bogs. Similarly as in the profile of Osłonki (Os 94-9), grains of *Spergula arvensis* type appeared prior to the record of cereals in the profile from the Darżlubie Forest site (northern Poland, Latałowa 1982) and from the Stanisławice site (southern Poland, Nalepka 2003) in the zones correlated with the early Neolithic period. Therefore, it can be assumed with fair probability that the presence of *Spergula arvensis* type in the diagram Os 94-9 proves that agricultural activities, probably on local scale, took place in the neighbourhood of the palaeolake. In the spectra in which the first *Spergula arvensis* type pollen grains are present, charcoal was not recorded. Nevertheless, between the spectra containing this pollen at 350–351 cm, blackening of sediment is visible, caused probably by the presence of charcoal. In the analysed profile from the bottom sediments of the palaeo-lake, charcoal must have been the remains of local fires (the sediment could not be burnt under water), and there is no evidence (lithology, sporomorphs, cladocera and molluscs) for such a drastic drying up of the basin that the bottom sediment was shifted to the surface and could be destroyed by fire. The presence of *Spergula arvensis* type confirms additionally that the boundary between the zones belonging to the Boreal and Atlantic has been disturbed.

LINEAR POTTERY CULTURE

The next local pollen assemblage zone (*Al-Co-Qu*) represents a period of development of mixed deciduous forests of the climatic optimum, composed of *Tilia*, *Ulmus*, *Fraxinus excelsior*, with increasing percentages of *Quercus* and high percentages of *Corylus avellana*. These forests covered most of the investigated region. There were a few open areas, which were probably developing periodically. Some of them existed due to human activity, who were preserving them, extending their area, or were creating them through deforestation. This zone (*Al-Co-Qu*) has been dated palynologically and by radiocarbon dating to the younger part of the Atlantic chronozone. The presence of mesophilous, deciduous tree pollen and scant percentages of farming-activity indicators links this zone with early Neolithic cultures. On the investigated area in the Miechowice settlement, on land adjoining the eastern basin in the north-east, early Neolithic artefacts belonging to the Linear Pottery culture (LPC) have been found. Scant palynological evidence of the earliest settlement in the vicinity of the eastern basin (Os 94-9) could come from a place where a small settlement existed, or it could reflect only a non-permanent, temporary visitation of some part of the landscape. However, the Os 16 profile, sampled at Miechowice in the closest vicinity of the LPC settlement, does not contain the *Al-Co-Qu* L PAZ at all. But it must be remembered that the Linear Pottery culture people had not constructed any permanent homesteads (Grygiel 2004), so the material remains of their settlement were hardly preserved. Nevertheless, from the area of their occupation charcoal of *Quercus*, *Pinus sylvestris*, *Alnus*, and *Betula* were dated, which was used for construction and fuel. The extended LPC settlement developed in the more distant vicinity, about 10 km to the east of the investigated sites at Brześć Kujawski (Grygiel 1986).

At the beginning of the pollen zone, under discussion at 344 cm of the Os 94-9 profile (Fig. 19), a large increase in the amount of charcoal particles is evidence of land burning. Also, the increase in percentages of *Pteridium aquilinum* spores should be treated as confirmation of the occurrence of fire. Land was burnt over in order to remove remains of those parts of plants which could not be removed by cutting. The exposure which took place due to cutting and burning the plants have been reflected palynologically in the form of single grains present already in the entire investigated zone or by an increase of pollen curves for plants growing in open areas (*Juniperus communis*, *Calluna vulgaris*, *Sedum*, *Anthericum* type, *Jasione montana*, *Spergularia* type, *Centaurea scabiosa*), and at the same time indicating the persistent presence of deforested areas. The increase in Poaceae pollen percentage also indicates the presence of larger, or more permanent, deforested areas.

Undoubtedly the presence in the analysed profiles (Figs 8, 10, 12) of *Triticum* type, *Hordeum* type, and Cerealia undiff. pollen, and also pollen of weeds *Polygonum aviculare* type, *Polygonum persicaria* type, *Ranunculus arvensis*, *Scleranthus annuus*, and *Spergula arvensis* type, are evidence of agricultural activity in the *Al-Co-Qu* L PAZ. At the beginning of that zone, cereal pollen grains do not occur in every analysed spectrum. Later on there become more frequent, and in diagrams from profiles from the southern basin (Os 94-5 and Os 1-2a) they form low, continuous curves (Figs 19–21).

From the presence of scarce amounts of pollen grains of these plants, it can be concluded that agriculture was practiced probably at some distance from the point where the investigated profile was collected. These plants are entomophilous or autogamous, and their pollen, produced in low quantities, is not adapted to long-distance transport, which accounts for their low values in sediments. Wheat and barley were cultivated not only on rich soils. The presence of weed pollen shows that poor soils were also used for agriculture. *Ranunculus arvensis*, a weed on the heavier soils rich in calcium carbonate, and *Scleranthus annuus*, a weed on lighter calcium-free soils or on soils poor in calcium carbonate (Szafer & Zarzycki 1972), are evidence that soils of varying base status were under cultivation. Probably *Ranunculus arvensis*, whose pollen occurred earlier in the profile, occurred in fields on rich habitats, and the presence of *Scleranthus annuus*, which grows most often on sandy soils, indicates a progressive impoverishment of these soils.

Indirect evidence for man's presence is the increasing percentages of ruderal plant pollen (*Artemisia*, Chenopodiaceae, *Urtica*) and the occurrence of sand interbedded within the gyttja (in part of a core from the eastern basin). The presence of these pollen types indicates the existence of surfaces temporarily stripped of vegetation cover, e.g. cultivated lands, paths, vicinities of refuse dumps, or terrain from which clay was collected, from where in winter it could be transported into the basin (Nowaczyk et al. 2002).

Based on the analysis of macroscopic plant remains sampled from the area of archaeological settlements at Miechowice (Bieniek 2002, 2003), dated to the Linear Pottery culture period, it can be suggested that on probably permanent plots of ground, a blend of wheat (*Triticum monococcum*, *T. dicoccon*, *Triticum* sp. type "new"), barley (*Hordeum vulgare*), and also flax (*Linum usitatissimum*) and probably pea (cf. *Pisum sativum*) was cultivated. Analysis of macroscopic remains of weeds and uncultivated plants indicated an intensive,

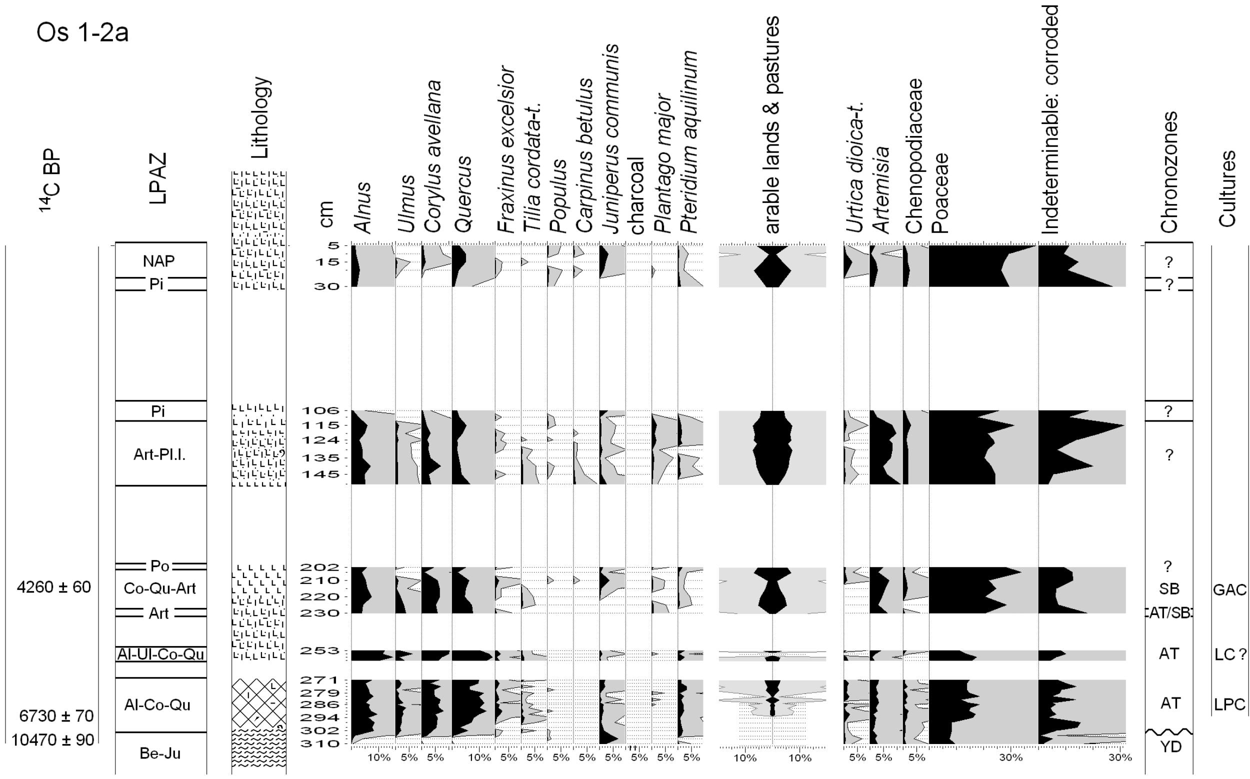


Fig. 20. Selected percentage curves of pollen taxa indicating the climatic optimum and the beginning of agricultural activities in the Os 1-2a profile from the southern basin

garden-type cultivation of cereals, especially using spring sowing (Bieniek op. cit.). The results of these studies are consistent with comparative analyses of modern weed assemblages and macroremains of Neolithic weeds from the loess belt of western Central Europe, which strongly suggested that the Neolithic crop fields were not freshly created from woodland vegetation but were long-established fields (Bogaard 2002).

Based on fluctuations in the *Betula*, *Ulmus*, *Corylus avellana*, and *Fraxinus excelsior* curves in the Os 94-9 diagram (Figs 12, 19), it can be presumed that man removed vegetation from the easier accessible, naturally over-exposed sites like forest edges and hazel scrub. It is likely that cultivated plots were maintained just on such sites. Temporary declines in the *Alnus* and *Salix* curves could also indicate destruction of vegetation on easier, more-accessible wet sites. Declines in the *Quercus* curve can be correlated probably with the cutting of oaks, which was also a component of elm-ash riverine assemblages. However, simultaneous declines of *Quercus* with peaks of *Corylus avellana* and *Betula* in some zones, may suggest succession of both on deforested areas.

Due to the lack of sediments from the early and middle Atlantic chronozone, it is not possible to determine into which natural environment the first settlers entered, and which plant communities were subjected first to the anthropopressure. Judging from the curves of taxa for the younger spectra, it seems that the activity of this population transformed the surrounding vegetation only to a minor degree, and the changes had a periodic and reversible character.

A graph of the curves for anthropogenic pollen indicators can be correlated with the tree pollen curves in the Os 94-9 diagram. But it is difficult to make such correlations for the Os 94-5 diagram (Figs 10, 21), where the curves are rather even, which is particularly visible in the AP/NAP, *Betula*, *Pinus sylvestris* and Indeterminable: corroded curves. In one pollen spectrum from 244 cm depth, there are declines of *Pinus sylvestris* and *Juniperus communis* and a decline of pollen anthropogenic indicators, together with a slight increase of *Quercus* pollen. A stronger differentiation is visible in the Os 1-2a diagram (Figs 8, 20). However, in this profile lower sums of sporomorphs were counted, due to their very bad preservation and the substantial amount of

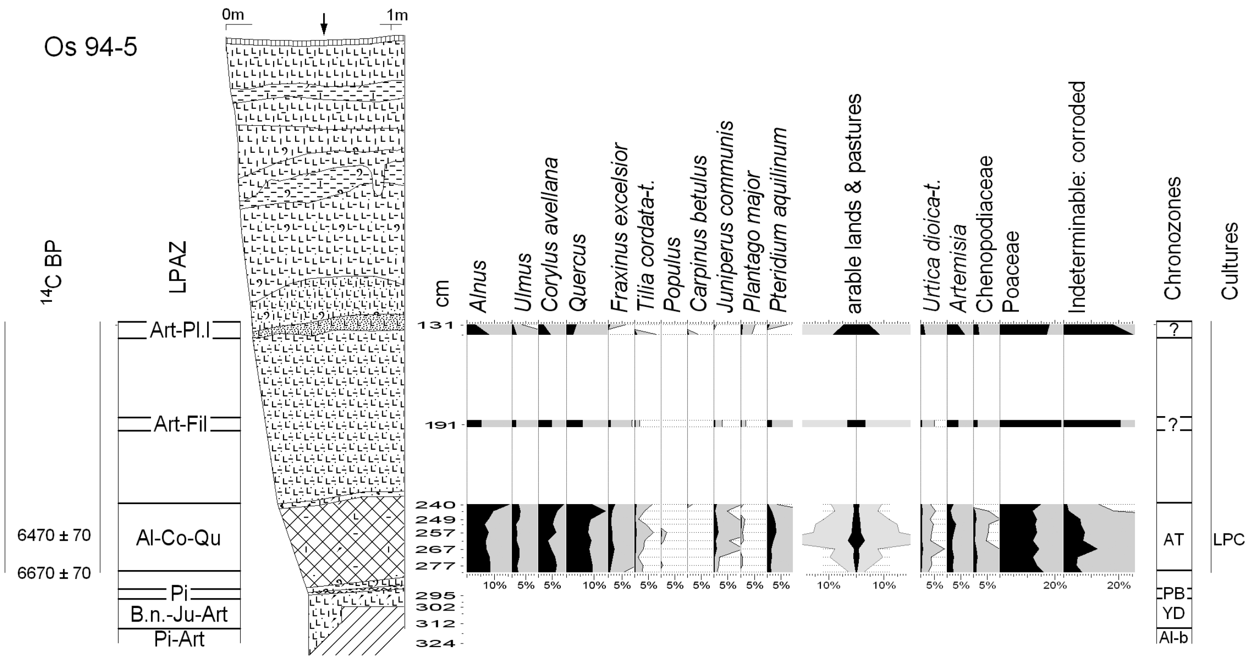


Fig. 21. Selected percentage curves of pollen taxa indicating the climatic optimum and the beginning of agricultural activities in the Os 94-5 profile from the southern basin

mineral particles which could not be removed during sample preparation in the laboratory.

Above the zone associated with the Linear Pottery culture, the sediments in all three analysed profiles (Os 94-9, Os 1-2a, and Os 94-5) do not contain any sporomorphs or contain sporomorphs damaged to such extent that they cannot be used in the analysis.

LENGYEL CULTURE

The next *Al-Ul-Co-Qu* L PAZ represented in the Os 94-9 (Fig. 19) and Os 1-2a (Fig. 20) profiles contains pollen indicators of agricultural activity of the same composition as in the previous zone. However, this zone in both profiles occurs above hiatuses in the sediment. In the Os 94-9 profile this zone is characterized by a somewhat higher percentage of agricultural pollen indicators than in the previous L PAZ and is situated on the layer of scorched peat containing sporomorphs damaged to such extent that their identification is impossible. On the other hand, in the Os 1-2a profile the percentages of agricultural pollen indicators seem to be unchanged compared to the zones lying below, despite the both local pollen assemblage zones are separated by a hiatus.

It can be stated based on pollen analysis that as described in the previous L PAZ, farming activity still involved cereal cultivation and cattle grazing. Cultivation of *Triticum* and *Hordeum* was reflected in the diagram by discontinuous pollen curves of these cereals. The presence of single pollen grains of the herbaceous plants *Fallopia convolvulus* and *Polygonum aviculare* is evidence of weedy areas. Both species prefer light and sandy soils (Szafer et al. 1969), though *Fallopia convolvulus* may grow also on medium soils (Skrzypczak & Blecharczyk 1995). Their presence indicates that poorer, somewhat impoverished soils were used for cultivation. *Polygonum aviculare* might also grow in stubble fields, fallow ground, and roadsides (Szafer et al. op. cit., Mowszowicz 1975), and *Fallopia convolvulus* could have been a weed, but it also could have grown on refuse heaps (Skrzypczak & Blecharczyk op. cit.). Always present and associated with humans were *Artemisia*, *Urtica*, Chenopodiaceae, and ruderal plants.

The previous pollen zone *Al-Co-Qu* has been correlated with the occurrence of the Linear Pottery culture in the region of Osłonki, and it seems that the younger zone *Al-Ul-Co-Qu* coincides already with the Lengyel culture period. As yet, distinguishing between the early Neolithic Linear Pottery culture and the Lengyel culture is not possible based on palynology alone. Archaeobotanical studies showed no significant differences in the patterns of farming characteristic for these cultures (Bieniek 2003). Based on few publications, the palynological data derived from sediments dated to the Linear Pottery culture and the Lengyel culture (e.g. Wasylikowa et al. 1985) indicate that during the early Neolithic period, human influence on the vegetation cover of both cultures had a similar character. The existing differences could concern intensity of farming, but the vegetation cover regenerated in a form similar to that it had before the introduction of agriculture in the investigated area.

Still, in the palynologically analysed materials from the region of Osłonki, some other data exist which support such an interpretation of the zones.

First, the differences would be expected based on a few archaeological traces of the Linear Pottery culture settlements and very numerous traces of the Lengyel culture collected in the vicinity of the study sites. Namely one could expect that spectra in the diagrams contained single only cereal pollen grains might be linked with that period, which is documented by a few archaeological traces (with the LPC). Samples, contained more cereal pollen, might be linked with period, that very numerous archaeological traces come from (with the LC).

Second, the ^{14}C dates (Table 6) from the southern basin (from maximum 6730 ± 70 ^{14}C BP [5700–5560 BC1 and 5750–5500 BC] to minimum 6470 ± 70 ^{14}C BP [5490–5360 BC1 and 5600–5310 BC2]), show that the *Al-Co-Qu* pollen zone corresponds with the earlier Linear Pottery culture (LPC). Then, the radiocarbon date from the eastern basin, from the Os 94-9 profile, from the bottom of the *Al-Ul-Co-Qu* zone (5790 ± 40 ^{14}C BP [4700–4570 BC1 and 4470–4530 BC2]) corresponds with the Lengyel culture dating. ^{14}C dates of 24 Lengyel samples collected at the Osłonki site 1 (Fig. 4) range from 5690 ± 140 ^{14}C BP to 4950 ± 150 ^{14}C BP, with the majority falling between 5500 and 5300 ^{14}C BP (Grygiel & Bogucki 1987). When calibrated and with their probability distributions pooled, the series of dates indicate that the development of the Lengyel culture period at the Osłonki site took about 500 years [4700–4200 cal BC] (Grygiel 2004) but flourish of the Lengyel settlement probably occurred between 4300 and 4050 cal BC (Grygiel & Bogucki op. cit.).

Third, the occurrence of sediment lacking sporomorphs below the distinguished zone suggests that sediment was damaged, probably due to very intensive pressure on the natural environment by the Lengyel population, as recorded by archaeological studies of that culture. This pressure would involve, first of all, thinning the plant cover on the larger areas around the basins, or even its completely removal, due to the utilization the land for construction and settlement functioning. It would involve also the destruction or even denudation of basin banks to such an extent that sediment flowing down into deeper part of basins got mixed, which caused the effect of this level becoming older then expected as well. Grygiel (2004) presents another opinion on the reasons for changes in the sediments linked with this period, and he suggests definitively that they were caused by climatic changes (drainage of land) and not by intensive human activity. This problem is discussed further on page 49.

Supplementary information is provided by separate studies on charcoal derived from the Linear Pottery and Lengyel culture settlements situated within a radius of up to several kilometres from the Osłonki basins. The Linear Pottery and Lengyel settlers were using large amounts of wood (Grygiel & Bogucki 1997, Grygiel 2004), primarily pine and oak timber (Nalepka et al. 1998, Bieniek 2003). Construction of houses and everyday activities involved the use of large amounts of wood also for energy production (e.g. cooking, heating houses) and other farming activities (Nalepka et al. 1998). In order to collect a large amount of wood, it had to be obtained in very close vicinity of the settlement. Although the vast collection of wood was indicated by the macroscopic remains, it is poorly reflected in the pollen diagrams. It is seen clearly only in the *Pinus sylvestris* pollen curve, where maximum and minimum values, visible in the lower part of the *Al-Co-Qu* zone, reflect very intensive use of pine by man and the very rapid regeneration of pine. Then, its pollen percentage decreases, and in the top of the zone, increases slightly again. But in the next zone (*Al-Ul-Co-Qu*), the *Pinus sylvestris* curve is relatively low, with minor fluctuations and does not attain such high percentages as in the previous zone. Pine is an easily accessible tree, as it usually grows in exposed sites and not on a thick stand, and owing to its rather soft timber it can be easily cut and processed. During the LPC period, the people probably cut most of the pine trees, which in the initial period very quickly regenerated. Pine could increase its area also in deeper lying, original parts of the forests, as deciduous trees were cut, and by natural succession pine could easily enter the gaps in the forest stands. Undoubtedly, it was cut out again also from those sites, as it was easier to do that in an area which already had been deforested than to clear a virgin primeval forest. However, after some time, pine did not regenerate to the same extent as previously, and its pollen percentages became significantly lower and more even. The difference in the amount of *Pinus sylvestris* pollen between the LPC and LC zones is also evident in the amount of pine charcoal and bark (Bieniek 2003). Of all recorded pine remains, both micro- and macroscopic, evidently more was found in materials dated to the Linear Pottery culture, and less in materials from the Lengyel culture period. Bieniek (2002, 2003) correlates this decline with the increase in the occurrence of the xerothermic grass *Stipa*, which according to her, results from rather intensive thinning of pine forests and development of light-demanding "steppe" vegetation. Such a concept agrees with occurence of pollen grains of plants growing on open sites such as *Anthericum*, *Jasione montana*, *Ononis*, and *Sedum*.

Oak, as indicated by the analysis of wood remains (Nalepka et al. 1998), also provided material for the constructional and farming needs of people inhabiting the Osłonki region in the early Neolithic period. It is difficult, however, to detect this in the *Quercus* pollen curve, as its silhouette is flat, with a depression marked in the middle part of the *Al-Ul-Co-Qu* zone. Probably oak was not eliminated as much as pine, most likely because it was less accessible to in thicker tree stands and also due to its significantly hard timber. One can also suspect that oaks were obtained first of all from riverine zones and not from the deeper parts of forests growing on dry areas. In such a case, when forests had been cut, the older, huge trees could probably still remain there, having better access to light, and producing larger amounts of pollen. It is also likely that they grew separately, left alone among cultivated fields (Kruk 1983, Bogaard 2002, Bieniek 2003).

An indirect evidence of the settlement's dynamic development and of intensive land-use for farming are the zones in sediments that contain damaged sporomorphs or do not contain any pollen at all. A palynologically sterile zone and a burnt layer (thereby zones containing palynological traces of LPC and LC), which divide the Os 94-9 profile (Fig. 19), indicate that the bottom sediments in the lake were subject to disturbances, maybe of a natural character, caused by seasonal poor flow of water. It seems more likely, however, that they were indirectly damaged due to intensive human farming activity, which took place in the vicinity of the lake and on its wet banks. These disturbances could be caused by supplies of larger portions of damaged matter from the banks in a form of larger sediment packages (maybe a layer of burnt peat over sterile clay in Os 94-9 profile was one such transported block), or by gradual washing out of older matter and its transport to deeper parts of the lake. Most of this damage could happen accidentally, during farming activities related to functioning of the settlement itself; maybe also during crossing the basin, during cattle watering, fishing, and dumping waste into the water. Temporary damage of plant cover in the close vicinity of the basin could also have caused transport of mineral particles to the sediments, especially during winter (Nowaczyk in prep.), and man-induced or accidental fires resulted in the increased amount of charcoal in the sediment.

The results of carpological analysis (Bieniek 2003) of fruits and seeds derived directly from the early Neolithic archaeological sites among others in Osłonki and Miechowice suggest directly that the Lengyel culture population was mainly responsible for the creation of xerothermic patches of herbaceous plants in the Kujawy region. This subject has been more broadly discussed by Bieniek (2002, 2003). The results of palynological analysis have contributed significantly less to the discusion of this subject, as the pollen curves of herbaceous plants, especially Poaceae, do not show any significant changes. Especially essential here is the genus *Stipa*, detected by macroscopic remains (Bieniek 2003). However, pollen grains of *Stipa*, similar to most grasses, do not have diagnostic features, so they are included in the Poaceae family category. Nevertheless, present in the analysed pollen zones are grains of *Anthericum*, *Jasione montana*, *Ononis*, and *Sedum* that may indicate a scant presence of xerothermic assemblages. At the same time one must remember that pollen of herbaceous plants that grew on dry terrain, could have natural barriers to spreading and dispersed into the lake, especially when xerothermic patches were small and distant from the basins that were naturally surrounded by wet habitats. Trees and shrubs could also form natural barriers, preventing the wide dispersal of pollen from these light-demanding herbaceous plants.

In the Os 94-9 *Al-Ul-Co-Qu* zone, compared to the previous zone, a decline in the tree percentage curve is marked, simultaneous with an increase in the *Alnus*, *Quercus*, *Fraxinus excelsior*, and *Tilia* curves (Fig. 19). However, the concentration pollen of these trees (Fig. 13) are lower, and that of *Pinus sylvestris* and *Betula* pollen are significantly lower. The absolute decrease in pine and birch pollen concentration may be the explanation for the relative increase in the pollen percentages of the remaining trees, although their concentration also decreased.

The presence of a few *Carpinus betulus* pollen grains in the *Al-Ul-Co-Qu* zone indicates that in the Kujawy region hornbeam had already arrived, whose pollen occurred in low quantities in Central Poland about 6000 ^{14}C BP (Ralska-Jasiewiczowa et al. 2004c).

GLOBULAR AMPHORAE CULTURE

In the Os 1-2a profile from the southern basin (pollen in the second profile from the same basin was not suitable for analysis, and the profile from the eastern basin did not have a corresponding zone) in the three higher local pollen assemblage zones (*Art* L PAZ, *Co-Qu-Art* L PAZ and Poaceae L PAZ) an increase of percentage of grazing indicators (*Plantago lanceolata* and *Rumex acetosella*) is noted (Figs 8, 20). This is evidence of an increasing role of cattle grazing in the farming activity at this time. Palynologically, these three zones are still related to the Neolithic period. Basing on radiocarbon dating (4260 ± 60 ^{14}C BP [2920–2720 BC1 and 3020–2640 BC2]) and the presence of archaeological relics in the basins' neighbourhood, this zone was linked with the Globular Amphorae culture (GAC) in addition to cultivation. The populations of the Globular Amphorae culture were engaged largely in pasturing. Therefore it seems that traces of this culture, differing from the older cultures in its intensive pastoral, are reflected in the pollen diagram. A definite indicator of pastoral activity is an increasing percentage of *Plantago lanceolata* pollen, which is evidence first of all of cattle grazing but also, to a lesser degree, of fallow land (Behre 1981). Cultivated lands were still surrounded by mixed deciduous forests. The analysed profiles, disrupted by hiatuses, do not provide data sufficient for determining of the forests regenerated or still existed with their original composition. It seems unlikely that after such long human pressure and under changing climatic conditions, the forest had regenerated back to its original form.

YOUNGER CULTURES (THE BRONZE AGE, THE IRON AGE, THE EARLY MIDDLE AGE)

As may be interpreted from the *Car*-NAP L PAZ, around the investigated site, the area covered by mixed deciduous forests decreased. Herbaceous plants invaded larger areas. This period was not older than the Subboreal, and very probably its younger part is correlated with the Bronze Age. Below this zone the percentage value of *Carpinus betulus* pollen was present, which indicates that hornbeam was already present in the investigated area. Maybe it started to grow also on areas where farming activity had been abandoned. However, the enormous percentage of destroyed sporomorphs indicates disturbance in the sediment causing difficulties in reconstruction of human farming activity in this period. It may be assumed that these disturbances were again induced by settlement surges in the neighbourhood of the overgrown basins, for in the region of Osłonki archaeological remains of the younger cultures (Bronze Age, Iron Age, early Middle Age) were also found, populations of which readily settled Kujawy. At the beginning of this pollen zone the low percentages of tree pollen, except for pine (Fig. 12), could result from climatic changes, but it can also indicate human interference in the forest structure. This interference could involve the destruction of large parts of the forest through cutting and burning. In this zone a high percentage of charcoal was recorded, and also a significant increase in the amount of corroded sporomorphs, providing additional evidence for the temporary occurrence of areas free of vegetation cover. Traces of intensive fires reveal their anthropogenic character, but at the same time, lower percentages of agricultural indicators are visible here. Probably at some time the settlement occupied by farmers was burnt down, together with the neighbouring tree stands. A extremely high peak of Chenopodiaceae pollen (10.5–14.3%) at the beginning of the zone (noted in three spectra, which rather excludes its over-representation) may also suggest the occurrence of larger areas of fallow land (barren, idle, abandoned cultivable fields) and/or more areas occupied by ruderal plant assemblages. On open terrain hornbeams may have grown.

The upper zones of biogenic deposits have been removed or destroyed to such an extent that they could not be used in palynological analysis. The contemporary pressure on the investigated basins resulted in their drainage and transformation into wet meadows, which in part were used as pastures. The southern basin, following exploitation of the organic deposits, was transformed in 2002 into a fishpond and effectively destroyed.

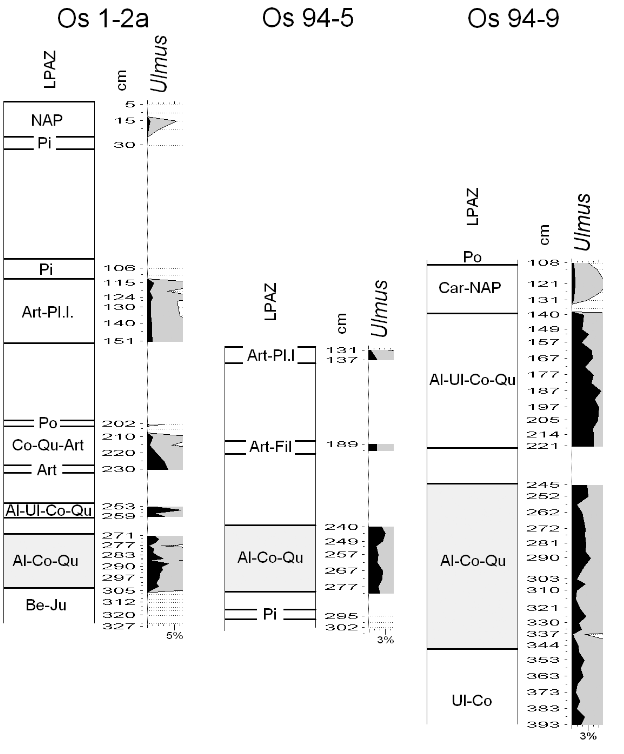


Fig. 22. Correlation of percentage curves of *Ulmus* and local pollen assemblage zones from the upper parts of the Os 1-2a, Os 94-5 and Os 94-9 profiles in the Osłonki region

ELM DECLINE

Based on the analysis of the pollen diagrams from the Osłonki region, no episode has been found that could be described as a "classical" elm decline (*Ulmus* fall), which took place around 5000 ^{14}C BP (e.g. Rackham 1980, Groenman-van Waateringe 1983, Ralska-Jasiewiczowa et al. 1998, 2003). After this period, the percentage values of elm pollen in diagrams from the European Lowlands, including also the Polish Lowlands (Zachowicz et al. 2004), did no achieve as high values as in previous periods. In the laminated sediments of Lake Gościąż, neighbouring the Osłonki region to the east, a classical fall of *Ulmus* was described in the G1/97 profile in 192, 192A, 192B, 192C pollen samples, and dated at around 5900 cal BP [around 5000 ^{14}C BP] (Ralska-Jasiewiczowa et al. 1998).

In the Os 94-9 diagram (Fig. 22), the *Ulmus* curve is rather even up to 140 cm depth. The curve in the previous zone attained its maximum (5.4%) at 187 cm depth. Up to this depth, several declines occur, but after each one the elm curve recovers to higher values than in previous spectra. The first and largest decline is visible at the beginning of *Al-Co-Qu* L PAZ in the spectrum from 337 cm depth (0.2%), in which there are also declines of the *Corylus avellana* and *Alnus* curves (Fig. 12). However, it must be noticed that at 344 cm depth, the beginning of the *Urtica* curve growth is recorded, and in the spectrum from 334 cm, the first Cerealia undiff. grain appeared. Based on numerical procedures (Nalepka & Walanus 2003b, Walanus & Nalepka 2004) the age of the 337 cm depth level is estimated to about 5900 ^{14}C BP, so it depicts a period, when, based on archaeology, the presence of the first agricultural tribes belonging to the Linear Pottery culture was indicated in the vicinity of Miechowice. However, it is unlikely that the *Ulmus* fall was caused by the arrival of this culture's population. It is possible that the noted decrease of elm percentages is an artefact caused by the lack of sediment, or by the disturbances of sediment deposited at the end of the Boreal and at the older and middle part of the Atlantic chronozone that were caused by early Neolithic tribes and does not reflect the actual decrease of elm pollen percentages in the pollen rain. After this fall, the *Ulmus* pollen curve gradually increases (Fig. 22), and its values range within 2–3% (in the spectrum from 290 cm depth it achieves 3.5%). At this section further slight declines in this curve are visible. In spectra 310 cm, 303 cm, and 257 cm it falls to 0.9%, and in spectrum 315 cm to 0.7%. In the next *Al-Ul-Co-Qu* L PAZ, the elm pollen curve still increases, oscillating around 4%. It achieves its maximum value (5.4%) in the spectrum from 187 cm depth. Following this maximum, a slight, gradual decline can be observed, up to 140 cm, where there is no elm pollen at all. Following this episode, the elm pollen percentage does not achieve 1%. Thus, in the vicinity of this zone, a classical *Ulmus* fall dated to 5000 ^{14}C BP should be expected. At the depth of 140 cm there is also a disruption in the pollen curves of the remaining deciduous trees with higher thermal requirements (*Quercus*, *Tilia*, *Fraxinus excelsior*, *Alnus*, and *Corylus avellana*) and in *Betula* also, but at the same time a rapid increase in corroded sporomorphs and a substantial increase in charcoal can be observed (Fig. 12). Such features may indicate a lack of sediment. It is likely that these have been caused by factors linked with the very intensive pressure exerted by humans on the natural environment. Based on conclusions drawn from archaeological data of Osłonki (Grygiel 2004) and regarding intensive activity of the Lengyel settlement, the dating of sediments lying below this hiatus to the Lengyel culture period seems justified. To a certain extent it has been confirmed by the radiocarbon date (5790 ± 40 ^{14}C BP) from 221cm depth (Os 94-9). Although this date is older in relation to the Lengyel culture (see page 51), it is generally within the early Neolithic dating range.

In the Os 94-5 and 1-2a diagrams there is no reason to discuss the issue of the *Ulmus* fall, as in these profiles only fragments of sediments between hiatuses are present.

FARMING ACTIVITY IN THE OSŁONKI REGION AND THE PLESZÓW SITE DURING THE EARLY NEOLITHIC

The farming of the early Neolithic settlers (Linear Pottery culture and Lengyel culture) in the Polish territory was described in detail based only on the palynological analysis for the site of Pleszów near Kraków (Wasylikowa et al. 1985). Biogenic materials sampled from the river Wisła palaeochannel in Pleszów (Fig. 1) contained fairly numerous microscopic and macroscopic plant remains, assumed to be indicators of farming activity by man. Their analysis enabled human cultures to be distinguished, and within them the phases of settlement to be identified (Wasylikowa et al. 1985, Godłowska et al. 1987, Wasylikowa 1989). The material sampled from the biogenic accumulation basins in the region of Osłonki contained only microscopic plant remains including a scant amount of sporomorphs assumed to be anthropogenic indicators. Their analysis enabled distinction of only those human cultures (see page 38) that were correlated with the results of archaeobotanical (Bieniek 2002) and archaeological studies (Grygiel 2004).

The interpretation of analyses for both sites shows a local character for both regions. In Pleszów the settlement activity was focused on loess soils at the edge of the higher terrace in a valley of a large river with a mountainous regime (Wasylikowa et al. 1985). In the Osłonki region in the Polish Lowlands, settlement was located on black soils of a small upland in the vicinity of the lake basins. Despite these differences, the results of the studies from both sites were compared in terms of the impact of the first farmers on the vegetation cover. Both sites include sediments accumulating in a similar period that relate to the same human cultures, and depict their impact on the surrounding natural environment. The results of comparison were supported by numerical correlations (see page 69).

The Pleszów site lies in the Wisła floodplain at the foot of the loess terrace on which settlements of various Neolithic cultures had been discovered (Godłowska et al. 1987). Sediments of a buried ox-bow lake, spanning the relatively short time between ca. 6500 and 4500 ^{14}C BP, revealed seven agricultural phases which were correlated (by radiocarbon dating and pollen spectra) with successive settlement episodes of the Neolithic. The oldest palynological phases probably reflect the activity of the Linear Pottery culture people. The next phases were correlated with the existence of a large settlement of the Lengyel culture (see page 69). In the pollen diagrams of Osłonki (Figs 19–21), the periods corresponding with the Linear Pottery culture and the Lengyel culture were also distinguished. But here the materials are not as complete as for Pleszów, as the zones containing the pollen record of farming are separated by hiatuses of unknown time span. These zones also do not cover the entire periods when the individual cultures existed in the investigated region and it is not known which fragments of these periods are represented in the sediment.

At the end of the Atlantic chronozone in Pleszów and in the region of Osłonki favourable conditions for settlement prevailed. Palynological analysis (Wasylikowa et al. 1985) indicates that both regions did not differ significantly in their forest types and various habitats ranging from dry through fresh to damp and wet. In the neighbourhood of the settled sites various biocenoses existed, which could be a potential source of food and material required for the construction of settlements and farming. Almost the entire land was covered with forests. On wet habitats damp meadows, alder forests, and willow scrub prevailed. On drier habitats mixed deciduous forests prevailed. Reeds covered banks along water basins. Farming in both regions developed based on the cultivation of *Triticum* and *Hordeum* and on cattle breeding. In Pleszów the agricultural practices of the Linear Pottery and Lengyel culture communities were based on land rotation: small areas were cleared by burning different forest stands, *Triticum* and *Hordeum* were cultivated for a time, then the fields were abandoned and cultivation moved to new clearances. Some of the fallow areas were never recultivated, thereby allowing forest recovery, while the others were used as pasture, hindering the spread of trees and shrubs. Land rotation extended over all kinds of landscape, from the valley floor to the loess terrace plateau (Godłowska et al. 1987, Wasylikowa et al. 1995, Nalepka & Wasylikowa 1998).

Based on palynological analysis, the early farming activity from the region of Osłonki can be characterized in less detail, even though it is supported by the results of archaeological and archaeobotanical studies. As at Pleszów, *Triticum* and *Hordeum* were cultivated. For the purpose of farming activities, large amounts of wood were obtained and wild plants collected (Nalepka et al. 1989). In Pleszów the areas used by the Linear Pottery culture tribes were larger, while in the Osłonki region, farming activity in this period was of a local scale. In the next period, with the larger extension of the Lengyel settlement, the land put into cultivation of the same cereals in the region of Osłonki must have been larger, although pollen analysis does not indicate quantitative differences compared to the previous period. Areas under arable land were obtained through clearance, but of a different type than these in Pleszów. Macroscopic analysis of weed remains indicates that clearances in the region of Osłonki were long-established (Bieniek 2002). In Pleszów, from the beginning of the Lengyel settlement, there were no conditions for the regeneration of the original forest assemblages. In the Osłonki region, on the other hand, the vegetation cover appear to regenerate back to the type as before the Lengyel culture had arrived.

The younger phases in both regions are less clearly defined and their correlation with cultural phenomena is problematic.

THE END OF EARLY NEOLITHIC SETTLEMENT IN THE REGION OF OSŁONKI IN LIGHT OF PALYNOLOGICAL ANALYSIS OF BIOGENIC SEDIMENTS

The reasons why the communities of the Linear Pottery culture ceased to exist in the study area are interesting. Based on radiocarbon dates derived from the archaeological sites in southern Kujawy, the end of LPC is dated to 4900/4800 BC years, followed by a break of around 200 years before the next settlers belonging to the Lengyel culture arrived (Grygiel 2004). Development of the Linear Pottery culture in Kujawy, though lasting only ca. 500 years, did not cover the entire development cycle, but only underwent a stage of beginnings and suddenly stopped, having not attained a stage of strategy (duration), according to the concept of Bogucki (1979). Grygiel (2004) is strongly inclined towards the view that the decline of the Linear Pottery culture was caused by a rapid and marked climatic change, which brought about a drying process in the central-eastern part of the European Lowlands and consequently the retreat of the LPC from Kujawy (and Ziemia Chełmińska) and the western part the Odra river.

Based on the palynological record of Osłonki, it is not possible to determine the causes of the Linear Pottery culture settlement decline. The zone corresponding to the LPC in profiles Os 1-2a (Fig. 20), Os 94-5 (Fig. 21) and Os 94-9 (Fig. 19) is disrupted by pollen steryle layers. From these tree profiles only one (Os 94-9) is suitable for further interpretation of the hiatus. In this profile the sediment is disrupted by homogeneous clay 3 cm thick, containing only scarce fragments of plant tissues. This layer could have been deposited in a short period, maybe even during one event. Above this mineral layer there is a 2 cm layer of charred, heterogeneous peat. It contains a small number of sporomorphs, unidentified due to destruction, and large, poorly distributed fragments of vegetation tissue. It seems likely that this layer was created during the inwashing process of soil material from periodically drained parts of the banks on which plants were burnt. The existence of such layers is evidence of some extreme events (Starkel 2000). However, it cannot be palynologically confirmed whether those events were caused by climatic fluctuations. Basing on comparison with neighbouring sites (Ralska-Jasiewiczowa et al. 1998) and regional data (Ralska-Jasiewiczowa & Latałowa 1996), the youngest pollen spectrum of the zone *Al-Co-Qu* covering the LPC period can be dated to 5700 ^{14}C BP, which is earlier than the accepted end of this culture. Below this spectrum, and in the spectrum lying above the clay and peat layers, the plants, which would foreshadow or follow climatic changes, do not show any such changes in the pollen curves. When plotting this fragment of the percentage diagram disregarding the hiatus, a continuous picture can be obtained. In the pollen diagram from the annually laminated sediment from Lake Gościąż, lying 30 km to the east, the spectra dated to this period (Tab. 13) show no clear evidence of climatic change either. It is worth noting that Lake Gościąż is located in the Wisła valley, so a climatic episode involving drainage should be more evident there than in the Kujawy Upland.

Table 13. Ages of samples corresponding to early Neolithic time from the Lake Gościąż profile (according to Ralska-Jasiewiczowa (ed.) 1998)

Gościąż G1/97		
Sample no.	Cal. age BC	Age ^{14}C BP
169	5047 ± 16	6120 ± 20
170	4995 ± 16	6100 ± 20
171	4935 ± 15	6040 ± 20
172	4887 ± 15	5980 ± 20
173	4835 ± 15	5970 ± 20
174	4785 ± 14	5900 ± 20

Basing on isopollen maps for *Alnus* (Szczepanek et al. 2004) and Cyperaceae (Latałowa et al. 2004a), no evidence was found for climatic fluctuations involving drainage in this part of Poland. These plants should react to a climatic change causing land drainage that would be reflected in a decline in their pollen curves. Isopollen maps indicate that around 6000 years ^{14}C BP conditions for development of alder and Cyperaceae assemblages were less favourable in the regions of Kujawy and Bory Tucholskie (Ralska-Jasiewiczowa et al. eds, 2004), compared to neighbouring regions.

Searching for short-term trends is now becoming an increasing activity in studies of the history of environment. They can eventually help in assessing trends and interpretation of climate on a local and regional scale (Birks 2003, Mackay et al. 2003). This is possible when multi-site studies are carried out, and for each site continuous, dated profiles are available, and biotic and abiotic characteristics of the components are examined. The profiles from the region of Osłonki cannot be used for such studies, as they do not contain continuous sequences. A complete sequence of Holocene sediments has not been found, and detailed numerical data on contemporary pollen fallout have not been collected in the region of Kujawy yet. Therefore, it is not possible to reconstruct short-term patterns of vegetation changes based on palynological analysis.

The end of the next stage settlement, the Lengyel culture, is dated based on archaeological records to 4200/4100 BC (Grygiel 2004). Based on biogenic materials it was not possible to find out the cause of this culture's decline, because of hiatuses in the examined profiles. It is very likely that the intensive settlement activity caused significant changes in the natural environment, which resulted in disturbances in the small neighbouring basins. These disturbances could be caused by the inflow to basal sediments of larger amounts of mineral and organic matter from the areas of direct land-use. That inflow could be facilitated by ditches, a remnant of which is a fortification ditch, whose traces exist in the eastern part of the Osłonki 1 archaeological site and approach the southern basin. At the end of this culture ca. 4400–4300 BC (ca. 5200–5300 ^{14}C BP), violent events were marked in archaeological records, which should be reflected in the form of a ubiquitous layer of disturbances in the lithological zones of the analysed profiles (Grygiel 2004). In face of such archaeological indications, and the evident hiatuses in the pollen diagrams, a date of 5300 ^{14}C BP was assumed for the end of the *Al-Ul-Co-Qu* L PAZ (in the profile from the eastern basin). In such a way it was acknowledged that disturbances could not be linked with later climatic changes, which took place around 5000–4500 ^{14}C BP and were reflected in palaeochannels and peat-bog profiles. These disturbances were provoked by an increase of river activity and changes in groundwater level (Ralska-Jasiewiczowa & Starkel 1988).

Generally, a fluctuation of water level in the south of Poland (in Pleszów) was responsible for the decline of an early Neolithic settlement (Godłowska et al. 1987). However, also there, as noted by these authors, the hiatus between the Linear Pottery and Lengyel cultures, lasting in Pleszów up to ca. 250 years, remains mysterious. In that period, accumulation of peat, regeneration of alder, oak, and elm, and the development of hazel took place. The gap in settlement does not mean a definite termination of farming activity in the lowland. That activity was probably linked with the burning down of reed-dominant assemblages (Godłowska et al. 1987).

DISCUSSION OF RADIOCARBON DATINGS

Radiocarbon dates of the examined samples are generally comparable with indirect dating based on palynological analysis, and some of them also with dating of over 30 samples derived from archaeological sites (Bogucki 1987, Grygiel 2004). However, some of the datings require discussion.

The first inconsistency with expectations from palynological analysis is that four radiocarbon dates from the Boreal section of the Os 94-9 profile (assigned based on palynology), are out of chronological order (Figs 12, 23, Tab. 6). These dates were obtained by accelerator-mass spectrometer (AMS) dating. In this case, the most likely hypothesis is that during the Boreal chronozone in the existing eastern basin water flow took place, which caused the outwashing of somewhat older and somewhat younger materials and carryied them to and from the bottom sediment. The traces of such disturbance were not visible in the macroscopic features of the sediment or in the palynological analysis. Latałowa et al. (2003) had described a similar redeposition of older macroscopic remains to the younger levels in the bottom sediments of Zalew Szczeciński. Indirect evidence for such waterflow through the lakes near the early Neolithic settlement in Osłonki may be the presence of bones of asps (*Aspius aspius*) a fresh-water fish found in the materials from the archaeological settlement (Makowiecki 2003). The presence of *Ephedra distachya* type pollen in this section of the profile (Fig. 12) could be regarded as evidence for reworking of sediment. Of course, fresh-water fish might be caught in some rivers far away from the settlement, e.g. in the river Zgłowiączka or Wisła. It can also be supposed that the ^{14}C dates from the eastern basin are influenced by the hardwater effect, because they derive not only from terrestrial material but also from remains of plants, such as *Carex*, Cyperaceae, and *Typha latifolia* growing on wet habitats. The open water surface in the basin might have been small, so only little organic terrestrial material could penetrate the basin, compared to the amount of deposited remains of aquatic plants. In this situation, these dates will be neglected in interpretation. Later on (Tab. 24, see page 74) they are marked with an asterisk (*).

The second issue is that radiocarbon dates from the southern basin are older than results from dating of archaeological artefacts alone. In the Os 1-2a profile there is a date 6730 ± 70 ^{14}C BP (in calibrated years 5700–5560 BC1 and 5750–5500 BC2) at peaty mud, and from the Os 94-5 profile: 6670 ± 70 ^{14}C BP (5660–5520 BC1 and 5710–5480 BC2) at gyttja, and 6470 ± 70 ^{14}C BP (5490–5360 BC1 and 5600–5310 BC2) at peaty mud (Tab. 6). These dates were obtained by the conventional ^{14}C dating technique on a few cubic centimetres of sediment, which contained a very small amount of carbon and are at the limit of the method's applicability. It is also known that radiocarbon dates obtained from peaty mud and gyttja will always have a larger error (as result of hardwater effect) than dates obtained on macroscopic remains of terrestrial plants (Pazdur 1995, Turney et al. 2000, de Klerk 2004, Walanus & Goslar 2004). Based on palynological analysis, geomorphologic conditions, and archaeological knowledge, the zones from

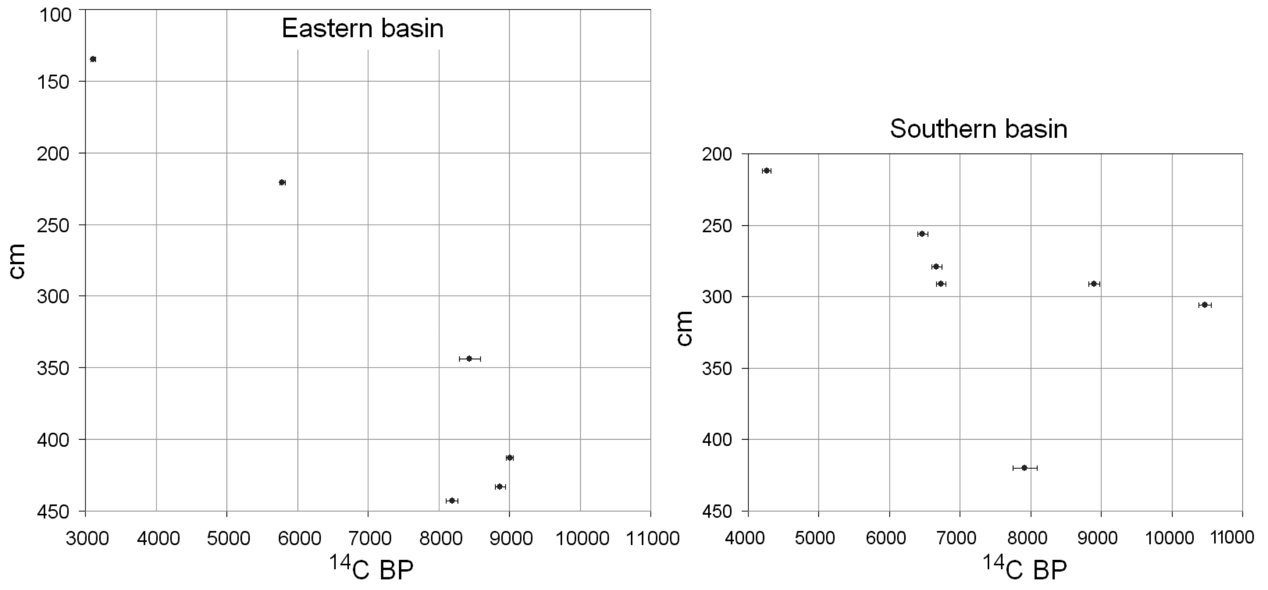


Fig. 23. Radiocarbon ages obtained from macrofossils from the eastern basin, Os 94-9 (left plot), and radiocarbon ages obtained from bulk sediments from the southern basin, Os 1-2a, Os 94-5 and Os 2/93 (right plot). For the ^{14}C data see Table 6

which the dates have been derived correspond with the Linear Pottery culture period. Grygiel (2004) places this culture within the range of 5400/5300–4900/4800 BC, so the dates should not be older than 6440 ± 120 ^{14}C BP. Up to the present, the oldest ^{14}C BP date of macroscopic plant remains derived from levels of the Linear Pottery culture from Meindling in Germany is 6380 ± 130 BP (Bieniek 2002 after Bakels 1992). In calibrated years this date is between 5460–5150 BC1 and 5600–4950 BC2.

The older than expected age of samples from the southern basin is supported by the fact that the material used for dating had little sediment lying below it. In the Os 1-2a profile, the sediment dated palynologicaly to the Younger Dryas turns, without a visible boundary, into sediment dated palynologicaly to the Atlantic chronozone. In the Os 94-5 profile, above the sediment dated palynologicaly to the Preboreal chronozone, clay lacking pollen was deposited, and directly above it there is sediment deposited during the Atlantic chronozone.

Dates from the southern basin were obtained from two profiles sampled in a very close neighbourhood, while dates from the eastern basin are derived from one profile only. Both basins are a few hundred metres apart, so the analysed radiocarbon dates can be treated as obtained from one site. Figure 24 demonstrates that the dates from the southern basin are older than the dates of archaeological materials from the LPC sites at the Osłonki region, here from the Miechowice settlement.

However, according to Grygiel (2004), within the Kujawy-Chełmno LPC community, the oldest populations could arrive from the south already ca. 5500-5400 cal BC, whereas their decline could happen around 4900–4800 cal BC. Within this context the date 6470 ± 70 ^{14}C BP [4700–4570 BC1 and 4470–4530 BC2] would correspond to the first arrival of the settlers.

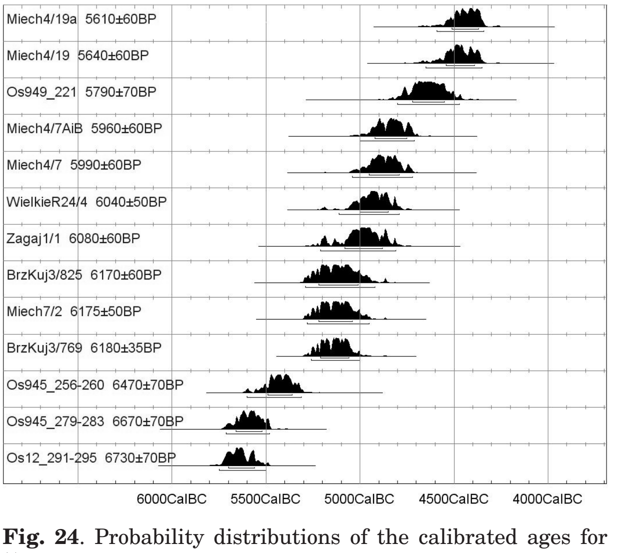


Fig. 24. Probability distributions of the calibrated ages for ^{14}C Linear Pottery culture dates from archaeological artefacts obtained from 4 sites at south Kujawy (Grygiel 2004) and dates from the organic samples derived from biogenic accumulation basins palynologicaly acknowleged as derived from this culture's period from the Osłonki region

EXTRACTION OF USEFUL INFORMATION FROM LARGE NUMERIC DATA SETS

Numerical data can be handled by applying appropriate numerical methods. The use of numerical methods means performing some forms of multivariate analysis. The practical aim of such numerical analysis on the pollen data is to extract information which is hard to summarize in large and complex sets of data (Kendal & Buckland 1975, Birks & Gordon 1985, Wołek 1992, Łomnicki 1995, Durka 2003). Numerical data obtained as a result of pollen analysis (identifying and counting of sporomorphs with the aid of microscope) represent a data set, which is displayed graphically in the form of standard pollen diagrams, presenting in stratigraphical order the percentages of individual taxa in the analysed spectra (e.g. Berglund & Ralska-Jasiewiczowa 1986, Faegri et al. 1989, Dybova-Jachowicz & Sadowska 2003). The other approach to palynological data is to look at them as a set of numbers, in a way which is not influenced by ecological knowledge a priori. Such a numerical approach can improve the repeatability and the impartiality (objectivity) of the conclusions, although the final results obtained by these methods will always depend on certain subjective decisions and selection of parameters (Walanus 1995).

The sections presented below illustrate the possibilities of using some available numerical methods (Birks & Gordon 1985 and others). The numerical methods are impartial with regard to the examined materials and are complementary to the ecological knowledge. They enable one to look at the examined material from a different point of view. They facilitate interpretation of data, help in searching for certain tendencies, and emphasise the conclusions. When they are completed, one can agree with the results or not, but one first need to see these results.

In the first part of this study, the development of the vegetation cover in the region of Osłonki based on the conventional interpretation of pollen diagrams was presented (see page 19). The chronology of events has been determined indirectly, based on similarity between spectra with the well-dated profiles from the neighbouring regions. The history of events has been ordered into chronozones. In all the profiles hiatuses were detected. In order to date chosen zones or to make dating more accurate, numerical methods were used, although it must be emphasized at the beginning that the raw data were poor, and scarcely suitable for such methods. This was caused by the occurrence of hiatuses in the examined profiles, dislocations found in some zones, and also a significant destruction of sporomorphs or their poor frequency resulting from the large content of mineral matter that could not be removed during sample preparation in the laboratory.

The first goal of numerical analyses of palynological data from the Osłonki region profiles was a division of individual profiles, independent of ecological knowledge, into sequences of similar groups of spectra and identification of the limits between them. This has been done with the standard, widely need numerical analyses: Constrained Single Link and Principal Components Analysis (Birks 1986, Prentice 1986, Nalepka & Walanus 1995, Walanus 1995, Walanus & Nalepka 1996).

The results of a Constrained Single Link (ConSLink) analysis display a profile's division in the form of dendrogram, the branches of which link samples or groups of previously aggregated samples, according to the appropriate measures of similarity (Walanus 1995).

Principal Components Analysis (PCA), by presenting the data in a more condenced form (Nalepka & Walanus 1995), enables us to distinguish the principal features of composition variability within a profile. As a result, quasi-taxa or latent variables (principal components) are created, ranked in terms of their numerical importance. Quasi-taxa are created as linear combinations of the percentages of the taxa. The first latent variables or quasi-taxon, namly the first principal component, includes the largest part of the common information contained in all taxa. The next principal components contain again the maximum amount of common information, but that information is independent of earlier components. The biological meaning of principal components (for instance, identification of certain ecological conditions) may be derived from so-called components loadings relevant to individual taxa. However, a principal components analysis diagram indicates the ranges of major changes in the course of all taxa included in PCA.

Graphical results of the above analyses have been shown together with the concentration pollen diagrams of the analysed cores (Figs 9, 11, 13, 15, 17). All conclusions resulting from the numerical analyses have been treated as auxiliary, and the interpretation of diagrams was based first of all on ecological knowledge.

Pollen diagrams from one region and from the same period are similar in terms of basic features, which permits their correlation. When one diagram has been dated absolutely, its timescale can be applied to the neighbouring profile (Walanus & Nalepka 1996, Ralska-Jasiewiczowa et al. eds, 2004). However, accuracy of such dating always depends on the precision and on the reliability of the correlation between profiles. Usually, levels of changes in pollen spectra can be correlated, if a series of samples of a relatively uniform composition is available (Walanus & Nalepka 1996).

Therefore, the second goal of numerical analyses performed on palynological tables was their comparison to indicate the most similar pollen spectra in different profiles (correlation), and then the assignment of ages to the spectra synchronised this way (relative dating). General similarities among available tables were assessed basing on ecological knowledge. A search for the most similar spectra sequences was completed only for the selected fragments of the pollen tables. It was acknowledged that it was advisable to correlate only spectra within enclosed in the same chronozones, and only in those cases when the fragments contained at least a few spectra. The correlation has not been made when in one of the profiles only one spectrum was included in a chronozone, while the other profile contained several spectra. As a result, only the Younger Dryas chronozone and fragments of the Atlantic chronozone (the ones with the anthropogenic pollen indicators) were selected for correlation. Based on palynological, cladoceran, malacological, and sedimentological analyses, no stratigraphical disturbances have been assumed in the selected fragments. It must be emphasised that not all fragments selected for correlation represent the entire chronozones. So, in both profiles from the southern basin, sediments from the middle and the younger part of the Younger Dryas chronozone were present, and in all three profiles from the Osłonki region, only fragments of the younger part of the Atlantic chronozone were present. Numerical analyses were repeated for many working options, but the results that were finally chosen yielded clear, and useful information.

Profiles from the Osłonki region were compared among themselves and also with the profiles from outside Kujawy: with one profile from Lake Gościąż (Ralska-Jasiewiczowa et al. 1998) and with one profile from a palaeochannel in Pleszów (Wasylikowa et. al. 1985, Godłowska et al. 1987). Numerical methods used were based on the comparison of percentage values of the selected taxa.

The measure of similarity between two spectra can be given through the calculation of differences of corresponding taxa percentages between the two spectra and then summing the absolute values of these differences (Manhattan metrics; Birks & Gordon 1985). The lower the resulting sum, the more similar are the spectra. This quantitative measure of similarity is taken relatively. It just determines which spectra are more and which are less similar, and based on this information, the profiles can be correlated (Walanus & Nalepka 1996).

Raw data can be pre-processed in a way which enables, for instance, putting more weight to those taxa, which from the very nature yield low pollen percentages. For such a purpose, square roots of percentages can be calculated. The selection of taxa to be included in the analysis is a subjective decision. It is crucial that a large number of combinations be examined each time (Walanus & Nalepka 1996).

The measures of similarity (or dissimilarity) are based on the differences between the percentages of given taxa in two samples. Data for the analyses have been taken in a basic form (percentages calculated for the TOTAL sum or for the sum of taxa enclosed in a set of taxa), or in a standardized form. As a result of standardization, all taxa get the same weights. However, standardization cannot be applied to non-abundant taxa, as such taxa would get too high weight and would have relatively too strong an impact on the overall result. For instance, if in group of 10 spectra a taxon with the value of 0.1% was present in only 2 spectra and has not been present in the remaining 8, then after standardization it would receive the maximum value twice. In other words, its weight from a statistical point of view would be very heigh. In such a case, for non-abundant taxa, a moderate standardization should be applied consisting in the calculation of the square root. This procedure causes the most frequent taxa to be less dominant, and those less frequent do not become too weak.

Analyses have been performed for the selected sets of taxa, and not for all taxa contained in the tables. Selection of sets was based on choosing the taxa that have been recognized as climatic indicators for a given chronozone or period important from the point of view of ecological interpretation. Many taxa identified during counting of pollen spectra have minor ecological importance. Around 10% of taxa are characterized by high counting values, but only a part of them provides substantial ecological information on the regional scale. Representation of the remaining 90% of taxa is low, and additionally, some of these taxa have only a local meaning. When such scarce taxa have been subjected to standardization, their role in the mathematical result could be exaggerated, inconsistent with the ecological knowledge.

Taxa that were represented in spectra by only a few grains have a small percentage value. They may be very important in a diagram's interpretation, but as a rule they have a low numerical value (low statistical weight). Thus it should be remembered that, e.g., *Juniperus communis*, *Artemisia* or *Betula nana* that are important for cold periods are not large pollen producers. On the other hand, *Pinus sylvestris* and *Betula* produce large quantities of pollen, which can be transported by wind over long distances, so a part of their representation in the examined zones may come from far-transport, especially for periods with low forest cover. Such knowledge must affect the decision whether the data should be subjected to standardization and to what extent, and this has an impact on the final result.

Applying numerical analysis to pollen data from the Osłonki region first, graphical analysis was applied, consisting of plotting the sample similarity matrix (SSM), which indicated the similar groups of spectra in two compared diagrams, thereby identifying their possible correlation, based on similar percentages of pollen of the indicative taxa. Then the correlation (by the MultCorr application) was completed, which indicated the most similar single spectra in two, three, or four compared profiles. SSM has presented groups of the most similar spectra in two tables, and the goal of MultCorr was to present the most similar single spectra based on several tables. Also conducted was a comparison of the average spectra, which were created as the arithmetic mean for each fragment of the profile. The goal of these analyses was to indicate the similarity between a fragment of one profile and some fragments from other profiles.

Afterwards, analysed pollen diagrams from the Osłonki region were correlated based on results of these correlations. The spectra have been dated in fragments of profiles using the Depth/Age algorithm included in the POLPAL program (Nalepka & Walanus 2003b, 2004, Walanus & Nalepka 2004). This last procedure of dating spectra in the profiles has been recently applied for the construction of a new edition of isopollen maps for Poland (Ralska-Jasiewiczowa et al. eds, 2004). The ultimate purpose of applying these procedures was to produce pollen percentage maps of chosen taxa in two time horizons (Younger Dryas and younger part of the Atlantic) in the Kujawy region.

SAMPLE SIMILARITY MATRIX (SSM)

SSM analysis has been performed in order to indicate the most similar spectra and groups of the most similar spectra in two data tables. It has been performed on taxon percentage values, calculated in relation to the pollen sum of selected taxa (enclosed in a set of taxa). Selection of indicative taxa was crucial here. The method visualizes the similarity between spectra (samples) between the first and the second profiles. The stratigraphical sequence of samples from the first profile is plotted vertically, and the second sequence is plotted horizontally (see graphs in Tabs 14, 16, 18, 20, 22). As a result, a matrix emerges with each node representing a pair of samples (pairs of pollen spectra): one from the first profile, and one from the second. In such a node there is a graphical representation of the similarity between given samples. It is plotted as a black square with the area proportional to the degree of similarity. The higher the similarity measure, the larger the blackened patch on the interface of the row and column corresponding to the samples from the two profiles.

In the SSM one or more areas (pairs of profile sections) of a certain correlation can be seen. In these areas a path of similarity should be visible that approximates a diagonal line (Walanus & Nalepka 1996). Spectra along one profile are autocorrelated, i.e. the neighbouring spectra are rather similar, and the global view of the matrix is not a chaotic pattern of larger and smaller squares, but a general correlation between two profiles is visible.

Sample Similarity Matrix analysis has been performed twice for each data set for row pollen percentages and for percentages transformed by calculation of square roots. Analysis has been completed by the computer application PPSSM.exe, included in the POLPAL system (Nalepka & Walanus 2003a, Walanus & Nalepka 2004).

CORRELATION (MULTCORR)

The other method of displaying similarities among data-sets was the Multi Correlation analysis performed by the program MultCorr (Walanus & Nalepka in prep.). In this analysis dissimilarities are calculated. The lower dissimilarity coefficient (DC), the higher similarity between spectra. The program indicates that a given spectrum in one table is similar to some spectra in the other tables. This program correlates several (up to 10) pollen tables. The program searchs for the most similar pollen spectra among the tables. In each step, one spectrum from each table is found, which gives the lowest value of the dissimilarity coefficient (DC). Lines connecting the most similar spectra (one set of spectra) illustrate the result (see Tabs 15, 19, 21, 23). In the next steps, the next set of spectra from the tables is searched, but the previous lines cannot be crossed.

The dissimilarity Coefficient (DC) between a pair of spectra is calculated as the sum of the absolute values of the differences in all (or in chosen) taxa. The DC for spectra from all sections is calculated as the sum of DC's for sections 1 and 2, 2 and 3, 3 and 4, and so on. But many different orders (e.g. sections 3 and 2, 2 and 1, 1 and 4 ...) of tables are checked in the search for the lowest DC. The final DC value is the sum of DC's from each step. Calculations in MultCorr analysis were done on raw pollen percentages and percentages previously transformed according to various options.

The analysis has been carried out in two stages, and calculations were made for sets of taxa considered pollen spectra ftom the Osłonki region palynologically assigned to the Younger Dryas and to the younger part of Atlantic chronozone.

MultCorr – Individual spectra

The first stage was made to find the most similar spectra in two or more profiles simultaneously. In other words it was expected to indicate several pairs of spectra between which similar sections existed. Procedures were conducted for two and three divisions of the tables that were illustrated by 2 or 3 lines. Tests have been conducted also for four and even five divisions, and the results confirmed the a priori assumptions that in the case when the analysed table comprises only several spectra (e.g. Os 94-5 YD section comprises 5 spectra), analysis must be done for a smaller number of divisions.

Calculations were completed for four options of transformation of the tables containing percentage values of sporomorphs. The first option (No) consisted in the correlation of raw data i.e. no transformation of pollen percentages was made. The second option (Standardization in profile = Stand. in profile), the third one (Standardization total = Stand. total), and the fourth option (Sqrt) were based on the transformed data.

Standardization is a transformation of a series of numbers in which the average value is subtracted from each number and then divided by the value of standard deviation. After standardization, each variable (taxon) has a zero mean and the same (unit) standard deviation, i.e. all taxa have the same statistical weight. Two kinds of standardization are used here, which differ in that the average and standard deviation are calculated within the given table or in all tables being considered.

MultCorr/Standardization in profile (common standardization). In each column the percentage values for each taxon are standardized by the subtraction of a mean value and division by a standard deviation. In all the tables one proceeds in the same independent way. As a result of such procedure, values in the column for a given taxon from the first table would have a different weight than the values for the same taxon from the second table and the next tables.

MultCorr/Total Standardization. The standardization is conducted for all values of a given taxon in all tables used in the correlation. As a result of this procedure, percentage values for a given taxon from the first table will have identical weight as the values for the same taxon from the second table. The Total Standardization assigns the same weight for a given taxon in all tables.

Calculation of square roots (Sqrt) is done for a given number in each node (independently of the values in the other nodes of the tables). This operation reduces the weight of the taxa with a higher percentage representation and increases the importance of taxa with a poor representation. The standardization transformes values of a given taxon depends on its values in one table or depends on its values in all tables, so the values within a given taxon are mutually influenced by themselves. Characteristic for the Sqrt option (and for No option) is that specific values are transformed independently of the other values in this and in the other tables.

MultCorr – Averaged spectra

While in the first stage of the MultCorr – Individual spectra analysis single spectra were correlated, the second stage is made to express a general similarity between the pollen tables based on average spectra. In this procedure, instead of taking into consideration separate spectra, they are summed to create a single “average spectrum”. In other words the average spectrum was created as the arithmetic means for one fragment of table and it represents the entire fragment of this table. In such a way, the counts from several spectra (from a chosen sequence of spectra) are added together (within taxa) and their percentages were calculated. The spectrum obtained in that way may be treated as an average spectrum or one spectrum obtained for a “thick” sample (thick fragment of sediment). In such a way the average spectra for selected sequences of the analysed tables were calculated. These average spectra have been indicated by the abbreviation “av.” (Os 1-2 av., Os 94-5 av., and Os 94-9 av.). Next the similarity between that average spectrum to the spectra from other table is checked. The connections between the average spectrum and the most similar spectra of another table are displyed as lines (see Figs 26, 27, 29, 31).

NUMERICAL COMPARISON (CORRELATION) OF POLLEN TABLES ASSIGNED TO THE YOUNGER DRYAS CHRONOZONE

Correlations of the pollen tables assigned to the Younger Dryas chronozone were conducted in the first stage only for the discussed fragments of tables from Osłonki, and in the second stage for the Os 94-9 table fragment from Osłonki and the G1/87 table fragment from Lake Gościąż (Ralska-Jasiewiczowa et al. 1998). The comparisons were based on the spectra similarity matrix (SSM) for two tables, and on the similarity between individual spectra from all the tables (MultCorr – Individual spectra) and the similarity between average spectra (MultCorr – Average spectra). The results of correlations were presented in tabular form (numerical and graphical). The results of correlations for the profiles from Osłonki (where spectra are identified by depth) with the profile from Gościąż (where spectra are identified by varve ages) were illustrated only in numerical form.

Correlation of pollen data from Osłonki

The results of palynological analysis indicated that the record of the Younger Dryas chronozone (see page 28) was complete in the Os 94-9 profile (eastern basin), whereas the profiles from the southern basin (Os 1-2a and Os 94-5) were only fragmentary. Correlation of these records was performed by means of correlation analysis. The analysis indicated which spectra from various tables were the most similar to each other.

In the first step, fragments of two profiles from the southern basin were correlated. The SSM and MultCorr algorithms were applied to two sets of taxa: a smaller set and a larger set. Both sets contained the taxa distinctive for the cold stadial: *Larix*, *Pinus cembra* type, *Betula nana* type, *Salix polaris* type, *Juniperus communis*, *Hippophaë rhamnoides*, *Artemisia*, *Selaginella selaginoides*. The larger set contained also *Betula* and *Pinus sylvestris*. The analysed fragments of the pollen diagrams (the larger sets of taxa) are shown in Figure 25.

The SSM analysis for the Os 1-2a and Os 94-5 records, consisting of only several spectra, proved (Tab. 14 row 3) that the most similar (the largest squares) were spectra from 315 cm in Os 1-2a and 312 cm in Os 94-5. The analysis completed for a larger set of taxa

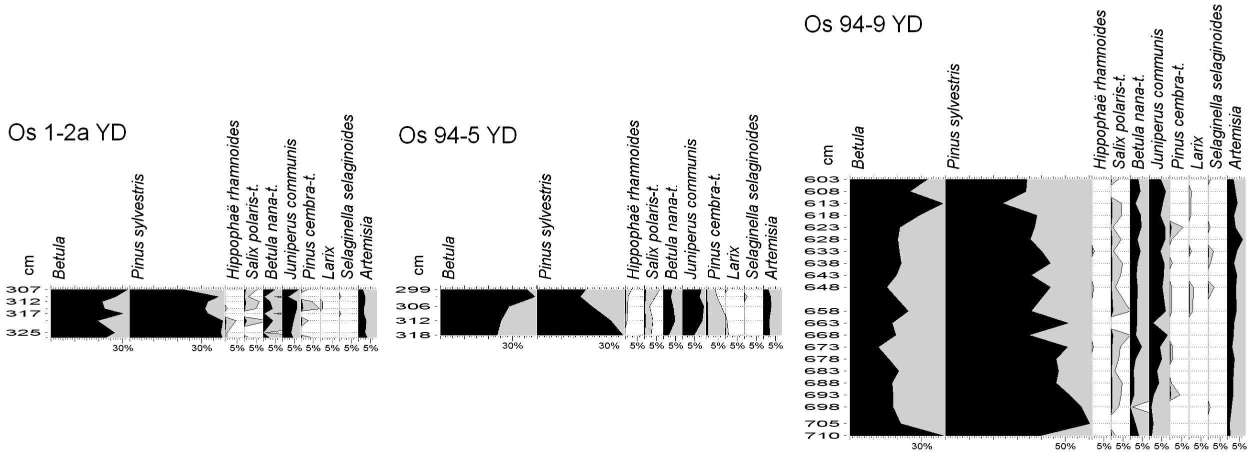


Fig. 25. Fragments of pollen diagrams of the Os 1-2a, Os 94-5 and Os 94-9 profiles, assigned to the Younger Dryas chronozone. The taxa selected indicate the Late Glacial stadials. These taxa were used in the SSM and MultCorr analyses

(row 3, columns A and B) yields a poor similarity between the other spectra.

For the smaller set of taxa (without *Pinus sylvestris* and *Betula*, Tab. 14, column C, D), the upper parts of the analysed records seem to be a little bit more similar.

The same records were also examined with the MultCorr analysis (Tab. 15), performed for four various transformations of pollen data (No, Standardization in profile, Total Standardization, Square root), using the larger (rows 4, 6) and the smaller (rows 7, 9) sets of taxa. This analysis did not prove a clear pattern of similarity between individual spectra. The results for different transformations linking different spectra in the examined range. Each time, however, the link between 312 cm (Os 1-2a) and the 315 cm (Os 94-5) spectra is indicated.

The second step of analyses, included the Os 94-9 profile, coming from the eastern basin, a few hundred meters away from Os 1-2a and Os 94-5 profiles (Fig. 3). The purpose of that correlation was to indicate to which part of the Os 94-9 record (the complete Younger Dryas chronozone) the fragments of the southern basin profiles are similar.

As a result of the SSM analysis for the larger set of taxa (Tab. 14, columns A, B), paths of possible similarity show that the fragment of the Os 1-2a profile is similar to the middle or the younger part of the Os 94-9 profile, and the fragment of the Os 94-5 profile is rather similar to the younger part of the Os 94-9 profile. Here, more clearly marked is the similarity between almost all spectra of Os 94-5 to the 623 cm spectrum of Os 94-9. It is visible when Percentages (%), (column A) as well as for Square roots of percentages (column B) are used for analysis. For the SSM correlation of the smaller set of taxa (Tab. 14, columns C, D), it is harder to find pathways of profile similarity. Here a clear similarity occurs, first of all between the oldest spectrum from Os 1-2a and most of the spectra from the Os 94-9 profile (row 5). Then, the youngest spectra of the Os 94-5 profile (row 7) indicate similarity to almost all spectra (excluding the oldest one) from the Os 94-9 profile. These similarities are visible when percentages or square roots are used in the calculations. Here also the similarity between almost all the spectra from Os 94-5 and the 623 cm spectrum from Os 94-9 is more clearly marked. The results indicate the both records from the southern basin (Os 1-2a and Os 94-5), assigned to the Younger Dryas, are not similar to the oldest part of the Younger Dryas section of the Os 94-9 record.

Next, the MultCorr correlation for all three records was conducted. The MultCorr results (Tab. 15), obtained for four various transformations of the pollen data, and for both sets of taxa with (rows 4, 10) and without (rows 7, 13) *Pinus sylvestris* and *Betula* did not show evident similarity between the individual spectra, the results for different transformations, linking different spectra in the examined range. The selection of which set of taxa did not have any impact on the results.

The MultCorr correlation was also made for average spectra from the Younger Dryas tables of Os 94-5 and Os 1-2a (Os 94-5 YD av. and Os 1-2a YD av.) with the Younger Dryas table of the Os 94-9 YD profile. The calculations were completed only for the larger set of

Table 14. Diagrams of the Sample Similarity Matrix (SSM) between the Younger Dryas section of the profiles from Osłonki. The SSMs were calculated for two different sets of taxa. The diagrams in columns "A" and "C", illustrate the results of SSM analysis for percentage data (%), the diagrams in columns "B" and "D" – for the option with Square root (%+Sqrt) transformation. In individual diagrams, the horizontal direction (X-axis) refers to Os 1-2a (rows 3, 5), and to Os 94-5 (row 7). The vertical direction (Y-axis) refers to Os 94-5 (row 3) and to Os 94-9 (rows 5, 7)

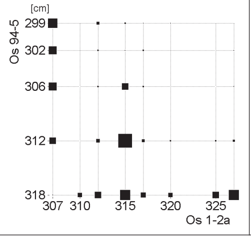
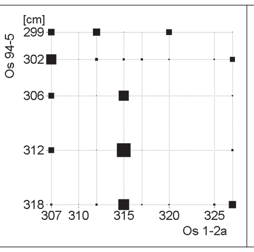
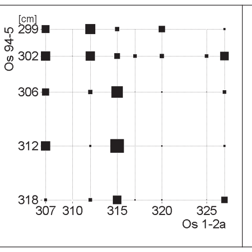
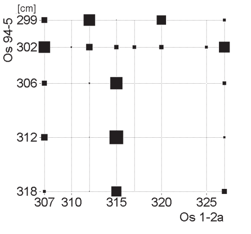
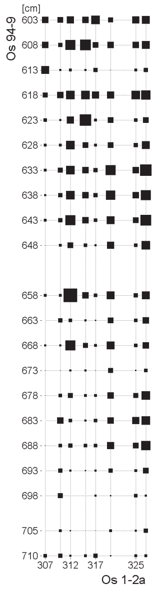
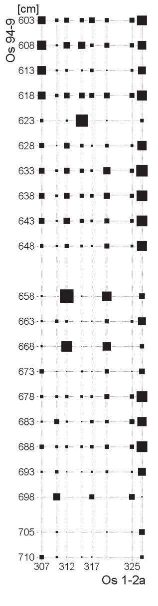
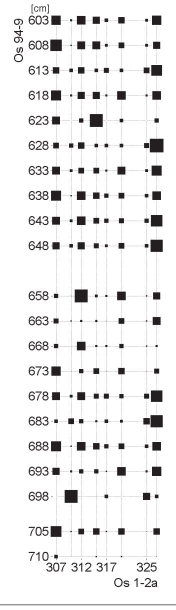
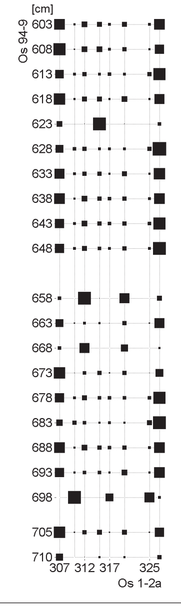
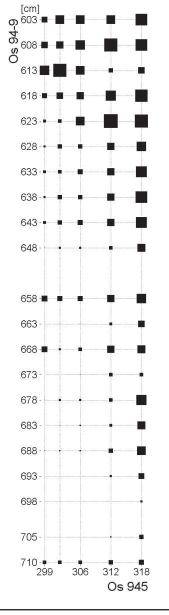
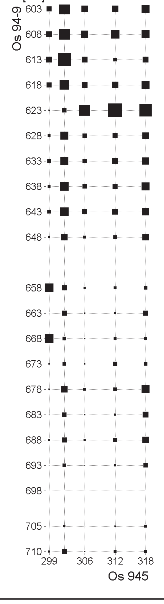
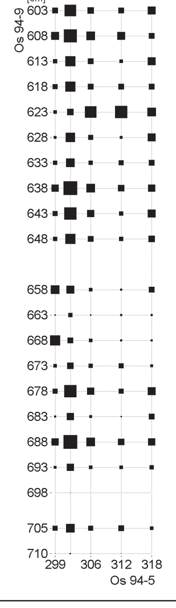
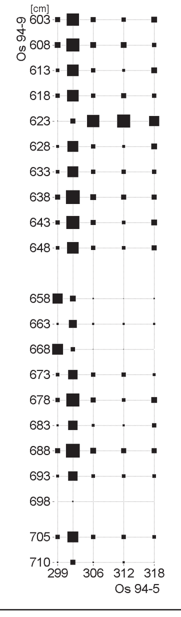
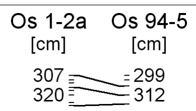
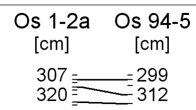
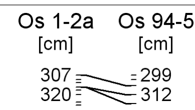
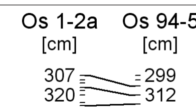
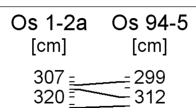
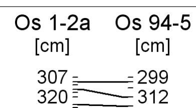
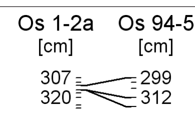
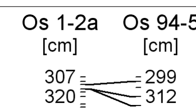
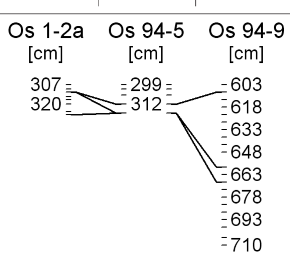
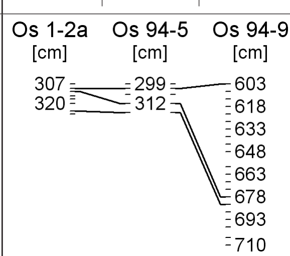
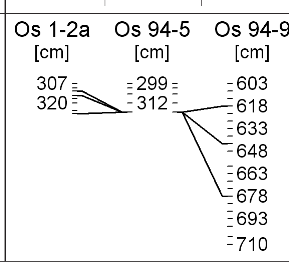
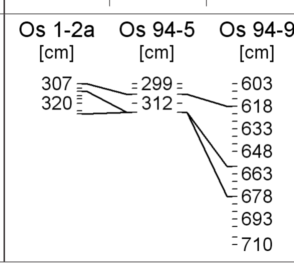
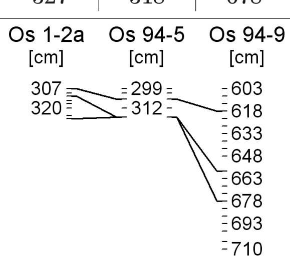
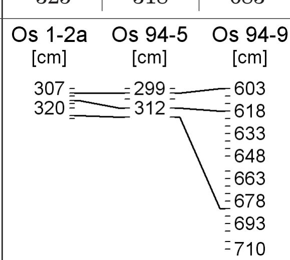
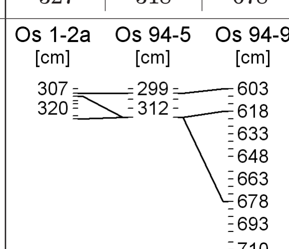
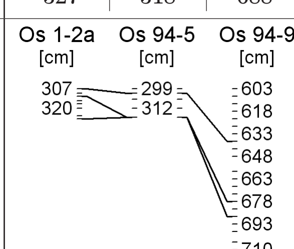
	Larger set of taxa		Smaller set of taxa	
	A	B	C	D
1	%	%+Sqrt	%	%+Sqrt
2	**Os 1-2a vs Os 94-5**			
3				
4	**Os 1-2a vs Os 94-9**			
5				
6	**Os 94-5 vs Os 94-9**			
7				

Table 15. Results of the MultCorr correlation based on the highest similarity of pollen spectra in the Younger Dryas sections of the Os 1-2a, Os 94-5, and Os 94-9 profiles, for 3 divisions of tables. The columns contain results of analyses for data without transformations (No), standardized separately within each of tables (Stand. in profile), standardized in all fragments of tables (Stand. total) and transformed by square roots (Sqrt)

1	No			Stand. in profile			Stand. total			Sqrt		
2	**Os 1-2a vs 94-5** (larger set of taxa)											
3	Os 1-2a	Os 94-5		Os 1-2a	Os 94-5		Os 1-2a	Os 94-5		Os 1-2a	Os 94-5	
	cm	cm		cm	cm		cm	cm		cm	cm	
	307	306		310	302		307	306		307	306	
	315	312		315	312		315	312		315	312	
	327	318		325	318		315	318		327	318	
4												
5	**Os 1-2a vs 94-5** (smaller set of taxa)											
6	Os 1-2a	Os 94-5		Os 1-2a	Os 94-5		Os 1-2a	Os 94-5		Os 1-2a	Os 94-5	
	cm	cm		cm	cm		cm	cm		cm	cm	
	312	302		310	302		312	299		312	302	
	315	312		315	312		315	312		315	312	
	327	318		325	318		315	318		315	318	
7												
8	**Os 1-2a vs Os 94-5 vs Os 94-9** (larger set of taxa)											
9	Os 1-2a	Os 94-5	Os 94-9	Os 1-2a	Os 94-5	Os 94-9	Os 1-2a	Os 94-5	Os 94-9	Os 1-2a	Os 94-5	Os 94-9
	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm
	312	312	608	310	302	603	312	318	618	307	306	618
	312	318	658	312	312	678	315	318	643	312	318	658
	327	318	668	325	318	683	327	318	678	327	318	678
10												
11	**Os 1-2a vs Os 94-5 vs Os 94-9** (smaller set of taxa)											
12	Os 1-2a	Os 94-5	Os 94-9	Os 1-2a	Os 94-5	Os 94-9	Os 1-2a	Os 94-5	Os 94-9	Os 1-2a	Os 94-5	Os 94-9
	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm
	312	302	638	310	302	603	310	302	608	307	302	638
	312	302	658	315	312	618	312	318	618	312	318	678
	327	318	678	325	318	683	327	318	678	327	318	688
13												

taxa (incl. *Betula* and *Pinus sylvestris*). The results (Fig. 26) indicate that fragments from both profiles from the southern basin coincide with the younger part of the Younger Dryas section from the eastern basin.

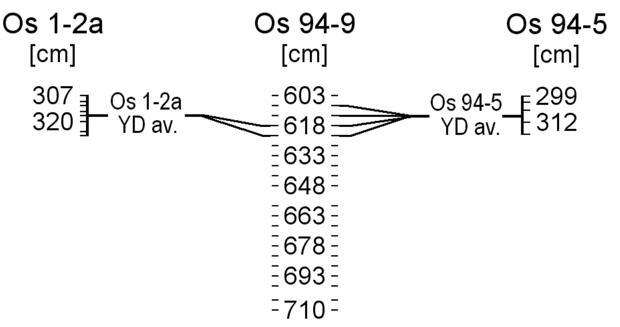


Fig. 26. Similarity of the average spectra (Os 1-2a YD av. and Os 94-5 YD av.) of pollen tables from the Os 1-2a and Os 94-5 profiles to the individual spectra from Os 94-9 profile. The tables comprised pollen spectra assigned to the Younger Dryas chronozone

The results of the three types of correlations (SSM, MultCorr – Individual spectra, and MultCorr– Average spectrum) indicate that the Os 1-2a and Os 94-5 records are similar to the upper part of the Os 94-9 record, with a distinct similarity between Os 94-5 and the 623-cm spectrum from the Os 94-9 profile. Both profiles from the southern basin do not cover the beginning of the Younger Dryas chronozone.

The presence or absence of *Pinus sylvestris* and *Betula* in the sets of taxa used for correlations did not have a major impact on the results.

Correlation of pollen data from Osłonki Os 94-9 and Lake Gościąż G1/87

In this stage correlation was conducted between the pollen records from Osłonki, analysed in the previous section, and the Younger Dryas fragment of the G1/87 table from Lake Gościąż (Ralska-Jasiewiczowa et al. 1998). Calculations were made for a modified set of taxa containing taxa distinctive for cold stadials: *Betula*, *Pinus sylvestris*, *Larix*, *Betula nana* type, *Salix polaris* type, *Juniperus communis*, *Hippophaë rhamnoides*, *Artemisia*. From the larger set of taxa, used when correlating the profiles records from Osłonki, *Pinus cembra* type, and *Selaginella selaginoides* were removed, although evident as indicators of cold periods, they were not present in the Younger Dryas section of the Gościąż profile. The purpose of correlation was to date the spectra from Osłonki within the Younger Dryas chronozone using the well-dated spectra from the Lake Gościąż profile G1/87.

First, correlation of the tables was determined using the SSM procedure. This analysis applied to the G1/87 and the Os 94-9 records from the southern basin demonstrated sufficiently good similarity of the analysed tables, as along the diagonal a pathway of the profiles' similarity is clearly visible (Tab. 16, columns A, B).

In the left – bottom corner of Table 16, another area of some similarity is marked (more visible in column B than in column A). It suggests a similarity of the almost entire Os 94-9 section to the younger spectra from G1/87. However, generally both columns (A and B) indicate some similarity of pollen spectra in both profiles in parallel with the stratigraphical order; in other words, deeper (older) spectra from the Os 94-9 profile are similar to the almost oldest spectra from G1/87. This trend continues upwards along the diagonal line.

The next step was an attempt to indicate the most similar individual spectra, rather than groups of spectra. However, the MultCorr analysis (Tab. 17, rows 3, 4, 5), performed using for four different transformations, did not show any clear similarity between individual spectra, as the results for different transformations linked different (but not the same) spectra from the examined tables.

The same analysis was also performed for three profiles from Osłonki and for G1/87. The results (Tab. 17, rows 8–10) performed using for four different transformations, did not show any clear similarity between individual spectra, as the results for different transformations linked different (but not the same) spectra from the examined tables.

Finally, a comparison of the average Younger Dryas spectra from the Osłonki tables (Os 94-5 YD av., Os 1-2a YD av. and Os 94-9 YD av.) with the G1/87 YD profile was performed. The results (Fig. 27) indicate that the Os 94-9 YD av. spectrum is most similar to the G1/87 spectrum dated to 10 230 ^{14}C BP. Also the Os 1-2a YD av. spectrum is the most similar to the same G1/87 spectrum. Then the Os 94-5 YD av. spectrum appears the most similar to the G1/87 spectrum dated to 10 290 ^{14}C BP, although a certain (but con-

Table 16. A diagram of the Sample Similarity Matrix (SSM) between the Younger Dryas secton of the profiles from Gościąż and Osłonki. Horizontal direction (X-axis) refers the G1/87 Gościąż profile; vertical direction (Y-axis) refers to the Os 94-9 profile. The diagram in column "A" illustrates results obtained for percentage data (%), the diagram in column "B" illustrates results obtained after the option with Square root (%+Sqrt) transformation of pollen percentages

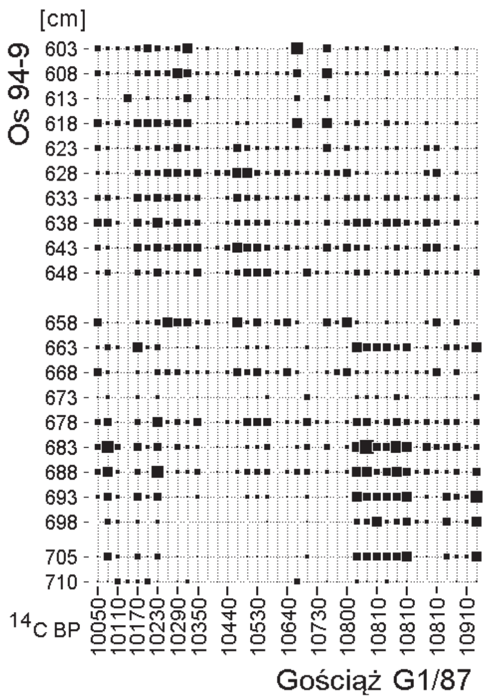
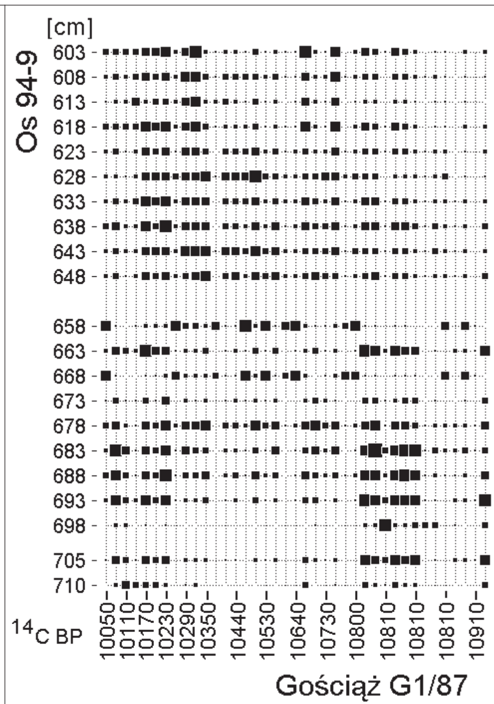
	A	B
1	%	%+Sqrt
2	**G1/87 vs Os 94-9**	
3		

Table 17. Results of the MultCorr correlation based on the highest similarity of pollen spectra between the Younger Dryas sections of the (G1/87, Os 94-9) and the four (G1/87, Os 1-2a, Os 94-5, and Os 94-9) profiles, for 3 divisions of tables. The columns contain results of analyses for data without transformations (No), standardized separately within each of tables (Stand. in profile), standardized in all fragments of tables (Stand. total) and transformed by square roots (Sqrt)

<table>
<tr><td>1</td><td colspan="4">No</td><td colspan="4">Stand. in profile</td><td colspan="4">Stand. total</td><td colspan="4">Sqrt</td></tr>
<tr><td>2</td><td colspan="16">G1/87 vs Os 94-9</td></tr>
<tr><td rowspan="5">3</td><td colspan="2">G1/87</td><td colspan="2">Os 94-9</td><td colspan="2">G1/87</td><td colspan="2">Os 94-9</td><td colspan="2">G1/87</td><td colspan="2">Os 94-9</td><td colspan="2">G1/87</td><td colspan="2">Os 94-9</td></tr>
<tr><td colspan="2">age</td><td colspan="2">cm</td><td colspan="2">age</td><td colspan="2">cm</td><td colspan="2">age</td><td colspan="2">cm</td><td colspan="2">age</td><td colspan="2">cm</td></tr>
<tr><td colspan="2">10810</td><td colspan="2">638</td><td colspan="2">10320</td><td colspan="2">603</td><td colspan="2">10560</td><td colspan="2">678</td><td colspan="2">10050</td><td colspan="2">658</td></tr>
<tr><td colspan="2">10850</td><td colspan="2">698</td><td colspan="2">10560</td><td colspan="2">678</td><td colspan="2">10810</td><td colspan="2">683</td><td colspan="2">10230</td><td colspan="2">688</td></tr>
<tr><td colspan="2">10910</td><td colspan="2">705</td><td colspan="2">10850</td><td colspan="2">693</td><td colspan="2">10850</td><td colspan="2">693</td><td colspan="2">10810</td><td colspan="2">693</td></tr>
<tr><td>4</td><td colspan="16">Gościąż G1/87 vs Os 1-2a vs 94-5 vs 94-9</td></tr>
<tr><td rowspan="5">5</td><td>G1/87</td><td>Os 1-2a</td><td>Os 94-5</td><td>Os 94-9</td><td>G1/87</td><td>Os 1-2a</td><td>Os 94-5</td><td>Os 94-9</td><td>G1/87</td><td>Os 1-2a</td><td>Os 94-5</td><td>Os 94-9</td><td>G1/87</td><td>Os 1-2a</td><td>Os 94-5</td><td>Os 94-9</td></tr>
<tr><td>age</td><td>cm</td><td>cm</td><td>cm</td><td>age</td><td>cm</td><td>cm</td><td>cm</td><td>age</td><td>cm</td><td>cm</td><td>cm</td><td>age</td><td>cm</td><td>cm</td><td>cm</td></tr>
<tr><td>10050</td><td>310</td><td>318</td><td>618</td><td>10320</td><td>317</td><td>302</td><td>603</td><td>10170</td><td>310</td><td>306</td><td>603</td><td>10170</td><td>310</td><td>318</td><td>618</td></tr>
<tr><td>10800</td><td>312</td><td>318</td><td>658</td><td>10500</td><td>327</td><td>306</td><td>643</td><td>10230</td><td>312</td><td>318</td><td>618</td><td>10230</td><td>312</td><td>318</td><td>658</td></tr>
<tr><td>10810</td><td>327</td><td>318</td><td>668</td><td>10560</td><td>327</td><td>312</td><td>678</td><td>10810</td><td>327</td><td>318</td><td>643</td><td>10810</td><td>327</td><td>318</td><td>668</td></tr>
</table>

siderably weaker) similarity was visible also with the spectrum at of 10 640 ^{14}C BP. In general (Fig. 27), the tables from Osłonki correlate with the younger spectra from the Lake Gościąż G1/87 YD table.

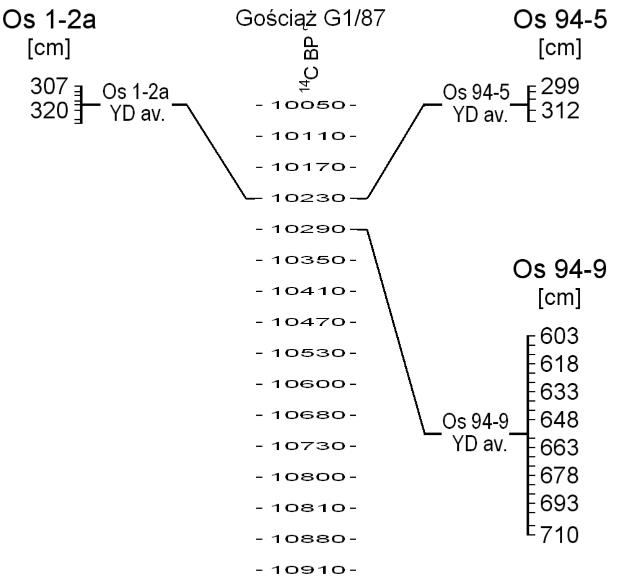


Fig. 27. Similarity of the average spectra (Os 1-2a YD av., Os 94-5 YD av. and Os 94-9 YD av.) of pollen tables from Osłonki, to the individual spectra from Lake Gościąż G1.87 profile. The fragments of tables comprised pollen spectra assigned to the Younger Dryas chronozone

Based on these results, correlation of Lake Gościąż G1/87 with the profile from the eastern basin at Osłonki (Os 94-9) was assumed, as the last one includes a much complete section than the profiles Os 94-5 and 1-2a from the southern basin. Thus for the bottom Younger Dryas spectrum (the oldest one, sampled at depth of 710 cm) from Os 94-9, a date of 10 800 ^{14}C BP was assigned, and for the upper spectrum (the youngest one, sampled at depth of 603 cm) a date of 10 000 ^{14}C BP was assigned.

NUMERICAL COMPARISON (CORRELATION) OF POLLEN DATA ASSIGNED TO THE YOUNGER PART OF ATLANTIC CHRONOZONE

Tables derived from three profiles from Osłonki were correlated with one another, while in the second stage the same tables from Osłonki were correlated with the table from Pleszów profile (Wasylikowa et al. 1985). The comparisons were based on the spectra similarity matrix (SSM) for two tables, similarity between individual spectra from all the tables (MultCorr) and similarity of average spectra. The results of the correlations were presented in tabular form (numerical and graphical). In the first trial a set of taxa containing the selected anthropogenic indicators (Cerealia undiff., *Triticum* type, *Hordeum* type, and *Plantago lanceolata*) was chosen. However, it turned out to be unsuitable, as in the analysed pollen zones some spectra exist where no grains of the above mentioned taxa are present.

Correlation of pollen data from Osłonki

In order to perform a correlation between fragments of profiles from the Osłonki region, taxa characteristic for the climatic optimum and anthropogenic indicators were chosen (*Fraxinus excelsior*, *Quercus*, *Tilia*, *Ulmus*, *Corylus avellana*, *Juniperus communis*, *Artemisia*, Cerealia undiff., Chenopodiaceae, *Rumex acetosa/acetosella*, *Urtica dioica*-type, *Pteridium aquilinum*). These taxa are presented on Figure 28 covering fragments of pollen diagrams from Osłonki palynologically assigned to the younger part of the Atlantic chronozone.

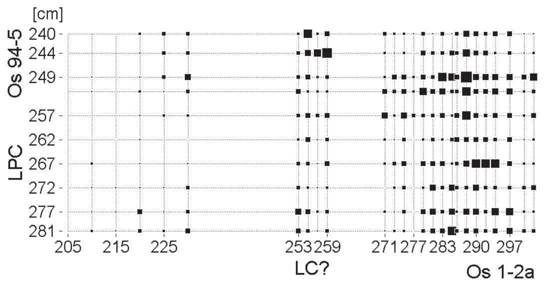
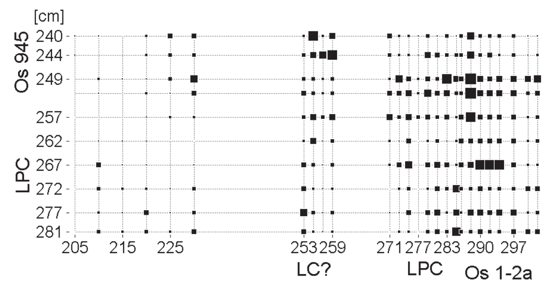
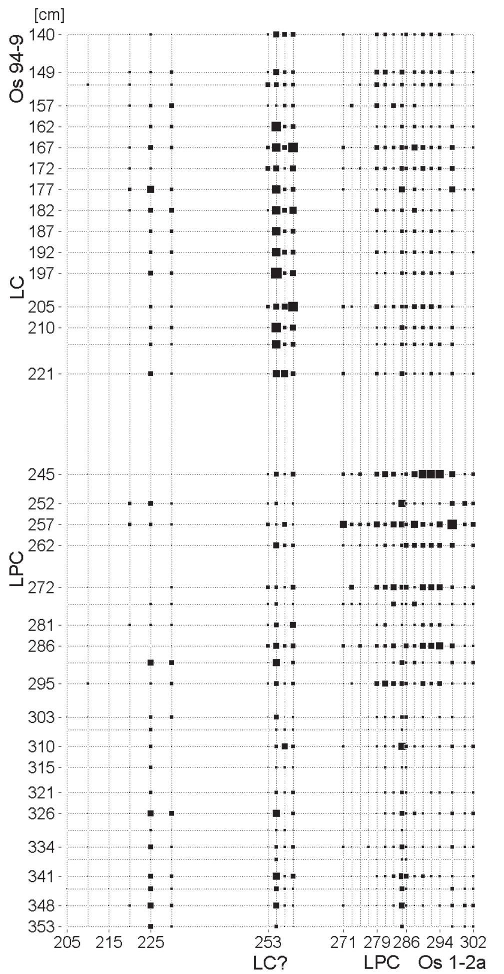
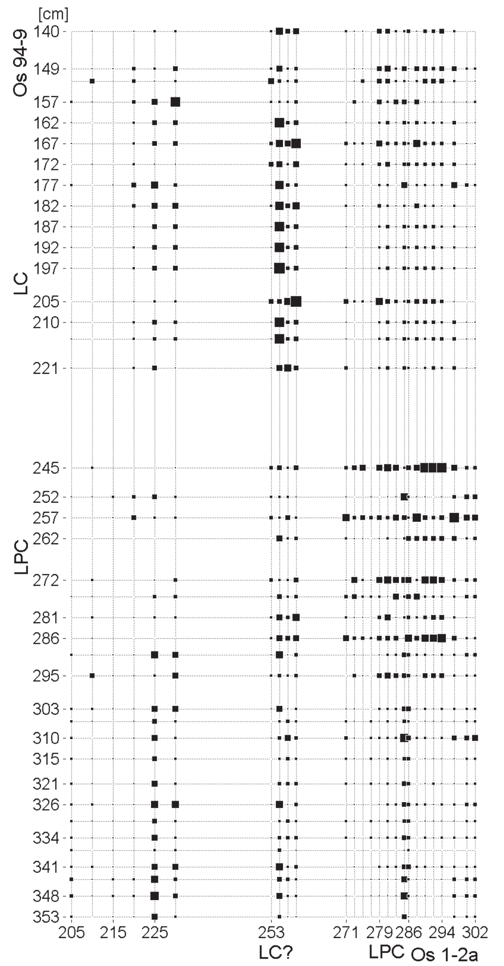
First, the SSM analysis for pairs of tables Os 1-2a, Os 94-5 and Os 1-2a, Os 94-9 (Tab. 18) was conducted, then the simultaneous MultCorr correlation for all three tables (Tab. 19) was performed.

The results of both analyses showed that the spectra from the upper Atlantic section (205–230 cm) of the Os 1-2a profile correlated very poorly (SSM), or did not correlate (MultCorr), with the spectra from the remaining Osłonki profiles. Therefore, for further correlation the Os 1-2a/ 253–302 cm profile fragment was considered only.

As a result of the SSM analysis (Tab. 20) for such defined profiles, path of similarity for the Os 1-2a and Os 94-5 fragments of profiles are outlined, which run more or less along diagonal lines (row 3, columns A, B).

The SSM matrix shows (Tab. 20, row 3) that most similar to each other are the spectra Os 1-2a/288 and Os 94-5/249, and simultaneously occurs generally similar to the middle and the upper fragments of these profiles. However, the MultCorr analysis (Tab. 21, rows 3, 4), performed using for four different transformations, did not show any clear similarity between individual spectra, as the results for different transformations linked different (but not the same) spectra from the examined tables.

Tab. 18. A diagram of the Sample Similarity Matrix (SSM) between the younger part of Atlantic section of the profiles from Osłonki. Horizontal direction (X-axis) refers to the Os 1-2a profile; vertical direction (Y-axis) refers to the Os 94-5 profile. The diagram in column "A" illustrates results obtained for percentage data (%), the diagram in column "B" illustrates results obtained after the option with Square root (%+Sqrt) transformation of pollen percentages

	A	B
1	%	%+Sqrt
2	**Os 1-2a vs Os 94-5**	
3		
4	**Os 1-2a vs Os 94-9**	
5		

The SSM matrix for the Os 1-2a and Os 94-9 tables shows that a path of synchronicity which indicates similarity between the lower spectra of Os 1-2a and the middle spectra of Os 94-9 and between the upper spectra of Os 1-2a and the middle and upper spectra of Os 94-9 (Tab. 20, row 5). The MultCorr analysis indicates the most similarity (Tab. 21, rows 6, 7) between the following pairs of spectra: Os 1-2a/259 and Os 94-9/167, and Os 1-2a/279 and Os 94-9/257. This is in agreement with the results of the SSM analysis. Then, the SSM analysis conducted for fragments of the Os 94-5 and Os 94-9 profiles did not show any clear path (Tab. 20, row 7). However, it can be seen that similar to each other are first of all groups of

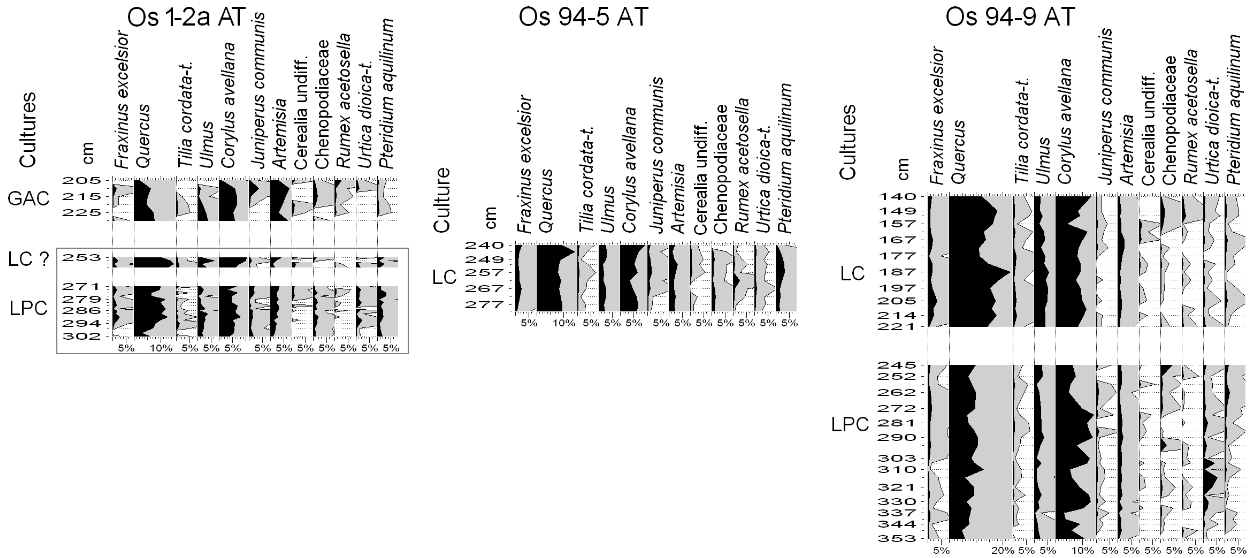


Fig. 28. Fragments of pollen diagrams of the Os 1-2a, Os 94-5 and Os 94-9 profiles, assigned to the younger part of the Atlantic chronozone. The taxa selected indicate the beginning of agricultural activities. The taxa were used in the SSM and MultCorr analyses. In a frame, the part of the Os 1-2a profile used for further analyses is enclosed

spectra from above the middle of both profiles (two upper spectra Os 94-5). In particular, the Os 94-5/277 spectrum, derived from a clay, is very similar to the Os 94-9/172 spectrum, and generally the two highest spectra of Os 94-5 are similar to the upper Os 94-9 spectra, but not to the highest ones. The MultCorr analysis (Tab. 21, rows 9, 10), conducted in the same way as before, indicated similarity between the Os 94-5/240 and Os 94-9/172 spectra and between Os 94-5/244 cm and Os 94-9/182 cm, confirming that the upper spectra of both tables are similar to each other. Then, the MultCorr correlation performed for the three tables (Os 1-2a, Os 94-5 and Os 94-9) did not show any clear similarity between individual spectra, as the results for different transformations linked different (but not the same) spectra from the examined tables (Tab. 21, rows 12, 13).

Finally, comparison of the average spectra from tables Os 94-5 and Os 1-2a (Os 94-5 AT av.

Table 19. Results of the MultCorr correlation based on the highest similarity of the pollen spectra in the younger part of Atlantic sections of three profiles (Os 1-2a, Os 94-5, and Os 94-9), for 3 divisions of tables. The columns contain results of analyses for data without transformations (No), standardized separately within each of tables (Stand. in profile), standardized in all fragments of tables (Stand. total) and transformed by square roots (Sqrt)

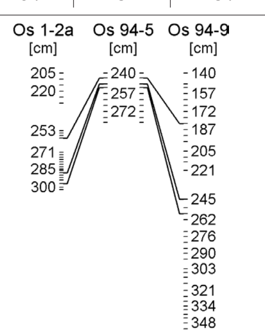
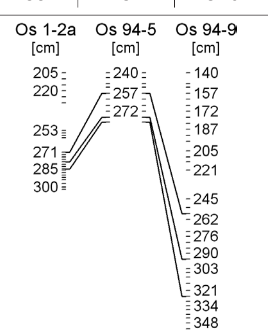
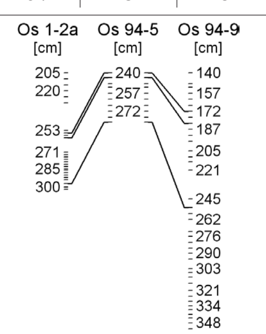
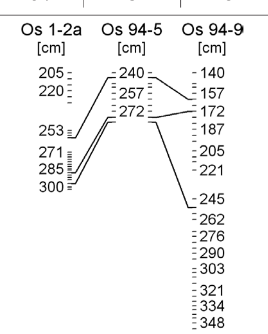
1	No			Stand. in profile			Stand. total			Sqrt		
2	**Os 1-2a vs 94-5 vs 94-9**											
3	Os 1-2a	Os 94-5	Os 94-9	Os 1-2a	Os 94-5	Os 94-9	Os 1-2a	Os 94-5	Os 94-9	Os 1-2a	Os 94-5	Os 94-9
	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm
	259	244	182	271	257	257	255	240	172	259	244	162
	288	249	245	279	277	295	259	244	182	288	277	172
	297	252	257	285	281	326	297	281	252	297	281	252
4												

Table 20. A diagram of the Sample Similarity Matrix (SSM) between the younger part of Atlantic section of the profiles from Osłonki. Horizontal direction (X-axis) refers to the Os 1-2a (row 3, 5) and to the 94-5 (row 7) profile; vertical direction (Y-axis) refers to the Os 94-5 (row 3) and to the Os 94-9 (row 5, 7) profiles. The diagram in column "A" illustrates results obtained for percentage data (%), the diagram in column "B" illustrates results obtained after the option with Square root (%+Sqrt) transformation of pollen percentages

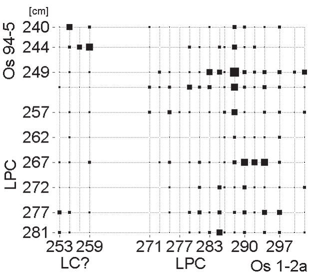
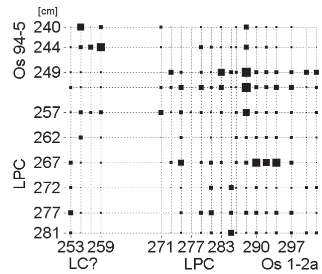
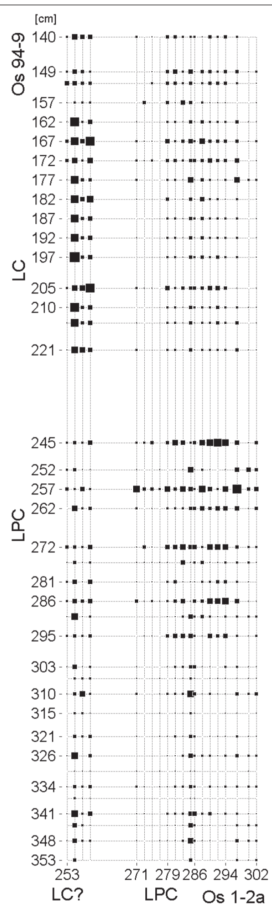
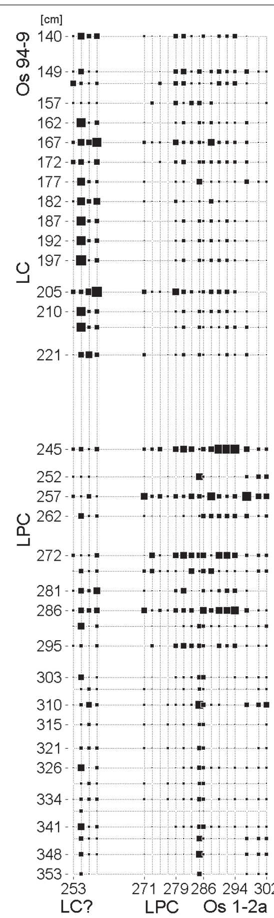
<table>
<tr><td></td><td>A</td><td>B</td></tr>
<tr><td>1</td><td>%</td><td>%+Sqrt</td></tr>
<tr><td>2</td><td colspan="2">Os 1-2a vs Os 94-5</td></tr>
<tr><td>3</td><td>
</td><td>
</td></tr>
<tr><td>4</td><td colspan="2">Os 1-2a vs Os 94-9</td></tr>
<tr><td>5</td><td>
</td><td>
</td></tr>
</table>

Table 20. Continued

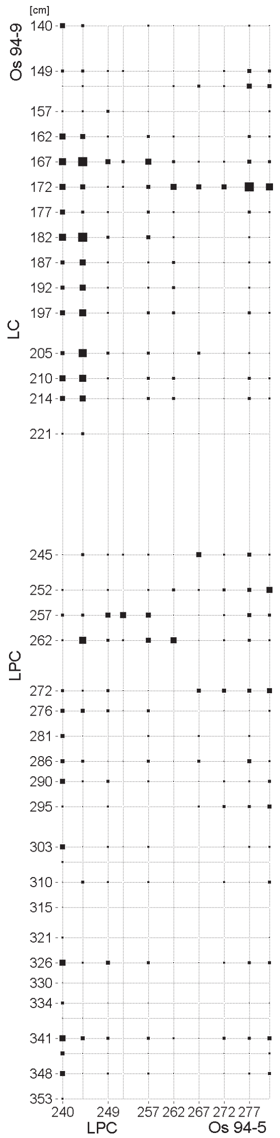
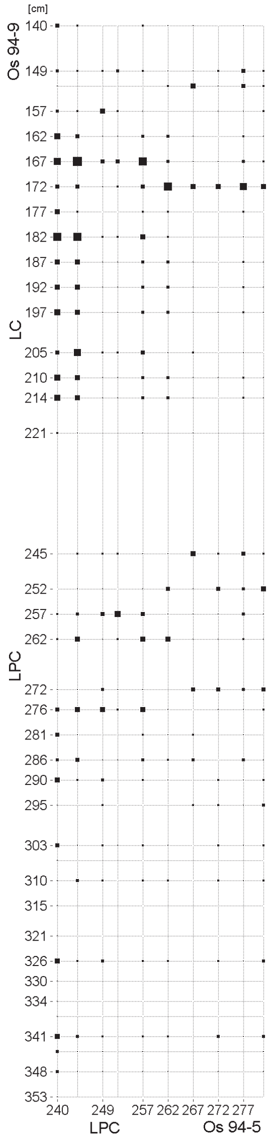
6	**Os 94-5 vs Os 94-9**	
7		

Table 21. Results of the MultCorr correlation based on the highest similarity of pollen spectra in the younger part of Atlantic section of the Os 1-2a, Os 94-5, and Os 94-9 profiles, for 3 divisions of tables. The columns contain results of analyses for data without transformations (No), standardized separately within each of tables (Stand. in profile), standardized in all fragments of tables (Stand. total) and transformed by square roots (Sqrt)

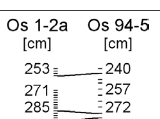
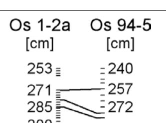
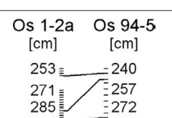
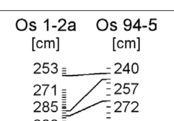
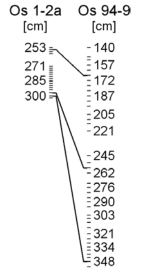
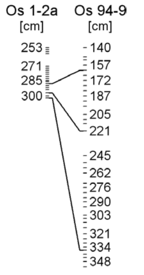
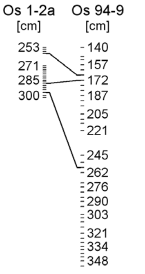
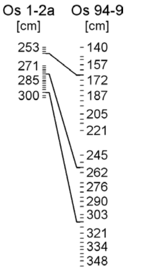
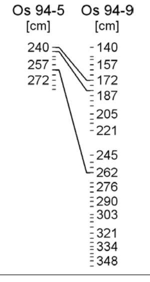
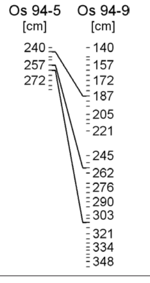
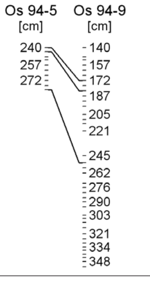
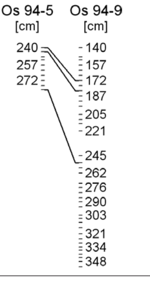
	A		B		C		D	
1	No		Stand. in profile		Stand total		Sqrt	
2	**Os 1-2a vs 94-5**							
3	Os 1-2a	Os 94-5	Os 1-2a	Os 94-5	Os 1-2a	Os 94-5	Os 1-2a	Os 94-5
	cm	cm	cm	cm	cm	cm	cm	cm
	259	244	271	257	259	244	259	244
	288	277	279	277	288	249	288	249
	297	281	285	281	297	281	292	267
4								

Table 21. Continued

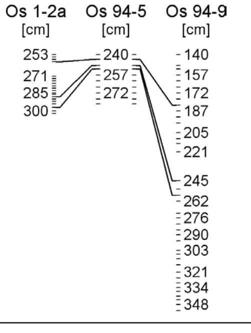
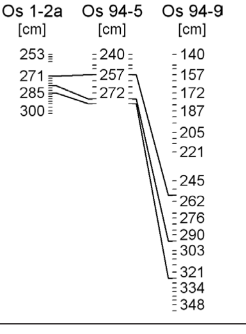
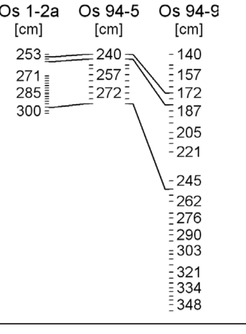
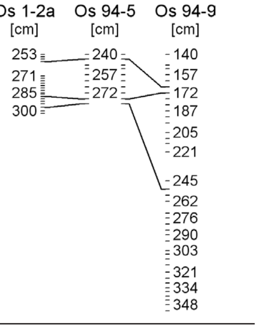
5	**Os 1-2a vs Os 94-9**							
6	Os 1-2a	Os 94-5	Os 1-2a	Os 94-5	Os 1-2a	Os 94-5	Os 1-2a	Os 94-5
	cm	cm	cm	cm	cm	cm	cm	cm
	255	167	288	162	259	167	259	167
	297	257	297	221	288	172	279	257
	300	348	302	337	297	257	297	306

7				
				

8	**Os 94-5 vs Os 94-9**							
9	Os 1-2a	Os 94-5	Os 1-2a	Os 94-5	Os 1-2a	Os 94-5	Os 1-2a	Os 94-5
	cm	cm	cm	cm	cm	cm	cm	cm
	240	172	244	187	240	172	240	172
	244	182	257	257	244	182	244	182
	262	262	262	310	281	252	281	252

10				
				

11	**Os 1-2a vs Os 94-5 vs Os 94-9**											
12	Os 1-2a	Os 94-5	Os 94-9	Os 1-2a	Os 94-5	Os 94-9	Os 1-2a	Os 94-5	Os 94-9	Os 1-2a	Os 94-5	Os 94-9
	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm
	259	244	182	271	257	257	255	240	172	259	244	167
	288	249	245	279	277	295	259	244	182	288	277	172
	297	252	257	285	281	326	297	281	252	297	281	252

13				
				

and Os 1-2a AT av.) with the Os 94-9 AT table was conducted. The results of such correlation (Fig. 29) indicated that both tables of profiles from the southern basin coincided with the middle of the Atlantic section of Os 94-9 between depths of 257 and 262 cm.

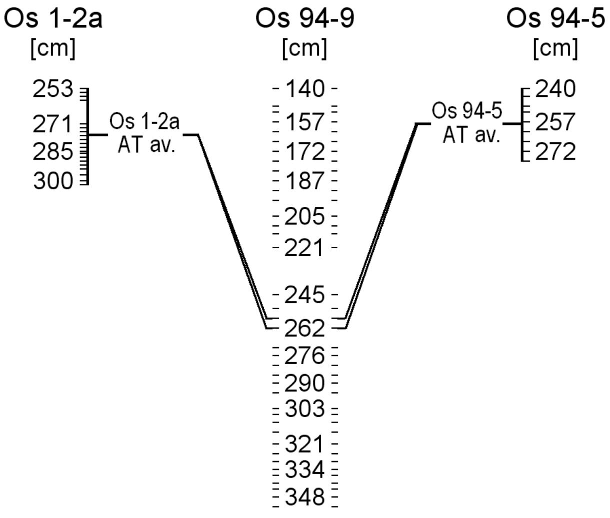


Fig. 29. Similarity of the average spectra (Os 1-2a AT av. and Os 94-5 AT av.) of pollen tables from the Os 1-2a and Os 94-5 profiles to the individual spectra from Os 94-9 profile. The fragments of tables comprised pollen spectra assigned to the younger part of the Atlantic chronozone

Correlation of pollen data from Osłonki and Pleszów

In the next stage of the analysis, the Atlantic parts of profiles (Os 1-2a, Os 94-5, and Os 94-9) from Osłonki were correlated with the profile from the early Neolithic site from Pleszów (Figs 1, 30) in southern Poland

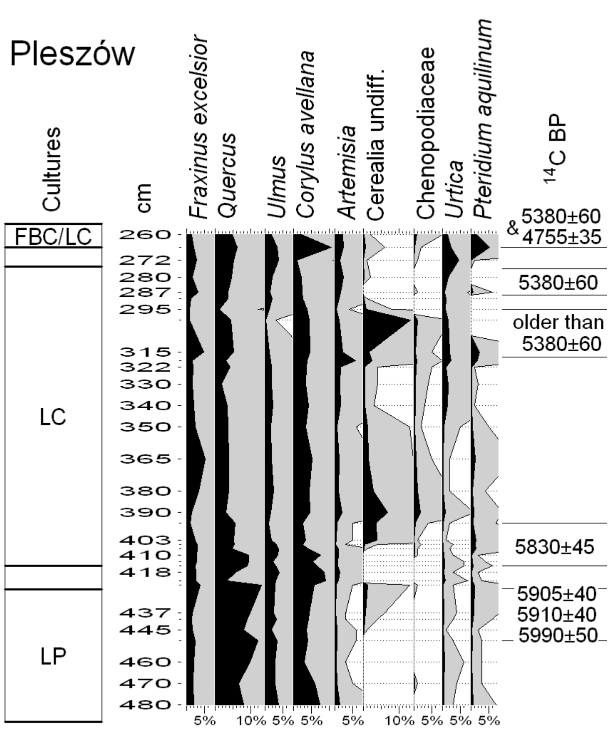


Fig. 30. The pollen diagram from the Pleszów site for selected taxa, indicating traces of human cultures. Division after Godłowska et al. 1979. **LP** – Linear Pottery culture, **LC** – Lengyel culture, **FBC/LC** – Funnel Beaker culture/Lengyel culture

(Wasylikowa et al. 1985, Godłowska et al. 1987, Wasylikowa 1989).

The mutual correlation of the profile fragments from Osłonki was presented in a previous section. A broader description of the Pleszów site is given on page 48 in this paper. The aim of comparison of sites located far away from each other (over 300 km) and situated in different geographical regions is to find a general indication of similarity (or dissimilarity) between profiles and not dating of the profiles from Osłonki. Therefore, for comparison using the MultCorr approach only two divisions were required, and thereby a lower precision lower compared to the previous correlations was permitted. On the other hand, the SSM analysis and the analysis of average spectra from Osłonki and a profile from Pleszów were conducted in the same way as previously.

For comparative purposes, the same set of taxa characteristic for the climatic optimum, along with anthropogenic indicators was used: *Fraxinus excelsior*, *Quercus*, *Tilia*, *Ulmus*, *Corylus avellana*, *Artemisia*, Cerealia undiff., Chenopodiaceae, *Rumex acetosa*/*acetosella*, *Urtica dioica* type, and *Pteridium aquilinum*. With respect to the former comparisons made between the tables from Osłonki, the set of taxa was diminished by *Juniperus communis*, as in the table from Pleszów, pollen grains of that taxon occurred only sporadically. Similarly as described in the previous section, the fragment 205–302 cm Os 1-2a appeared not to correlate with the record from Pleszów, so further correlations were conducted only for the fragment covering the spectra 253–302 cm.

For such defined profiles, the SSM (%) analysis indicated (Tab. 22, row 3, column A) that the Os 1-2a AT spectra, including especially that from 255 cm depth, correlated first with the spectra from Pleszów, linked by Wasylikowa (Wasylikowa et al. 1985) with the Linear Pottery culture, and with all the oldest spectra from the Lengyel culture.

The option %+Sqrt (column B) indicates the more precise correlation of the Os 1-2a spectra with the upper spectra from Pleszów, assigned to the Lengyel and the Funnel Beaker/Lengyel cultures. On the other hand, the MultCorr analysis (Tab. 23, rows 3, 4 columns A, B) for the same tables assigned to the Atlantic chronozone, performed for four various transformations, did not show any clear similarity between individual spectra.

The SSM analysis for Os 94-5 and Pleszów demonstrated that the Os 94-5 spectra are similar to the upper Linear Pottery culture and the lower Lengyel culture spectra (Tab. 22, rows 4, 5). The MultCorr results for different transformation options linked different spectra from the tables (Tab. 23, rows 6, 7).

Next, the SSM analysis for Os 94-9 and Pleszów showed that the Os 94-9 AT spectra correlated with the spectra from Pleszów (Tab. 22, row 7) linked with the Linear Pottery culture and the oldest spectra from the Lengyel culture. But here, some inversion is visible: the upper spectra of Os 94-9 correlate better with the Linear Pottery culture and worse with the Lengyel culture, while the lower spectra of Os 94-9 correlate with the Lengyel culture. Also in this case, the MultCorr analysis (Tab. 23, rows 9, 10) did not establish a clear similarity between individual spectra. Similarly, simultaneous MultCorr analysis (Tab. 23, rows 12, 13) of all four profiles did not confirm any explicit similarity between individual spectra. The results linked different spectra from the examined table, or the MultCorr correlation indicated that the three profiles from the Osłonki region do not correlate with the upper spectra from Pleszów or they are similar to the Pleszów spectra from the Linear Pottery culture/ Lengyel culture transition.

The comparison of the average spectra the Atlantic section from the southern basin from Osłonki profiles with the Atlantic section from Pleszów was also conducted. The results of

Table 22. A diagram of the Sample Similarity Matrix (SSM) between the younger part of Atlantic section of the profiles from Osłonki and Pleszów. Horizontal direction (X-axis) refers to the Os 1-2a (row 3), Os 94-5 (row 5) and Os 94-9 profiles (row 7) profiles; vertical direction (Y-axis) refers to the Pleszów profile. The diagram in column "A" illustrates results obtained for percentage data (%), the diagram in column "B" illustrates results obtained after the option with Square root (%+Sqrt) transformation of pollen percentages. LP – Linear Pottery culture, LC – Lengyel culture, FBC/LC – Funnel Beaker culture/Lengyel culture

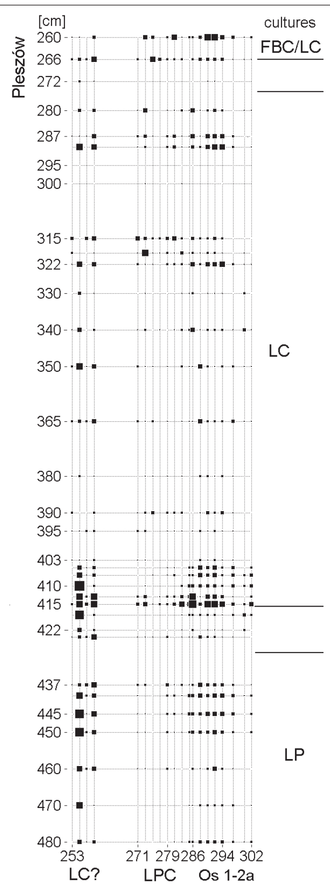
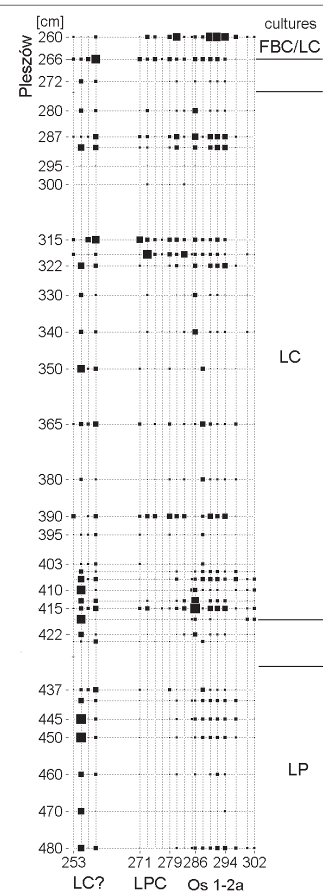
<table>
<tr><th></th><th>A</th><th>B</th></tr>
<tr><td>1</td><td>%</td><td>%+Sqrt</td></tr>
<tr><td>2</td><td colspan="2">Os 1-2a vs Pleszów</td></tr>
<tr><td>3</td><td>
</td><td>
</td></tr>
</table>

Table 22. Continued

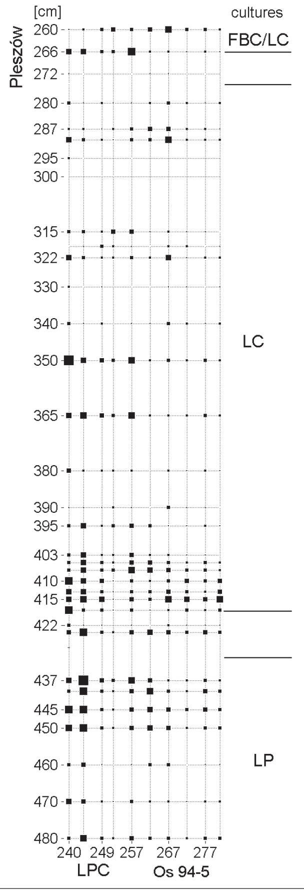
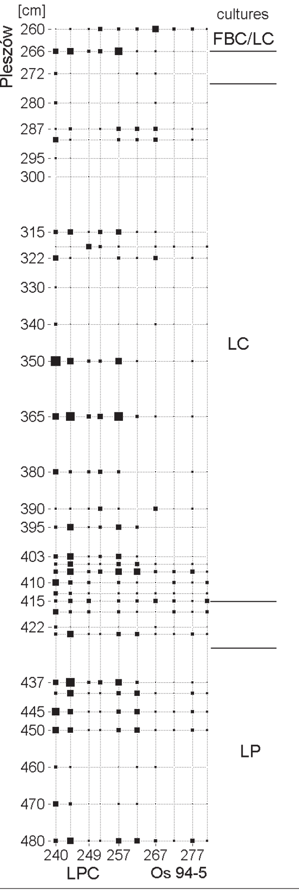
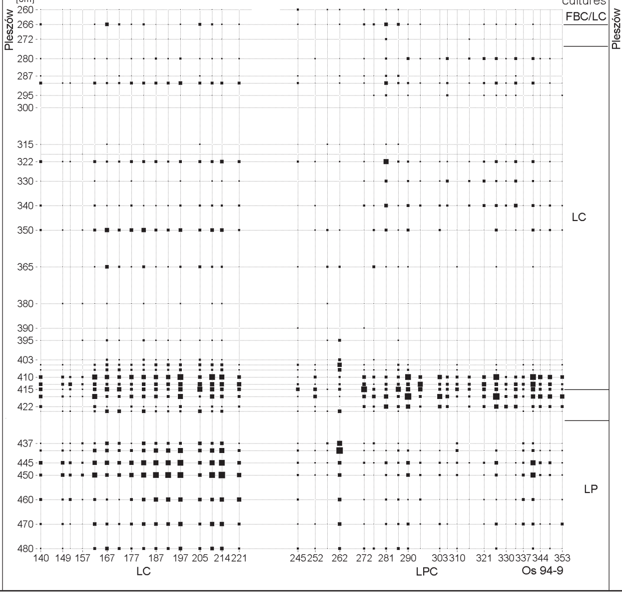
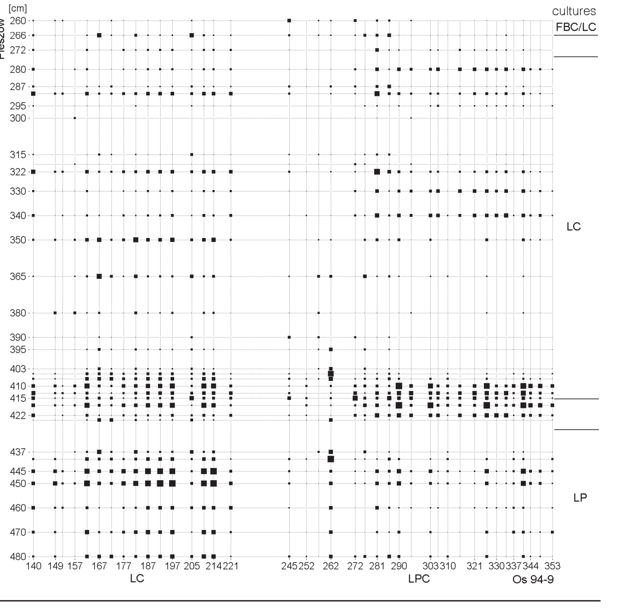
<table>
<tr><td>4</td><td colspan="2">Os 94-5 vs Pleszów</td></tr>
<tr><td>5</td><td>
</td><td>
</td></tr>
<tr><td>6</td><td colspan="2">Os 94-9 vs Pleszów</td></tr>
<tr><td>7</td><td>
</td><td>
</td></tr>
</table>

Table 23. Results of the MultCorr correlation based on the highest similarity of pollen spectra in the younger part of Atlantic section of the Os 1-2a, Os 94-5, Os 94-9 and Pleszów profiles, for 2 divisions of tables. The columns contain results of analyses for data without transformations (No), standardized separately within each of tables (Stand. in profile), standardized in all fragments of tables (Stand. total) and transformed by square roots (Sqrt)

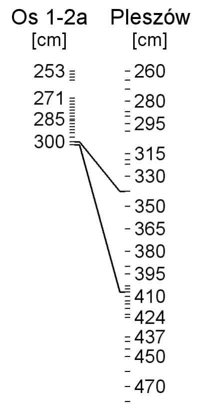
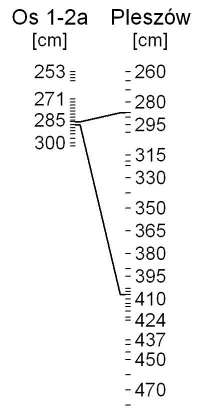
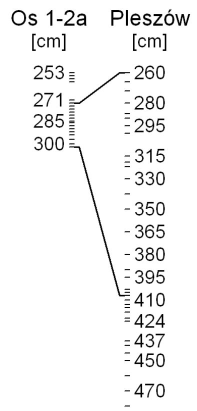
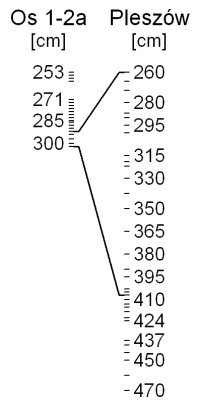
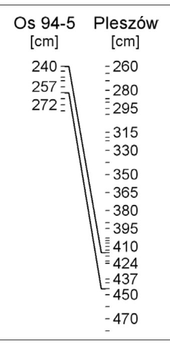
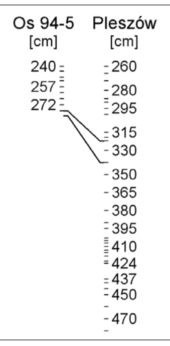
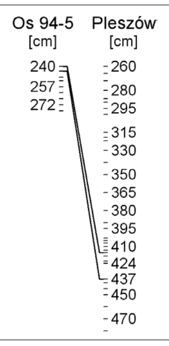
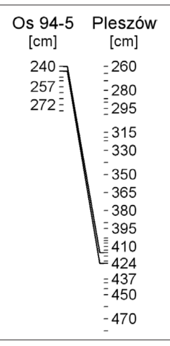
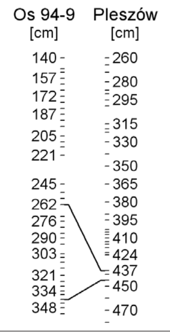
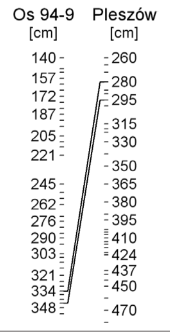
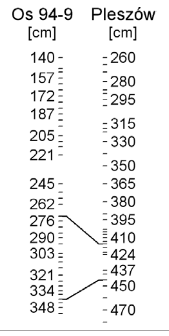
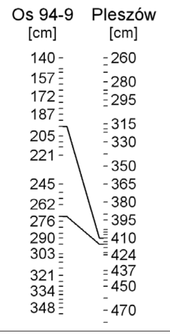
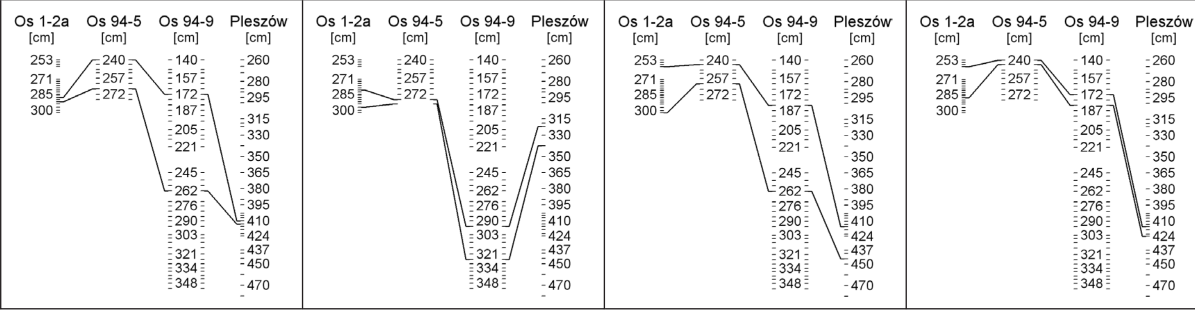
	A	B	C	D
1	No	Stand. in profile	Stand total	Sqrt
2	**Os 1-2a vs Pleszów**			
3	Os 1-2a / Pleszów cm / cm 300 / 340 302 / 407	Os 1-2a / Pleszów cm / cm 286 / 287 288 / 407	Os 1-2a / Pleszów cm / cm 273 / 260 302 / 407	Os 1-2a / Pleszów cm / cm 292 / 260 302 / 407
4				
5	**Os 94-5 vs Pleszów**			
6	Os 94-5 / Pleszów cm / cm 240 / 415 262 / 445	Os 94-5 / Pleszów cm / cm 277 / 322 281 / 340	Os 94-5 / Pleszów cm / cm 240 / 415 244 / 437	Os 94-5 / Pleszów cm / cm 240 / 415 244 / 424
7				
8	**Os 94-9 vs Pleszów**			
9	Os 94-9 / Pleszów cm / cm 262 / 437 341 / 445	Os 94-9 / Pleszów cm / cm 334 / 280 344 / 295	Os 94-9 / Pleszów cm / cm 272 / 415 341 / 445	Os 94-9 / Pleszów cm / cm 197 / 410 272 / 415
10				

Table 23. Continued

11	Os 1-2a vs Os 94-5 vs Os 94-9 vs Pleszów															
12	Os 1-2a	Os 94-5	Os 94-9	Pleszów	Os 1-2a	Os 94-5	Os 94-9	Pleszów	Os 1-2a	Os 94-5	Os 94-9	Pleszów	Os 1-2a	Os 94-5	Os 94-9	Pleszów
	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm
	288	240	172	410	281	277	295	322	259	244	182	415	259	240	172	415
	292	267	262	413	297	281	326	340	302	262	262	445	288	244	182	424
13																

such correlation indicated that both profiles fragments from these basin (Os 1-2a AT av. and Os 94-5 AT av.) correlate with the spectra from 413 cm and 423 cm of the profile from Pleszów, and those from the eastern basin (Os 94-9 AT av.) correlate with the Pleszów section from 418–422 cm (Fig. 31). These spectra cover the end of the Linear Pottery culture and the beginning of the Lengyel culture, centring mainly at the determined hiatus between these cultures.

The SSM and MultCorr analyses have proved that each of the three tables from Osłonki, assigned to the younger part of the Atlantic chronozone, correlates with the lower part of the profile from Pleszów, linked by Wasylikowa (op. cit.) to the younger levels of the Linear Pottery (LP) and the older levels of the Lengyel culture (LC). This indication is not confirmed when the MultCorr analysis is applied simultaneously to all the fragments of profiles. Nevertheless some similarity in the Osłonki tables can be recognized that is related to the younger part of the Atlantic chronozone and the oldest horizon of Pleszów table can be related to the Lengyel culture. Certain similarities were revealed despite the fact that both sites differed significantly with regard to geographical position. The Linear Pottery culture (LP) existed in both areas at the same time, but in the region of Osłonki it was found on an upland area without rivers, while in Pleszów it settled on a terrace of a large river. With such a result the correlations brought an unexpectedly positive result.

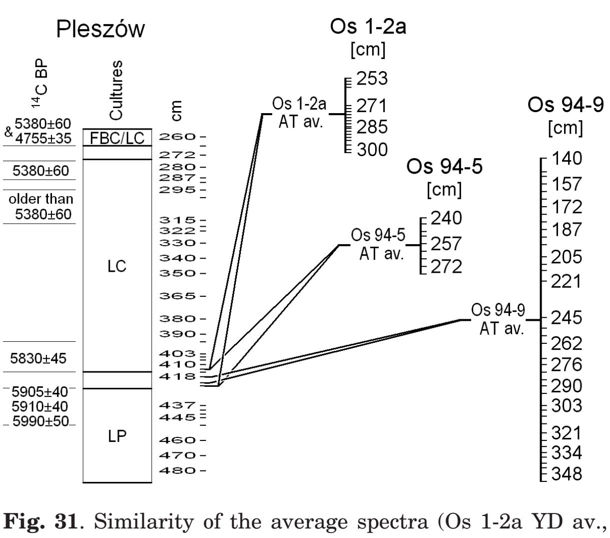


Fig. 31. Similarity of the average spectra (Os 1-2a YD av., Os 94-5 YD av. and Os 94-9 AT av.) of pollen tables from Osłonki profiles to the individual spectra from Pleszów. The tables comprised pollen spectra assigned to the younger part of the Atlantic chronozone. **LP** – Linear Pottery culture, **LC** – Lengyel culture, **FBC/LC** – Funnel Beaker culture/ Lengyel culture

SUMMARY OF CORRELATION BASED ON THE NUMERICAL ANALYSES

In this study three different methods of correlation were used. The SSM analysis correlated pairs of tables, indicating paths of similarity covering the groups of similar spectra. The MultCorr – Individual spectra analysis correlated simultaneously and indicated the most similar spectra in two or more tables. The MultCorr – Average spectra analysis correlated average spectra from one table with the individual spectra of another table and indicated general similarities between tables.

The use of the MultCorr – Individual spectra method has given no clear results, although clear results emerged in the analysis of average spectra (MultCorr – Average spectra). Correlation was poor in the SSM analysis.

After several repeats of all numerical analyses for various sets of taxa, and for various options of transformation of pollen data, the earlier presented divisions based on palynological analysis, and on comparison with the bench-mark profiles from the Polish Lowlands (Ralska-Jasiewiczowa & Latałowa 1996) were confirmed. Additionally, the numerical analyses facilitated the decisions of establishing boundaries in the diagrams. Moreover, the results of these analyses helped for relative dating some levels in pollen tables and in the construction of maps of pollen percentages.

The analyses presented here and their results are only a proposal for applying numerical analyses as additional methods to enable consideration of pollen data from another point of view, useful especially when it is difficult to interpret them based on ecological knowledge only.

THE AGE DETERMINATION OF THE OTHER SPECTRA FROM THE OSŁONKI PROFILES

Pollen diagrams obtained from profiles collected close to one another in neighbouring regions are similar in general features. These diagrams could be correlated, based on similarity between spectra. The correctness of any correlation must be supported by similar percentage values of taxa important from an ecological point of view or by their similar trends of changes (decreasing, increasing). To those spectra where changes in pollen taxa composition were clearly visible, the ages known from the nearest, absolutely dated profiles could be assigned. Such a procedure, based on palynological correlations supported by numerical analysis (described in previous sections) was conducted and as a result few spectra in the Osłonki profiles were given estimated ages (Tab. 24).

The tables from Osłonki assigned to the Younger Dryas chronozone were dated based on correlation with the spectra from the G1/87 profile from Lake Gościąż. Tables assigned to the younger part of the Atlantic chronozone were dated by correlation with ^{14}C dates of artefacts derived from archaeological sites (Grygiel 2004). In the Os 1-2a fragment the Linear Pottery culture (LPC), Lengyel culture (LC), and Globular Amphorae culture (GAC) were distinguished, whereas in the Os 94-5 profile, LPC was distinguished only, and in the Os 94-9 profile – LPC and LC.

Table 24. Measured (with asterisk) and estimated radiocarbon ages of the pollen samples in the Os 1-2a, Os 94-5 and Os 94-9 profiles from the Osłonki region. Estimated ages are based on palynological correlations, results of numerical analyses, and radiocarbon dating. GAC – Globular Amphorae culture, LC – Lengyel culture, LPC – Linear Pottery culture

Chronozone	Culture	Cm	^{14}C BP
Osłonki Os 1-2a			
AT	GAC	205	4100
		212–217	4260±60*
		228	4400
	LC	253	5300
		257	5400
	LPC	271	5700
		302	5900
YD		305	10200
		306–315	10470±90*
		327	10500
Al-b		423	11200
Osłonki Os 94-5			
AT	LPC	240	5700
		281	5900
PB		297	9500
YD		299	10000
		302	10100
		318	10500
Al-b		324	11400
Osłonki Os 94-9			
SB		140	5300
AT	LC	221	5600
		245	5700
	LPC	344	5900
		353	6000
PB		510	9500
YD		603	10000
		710	10800
Al-a		805	11800
OD		815	12000
BØ		851	12400

In the Younger Dryas and Atlantic sections, where palynological dating of profiles was possible, changes in the pollen spectra are not expressed so clearly (relatively uniform composition or rather similar rate of changes). In order to estimate ages of those remaining spectra, linear interpolation between the well-dated sections was conducted (Fig. 32).

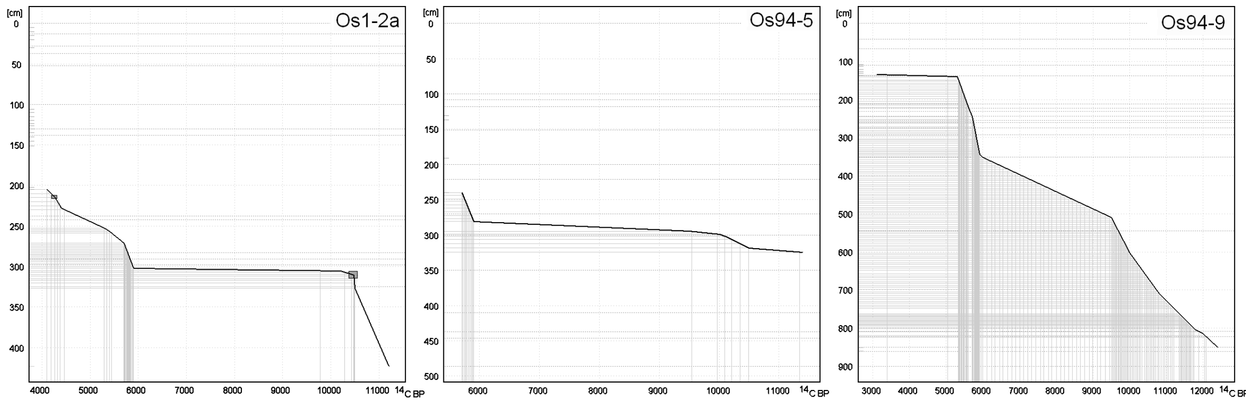


Fig. 32. The age-depth curves for the Os 1-2a, Os 94-5 and Os 94-9 profiles. The curves were obtained through linear interpolation between well dated levels. Lithological boundaries are plotted as dotted lines. Radiocarbon dates (plot Os 1-2a) are represented by rectangles of dimensions defined by dating error and sample thickness

The dating of all individual pollen spectra was performed basing on the depth-age relationship (Maher 1997, Nalepka & Walanus 2003a,b, 2004), where the depth-age lines explicitly link the depths with the ages. Every spectrum from a given depth in a given profile has only one age.

The dated spectra were used for drawing maps to show spatial distribution of pollen percentages (see next section).

MAPS OF POLLEN PERCENTAGES

In order to resolve some questions regarding vegetation cover in the Younger Dryas and the younger part of Atlantic chronozones, several series of pollen percentage maps illustrating the distribution of pollen percentages in the area of interest (Fig. 33) were created at several selected time horizons (on the scale of ^{14}C years BP).

The construction of maps of spatial distribution of pollen percentages involves the calculation of percentages at every point in a given area, based on values from several sites. Such maps have a form of iso-line maps or pollen percentages. The iso-line maps with lines linking the same percentage values for a given taxon at a given time horizon are called isopollen maps (Ralska-Jasiewiczowa 1983, Ralska-Jasiewiczowa et al. 2003, Ralska-Jasiewiczowa et al. eds, 2004, Walanus & Nalepka 2004). However, the strict isolines on the maps suggest precise information, what is not the case in this study, because of the limited number of sites available, and limited time precision. That is the reason why on the presented maps, values of pollen percentages are shown in a smooth form of continuously changing grey density.

For the Kujawy region and neighbouring areas, pollen percentage maps for selected taxa have been made. The purpose was to observe the main tendencies in the distribution of the pollen percentages in the examined area in the past, and no more precise interpretation were intended.

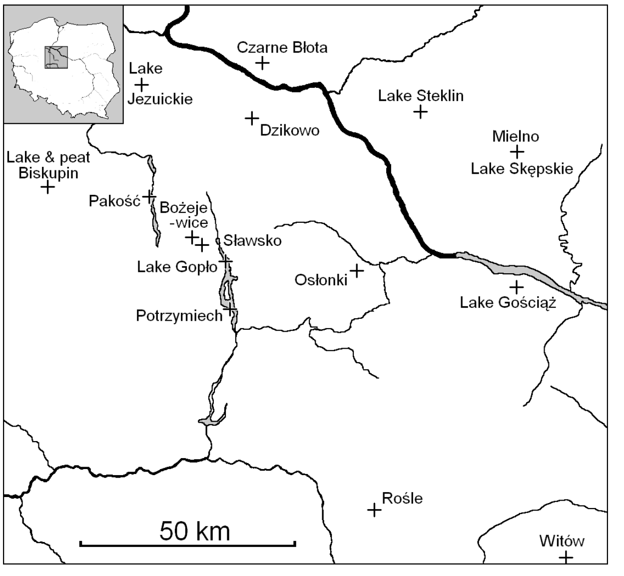


Fig. 33. Distributions of sites on which the pollen percentage maps are based

A list of sites from which the palynological data have been derived is shown in Table 25, and the time ranges covered by individual profiles, is presented in Figure 34. The most of these data have been used earlier for the construction of isopollen maps for Poland (Ralska-Jasiewiczowa et al. eds, 2004). In the present study, the pollen data from the

Table 25. Alphabetical list of the sites, used for the construction of pollen percentage maps

Site	Author	Coordinates
Biskupińskie Peat	Niewiarowski W. & Noryśkiewicz A. 1995	52°47′N 17°44′E
Bożejewice	Makohonienko M. et al. 1998	52°41′N 18°14′E
Czarne Błota	Niewiarowski W. & Noryśkiewicz B. 1983	52°57′N 19°01′E
Dzikowo	Tomczak A. 1987	53°03′N 18°28′E
Lake Biskupińskie	Noryśkiewicz B. 1995	52°47′N 17°44′E
Lake Gopło III	Jankowska B. 1980	52°38′N 18°21′E
Lake Gościąż	Ralska-Jasiewiczowa M. et al. 1998	52°35′N 19°21′E
Lake Jezuickie	Noryśkiewicz B. unpubl.	53°00′N 18°03′E
Lake Steklin	Noryśkiewicz B. 1987	52°57′N 19°01′E
Mielno Lake Skępskie	Kępczyński K. 1960	52°52′N 19°21′E
Osłonki Os 1-2a	Nalepka D. 2004a,b	52°37′N 18°48′E
Osłonki Os 94-5	Nalepka D. 2004a,b	52°37′N 18°48′E
Osłonki Os 94-9	Gąsiorowski M. & Nalepka D. 2004	52°37′N 18°48′E
Pakość	Noryśkiewicz B. unpubl.	52°46′N 18°05′E
Potrzymiech	Molewski P. K. & Noryśkiewicz B. 2000	52°32′N 18°22′E
Rośle	Krajewski K. & Balwierz Z. 1984	52°07′N 18°52′E
Sławsko	Milecka K. 2000 (in print)	52°40′N 18°16′E
Witów	Wasylikowa K. 1964, 2001	52°01′N 19°31′E

Os 1-2a and Os 94-5 profiles and the younger part of Os 94-9 were additionally included.

The procedure of map construction (a comprehensive description of the methods and their theoretical bases) was based on the algorithm included in the POLPAL program (Nalepka & Walanus 2003a,b, 2004, Walanus & Nalepka 2004). As a basis for the calculation of percentages of each taxon, the sums of trees, shrubs, and terrestrial herbaceous plants were used. Cyperaceae were assumed to be a local element (palynological data are derived mainly from lake sediments), so they were not included in the total sum. A similar assumption was used for the creation of isopollen maps for the whole territory of Poland (Ralska-Jasiewiczowa et al. eds, 2004).

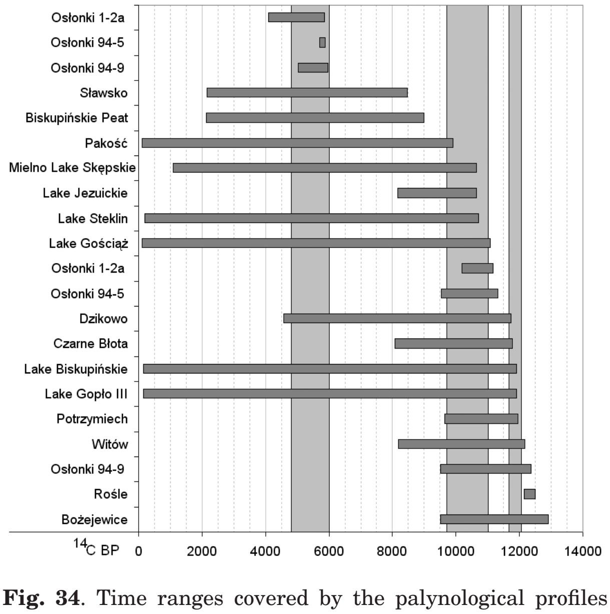


Fig. 34. Time ranges covered by the palynological profiles from the Kujawy region and the neighbouring areas. Vertical belts display periods for which the pollen percentage maps were plotted

The pollen percentage maps were drawn using shades of greyness. The darkest are the sites with maximum percentages, while lighter areas denote lower values. For each taxon the most intensity of darkness corresponds to the absolute maximum of percentages (in the whole area). In other terms, colour intensity does not reflect a real abundance of the taxon with regard to other taxa. The purpose for such a convention was just to reflect the tendencies of a given feature (increasing, decreasing, or constant) and not to describe mutual quantitative relations between the taxa.

Pollen percentage values at any point of the map were obtained as weighted averages for all the sites. The weight was inversely proportional to the square of distance between the point and the given site.

The pollen percentage maps were drawn for 6 taxa (*Juniperus communis*, Cerealia undiff., Poaceae, *Quercus*, *Pinus sylvestris*, and *Artemisia*) and 16 time horizons (Tab. 26).

One question was whether the *Juniperus communis* pollen percentage distribution depends on geomorphology (hypsometry) during the Younger Dryas chronozone (see page 28).

Table 26. Numbers of sites used in the construction of pollen percentage maps for given time horizons. The time windows covered with individual maps (±yr) were different in different periods

^{14}C BP	±yr	Number of sites
Younger Dryas		
10 800	50	7
10 700	50	11
10 600	50	10
10 500	50	11
10 400	50	9
10 300	50	10
10 200	50	11
10 100	50	11
10 000	50	9
Younger part of Atlantic		
6000	100	9
5800	100	9
5600	100	9
5400	100	8
5200	100	8
5000	100	9
4800	100	8

Sets of pollen percentage maps were examined at several time horizons, starting from every 250 years (covering period ±125 years) up to every 100 years (covering period ±50 years). Finally, pollen percentage maps were drawn at every 100 years (Tab. 26, Fig. 35). The ages are expressed in conventional years ^{14}C BP. It was possible to use that convention, as for the analyses, stratigraphical sequences well palynologically dated used were and assumed to represent the Younger Dryas chronozone. The precision ±50 years cannot be treated as absolute i.e. defining the date of time horizon. It is rather the resolution of profiles expressed in ^{14}C years BP. Using an artificially high "time" resolution enables using of all data (samples) on the maps.

The next purpose was to show variability of pollen percentages of taxa indicating human influence on vegetation cover during the Atlantic: Cerealia undiff., Poaceae, *Juniperus communis*, *Quercus*, *Pinus sylvestris*, and *Artemisia*. Here, horizons of every 200 years ±100 years (Tab. 26, Fig. 36) were chosen. For Cerealia undiff. pollen, point maps were created, due to the very low values of this pollen in the analysed spectra. Plotting pollen percentage maps for this taxon would give a false picture of the coverage the broader area with the human impact.

CASE STUDIES IN THE USE OF POLLEN PERCENTAGE MAPS FOR THE KUJAWY REGION AND NEIGHBOURING AREAS

Spreading of *Juniperus communis* pollen in the Younger Dryas chronozone, depending on land configuration

During the Younger Dryas chronozone, *Juniperus communis* pollen shows remarkable differences in its distribution and abundance in the Kujawy region and neighbouring areas (see page 28). In this period, in the region of Lake Gopło, juniper assemblages were poorly developed (Jankowska 1980), whereas west of the Gopło glacial channel in the Biskupin region, juniper assemblages were dominant (Molewski & Noryśkiewicz 2000). They were more abundant also east of Lake Gopło, in the region of Osłonki, and further to the east in the Wisła valley in the region of Lake Gościąż (Ralska-Jasiewiczowa et al. 1998). This local phenomenon was attributed by Molewski and Noryśkiewicz (2000) to differences in altitude, and (among other factors) the existence of dry elevated areas in the bottom of the trough (which favoured the development of shrub assemblages) contrary to the lower, flat, and open Lake Gopło region. Additionally, these shrub communities would have been a natural barrier/filter for the distribution of herbaceous sporomorphs. As a consequence, the amount of herbaceous pollen in the palynological spectra was low. In the neighbourhood of Biskupin, the morainic upland situated at 100–108 m a.s.l. is developed as a flat, undulating plateau (relative heights up to 5 m). At the bottom of a flat, even glacial trough, there are hills of low heights, (4–7 m, Niewiarowski & Sinkiewicz 1995). Lake Gopło, on the other hand, lies in a glacial channel around 80 m above sea level within the Kujawy Upland, which in the northern part (the highest one) reaches to the 90–93 m above sea level (Jankowska 1980). The Osłonki region, similar to the Biskupin region, is situated a little higher than the sites in the glacial channel of Lake Gopło. In the region of Osłonki, the height differences are from 86 to 94 m above sea level (Nowaczyk 2005). Then, the Wisła valley is a flat region, lying 60 m above sea level and is still covered with sandy soils favouring juniper development (Ralska-Jasiewiczowa et al. 1998).

In order to verify the hypothesis of the influence of geomorphology on the spreading

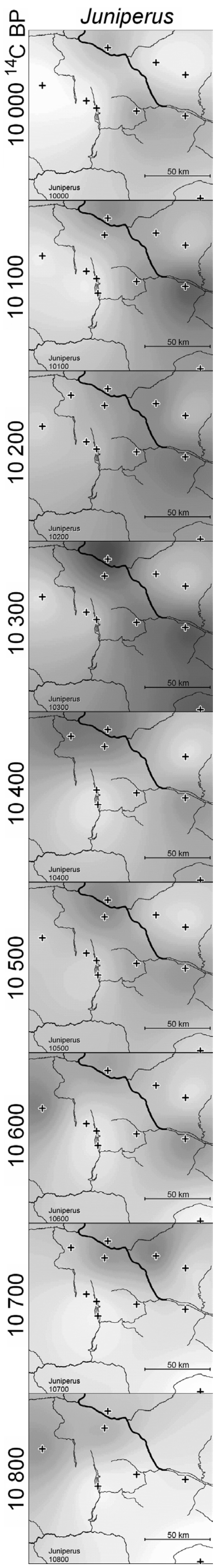


Fig. 35. Pollen percentage maps of *Juniperus communis* at selected time horizons in the Younger Dryas chronozone. The time horizons were determined for every 100 years

of juniper in the Younger Dryas, sets of maps at different time resolutions (±125 yr, ±100 yr and ±50) were studied. On the maps with a resolution of ±125 yr, a division into two parts (older and younger) was marked. In the older part (horizons 10 750 and 10 500), the lowest percentage of *Juniperus communis* pollen was visible in the Lake Gopło region, compared to the surrounding, more geomorphologically-differentiated regions. In the younger part (horizons 10 250, 10 000) the percentage of *Juniperus communis* pollen was increasing, but only in the eastern part of this area in the direction of the Wisła valley (sites at Osłonki and Lake Gościąż), and was decreasing at the west of Lake Gopło. The analyse of maps in horizons of every 200 years ± 100 yr informed that this situation was marked till ca. 10 400 ^{14}C BP and was no longer present after 10 200 ^{14}C BP. The boundary at the 10 400 ^{14}C BP horizon is confirmed on the maps for 100 years ±50 (Fig. 35). The larger percentage of *Juniperus communis* pollen is visible in the region of Kujawy, and mainly in the Wisła valley. Pollen percentage maps confirmed the hypothesis for the older and middle parts of the Younger Dryas chronozone. So it can be concluded that a geomorphologic altitude factor may have been important for the distribution and abundance of juniper in the older and middle Younger Dryas. However, the influence of geomorphology is not visible in the younger part of this period, when the distribution of *Juniperus communis* was influenced mostly by climatic changes. This is consistent with an interpretation resulting from the studies of Lake Gościąż sediments (Ralska-Jasiewiczowa et al. 1998), which indicate that the older part of Younger Dryas was cold and dry, then climatic humidity started to increase, and the last 300 years of the Younger Dryas were somewhat warmer and milder (Ralska-Jasiewiczowa et al. eds, 1998). Other factors, e.g. edaphic factors, were not considered.

Influence of early Neolithic people on the vegetation cover in the region of Osłonki

On the next set of pollen percentage maps, the variability of pollen taxa illustrating the impact of human on vegetation in the early Neolithic period (Fig. 36), was presented. The pollen percentage maps were plotted for every 200 years between 6000 ^{14}C BP and

4800 ^{14}C BP (Tab. 26), that is for the early Neolithic period. On the maps the following taxa were presented: Cerealia, *Pinus sylvestris*, *Quercus*, *Juniperus communis*, *Artemisia*, and Poaceae. The set of these maps is a graphical illustration of events described on page 41, which were happening in the Osłonki region at that period.

The maps for Cerealia pollen (Fig. 36) show a period when cereal pollen were present south of Kujawy. On the first map (horizon 6000 ^{14}C BP ±100), in the region of Osłonki, cereal pollen grains do not occur. On this map a minor (sporadic) Cerealia pollen percentage was revealed only in the northern part of Lake Gopło region and in ride bank of Wisła river (Ziemia Chełmińska), reflecting the presence of communities that settled in the Kujawy region at the beginning of the early Neolithic period (Czerniak 1994, Kukawka et al. 2002, Grygiel 2004). The following maps, for a period from 5800 to 5200 ^{14}C BP, indicate a large abundance of Cerealia pollen in the region of Osłonki. In small quantities pollen of Cerealia is visible at 5600 and 5400 ^{14}C BP in the northern part of Lake Gopło region and in Ziemia Chełmińska again. On the last two maps (5000 and 4800 BP) Cerealia pollen does not occur in Osłonki, whereas it is visible in quite high percentages west of Osłonki in the neighbourhood of Lake Gopło

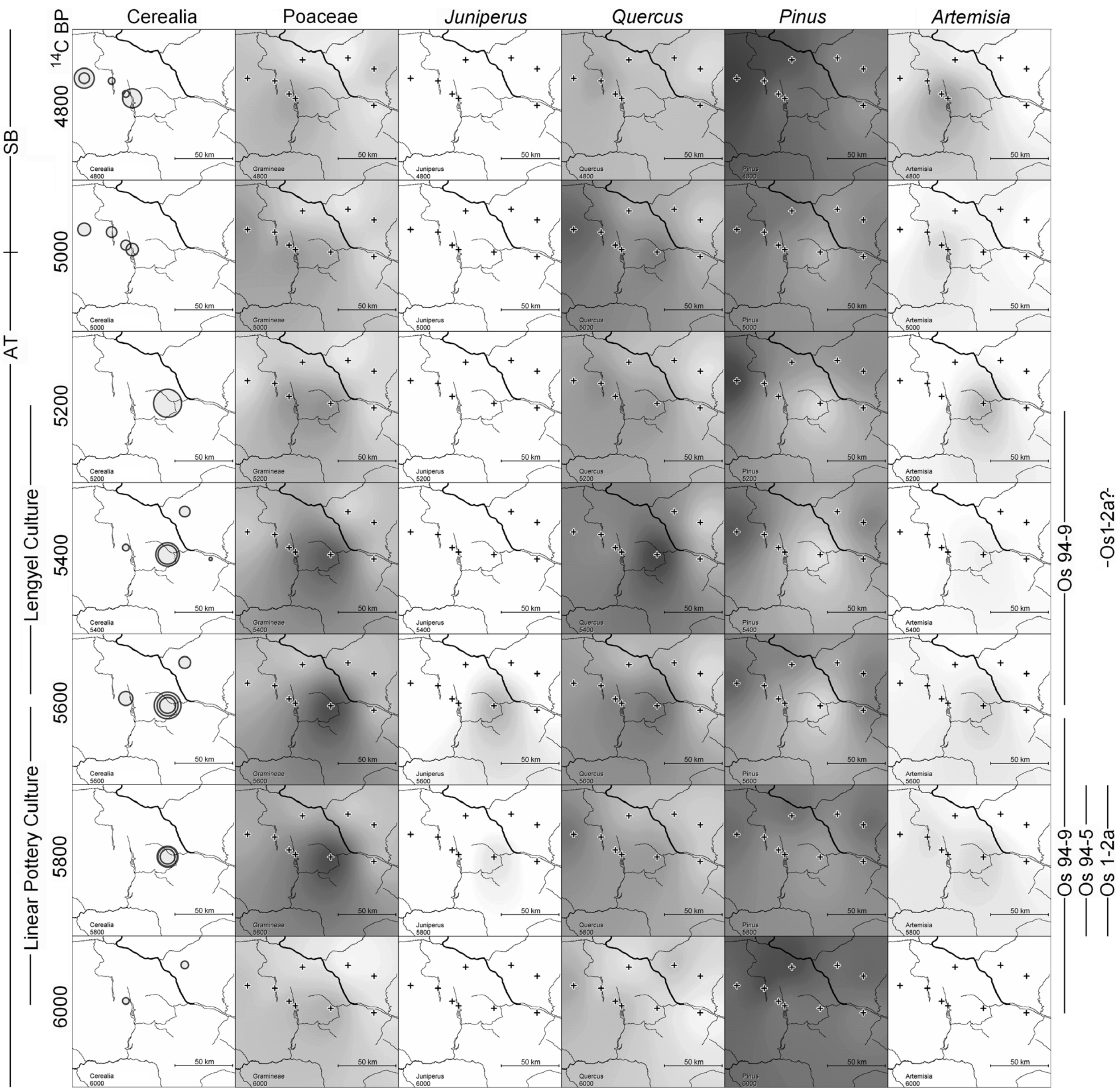


Fig. 36. Pollen percentage maps of Cerealia excl. *Secale*, Poaceae, *Juniperus communis*, *Quercus*, *Pinus sylvestris*, and *Artemisia* at selected time horizons in the younger part of Atlantic chronozone. The time horizons were determined for every 200 ^{14}C years. The presented time interval overlapped the early Neolithic cultures, indicated at the left-hand side of the picture

(Jankowska 1980) and in the Biskupin area (Noryśkiewicz 1995). However, it is not present in Ziemia Chełmińska at this time.

On the maps, clear correlations between increases in Cerealia pollen percentage and increases in Poaceae and *Juniperus communis* are visible. Weaker correlated are changes at *Artemisia* (increase) and *Pinus sylvestris* (decrease) pollen percentages and also those (increase) of the *Quercus* pollen. The increase in percentages of light-demanding Poaceae (which undoubtedly includes some cereal pollen grains), *Juniperus communis* and *Artemisia* (which at the same time occur as ruderal plants, always accompanying man) is a confirmation of the intensive activity of an agricultural population in the Osłonki region. Archaeological studies shown that inhabitants of settlements at Miechowice and Osłonki both in the Linear Pottery culture as in the Lengyel culture periods, used very large amounts of wood for domestic purposes (Grygiel 2004). Anthracological analyses proved (Nalepka et al. 1998) that the largest amounts used were of *Pinus sylvestris* and *Quercus* wood. In the pollen diagram from Osłonki a clear decline was marked in the *Pinus sylvestris* curve, but a weaker one in the *Quercus* curve (Figs 12, 19, 28). The pollen percentage maps clearly illustrate this effect. Along with the occurrence of Cerealia pollen, darkening on the *Pinus sylvestris* maps decreases, while it increases on the *Quercus* map (Fig. 36). The decrease in *Pinus sylvestris* pollen percentages is linked undoubtedly with deforestation near the settlements because of agriculture or other activities like constructing houses, manufacturing of tools, or activities linked with energy production. However, the evident increase in *Quercus* pollen percentages at the same horizon does not reflect the coverage of area with oak woods, but rather the existence of scattered trees that were not cut down during deforestation, which may have caused their increased blooming and hence the relative increase in pollen production. This topic was described in more detail on page 45.

The maps described here indicate clearly that the region of Osłonki is an important area from the point of view of settlement and land-use in the early Neolithic period. However, it was not the only area where early Neolithic communities settled. The entire region of Kujawy and neighbouring areas, covered by the maps presented here, were colonised and readily settled by this population. The archaeological studies revealed many sites of intensive Neolithic settlement. However, these sites are not visible on the maps presented here, as there were no conditions for the formation of biogenic sediments that would preserve materials for palynological analysis. It is known, for example, that in the neighbourhood of Brześć Kujawski, the Linear Pottery culture was very well developed, but there are no sediments suitable for palynological studies, although they have been intensively sought (Grygiel 1986, 2004). Therefore, one could consider the presented maps from the point of view of mutual relations between individual components of the vegetation cover only within the local region around Osłonki. These maps cannot be a basis for regional conclusions.

CONCLUSIONS

LATE GLACIAL AND HOLOCENE HISTORY OF VEGETATION IN THE OSŁONKI REGION BASED ON POLLEN ANALYSIS

The palynological reconstruction of the vegetation history in the Osłonki region considers the Late Glacial, and the older and middle part of the Holocene up to the Subboreal chronozone. Palynological records in the uppermost parts of all the analysed diagrams are scattered and discontinuous, and they cannot be correlated with precisely dated archaeological artefacts collected during excavations. The description of the vegetation history in the Osłonki region on the basis of pollen data encompasses longer or shorter episodes, which were interrupted at times when sediments were destroyed during the Holocene.

Bølling. In wet habitats, low mats of *Salix polaris* and *Betula nana* were growing in the developing patches of tundra. In dry sites of the study area scattered specimens of the light-demanding and cold-resistant *Larix*, *Pinus cembra* and some instances of an arborescent *Betula* and *Pinus sylvestris* have been noted. In similar habitats shrubs of *Juniperus communis* and *Hippophaë rhamnoides* were present. In the various habitats, from dry to wet, new plants appeared; mainly light-demanding types represented by e.g. *Gypsophila*, *Helianthemum*, *Peplis*, and *Selaginella selaginoides*.

Older Dryas. This climate deterioration was reflected by changes in the vegetation. In the landscape there was a decrease in the participation of pine and birch. Cold-resistant larch trees were growing as scattered specimens. More favourable conditions were becoming prevalent for the development of light-demanding plants, both herbaceous and shrubs. They resulted in the good development of juniper stands in the study area. *Hippophaë rhamnoides* was growing in great abundance. Wet habitats were very favourable for the development of willow thickets. Stands of *Betula nana* were still well developing.

Allerød. Open birch and pine forests occurred in this area. However, a part of the study area was still occupied by light-demanding and herbaceous plants, shrubs, and cold-resistant trees of *Pinus cembra*, *Populus*, and Larix. In the younger part of this period, open pine forest with an admixture of birch predominated in dry areas but did not cover the whole terrain, allowing for the development of heliophilous plants. The stands of tundra communities with *Betula nana* and *Salix polaris*, as well as other *Salix* shrubs occupied moist sites.

Younger Dryas. Heliophilous herbs and shrubs dominated the landscape that was more open than in the previous period. Thickets of *Juniperus communis* and *Hippophaë rhamnoides* expanded, different communities of herbaceous plants, which have been already present in the Allerød, invaded new areas. In this period tundra communities with *Betula nana*, *Salix polaris*, and *Selaginella selaginoides* attained optimal conditions in mesic habitats. Scattered trees of *Pinus cembra*, *Larix*, and *Populus* continued to grow, while *Pinus sylvestris* and *Betula* appeared as scattered trees only and did not form forest stands.

Preboreal. During the older part of this period climate warming resulted in the final disappearance of the arctic tundra communities and in the development of forests. At first there were birch and birch-pine forests, as the mesophilous trees had not yet reached the study area due to their slower dispersal rates. Not far from the study site the first trees of *Ulmus* could have been growing. During the younger part of this chronozone, the final disappearance of the tundra communities with *Betula nana* took place. Pine-birch and birch-pine forests dominated the landscape. *Ulmus*, which had already reached the study area, could have formed a small admixture within these forests.

Boreal. During this chronozone the birch and birch-pine forests were still developing in the study area. In the forests with birch dominance elm was slowly spreading in small amounts. In the lower layer of the forest shrubs of *Corylus avellana* gradually obtained better conditions, indicating some amelioration of climate. Hazel developed plentifully and was probably overgrowing open patches of pinewood and dry edges of the forests. Since the middle part of this period, wet communities may have comprised *Quercus* and slightly later also *Fraxinus excelsior*. At the end of this period, in the landscape with the fertile habitats there were already deciduous forests in which oak, lime, elm, and ash trees were growing, with hazel in the understory, as well as birch copses.

Atlantic. Mixed deciduous forests, composed of *Quercus*, *Tilia*, *Ulmus*, *Fraxinus excelsior*, and *Corylus avellana* in various combinations, were dominant in the landscape. In the forest undergrowth – in burnt areas – the fern *Pteridium aquilinum* grew abundantly. On the permanently deforested areas various herbaceous communities developed, such as wet and fresh meadows and dry grasslands. Good conditions existed for the spread of herbaceous plants that demanded a higher amount of nitrogen in the soil, such as *Urtica* and *Plantago major*, resulting in ruderal communities. The presence of arable fields at that time is confirmed in the Osłonki profiles by the occurrence of single pollen grains of Cerealia undiff., *Triticum* type, and *Hordeum* type accompanied by pollen of segetal weeds such as *Ranunculus arvensis* and *Spergula arvensis*. The presence of arable fields was connected with the time when people of the Linear Pottery and Lengyel cultures inhabited the vicinity of Osłonki.

Atlantic or Subboreal. Mesophilous deciduous mixed forests continued to be the predominant vegetation type, but human impact on vegetation caused reduction of the forested areas.

Subboreal. Forested areas diminished, but the composition of forest did not change. Grasses dominated the herbaceous communities in open areas. In the close neighbourhood of villages, open areas were covered with ruderal plants, by crops on the arable fields, and by *Rumex* and *Plantago* in the pastures and fallow lands. The higher amounts of *Artemisia* and Poaceae pollen together with the decrease of deciduous tree pollen are in agreement with the archaeologically documented presence of the Globular Amphorae culture settlement.

Subatlantic. In an open landscape, forests covered only a small area and their composition was changed as *Pinus sylvestris* replaced deciduous trees. Juniper shrubs and various herbaceous communities occupied vast open areas. The high degree of deforestation and the presence of synanthropic plants indicated the use of large areas for economic purposes by farmers. The spread of *Juniperus communis* and *Rumex acetosella*, which grew on poor soils, may be evidence of impoverishment of various habitats. Open sites were used for agriculture (cultivation of fields and cattle breeding). The high increase of pollen of ruderal community indicators (e.g. *Artemisia*, *Urtica dioica*-type, *Plantago major*) suggests the existence of permanent settlements in the neighbourhood of the studied sites. The uppermost spectra indicate an open, almost tree-less landscape. Herbaceous plants are dominant, mainly grasses and ruderals. The agricultural activity increased, including both crop cultivation (Cerealia) and pasturage (*Plantago lanceolata*). Waste areas on poorer soils were present, where *Juniperus communis* shrubs had spread. Oak, poplar, alder and willow grew as scattered trees only. Temporary pine regeneration occured.

EARLY NEOLITHIC FARMING IN THE OSŁONKI REGION BASED ON POLLEN ANALYSIS

Palynologically identified agricultural activities of Neolithic farmers and their impact on changes in the plant cover are referred to individual cultures on the basis of detailed correlations with the results of archaeological studies in the Osłonki region and are supported by radiocarbon dating and numerical methods.

In the Osłonki region the early Neolithic occupation was revealed: the first by people of the Linear Pottery culture, and the second when people of the Lengyel culture settled at the site. The settlers of the Lengyel culture in Osłonki made high demands on the local environment and probably altered it significantly by land clearance, timber cutting for construction and firewood, crop cultivation, and grazing of livestock. The late Neolithic groups followed the changings initiated by the early Neolithic settlers.

Before the development of the early Neolithic occupation, primeval mixed deciduous forests with oak, lime, elm, ash, and hazel covered the landscape of the vicinity of Osłonki. Only small open areas with heliophilous herbs were present. The first farmers appeared in a forested environment. Cereals along with segetal weeds and ruderals reflected the spread of agriculture. Wheat and barley were cultivated. The inhabitants of Osłonki exploited wild resources, which were available in the neighbourhood. They used wood, first of all oak and pine but also of other trees and shrubs like birch, poplar, and hazel, although probably in smaller quantity. The landscape around the Lengyel settlement should be exploited quite heavily in the immediate vicinity of the houses and furthermore, the timber requirements of long-house construction would have resulted in the cutting of substantial timber, to which the constant requirements for fuel, tool use, and house repair should be added. Generally there is a picture of a very intensive local landscape use. After the end of the Lengyel settlement at Osłonki, the traces of the late Neolithic (Globular Amphorae culture) sites in this area are found. In the upper part of the analysed profiles palynological records of human presence are scattered and discontinuous. They cannot be correlated with precisely dated archaeological artefacts collected from excavations.

NUMERICAL ANALYSIS

Numerical analyses were applied to the analysed material. They supported the division of diagrams into L PAZ, the identification of cultural phases in the diagrams, and relatively dating of the palynologically investigated material.

In this study three different methods of correlation were used. The Sample Similarity Matrix analysis correlated only two tables covering groups with similar spectra. The MultCorr – Individual spectra analysis indicated the most similar spectra in two or more tables simultaneously. The MultCorr – Average spectra analysis compared average values of all spectra from one table with individual spectra from another table. The last method of average spectra seems to be, in the author's opinion, appropriate for correlation. The SSM analysis gives less precise results. The performance of the MultCorr – Individual spectra method is very poor. After several repeats of the numerical analyses, using various options and various sets of taxa, the divisions proposed based on palynological analysis have been confirmed. Additionally, the numerical analyses facilitated the decision of placing boundaries in pollen diagrams. Results of these analyses helped to assign absolute ages to samples of the examined profiles. The numerical analyses used here were treated only as a certain proposal of applying additional methods enabling consideration of the assembled data from another point of view, especially when it is difficult to interpret clearly available materials in a classical way, based on ecological knowledge.

POLLEN PERCENTAGE MAPS

The maps of the spatial distribution of the pollen percentages for a given taxon at a given time reflect changes in pollen values (pollen %) within a given area. Construction of maps involves the calculation of percentages at every point of a given area based on the values from several sites.

Several series of pollen percentage maps illustrating the pollen percentage distribution in the Kujawy and the neighbouring areas at several selected time horizons (on a scale of ^{14}C years BP) were created. The purpose was to observe the main spatial trends in pollen percentage distribution in the examined area in the past. First, a series of pollen percentage maps created for *Juniperus communis* supported the hypotesis that in the Younger Dryas chronozone juniper bushes were better developed locally in the Kujawy region. The role of geomorphologic altitude was crucial here. This hypothesis is valid in relation to the older and middle part of the Younger Dryas chronozone. However, this phenomenon is not visible in the younger part of this period.

The second series of maps provided a visualisation of changing pollen percentages of taxa related to the early Neolithic agricultural activity. On these maps clear correlations between increases in Cerealia pollen percentage and increases in Poaceae and *Juniperus communis* are visible. Weaker are correlations with the increase of *Artemisia*, the decrease of *Pinus sylvestris* pollen percentages and also the increase in *Quercus* pollen. Increases in the percentages of light-demanding Poaceae, *Juniperus communis* and *Artemisia* provide confirmation of the intensive agricultural activity in the Osłonki region.

This study indicates suitability of pollen percentages maps, characterized by a high degree of generalization, for testing general tendencies in development of vegetation cover.

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