Multiproxy environmental archaeology of Neolithic settlements at Osłonki, Poland, 5500–4000 BC

Peter Bogucki, Dorota Nalepka, Ryszard Grygiel and Bolesław Nowaczyk

Archaeological research on Neolithic settlements (ca. 5500–4000 cal BC) at and near Osłonki, Poland, is complemented by palaeoenvironmental investigations in three basins with biogenic sediments adjacent to the archaeological sites. Research included sedimentology, palynology, malacology and cladoceran analysis. Complementary lines of evidence indicate that Linear Pottery pioneer farmers of the late 6th millennium BC caused minimal environmental impact, but intensive settlement and land use by the Brześć Kujawski Group during the 5th millennium BC triggered pronounced human-induced effects on the local landscape. Of particular significance is the evidence for erosion and aeolian ablation of exposed soil in the vicinity of the Neolithic settlements, presumably reflecting widespread land clearance, agricultural activity and settlement construction.

Keywords: Neolithic, Europe, pollen analysis, geomorphology, malacology, cladoceran analysis, land use, human impact

Introduction

This article presents results of a combined program of archaeological and palaeoenvironmental research on Neolithic sites at Osłonki, Poland, where several Neolithic settlements lie next to basins containing rich biogenic sediments. The main Neolithic site in this cluster is Osłonki 1, excavated between 1989 and 1994, with other sites subsequently investigated at Miechowice 4, Miechowice 4a, Konary 1 and Konary 1a. Among these sites are three basins containing biogenic sediments up to 8 m deep. Such proximity of archaeological and palaeoenvironmental sites is rare for early farming settlements in central Europe outside the Alpine Foreland and the lowlands of Holland and Denmark.

The palaeoenvironmental research intensively studied the sedimentation, palynology, malacology and cladocera of the biogenic sediments with particular attention to evidence for anthropogenic impacts on local and regional environments during the 6th and 5th millennia BC (all dates in this paper are based on calibrated radiocarbon dating), when an agricultural economy based on cereals and livestock was established throughout central Europe (Bogucki 1996). Osłonki lies near the northern edge of the distribution of early Neolithic settlement in central Europe, beyond which lay borderlands separating farming communities from the foragers of the Baltic zone. Such a frontier location provides an opportunity to examine the environmental impact of early farming communities against the backdrop of a landscape that presumably had undergone minimal anthropogenic modification.

Research context and motivation

The spread of agriculture into central Europe combined dispersal of farming communities and adoption of new technology and values by indigenous peoples (Bogucki 1996). We distinguish two main zones of early agricultural settlement in central Europe. In loess-filled basins along the upper reaches of major central European rivers, Neolithic farmers settled along small rivers and creeks. Another, less-studied region of early farming settlement in central Europe is the North European Plain, a lowland zone stretching from Holland to Russia, covered either by

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ice or with glacial outwash during the Vistula (in Polish, *Wisła*) Glaciation. Retreating ice left a landscape of moraines, outwash plains, sub-ice meltwater channels and dead-ice features such as kettle holes. Lakes and slow-flowing streams constitute the hydrological system. Northward-flowing rivers (most prominently the Elbe, Oder and Vistula) and east–west meltwater valleys divide the region into smaller physiographic provinces.

One such province is Kuyavia (in Polish, *Kujawy*), a region of clay ground moraine dissected by glacial tunnel valleys and sandy outwash, bounded on the east by the Vistula river, on the north by the proglacial Toruń-Eberswalde meltwater valley and in the south by the Warsaw-Berlin meltwater valley. In the west it abuts the similar region of Great Poland (in Polish, *Wielkopolska*). Neolithic settlement in Kuyavia has been investigated since 1933, when excavations at Brześć Kujawski revealed a multiperiod occupation (Jażdżewski 1938). Today Kuyavia is one of the most extensively studied areas of early farming settlement in central Europe.

Neolithic farmers were drawn to Kuyavia soon after settlement of the loess basins. Sites of the Linear Pottery culture, dating between 5400 and 5000 BC, lie primarily on low fingers of land along tunnel valleys or shallow lakes. Lowland Linear Pottery settlements have dense deposits of rubbish but sparse structural remains. Rectangular houses have been reported (Czerniak 1998; Grygiel 2004; Pyzel 2009), but extensive multi-phase longhouse settlements have yet to be found.

Shortly after 4700 BC, sites of the Brześć Kujawski Group appeared in the lower Vistula drainage. The Brześć Kujawski Group is a late variant of the Lengyel Culture, contemporaneous with the initial florescence of copper-using societies in south-eastern Europe. Longhouses and contracted burial clearly link the Brześć Kujawski Group with Linear Pottery precursors. The Brześć Kujawski Group flourished for several centuries, roughly 4700/4600 to 4200/4100 BC. Large sites like Brześć Kujawski and Osłonki contain dozens of longhouses rebuilt over multiple generations in continuous developmental sequences.

Despite the concentration of early farming settlement in Kuyavia, few localities have been investigated palynologically (Nalepka 2004a). Bottom sediments of Lake Gopło, 27 km W of Osłonki, were the subject of pollen analysis in the 1970s (Jankowska 1980), but they were not dated with absolute methods. Laminated sediments of Lake Gościąż (Ralska-Jasiewiczowa *et al.* 1998), in the Vistula valley 35 km E-SE of Osłonki, were radiocarbon dated and serve as a reference site to which pollen diagrams in central Poland can be related.

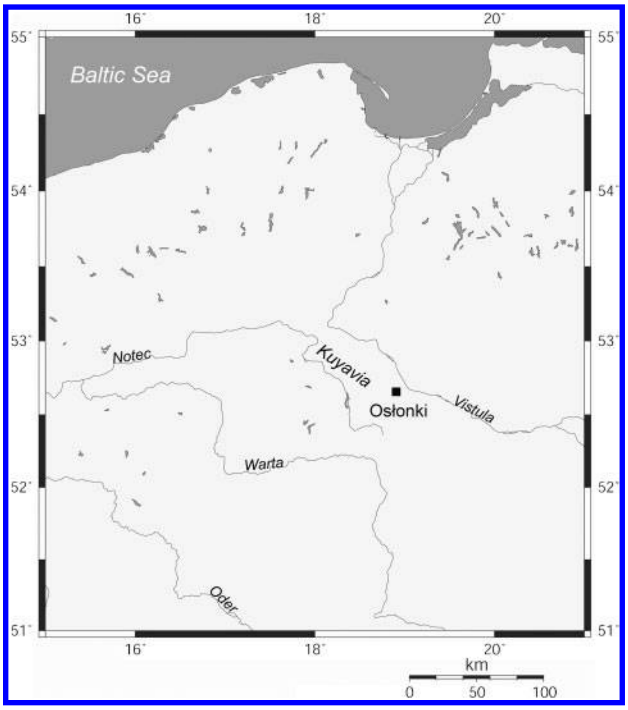


Figure 1 Map of northern Poland showing location of Osłonki in SE Kuyavia

Neolithic settlements at Osłonki, Miechowice and Konary

Osłonki is located in SE Kuyavia about 10 km west of Brześć Kujawski (Fig. 1). The main Neolithic settlement at Osłonki 1 lies on a low spur 90 m above sea level. On the north, the spur is bordered by a trough that widens into two irregular basins, one NE and one NW of the settlement (Fig. 2). South of the spur is a small oval depression forming a third basin. Surfaces of these basins lie 1·5 to 3·5 m below the adjacent ground moraine on which Neolithic settlements are located. In light of the role that the Vistula glaciation played in shaping the relief of Kuyavia, the trough and depressions were presumed *ab initio* to be traces of sub-ice channels and the melting of blocks of buried ice.

No Neolithic occupation was known at Osłonki before 1985. Extensive excavations at Osłonki 1 between 1989 and 1994 revealed a settlement of the Brześć Kujawski Group with over 30 longhouses and over 80 graves (Grygiel and Bogucki 1997). In 1995–97, excavations at Miechowice 4 and 4a, lying north of the NE basin, exposed a smaller Neolithic settlement with occupations of both the Linear Pottery Culture and the Brześć Kujawski Group, the latter represented by additional longhouses and burials. In 1998–99, excavations at Konary 1 and 1a

Figure 2 **Aerial photo looking west showing main Neolithic sites at Osłonki and adjacent basins with biogenic sediments. Key: 1 – Osłonki 1; 2 – Konary 1; 3 – Konary 1a; 4 – Miechowice 4a; 5 – Miechowice 4; A – NE basin; B – NW basin; C – S basin (surrounded by trees)**

north of the NW basin revealed occupations by the late Stroke-Ornamented Pottery Culture and the Brześć Kujawski Group. Aerial reconnaissance in 2003–04 and test excavations revealed further settlement with longhouses south of the NE basin and east of Osłonki 1, designated Osłonki 1a.

Results of the excavation of over 25,000 m^2 at Osłonki 1 and 1a, Miechowice 4 and 4a, and Konary 1 and 1a Grygiel (2004; 2008) have documented (1) initial settlement by Linear Pottery farmers at Miechowice 4 during the late 6th millennium BC with multiple pit features and light post structures; (2) a hiatus of about two centuries reflecting a general interruption in settlement throughout the Polish lowlands at the beginning of the 5th millennium BC, relieved by settlement during the latest phase of the Stroke-Ornamented Pottery Culture at Konary 1; and (3) widespread settlement with many longhouses and burials at multiple locations on the spur and on the north and east sides of the basins by the Brześć Kujawski Group between ca. 4700/4600 and 4200/4100 BC (traces of later Neolithic settlement of the Funnel Beaker Culture at Osłonki 2 south of the southern basin and of the Globular Amphora Culture at Osłonki 1 have not been fully studied and are beyond the scope of this paper). The occupations of the Brześć Kujawski Group can be further divided into three phases: early (4700–4500 BC), classic (4500–4300 BC) and late (4300–4100 BC).

Archaeobotanical evidence reflects use of a suite of domestic plants by both the Linear Pottery inhabitants of Miechowice 4 and the Brześć Kujawski Group inhabitants of all sites, including einkorn and emmer wheat, a 'new' type of glume wheat, hulled barley and peas, accompanied by an assemblage of segetal weeds common at early farming sites in central Europe (Bieniek 2002; 2007). Of particular interest are hundreds of feathergrass awns (*Stipa pennata*) found in multiple Brześć Kujawski Group features at Osłonki 1, Konary 1 and 1a, and Miechowice 4 and 4a (Mueller-Bieniek and Nalepka 2010). This steppe species is unusual in central

Europe and reflects a hitherto-unexpected heterogeneity in habitat types.

There is marked difference between faunal samples from Linear Pottery settlements of southeastern Kuyavia, including Miechowice 4 and those of the Brześć Kujawski Group (Bogucki 2008). Linear Pottery faunal samples are composed almost exclusively of domestic cattle bones, with low representation of sheep and goat, almost no pigs and wild herbivores like red deer and roe deer. Faunal samples of the Brześć Kujawski Group are much more varied. Cattle are still the most abundant taxon, comprising 40 to 50% of most samples, but sheep and goat constitute about 30% of many assemblages, while pigs make up 20–25% of most samples. Red deer and roe deer remain scarce, but have a stronger presence than in Linear Pottery samples. Birds (both terrestrial and aquatic), fish (pike, perch and Cyprinidae) and pond tortoises (*Emys orbicularis*) are abundant in features of the Brześć Kujawski Group.

Research methods and primary data

Palaeoenvironmental research at Osłonki was initiated to address archaeological questions of Neolithic land use and impact on the environment (Table 1). Field research was carried out during the summer excavation seasons, with most individuals responsible for palaeoenvironmental research working closely with archaeological staff. Coring and sampling for geomorphological and palaeoenvironmental research proceeded in parallel.

Data for geomorphological analysis was obtained from coring the infilled lake basins and surrounding ground moraine, as well as examination of geological structures exposed by archaeological research. Profile lines were laid out perpendicular to long axes of the basins (Fig. 3.11). Along these lines, coring was done with an Instorf (Russian) sampler (cup diameter 5 cm) approximately every 30 metres, with closer spacing along the edges of the basins.

The coring survey produced a geological characterisation of the three basins as follows (Nowaczyk 2008):

1. The NE basin is deepest, reaching a maximum depth of 8·6 m beneath the accumulation surface on its southern side; a secondary deep spot reaches 3·5 m in the north-eastern part.
2. The NW basin is shallower, with a trough in its south-eastern portion reaching 5·3 m beneath the accumulation surface and a smaller depression in the north-eastern part 4·5 m deep; over the rest of the basin, deposits range up to 2 m deep.
3. The southern basin is a small regular oval with biogenic deposits reaching a maximum depth of 4·1 metres.

After preliminary analyses, several points were selected for coring with a Russian corer with a cup diameter of 8 cm for palaeobiological, physical and chemical analyses (Fig. 3.12). Two cores, each 9 m long, were extracted from the deepest part of the NE basin. One, designated Os 94-9, was reserved for palynological and cladoceran analysis, while the other (Os 94-9A, a twin to 94-9 taken 25 cm away) was divided into 10 cm sections for malacological analysis, determination of $CaCO_3$ and organic content. Core Os 16 was taken from the same basin, about 190 m NNE of Os 94-9, while core Os 57 was taken from the deepest point in the NW basin, adjacent to the settlement at Konary.

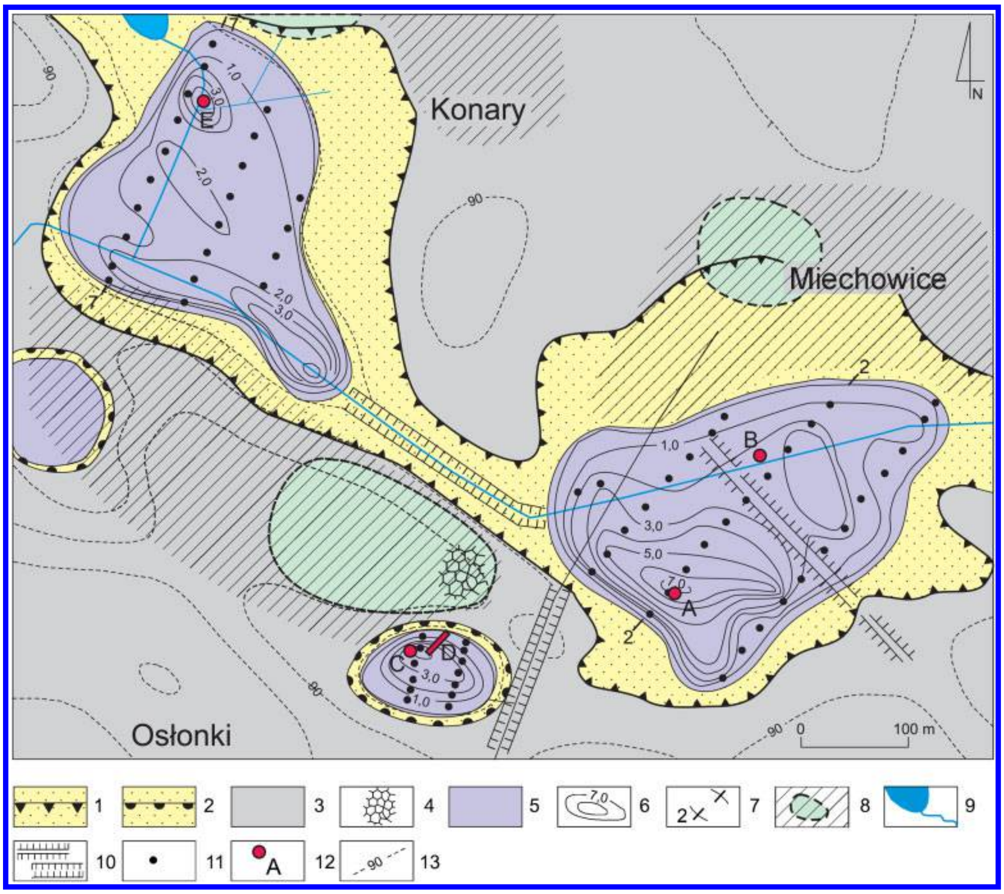
In the southern basin, core Os 1–2a was collected by Więckowski piston corer (similar to a Livingstone corer) with a diameter 8 cm. Os 94-5 was taken in this same basin, from the wall of a trench 25 m long, 1·50 m wide and up to 4 m deep dug perpendicular to the shoreline next to the Osłonki 1 archaeological site, running in a south-eastern direction. Os 94-5 was taken as monolithic column segments in $25 \times 8 \times 5$ cm metal boxes. Samples from this column were used to assess grain size and chemical properties.

The purpose of digging the trench and sampling its wall was to see if layers related to archaeological deposits at Osłonki extended into the basin and contained diagnostic artefacts that could be linked to the occupation of the site. Although this did not turn out to be the case, it provided an opportunity to take complete column samples that were not subjected to the trauma of extraction by corer. The samples from the trench wall also resolved a problem that had emerged with cores taken earlier by the Więckowski corer. The core samples had been incomplete and broken, and the column samples revealed the presence of thin sandy layers cutting through the organic sediments. The core samples had broken along these sandy layers during extraction.

Table 1 summarises methods used in the recovery and analysis of palaeobiological data from the Osłonki basins. Cores Os 1-2a, Os 94-5 and Os 94-9 were subjected to complete palynological and macrobotanical study, while Os 16 and Os 57 were used for auxiliary palynological investigations (Nalepka 2005; 2008). Simplified pollen diagrams from cores Os 1-2a and Os 94-9 and the Os 94-5 column are shown in

Table 1 Summary of methods used in Osłonki palaeoenvironmental analysis

Core	Os 1-2a	Os 94-5	Os 94-9	Os 16	Os 57	Procedures	Analysis
Localisation	Southern basin	Southern basin	NE basin	NE basin	NW basin		
Recovery method	Więckowski (Livingstone) corer	Trench (outcrop)	Russian corer	Russian corer	Russian corer		
Depth	Up to 5 m	Up to 4·3 m	Up to 9 m	Up to 140 cm	Up to 130 cm		
Lithology description	in the field	in the laboratory	in the laboratory	in the field	in the field	Troels-Smith (1955), Munsell (1954)	
Botanical analysis	Palynology – full (Nalepka)	Palynology – full (Nalepka) Plant macrofossils (Nalepka)	Palynology – full (Nalepka) Plant macrofossils (Nalepka)	Palynology – auxiliary (Nalepka)	Palynology – auxiliary (Nalepka)	Palynology: 1 cm^3 of sediment by Erdman's acetolysis and HF (Faegri et al. 1989), and indicator added (Stockmarr 1971) Plant macrofossils: 10% KOH (Faegri et al. 1989)	Pollen sum of trees, shrubs and herbs, excluding aquatic and swamp plants and spores, was used as the basis for calculating the percentages. LPAZ: Birks (1986)
Zoological analysis		Cladocera (Gąsiorowski)	Malacology (Alexandrowicz) Cladocera (Gąsiorowski)	Malacology (Alexandrowicz)		Malacology: (Ložek 1964, Evans 1972, Alexandrowicz 1999) Cladocera: Frey (1986)	Malacology: Spectra of species (MSS) and specimens (MSI), indices of species constancy and domination (C-D) supplemented by their arithmetic mean (Q index) and normalized values (C-D), number of taxa (Nt) and of specimens (Ns), the Shannon-Weaver index of species diversity (SWI)
Dating	^{14}C conv. (Lod)	^{14}C conv. (Lod)	^{14}C AMS (Poz)	no	no	Lod – Łódź Radiocarbon Laboratory; Poz – Poznań Radiocarbon Laboratory	
Graphics	diagrams	diagrams	diagrams	diagrams	diagrams	POLPAL (Nalepka, Walanus 2003)	



Key: 1- margins of glacial trough showing extent of ablation sands; 2-depressions resulting from melting of buried ice; 3-flat ground moraine – moraine till; 4-frOs t fissure polygons in ground moraine; 5-biogenic accumulation plains – peats, gyttja, organic silts; 6-depth contours of biogenic depOs its; 7-lines of geological sections 2 and 8 (see Fig. 9); 8-approximate extent of Neolithic settlement; 9-hydrological network; 10-contemporary anthropogenic landforms (embankments/ banks and cuttings/ditches); 11-borings in biogenic basins; 12-locations of cores used for palaeobiological physical-chemical analyses were taken. (A – Os 94-9 and Os 94-9A, B - Os 16, C - Os 1-2a, D - Os 94-5, E - Os 57); 13-contour lines in 1·25 m intervals

Figure 3 **Geological sections through reservoirs with biogenic accumulation, adjacent moraine upland and location of coring transects and profiles selected for study in the Os łonki basins (after Nowaczyk *et al.* 2002 and Nowaczyk 2008, modified)**

Figs 4–6. Pollen diagrams from Os 1-2a, Os 94-5 and Os 94-9 were divided into local pollen assemblage zones (LPAZ) on the basis of visual analysis of individual pollen curves supported by ConSLink and PCA (Birks 1986). The LPAZ units were correlated with chronostratigraphic subdivisions established for Poland (Ralska-Jasiewiczowa and Latałowa 1996).

Malacological analysis by Stefan Witold Alexandrowicz (2008) was based on 76 samples from Os 94-9A (Fig. 7) and 8 from core Os 16 using standard malacological techniques for species quantification (Alexandrowicz 1999). Cladocera (water fleas) preserved in biogenic sediments are indicators of the water environment and its trophic state. Some species are especially sensitive to shortages or overloads of nutrients. Cladoceran analysis was carried out by Michał Gąsiorowski (2008, Gąsiorowski and Nalepka 2004) on 38 samples from core Os 94-9 (Fig. 8) and 18 samples from core Os 94-5 using procedures described by Frey (1986). Table 1 also summarises methods employed in malacological and cladoceran analysis.

Radiocarbon dating of biogenic sediments

Radiocarbon determinations from profiles Os 1-2a and Os 94-5 have been made by the Radiochemical Laboratory of the Museum of Archaeology and Ethnography in Łódź (Lod), using conventional (beta-counting) techniques on bulk samples consisting of peat or peaty mud. AMS radiocarbon determinations from core Os 94-9 have been made by the Poznań Radiocarbon Laboratory (Poz) on samples composed of selected macroscopic plant remains. Bulk samples were not used for AMS dating due to concerns about freshwater reservoir effects. These dates (Table 2) complement radiocarbon

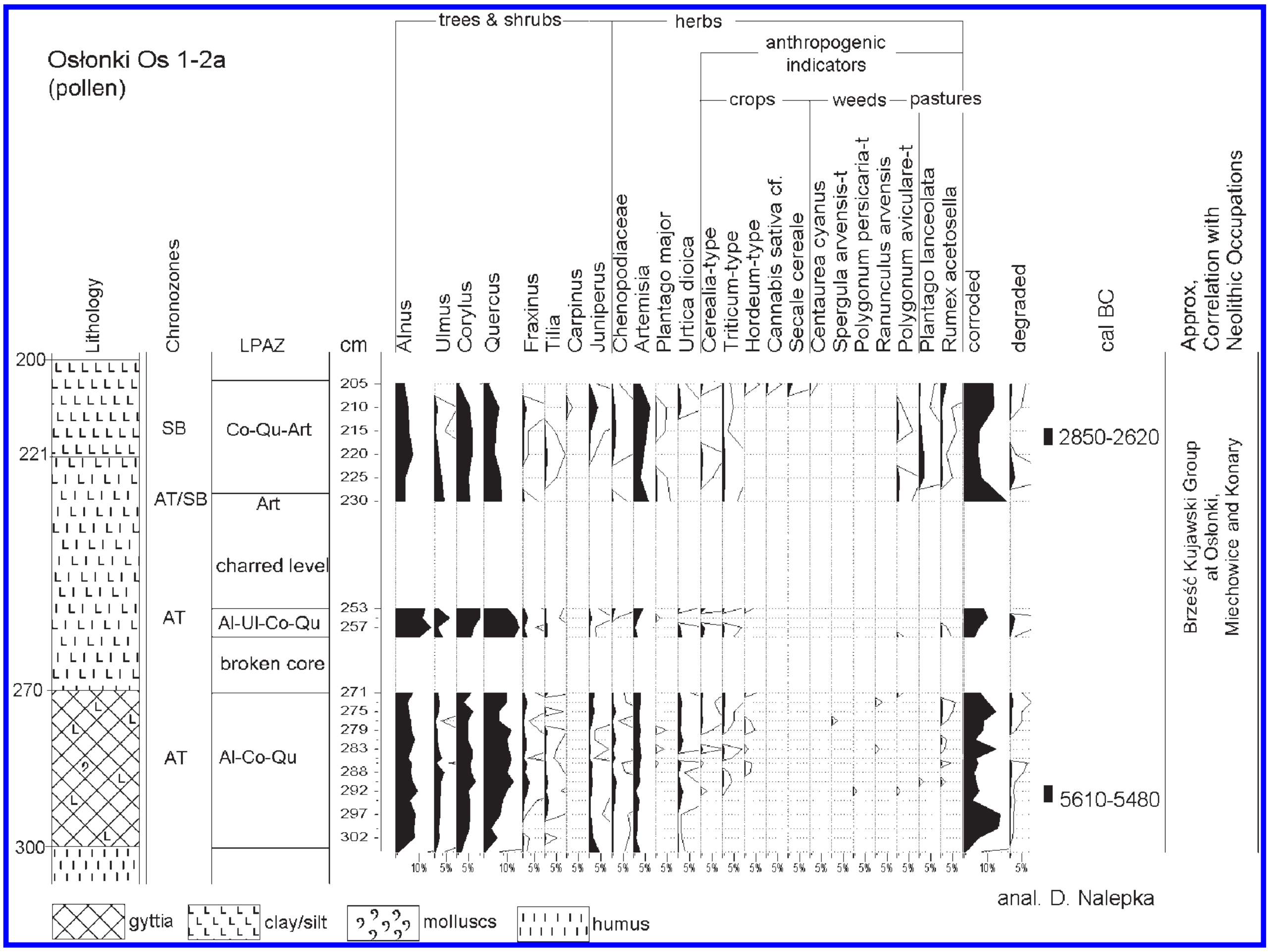


Figure 4 **Simplified pollen diagram from core Os 1-2a. Key: LPAZ = Local Pollen Assemblage Zone; Al = *Alnus* (alder); Co = *Corylus* (hazel); Qu = *Quercus* (oak); Ul = *Ulmus* (elm); Art = *Artemisia*; AT = Atlantic period; SB = Subboreal period (after Nalepka 2004b; 2005, modified)**

determinations from archaeological contexts at Osłonki and Miechowice (Grygiel 2004; 2008). Calibrated ranges were determined with OxCal 3·5 for the Łódź dates and OxCal 3·8 for the Poznań dates (see http://c14.arch.ox.ac.uk for version notes), both using the INTCAL98 dataset (Stuiver *et al.* 1998).

Of the dates in Table 2, Poz-836 is much earlier than any Neolithic occupation and would be contemporaneous with presumed habitation of the area by foragers whose traces are hitherto unknown in the immediate Osłonki environs. Another date, Poz-840, is substantially later than Neolithic settlement and is contemporaneous with Late Bronze Age settlement in the region. Lod-1179 from core Os 1-2a correlates with regional settlement by the Late Neolithic Globular Amphora culture, traces of which are found at Osłonki 1 but not in such abundance as those of earlier Neolithic societies.

The most relevant dates for this discussion are Lod-1176, Lod-1177, Lod-1181 and Poz-839. Lod-1176 and 1177 date the sediments in Os 94-5 between 256 and 283 cm below the surface to the middle of the 6th millennium BC, just prior to the appearance of the Linear Pottery Culture at Miechowice 4 ca. 5400 BC. The same is true of Lod-1181 in the Os 1-2a profile between 291 and 295 cm deep. Since these are conventional radiocarbon dates, their precision is low, but together they establish a general chronological baseline at or immediately before the appearance of Neolithic settlement. Material in cores above levels from which these samples were taken can be considered contemporaneous with Neolithic and later activity in the vicinity.

The Poz-839 date, 4750–4530 BC, from Os 94-9 correlates with occupation by the Brześć Kujawski Group at Osłonki, Miechowice and Konary, as established by dates from these sites reported by Grygiel (2008). As an AMS date from the most informative core, Poz-839 anchors an important point in the profile in the middle of the 5th millennium BC, permitting many of the inferences

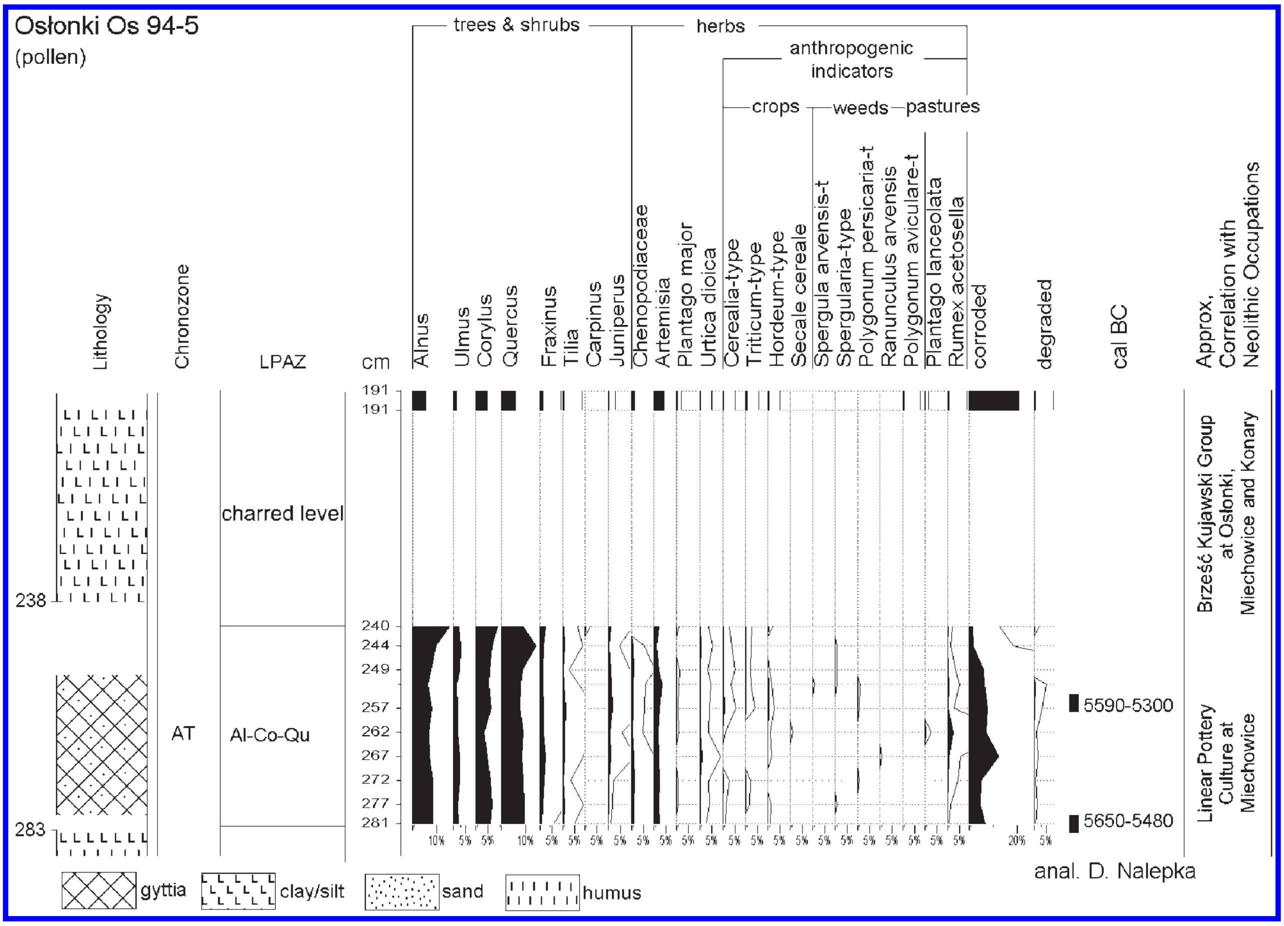


Figure 5 **Simplified pollen diagram from core Os 94-5. Key: LPAZ = Local Pollen Assemblage Zone; Al = *Alnus* (alder); Co = *Corylus* (hazel); Qu = *Quercus* (oak); AT = Atlantic period (after Nalepka 2004b; 2005, modified)**

about human activity discussed below. Its relationship at or slightly above the level with charcoal and corroded pollen is especially important. Allowance for a possible freshwater reservoir effect could render this date slightly later and thus bring it even more fully into alignment with dates from archaeological contexts at Osłonki. Although additional AMS dates will eventually refine the dating of this level, its association with the occupation of the Brześć Kujawski Group is apparent.

Geomorphological and palaeoenvironmental data analysis

Analysis of geomorphological, palynological, malacological and cladoceran data from the biogenic sediments in the three basins that border Osłonki, Miechowice and Konary enable a characterisation of the development of terrain features, sedimentary history and vegetation history during the Late Glacial and Holocene. The focus below will be on data that bear on the mid-Holocene period correlated with settlement by the Linear Pottery Culture and the Brześć Kujawski Group, ca. 5400–4000 BC.

Description of deposits and lithostratigraphy

Observations in the archaeological excavations, survey coring in the surrounding ground moraine and detailed coring in the basins show that the Osłonki area is covered almost entirely by moraine till (Fig. 3.3). Patches of ablation sand, about 1 m thick, lie on the moraine till, including a large area NW of Miechowice (Fig. 3.1). Depressions in the till are filled with biogenic deposits (Figs 3.5). At the Neolithic settlements, sandy ablation till was identified at the top of the soil profile, upon which the humus layer developed. Along the borders of basins with biogenic sediments, clayey ablation sands of various thicknesses lie under the humus. Beneath all these deposits lies dense basal moraine till, brown in colour, sometimes exceeding 5 m in thickness. Pieces of Scandinavian rocks, including granites, sandstones, limestones, quartzite, porphyry, gneiss, gabbro and others are found in the basal till.

Biogenic deposits in the basins consist of organic (peat, gyttja, humus) and mineral (silt, sand) sediments (Fig. 9). Analysis of cores and sections shows that a thin basal layer of peat, only a few centimetres

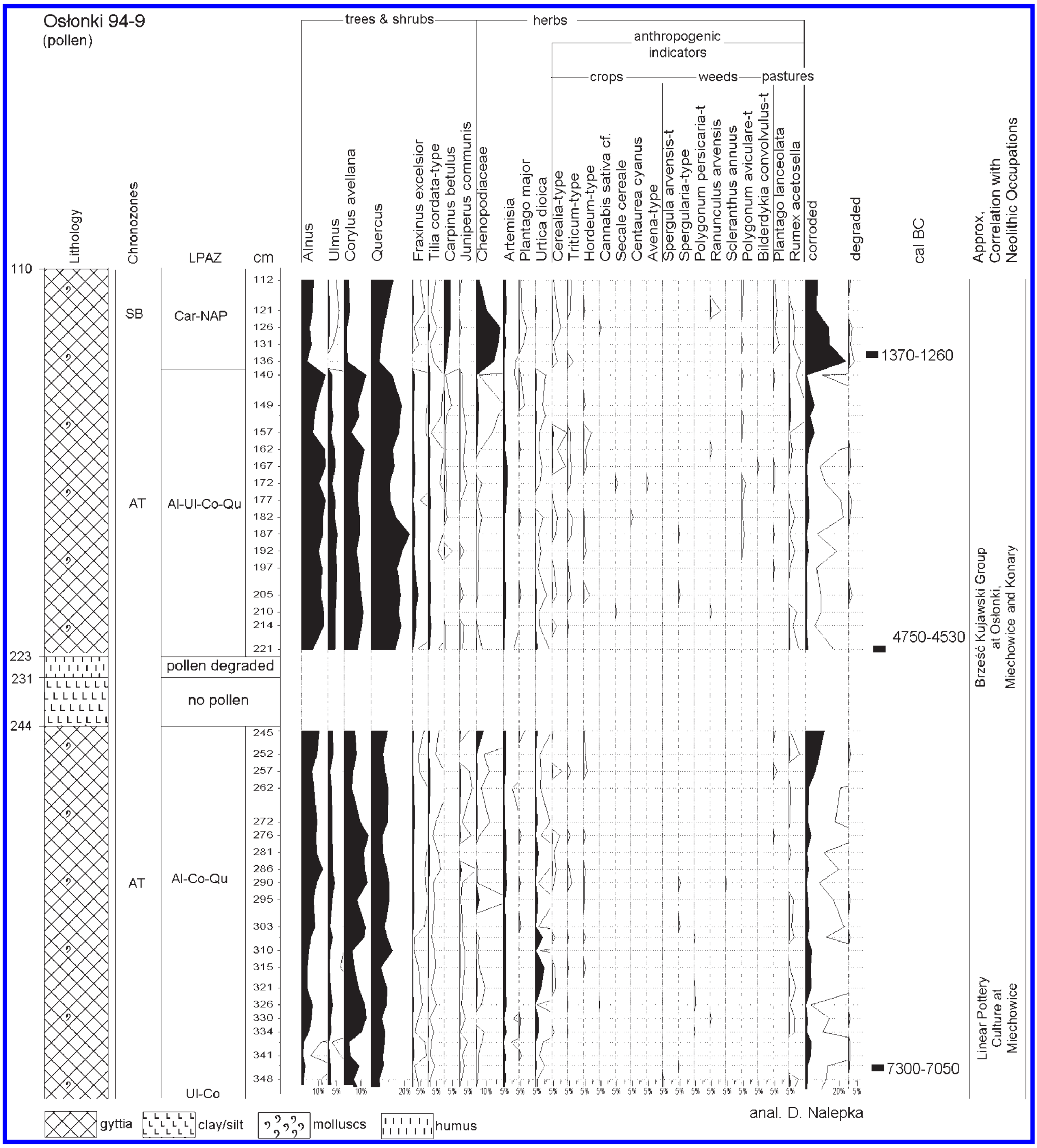


Figure 6 **Simplified pollen diagram from core Os 94-9. Key: LPAZ = Local Pollen Assemblage Zone; Al = *Alnus* (alder); Co = *Corylus* (hazel); Qu = *Quercus* (oak); Ul = *Ulmus* (elm); Car = *Carpinus* (hornbeam); NAP = Non-Arboreal Pollen (herbaceous pollen); AT - Atlantic period; SB = Subboreal period (after Nalepka 2004b; 2005, modified)**

thick, lies at the bottom of the basins, a common feature in central European glacial basins with biogenic accumulation. This peat layer is covered by calcareous gyttja or marl containing malacofauna, ranging in thickness from a few centimetres to several metres. In a few places, this layer lies directly on the basal moraine till without the intervening peat. Detritus gyttja was found in several cores. In some cores in the NE basin, a compressed layer of black-olive gyttja with a low level of $CaCO_3$ and minimal malacofauna occurred near the bottoms of the cores.

In littoral zones at the basin margins, layers of sand were interstratified with calcareous gyttja and

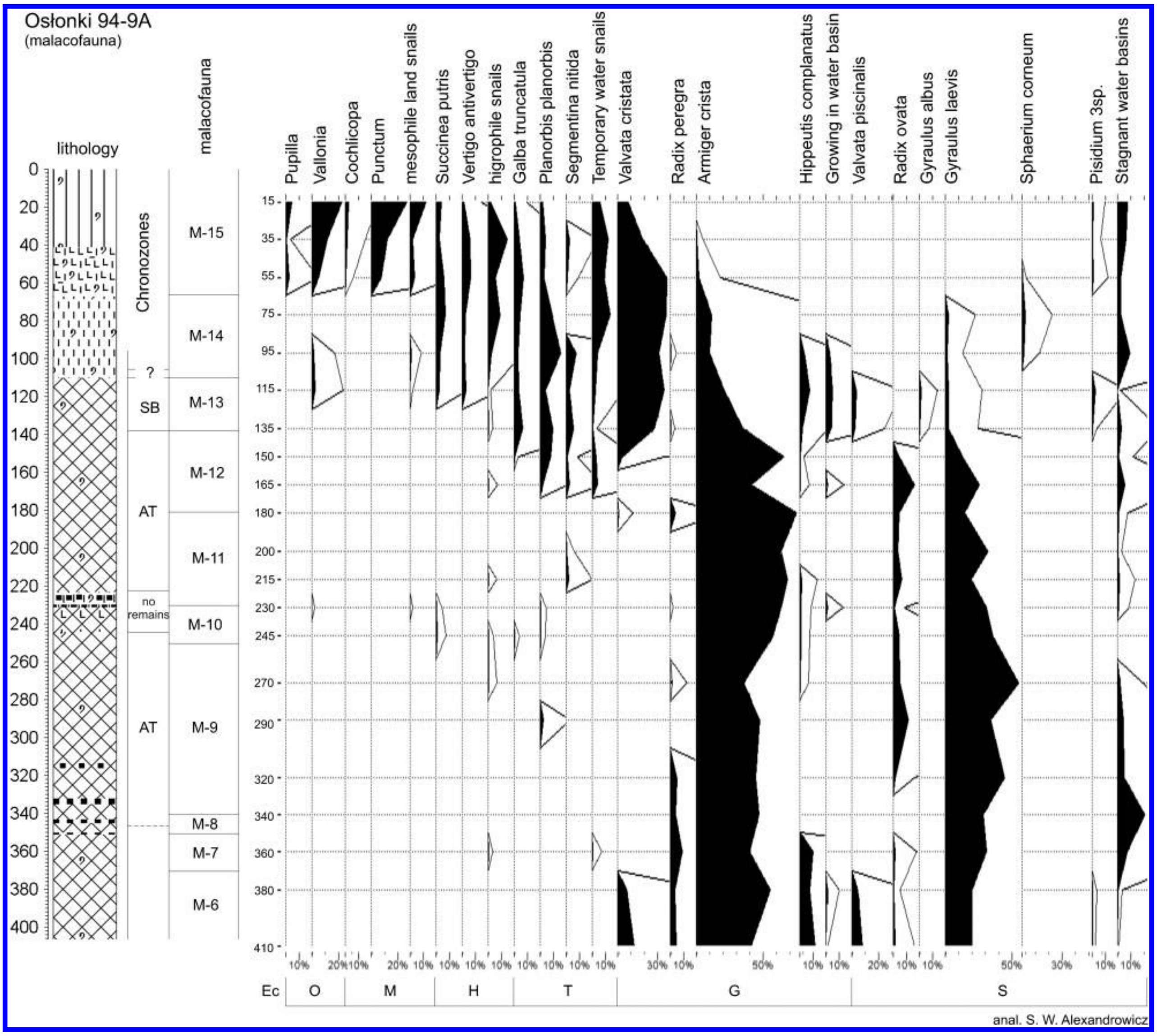


Figure 7 Simplified malacofauna diagram from core Os 94-9A. Key: AT = Atlantic period; SB = Subboreal period; Al = *Alnus* (alder); Co = *Corylus* (hazel); Qu = *Quercus* (oak); Ul = *Ulmus* (elm); Car = *Carpinus* (hornbeam); NAP = Non-Arboreal Pollen (herbaceous pollen). O = land snails typical of open environments; M = mesophile land snails living in both shaded and open habitats; H = hygrophile snails characterising swamps and marshes; T = water molluscs connected with temporary drying up water bodies; G = species of water basins with rich vegetation; S = euryecological (indifferent) water molluscs living mainly on more or less muddy bottom. (After Alexandrowicz 2008, modified)

marl, suggesting ablation at the edges of the basins. Within the biogenic sediments, some layers contained elevated levels of sandy particles. Even more interesting was the presence of sandy lenses, 1–3 cm thick, at spots in the middle of the basins. These are interpreted as artefacts of aeolian processes occurring during the winter in the area surrounding the basin. In this interpretation, wind blew sand off the surrounding land onto the frozen lakes, leading to accumulation of a non-continuous layer of sediment on the ice surface. When the ice melted, this layer settled on the lake bottom gyttja. Thicker sand layers on the ice caused the formation of sandy lenses, while thin layers resulted only in greater admixture of sand in the biogenic deposits.

A consistent pattern of sedimentation was observed:

1. An initial layer of peat, from a few cm to a few metres, lying on the basal mineralogical sediments.
2. A thick layer of calcareous gyttia with malacofauna, overlain in places with an organic muck.
3. Intrusive erosion material occurring in tongues near the shore or as lenticular patches in the middle of basins.
4. Occasional thin layers of peat a few centimetres thick interrupting gyttia and organic sediments.
5. A final layer of peat.

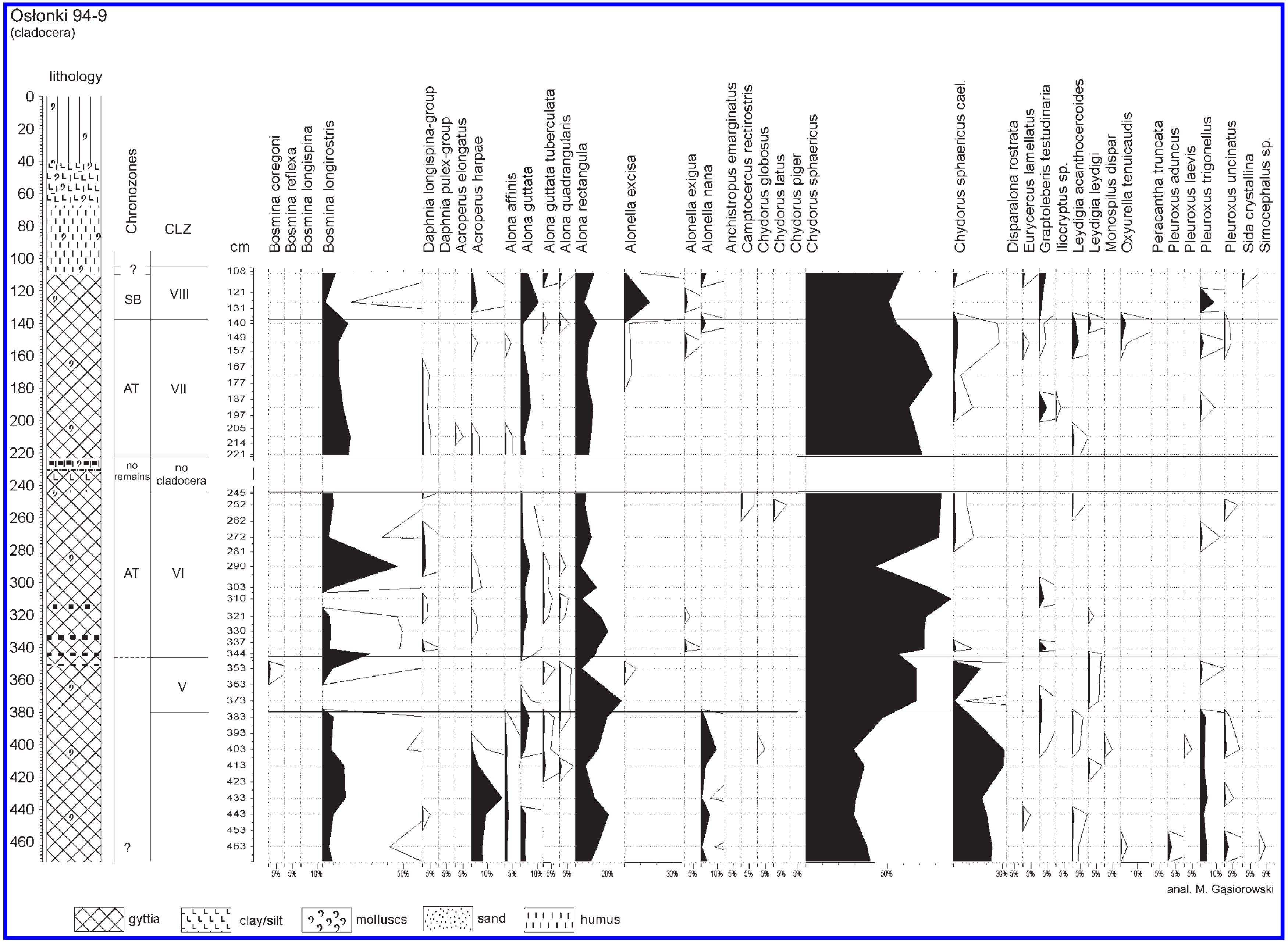
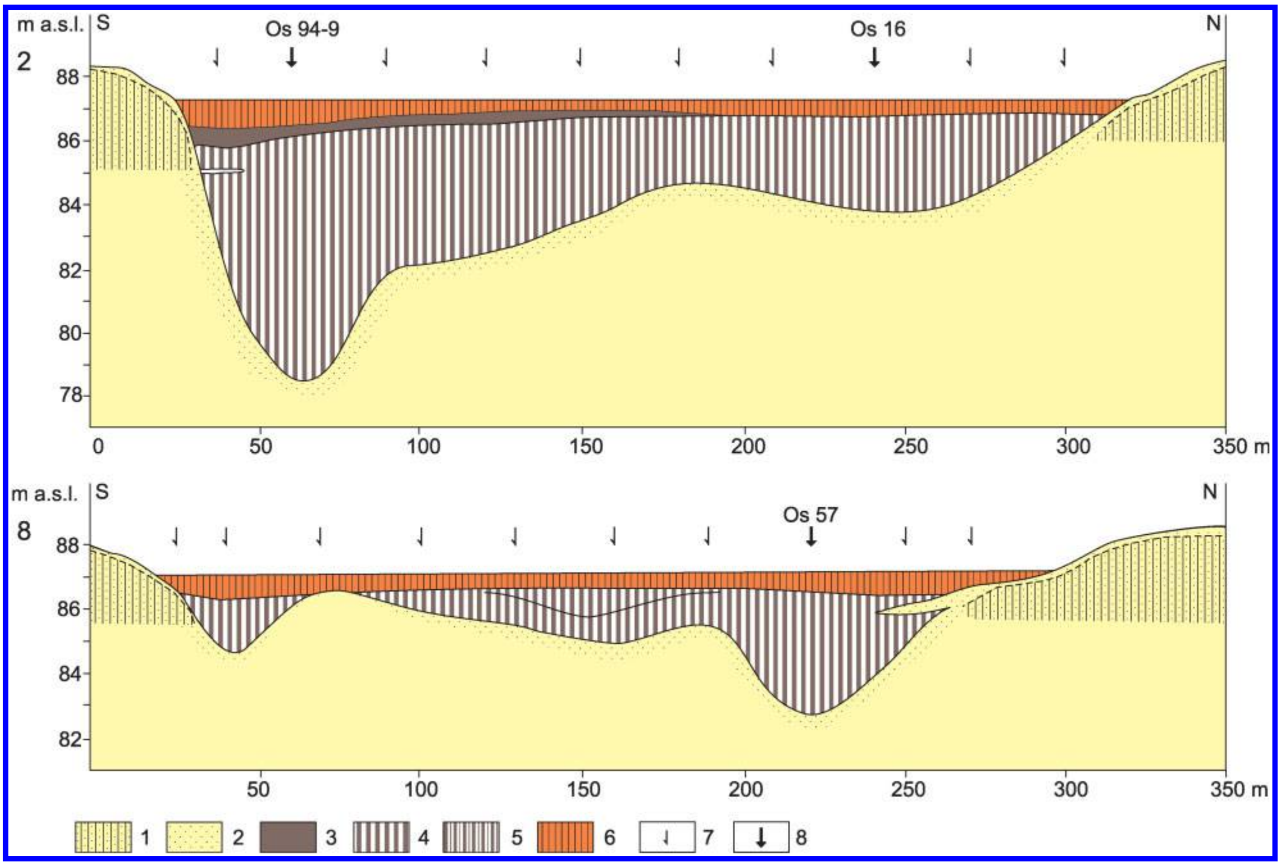


Figure 8 Simplified cladocerean diagram from core Os 94-9. Key: CLZ = Cladocerean Local Zone; AT = Atlantic period; SB = Subboreal period; Al = *Alnus* (alder); Co = *Corylus* (hazel); Qu = *Quercus* (oak); Ul = *Ulmus* (elm); Car = *Carpinus* (hornbeam); NAP = Non-Arboreal Pollen (herbaceous pollen). (After Gąsiorowski and Nalepka 2004, modified)



Key: 1.– ablation sands; 2.– moraine till; 3.– calcareous gyttja, lake chalk and detritus gyttja with malacofauna; 4.– organic silt; 5.– loams; 6.– locations of borings; 7.– locations of cores used for palaeobiological and physical-chemical analyses

Figure 9 Geomorphological-lithological profiles 2 and 8 (see Figure 3) of biogenic deposits of the area surrounding Neolithic sites at Osłonki (after Nowaczyk *et al.* 2002 and Nowaczyk 2008, modified).

These sediments are interpreted as reflecting the Late Pleistocene-Holocene palaeolimnology of the basins:

1. A brief initial episode of peat accumulation.
2. The basins filled with water to form lakes of significant depth in which biogenic sediments steadily accumulated.
3. Ablation by wind and water of adjacent ground moraine caused intrusive deposits.
4. Temporary lowering of water level led to formation of thin layers of peat.
5. The basins reverted to peat bogs.

Table 2 Radiocarbon dates from the Osłonki cores

Core	Depth (cm)	Lab No.	^{14}C BP	cal BC
Os 1-2a	212–17	Lod-1179	4260±60	2850–2620
Os 1-2a	291–95	Lod-1181	6730±70	5610–5480
Os 94-5	256–60	Lod-1176	6470±70	5590–5300
Os 94-5	279–83	Lod-1177	6670±70	5650–5480
Os 94-9	135	Poz-840	3110±35	1370–1260
Os 94-9	221	Poz-839	5790±40	4750–4530
Os 94-9	344	Poz-836	8440±150	7300–7050

Although the Late Pleistocene-Early Holocene environmental history of this area is beyond the scope of this paper, the geomorphological investigations permitted reconstruction of the formation of the landforms adjacent to the Neolithic sites (Nowaczyk 2008: 23–26). The trough north of Osłonki and south of Konary and Miechowice was formed when meltwater accumulating under the Vistula ice sheet eroded a channel in a tunnel beneath the ice. Glacial movement as the ice sheet grew thinner caused the ice roof of the tunnel to collapse. Meltwater continued to flow in the open channel and the sediment that it transported accumulated over the fallen blocks of ice and protected them from melting. After the retreat of the ice sheets, a basal layer of moraine till and ablation sediments was deposited to form an extensive area of ground moraine. The exposed ground moraine was subject to perennial permafrost, as documented by frost-wedge polygons visible in the subsoil at Oslonki 1 (Fig. 3.4). The buried ice blocks began to melt late in the Allerød and in the Younger Dryas, after which first peat and then gyttja began to accumulate.

Mid-Holocene vegetation history of the Osłonki catchment

The complete pollen record from Osłonki has been discussed extensively by Nalepka (2005; 2008). Pollen analysis was performed using a Nikon microscope with phase contrast and magnification from 600 × up to 1000 × . Taxonomic identification was based on standard keys such as Moore *et al.* (1991) and Beug (2004), and on the reference pollen and spore collection of the Department of Palaeobotany, W. Szafer Institute of Botany, Polish Academy of Sciences.

Here, the focus is on those associated with periods immediately before, during and after the Neolithic occupations at Osłonki and neighbouring sites. The description of the relevant LPAZs from core Os 94-9 is shown in Table 3 while the correlation between the LPAZs in Os 94-9, Os 1-2a and Os 94-5 is illustrated in Fig. 10. The principal LPAZs relevant to this study are *Alnus*-*Corylus*-*Quercus* (Os 94-9/10, Os 1-2a/3 and Os 94-5/4) and *Alnus*-*Ulmus*-*Corylus*-*Quercus* (Os 94-9/11 and Os 1-2a/4). In core Os 94-9, *Alnus*-*Corylus*-*Quercus* is preceded by *Ulmus*-*Corylus* (Os 94-9/9).

It is not possible to provide definite chronological boundaries to the LPAZs due to the challenging nature of the Osłonki sediments. The scarcity of macroscopic plant remains suitable for AMS dating in many levels of core Os 94-9 did not permit additional radiocarbon determinations. Hiatuses, compression of deposits and small-scale sediment reworking contribute to variations in the upper and lower LPAZ boundaries. On the other hand, the fact that both the Linear Pottery and the Brześć Kujawski Group occupations lasted for several centuries gives us confidence that the phenomena described below can be correlated with major Neolithic settlement phases.

Ulmus-*Corylus* represents conditions during the Boreal and possibly the early part of the Atlantic chronozones, before ca. 6000 BC, when elm spread slowly but steadily and hazel expanded rapidly. Oak and eventually ash combined with elm to form forest communities in wetland areas, while on sandy soils coniferous or pine-oak forests developed. The upper part of this LPAZ (between 353 and 348 cm in core Os 94-9) shows the dominance of deciduous forests by trees characteristic of the Holocene climatic optimum.

The uppermost boundary of the *Ulmus*-*Corylus* LPAZ in core Os 94-9 is not sharply marked, but in Os 1-2a and Os 94-5, the transition to the succeeding *Alnus*-*Corylus*-*Quercus* LPAZ is well-defined. This LPAZ correlates with the younger part of the Atlantic chronozone and thus is relevant to the study of anthropogenic impact on the vegetation. During

Table 3 Description of mid-Holocene LPAZ in profile Os 94-9 and correlation with the local archaeological record (according to Nalepka 2005)

Name of LPAZ	Depth (cm) from surface	Description of pollen spectra	Approx. correlation with Neolithic occupations
Os $_{94\text{-}9}$ 11, *Alnus-Ulmus-Corylus-Quercus*	140–221	The maximum of *Quercus*, *Alnus*, *Corylus avellana*, *Ulmus*, *Fraxinus excelsior*, and *Tilia cordata*-t. Slight rise of *Artemisia*. Low and discontinuous curves of Cerealia undiff., *Triticum*-t, *Hordeum*-t. Continuous presence of *Pteridium aquilinum*. Appearance of first pollen grains of *Carpinus betulus*. Relatively high frequency of charcoal. Upper limit: drop of *Alnus*, *Ulmus*, *Corylus avellana*, *Quercus*, and significant rise of corroded sporomorphs.	Brześć Kujawski Group at Osłonki, Miechowice, and Konary
	222–231	Charred level, pollen undeterminable	
	231–244	Mineral level, pollen absent	
Os $_{94\text{-}9}$ 10, *Alnus-Corylus-Quercus*	245–344	High frequency of *Alnus*, *Corylus avellana*, *Quercus*, *Ulmus*, *Fraxinus excelsior*, *and Tilia cordata*-t. Higher frequency of *Artemisia*. Low frequency of *Betula*, gradual decrease of *Pinus sylvestris*. Appearance of single pollen grains of Cerealia undiff., *Triticum*-t, *Hordeum*-t,. The rise of *Urtica dioica*-t, particularly in the lower part. Presence of charcoal. Upper limit: not known due to charred level.	Linear Pottery Culture at Miechowice; ? Mesolithic activity ?
Os $_{94\text{-}9}$ 9, *Ulmus-Corylus*	348–508	Gradual increase of *Corylus avellana*. Low and continuous curve of *Ulmus*; *Filipendula* curve still at relatively high. In upper part, rise of *Quercus*, *Alnus*, and *Fraxinus excelsior* as well as charcoal. Upper limit: significant decrease of AP curve.	? Mesolithic activity ?

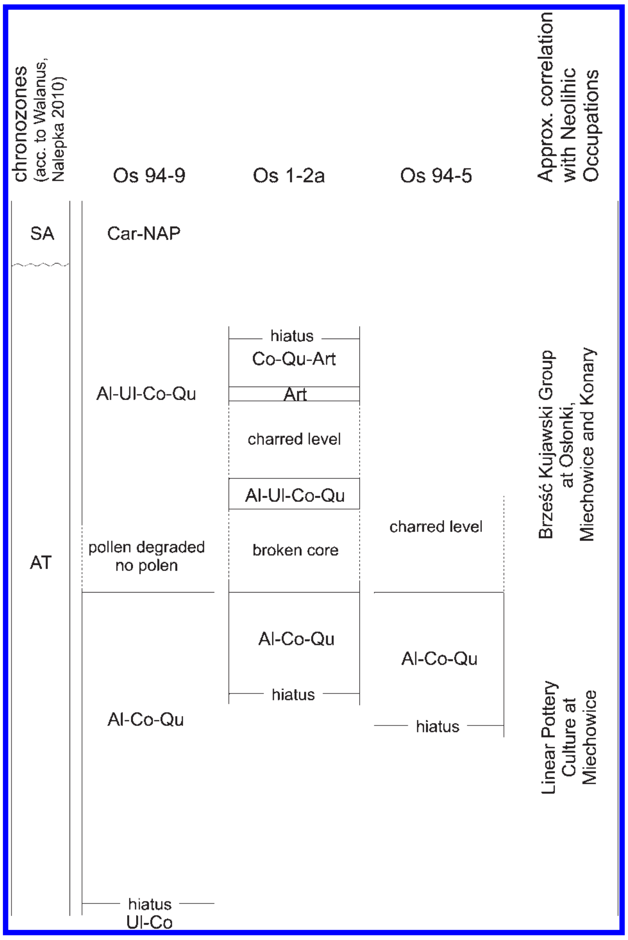


Figure 10 **Correlation of three pollen diagrams according to local pollen assemblage zones (LPAZ). Key: LPAZ = Local Pollen Assemblage Zone; AT = Atlantic period; SB = Subboreal period; Al =** ***Alnus*** **(alder); Co =** ***Corylus*** **(hazel); Qu =** ***Quercus*** **(oak); Ul =** ***Ulmus*** **(elm); Art =** ***Artemisia*****; Car =** ***Carpinus*** **(hornbeam); NAP = Non-Arboreal Pollen (herbaceous pollen). (After Nalepka 2004b; 2005, modified)**

this period, the landscape was dominated by mixed deciduous forests comprised of oak, linden, elm and ash, with hazel in the lower layer and forest gaps. No single species dominated and additional shade-tolerant species were found in the forest understory. Expansion of bracken (*Pteridium aquilinum*) is interpreted as reflecting burning in the surrounding catchment (e.g. Page 1986). Burning is also reflected in the charcoal particles that appear in almost every sample of this LPAZ.

In treeless areas, including wet meadows and forest-edge thickets, communities of herbaceous plants developed. Ruderal plants requiring nitrogen-rich soil such as broadleaf plantain (*Plantago major*) and nettles (*Urtica*) found good conditions. *Urtica,* a natural component of wetland forests, grows abundantly in nitrogen-enriched soils under conditions of increased light. The diversity of herbaceous plants suggests that many types of ecotones emerged in the landscape during this period.

An important development in the *Alnus*-*Corylus*-*Quercus* LPAZ is the appearance of indicators of agricultural activity, including isolated pollen grains of wheat (*Triticum* type) and barley (*Hordeum* type) as well as segetal species including corn spurrey (*Spergula arvensis*), corn buttercup (*Ranunculus arvensis*) and knotweed (*Scleranthus annuus*). Cow-wheat (*Melampyrum*), ribwort (*Plantago lanceolata*), sorrel (*Rumex acetosella*) *and* some species of the goosefoot family (Chenopodiaceae) could have grown on fallow land.

In the NE and NW basins, reeds (*Phragmites australis*) increased in abundance. Along the wet shores of the southern basin, alder and willow thickets developed, and a diverse reed community emerged. The presence of stagnant water is marked by the presence of water-milfoils (*Myriophyllum spicatum* and *M. verticillatum*), while cenobia of the algae *Pediastrum* indicate a decrease in water depth.

In the upper part of the *Alnus*-*Corylus*-*Quercus* LPAZ, the number of corroded sporomorphs increases significantly, apparently due to the inflow of mineral material into the basins. It ends abruptly at a clay layer devoid of pollen, which in turn is covered by a layer of burnt peat with severely damaged, and thus unidentifiable, sporomorphs. This break in the vegetation history of the Osłonki locality appears most distinctly in core Os 94-9 but can be seen in the other cores as well, reflecting a widespread event, or perhaps multiple events, within all three basins.

Above the layer with burnt peat and unidentifiable, corroded sporomorphs, the vegetation history resumes with the *Alnus*-*Ulmus*-*Corylus*-*Quercus* LPAZ. It is characterised by pollen taxa similar to the *Alnus*-*Corylus*-*Quercus* LPAZ below, although their quantity and proportions differ slightly. Deciduous forests still dominated without significant changes. The presence of forest gaps and burning is indicated by the spread of bracken (*Pteridium aquilinum),* while a steady curve of *Corylus avellana* suggests that hazel thickets overgrew open areas before being replaced by trees. The presence of poplar (*Populus*) pollen also indicates forest gaps, while hornbeam (*Carpinus betulus*) appears for the first time as individual pollen grains. Agricultural indicators continue to manifest themselves as isolated grains of *Triticum, Hordeum and* indeterminate cereal (Cerealia undiff.) pollen. Herbaceous communities include plants of fields, meadows, fallow lands and pastures in similar quantities to those seen in the earlier *Alnus*-*Corylus*-*Quercus* LPAZ. This LPAZ contains a relatively high frequency of charcoal particles, which point to an extensive use of fire in the surrounding catchment.

In core Os 94-9, the upper limit of the *Alnus*-*Ulmus*-*Corylus*-*Quercus* LPAZ is marked by a drop in *Alnus, Ulmus, Corylus avellana* and *Quercus* pollen and a rise in corroded sporomorphs. Subsequent LPAZ in the various cores reflect a progressive opening of the vegetation and its increased heterogeneity in the Subboreal chronozone. The *Artemisia* and the *Corylus*-*Quercus*-*Artemisia* LPAZ in the upper section of core Os 1-2a are characterised by a decreased quantity of tree pollen and an increase in that of herbaceous plants, including indicators of pasture such as *Rumex acetosella* and *Plantago lanceolata*. In the upper section of Os 94-9 the *Carpinus*-NAP LPAZ also has diminished amounts of arboreal pollen and increased quantities of non-arboreal pollen, while *Carpinus* pollen grains appear as a continuous curve. These developments, however, postdate activities of the Linear Pottery and Brześć Kujawski Group communities around the Osłonki basins.

Cladoceran and malacological analyses

The principal cladoceran zones (CLZ) correlated with Neolithic settlement are CLZ VI and VII in core Os 94-9 (Table 4) and CLZ III in core Os 94-5. CLZ VI is generally equivalent to the *Alnus*-*Corylus*-*Quercus* LPAZ while CLZ VII correlates with the *Alnus*-*Ulmus*-*Corylus*-*Quercus* LPAZ. The intervening burnt and mineralised layer in Os 94-9 contained no cladoceran fragments.

CLZ VI is characterised by a strong increase in the pelagic species *Chydorus sphaericus* and a decline in taxa associated with plant growth. It suggests an increase in the nutrient load (Jeppesen *et al.* 2001) and partial damage to benthic communities (Vadeboncoeur *et al.* 2003). The overall composition of the cladoceran assemblage from CLZ VI reflects continued eutrophication that began during the previous CLZ, probably reaching its greatest intensity resulting in a transition of the basin from oligotrophic to eutrophic. This was accompanied by an increase in water turbidity and pH. These physico-chemical changes also altered the composition of the aquatic plants, indicated by intermittent appearances of cladoceran taxa associated with macrophytes.

The cladoceran assemblage of CLZ VII indicates a return to lower trophic levels, indicated by the return in small numbers of *Acroperus harpae*, *Alonella nana*, *Eurycercus lamellatus,* although eutrophic conditions were probably maintained. Periodically, especially in the upper level of CLZ VII, cladoceran taxa associated with water pollution appear (for example, *Leydigia acanthocercoides* and *Leydigia leydigi*).

Malacological samples contained 14 species of land snails, 19 species of water snails and 6 species of bivalves, as well as shells of slugs (Limacidae) and opercula of the water snail *Bithynia*. A succession of 15 malacological communities (M-1 to M-15) have been distinguished in core Os 94-9A, of which M6 to M13 are relevant to this study (Table 5 and Fig. 7).

Table 4 Description of mid-Holocene CLZ in profile Os 94–9 and correlation with the local archaeological record (according to Gąsiorowski & Nalepka 2004).

Name of CLZ	Depth (cm) from surface	Description of Cladocera samples	Approx. correlation with Neolithic occupations
VII	138–221	The same taxa as in CLZ VI dominate. In the uppermost samples from this zone several taxa which were either rare or not found in CLZ V and VI appear, including *Alonella nana*, *Leydigia acantocercoides*, *Leydigia leydigi*, *Oxyurella tenuicaudis*, and *Pleuroxus trigonellus*).	Brześć Kujawski Group at Osłonki, Miechowice, and Konary
	222–231	Charred level, without cladoceran remains	
	231–244	Mineral level, without cladoceran remains	Linear Pottery Culture at Miechowice
VI	245–346	Period of maximum development of *Alona rectangula*, *Chydorus sphaericus*, and *Bosmina longirostris*. Outside of these taxa, a general drop in the heterogeneity of species represented in the sample.	
V	346–380	Disappearance of several taxa (*Acroperus harpae*, *Alona affinis*, *Alonella nana*, *Pleuroxus trigonellus*) that characterized earlier levels. Drop in frequency of *Chydorus sphaericus caelatus.*	? Mesolithic activity ?

Stratigraphically, malacological communities M-6 and M-7 correlate with LPAZ Os 94-9/9 (*Ul-Co*), M-8 and M-9 with LPAZ Os 94-9/10 (*Al-Co-Qu*), M-10 with the charred and mineralised layer, and M-11 and M-12 with LPAZ Os 94-9/11 (*Al-Ul-Co-Qu*), as shown in Fig. 11. The presence of terrestrial specimens among the largely aquatic composition of the sample in M-10 can be interpreted as an indication of the delivery of material from adjacent land surfaces into the basins.

Interpretation: effects of Neolithic activity

The convergence of the lines of data permits interpretations about the timing and scale of the environmental impact of the Linear Pottery culture and the Brześć Kujawski Group between ca. 5500 and 4000 BC.

Pre-Neolithic conditions

Before the establishment of Neolithic settlement at Osłonki, the landscape was covered with mixed deciduous forest containing, in various combinations, oak, linden, elm and ash. In less dense stands of trees were pine, birch and hazel. In clearings and near bodies of water, meadow communities developed. Nettles, campion and members of the crowfoot family grew on cool and moist soils. In unforested locations on dry soils, small patches of grasses contained plantains, rock-rose and mullein. Such open terrain occupied a very small area.

The development of aquatic flora resulted in the accumulation of biogenic sediments in the lake basins, which caused them to become progressively shallower. In the NE basin, the deepest of the three, water depth decreased from about 3·4 m to only about 1·4 m through the postglacial climatic optimum. Throughout the lake's existence, its greatest depth was found only in its southern part, adjacent to the Neolithic settlement at Osłonki. When Neolithic settlers appeared, the ecological conditions in the lake had stabilised. It was overgrown by macrophytes and inhabited by rich and differentiated mollusc populations.

Neolithic attraction to meltwater channels and dead-ice depressions

Research at Osłonki highlights a salient feature of Neolithic land use in the Polish lowlands before 4000 BC, namely its concentration on glacial relic features that are major elements of the surface hydrology of the Kuyavian plateau. Such a choice of location along a sub-glacial channel and associated dead-ice basins is consistent with that of other

Table 5 Malacological communities in core Os 94–9A

Number	Depth [cm] from surface	Description of malacological samples	Approx. correlation with Neolithic occupations
M-13	110–140	Rich and differentiated assemblage (28 taxa) dominated by *Armiger crista* (L.) and *Valvata cristata* Müller, with the significant content of snails living in temporary water bodies: *Planorbis planorbis* (L.), *Segmentina nitida* (Müller), *Galba truncatula* (Müller), and with the admixture of higrophile land snails.	
M-12	140–170	Fauna with *Armiger crista* (L.), *Gyraulus laevis* (Alder) and *Radix ovata* (Drap.), enriched in species characterising temporary water bodies, such as *Planorbis planorbis* (L.) (15 species).	Brześć Kujawski Group at Osłonki, Miechowice, and Konary
M-11	180–220	A quite similar assemblage (9 taxa) distinctly dominated by *Armiger crista* (L.).	
M-10	230–250	Similar fauna (14 taxa) with distinctly increased number of two last mentioned species enriched in few specimens of land snails.	
M-9	260–340	Poor fauna (8 taxa) with *Armiger crista* (L.) and *Gyraulus laevis* (Alder).	Linear Pottery Culture at Miechowice
M-8	340–350	Sragments of shells of *Unionidae* associated by few specimens of water snails.	
M-7	350–370	Similar community (13 taxa) with numerous specimens of *Armiger crista* (L.) and *Gyraulus laevis* (Alder), devoid of *Valvata cristata* Müller and *V. piscinalis* (Müller).	? Mesolithic activity ?
M-6	380–440	A quite similar assemblage (12 taxa) with the increased number of *Armiger crista* (L.), *Valvata cristata* Müller and *Hippeutis complanatus* (L.).	
M-5	450–510	Fauna composed of 16 species, dominated by *Armiger crista* (L.) and *Gyraulus laevis* (Alder), with few specimens of land snails.	

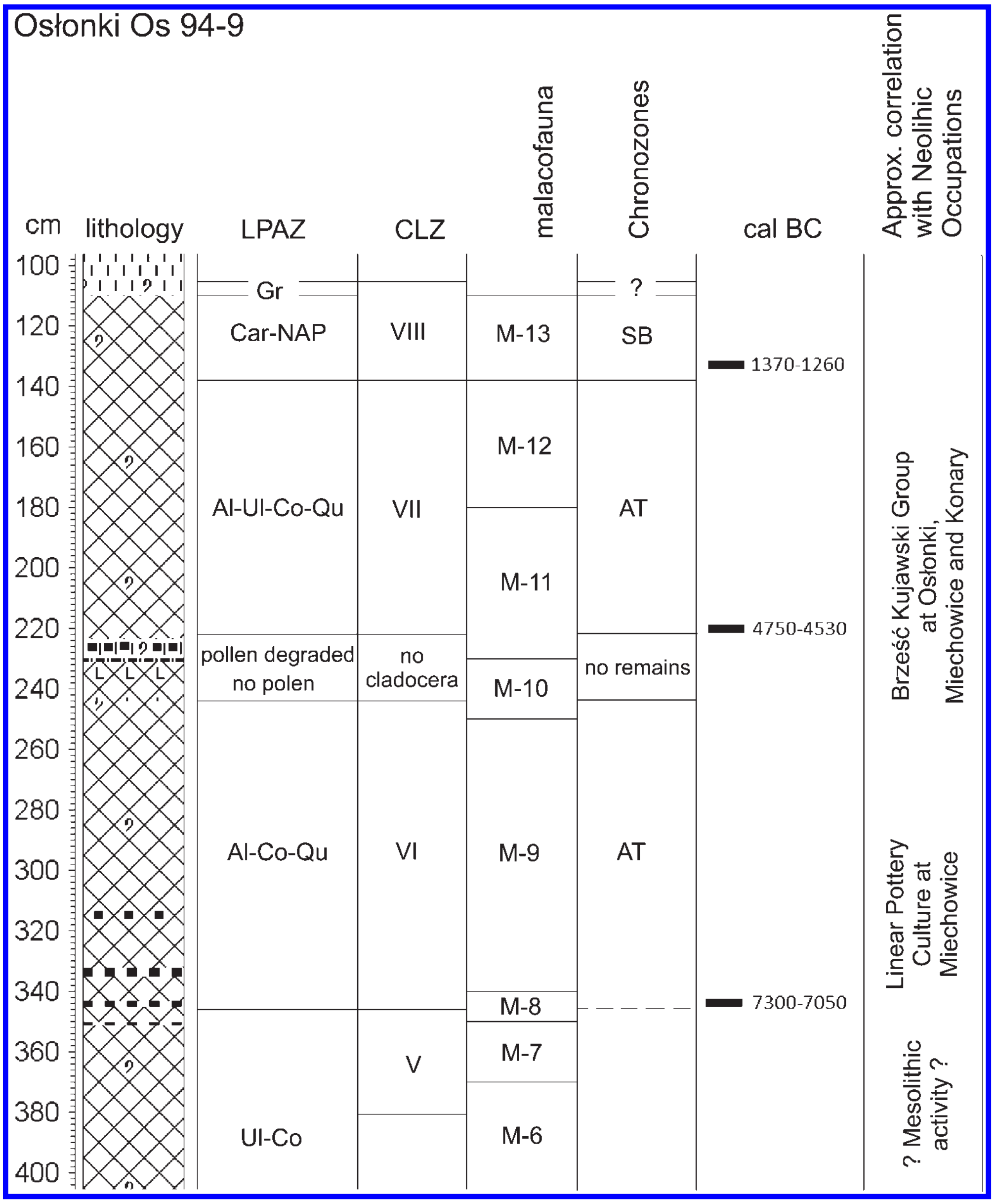


Figure 11 Correlation of pollen, cladocerean and molluscs diagrams according to the depth of sediments. Key: LPAZ = Local Pollen Assemblage Zone; CLZ = Cladocerean Local Zone; M = assemblage of molluscs; AT = Atlantic period; SB = Subboreal period; Al = *Alnus* (alder); Co = *Corylus* (hazel); Qu = *Quercus* (oak); Ul = *Ulmus* (elm); Car = *Carpinus* (hornbeam); NAP = Non-Arboreal Pollen (herbaceous pollen)

sites of the Linear Pottery culture and the Brześć Kujawski Group on the Kuyavian plateau. Early Neolithic settlement in Kuyavia is almost always associated with a meltwater channel/dead-ice depression combination. For example, the complex of Neolithic sites at Brześć Kujawski (Bogucki and Grygiel 1983) lies on a configuration of landforms very similar to that seen at Osłonki, while contemporaneous settlements elsewhere in Kuyavia are also found along sub-glacial channels.

Such an attraction for sub-glacial channels and dead-ice basins is not surprising. Regionally, the network of glacial relic landforms relieves the expanse of ground moraine and introduces diversity and heterogeneity into the flat landscape. Pioneer farmers would have found them to provide natural breaks in the vegetation of the surrounding ground moraine, what Verboom (1977) called 'zones of weakness' in the primeval forest. Such channels would have been lowland analogues to the small streams in the loess basins of upland central Europe along which Linear Pottery farmers chose to settle. Subsequent prehistoric societies generally did not exhibit such a specific preference for glacial relic landforms in their settlement locations.

Earliest farming traces during the 6th millennium BC

The earliest archaeological traces of farming around the Osłonki basin are found at the Linear Pottery settlement of Miechowice 4, dated ca. 5300–5200 BC. Archaeobotanical and archaeozoological data show that the inhabitants of Miechowice 4 cultivated crops and kept livestock. The case for local cultivation during the late 6th millennium BC is made by numerous chaff fragments among the carbonised macrobotanical remains (Bieniek 2007, table 18·1). Emmer and einkorn wheat are the most abundant taxa. The small sample of Linear Pottery domestic animal bones from Miechowice 4 is comprised of 80·5% cattle, 17% sheep and goat, and 2·5% pig (Grygiel 2004, 546), a pattern consistent with other sites in this region (Bogucki 1982; 2008).

Palaeoenvironmental data, however, provide little evidence of a dramatic impact on the environment during most of the period represented by the *Alnus*-*Corylus*-*Quercus* LPAZ. The high presence of forest taxa (*Ulmus*, *Quercus*, *Tilia*, *Fraxinus*) shows that the area was covered by mixed deciduous forests on fertile soils, while on poorer sandy soils pine woods developed. Some open areas with herbs (NAP summary curve) must also have existed nearby, but whether they were caused naturally or anthropogenically cannot be determined. The initial appearance of cereal pollen (*Cerealia*, *Hordeum*, *Triticum*), segetal weeds (*Spergula*, *Polygonum*, *Ranunculus arvensis*), isolated pollen from indicators of pasture (*Plantago lanceolata*, *Rumex acetosella*) and a continuous but low presence of ruderals (*Artemisia*, *Urtica*) reflect a low level of agricultural activity in the immediate vicinity of the basins. While the possibility exists that pollen evidence for larger-scale agricultural activity further away from the basins was filtered out by intervening trees and shrubs and thus does not appear in the sediments, absence of substantial Linear Pottery settlement set further back from the basins makes this unlikely.

The sedimentation history in the Osłonki basins also does not appear to have been significantly affected by the Linear Pottery settlement. Calcareous gyttja continues to accumulate as before and there is little evidence at this time of mineralogical inflow into the basins. Evidence suggests placid bodies of water about 3·5 metres deep.

Changes in the cladoceran community in the beginning of CLZ VI coincide with the appearance of indicators of cultivation in the pollen record of the *Alnus*-*Corylus*-*Quercus* LPAZ. In particular, the marked increase in *Chydorus sphaericus* indicates intensification of the eutrophication that had begun earlier. Even relatively low human-induced increases in nutrient load during the late 6th millennium BC triggered changes in the ecosystem dynamics of the lake basins that are reflected in the cladoceran record. The intensity of the change in the cladoceran community during this time, however, must be viewed in contrast to that seen in the upper ranges of CLZ VI and then in CLZ VII discussed (see below).

It appears that the Linear Pottery farmers at Miechowice 4 and other (as yet undiscovered) sites in the Osłonki area had a relatively low impact on the thick, heterogeneous, mesophyllous deciduous forest around the lake basins. Cultivation and stock-breeding in this area during the later part of the 6th millennium BC apparently did not require extensive deforestation. Small clearings would have been made for garden plots and habitation sites, perhaps opportunistically taking advantage of natural breaks in the vegetation. Cattle could have been grazed at low stocking rates within the forests well away from the lake basins.

Archaeologically, the Linear Pottery settlement at Miechowice 4 appears to have been short-lived, with one or more occupations, each not longer than a single generation. Traces of small post structures suggest minimal timber cutting for house construction. While traces of more substantial structures possibly have been removed by erosion, the overall accumulation of rubbish and the spatial extent of the Linear Pottery occupations at Miechowice does not appear to reflect a very large settlement.

In summary, it appears that during the late 6th millennium BC Neolithic settlement did not cause a persistent or permanent transformation of significant tracts of forest. Instead, clearings for habitation, timber, crops and pasture were ephemeral and regenerated so quickly after abandonment as to cause no lasting effect in the pollen record. Human activity is documented, however, in the cladoceran record due to the increase in nutrient load in the lakes that resulted from it. The palaeoenvironmental evidence thus appears to support the archaeological interpretation of the Linear Pottery settlement as a series of pioneer occupations which did not persist long enough to have a significant environmental impact.

Neolithic landscape modification during the 5th millennium BC

During the 5th millennium BC, the pattern of land use changed in the vicinity of the settlements of the Brześć Kujawski Group at Osłonki, Miechowice and Konary. The sedimentology of the lake basins and the pollen record track developments in the surrounding landscape, while malacological and cladoceran data reflect water conditions in the basins themselves.

Key evidence for transformation of the local environment comes from the evidence for increased erosion on land surfaces around the lakes, taken to reflect exposure of bare soil through clearance and cultivation. Areas adjacent to the lakes were either continuously or intermittently cleared of vegetation with bare soil exposed. These exposures included habitation areas and cultivated fields from which loose ablation sands, humus, silt aggregates and charcoal particles were blown or washed into the lake basins. Heavy rains or rapid snow melts incised gullies that drained into the lakes and transported sediment to form deltas on the gyttja along the shoreline, while it appears that exposure of soil during the winter enabled aeolian ablation that led to formation of sandy lenses in the middle of the basins.

This inflow of mineral sediment and carbonised material resulted in poor preservation conditions for pollen grains. It can be attributed to the Brześć Kujawski Group's use of larger areas for cultivation and pasture, as well as building more extensive settlements. Agriculture and habitation would have exposed bare soils to erosion, bringing about the increased input of mineral matter to the basin, and would also account for the greater quantity of charcoal particles seen in deposits with increased mineral sediments. It is uncertain whether these particles came from the settled areas, where there are considerable traces of digging to obtain clay, build fortifications, bury the dead and dispose of rubbish, or from nearby fields and pastures.

It is also necessary to consider the possibility that direct human and animal activity resulted in introduction of mineralogical material and charcoal to the lake basins. The inhabitants of Osłonki and the other sites may have dumped burnt wood, ash and leaves, as well as building materials (including clay plaster) from demolished structures along the lake edges. In addition, they disturbed the lake shores to provide access for livestock, fishing and fowling, or launching boats. Damage by cattle to banks and riparian vegetation, promoting erosion, is also possible (Kaufmann and Kreuger 1984; Trimble and Mendel 1995).

Although the pollen record is interrupted during the period represented by the mineralised layer, broad continuities between the *Alnus*-*Corylus*-*Quercus* LPAZ below it and the *Alnus*-*Ulmus*-*Corylus*-*Quercus* LPAZ above it suggest that the basic composition of the surrounding woods did not change. Instead, they were thinned out and cut back by the opening of fields around the basins, but they regenerated in a similar composition to that which prevailed before the establishment of Brześć Kujawski Group settlements. The proliferation of ruderal and segetal weeds attests to the use of the surrounding landscape for cultivated fields and the creation of disturbed habitats near the settlements.

Conditions in the lake basins began to change from this level onward as the lakes became shallower, with enlarged near-shore areas caused by fluctuating water levels. The presence of land snails among an otherwise aquatic snail population in the malacological sample from layers containing charcoal and mineralogical materials points toward the delivery of material from adjacent land surfaces into the lake basins, especially near settlements. The implication is that material washed in through erosion or dumped in by people contained terrestrial snails or their shells.

Intensification of eutrophication that began in the lower part of CLZ VI was amplified in the upper part up to the mineralised layer containing charcoal fragments in CLZ VII and above it. Cladoceran species preferring clear water effectively vanish, while taxa that tolerate or prefer a high level of nutrients, such as *Chydorus sphaericus*, are abundant. The high inflow of nutrients can be attributed to human activity, particularly the dumping of rubbish and the inflow of sewage from people and animals.

Conclusion: Neolithic land use in Kuyavia before 4000 BC

The palaeoenvironmental record from Osłonki indicates that the initial occupation by Linear Pottery settlers had minimal impact on the regional environment. In light of the fact that the only Linear Pottery settlement found so far at the Osłonki basins is at Miechowice 4, apparently small and of limited duration, it is not surprising that the pollen record and basin sediments do not reflect large-scale deforestation. Instead, isolated indicators of cultivation and stockherding appear in the pollen record, reflecting not only activities at Miechowice but also at other Linear Pottery settlements in the surrounding pollen catchment. Such an interpretation is consistent with the emerging view of Linear Pottery agriculture as intensive cultivation of garden plots rather than widespread fields (Bogaard 2004). At the same time, it does not preclude possible use of the forest interior for additional cultivation and grazing.

After ca. 4700 BC, land use around the Osłonki basins intensified dramatically. Intensive and sustained use of the terrain around the Osłonki basins for several centuries, either continuously or with minor interruptions, can be presumed to have had a strong impact on the local environment. Although the pollen record is interrupted during much of this period, the mineralogical inflow that corroded the pollen grains attests to increased delivery of soil particles by water, wind and human activity into the basins. In addition, cladoceran evidence for an episode of eutrophication documents an increase in nutrient load probably from human activity and livestock. Multiple lines of evidence converge to indicate that settlements of the Brześć Kujawski Group at Osłonki, Miechowice and Konary caused significant local disturbance in environmental conditions.

Nonetheless, the palaeoenvironmental record correlated with the Brześć Kujawski Group does not suggest widespread or persistent transformation of the vegetation on a larger spatial and temporal scale. When the pollen record resumes after the disturbance layer, there do not seem to have been substantial changes in the composition of the surrounding forest from the *status quo ante* at the start of the 5th millennium BC. As a result, we infer that the impact of settlement by the Brześć Kujawski Group was intense but localised in the immediate environs of the basins. The surrounding forests may have been utilised for grazing and gathering more than during the Linear Pottery occupation and it is likely that trails to contemporaneous settlements, such as Brześć Kujawski and Pikutkowo, led to the development of modified corridors. Yet the effects of such activity appear to have been confined to locations of intensive settlement such as Osłonki.

The question of the persistence of the impact of occupation by the Brześć Kujawski Group following abandonment of its settlements and the regional transition to the Funnel Beaker Culture is of considerable interest. Midgley (2005) suggests that earthen long barrows with elongated trapezoidal plans built by the Funnel Beaker Culture early in the 4th millennium BC were inspired by traces of abandoned longhouses of the Brześć Kujawski Group. If further research indicates that the environmental footprint of the settlements continued for several centuries, this theory gains plausibility. These sites may also have been seen as particularly fertile locations due to the accumulation of organic settlement debris and maintained in cleared and cultivated condition by subsequent Neolithic communities. On the other hand, the cladoceran record following the eutrophication associated with the Brześć Kujawski Group attests to the recovery of the lake waters and a return to lower nutrient levels.

Multi-proxy environmental archaeology at Osłonki has provided a set of baseline data and generated testable hypotheses about Neolithic land use between ca. 5500 and 4000 BC in the Polish lowlands. Future research at Neolithic settlements in this region should include a palaeoenvironmental component including provision for fine-grained chronological control. Complications posed by the proximity of prehistoric habitation to biogenic deposits, such as destruction of pollen by the inflow of mineral sediments, should be evaluated in future investigations.

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