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ORIGINAL ARTICLE

Palynological investigations into the Late Pleistocene and Holocene history of vegetation and settlement at the Löddigsee, Mecklenburg, Germany

Susanne Jahns

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Abstract A Late Pleistocene and Holocene sediment core from the nowadays terrestrialised portion of the Löddigsee in Southern Mecklenburg, Germany was palynologically investigated. The lake is situated in the rarely investigated Young moraine area at the transition from the Weichselian to the Saalian glaciation. The high-resolution pollen diagram contributes to the establishment of the north-eastern German Late Pleistocene pollen stratigraphy. The vegetation distribution pattern after the end of the Weichselian is in good agreement with other studies from North-eastern Germany, but also has its own characteristics. The Holocene vegetation development reveals features from the north-eastern and north-western German lowlands. A special focus was laid on the environmental history of the two settlements on an island within the lake (Late Neolithic and Younger Slavic period), which were preserved under moist conditions. Both settlements were constructed during a period of low lake level. Although there is evidence of agriculture in the area during the respective periods, the two island settlements seem to have served other purposes.

Keywords Vegetation history · Late Pleistocene · Holocene · Northern Germany · Late Neolithic settlement · Younger Slavic settlement

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S. Jahns (✉)
Brandenburgisches Landesamt für Denkmalpflege und Archäologisches Landesmuseum,
Wünsdorfer Platz 4-5, OT Wünsdorf,
15806 Zossen, Germany
e-mail: susanne.jahns@bldam-brandenburg.de

Introduction

The Löddigsee in Southern Mecklenburg lies in an area where only a few modern palynological studies have so far been carried out. The pollen diagrams published by Lesemann (1969) from the Wendland, Schoknecht (1996) from the Müritz area and Dörfler (in press) from the Rugensee close to Schwerin are situated within a 50 km radius of the Löddigsee site. Only the Rugensee diagram is well radiocarbon dated. The sediments of the Löddigsee include deposits from the Late Glacial and the Holocene and provide a good opportunity to investigate the vegetation history of a transitional area from the Weichselian to the Saalian glaciation. Moreover Löddigsee is a site of great archaeological interest, as two important settlements, which were preserved under moist conditions, have been excavated on an island within the lake. The older one dates to the Late Neolithic period (Single Grave and Kugelamphoren Culture, Becker and Benecke 2002), and the younger one to the Younger Slavic period (Paddenberg, in press). The deposits relating to the Slavic settlement were investigated within the framework of the ongoing DFG project (BE 169/19) "Slawen an der unteren Mittelelbe."

Study area

The Löddigsee is situated in Southern Mecklenburg, Germany, in the transitional area of the Saalian and the Weichselian glaciations, the moraines from which lie 7 km and 2 km south of the site respectively. The small river Elde flowed in a series of meanders within a Weichselian valley between the Frankfurt and the Brandenburg ice margin during the Holocene. The river formed many basins, the biggest one being the Löddigsee with an area of ca. 1.5 km^2

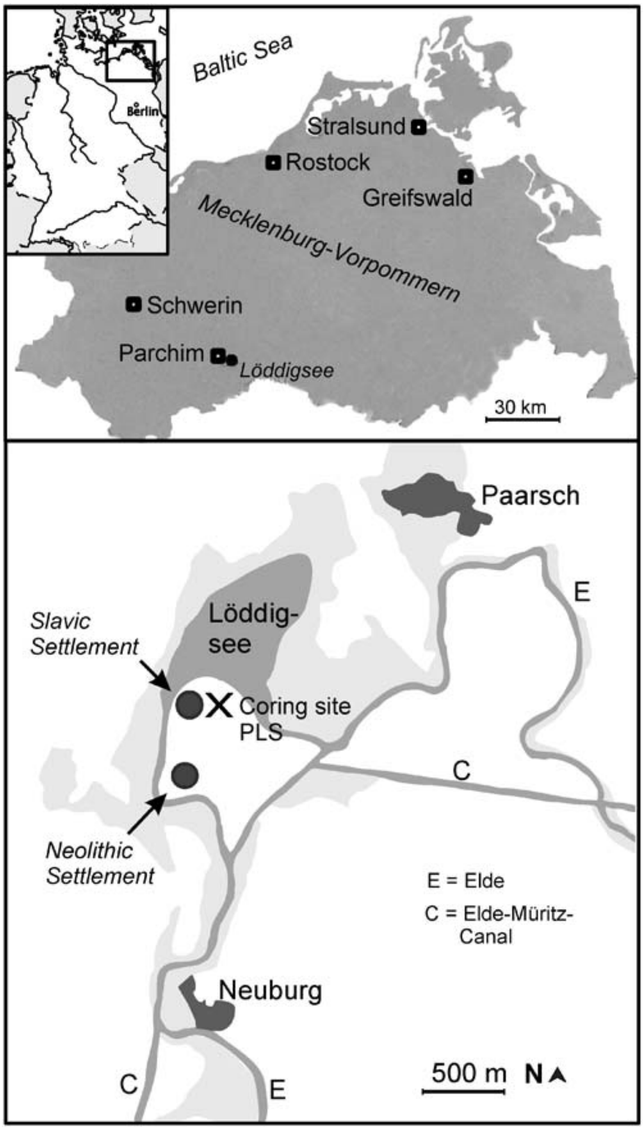

Fig. 1 Study area and location of the coring site in Northern Germany (after Becker and Benecke 2002, modified)

(Fig. 1). Today only the northern part still exists as open water, the major part of the lake being filled with mud and peat. The Elde was canalised in 1752, a measure which further favoured infilling by peat. When the Elde-Müritz Canal was built in the 1930s the water table was lowered by 1.5 m.

The climate of the area belongs to the inner lowland of Western Mecklenburg with a strong maritime influence. Mean annual precipitation is 593 mm and the mean annual temperature 8 °C. The prevailing soil surrounding the lake is largely sandy brown earth (areno-cambisol).

The island within the lake is formed by a sand bar covered by 0.3 m of fen peat. It is surrounded by a fen in which the peat reaches a thickness of up to 5 m. The fen peat covers a lake sediment, indicating open water conditions earlier in the Holocene.

Material and methods

Two overlapping cores of 11.5 m were taken in December 2001 using 8 cm and 5 cm diameter Usinger piston corers at a position of N 53° 26′, E 11° 51′, 40 m east of the former Slavic settlement and ca. 500 m north of the Neolithic site (Fig. 1).

Samples were taken at 1–8 cm intervals. Standard methods (conc. HCl, 10% KOH, 70% HF, acetolysis, ultrasonic sieving; Moore et al. 1991) were used for pollen sample preparation. *Lycopodium* spore tablets were added to enable an estimation of the pollen concentration (Stockmarr 1971). The pollen preservation was excellent. The samples were counted at a magnification of 400 × –1000 × to a total of at least 500 AP. The pollen diagrams (Figs. 2–4) show the results as percentages calculated from the total terrestrial pollen sum AP + NAP, excluding Poaceae and Cyperaceae. Curves are plotted in black as percentage values and in white with depth bars, with an exaggeration factor of × 5. The diagrams were produced with the help of the programs TILIA, TGView (Grimm 1990) and CorelDraw.

AMS ^{14}C dating was carried out at the Leibniz Laboratory for Radiometric Dating and Isotope Research, Kiel University. The samples consisted of peat or macrofossils, where available, and of pollen concentrates, which were prepared using procedures modified after Brown (1994) and Regnéll and Everitt (1996). The dates were calibrated after Stuiver et al. (1998). The results are presented in Table 1. Calibrated ages as used in the text and in the pollen diagrams are given as mean values of the calibrated ages within the 1σ range.

Three of the dates were rejected for the age model. The samples KIA 18146 and 20722, both pollen concentrates, provided ages that were unreasonably old. Most probably the pollen fraction was "aged" by residues from other material, as the samples could not be completely cleaned. Both dates were checked by parallel dates, one very pure pollen fraction (KIA 24714) and one macrofossil sample of pure *Carex rostrata* fruits (KIA 26583). Both parallels gave distinctly younger ages. The age of KIA 26586 (*Carex* fruits) is certainly too young, the reason being unclear. This leaves 11 ^{14}C-dates for the age model.

Results and discussion

The pollen diagram was divided into 19 local pollen zones PLS 1–19, based on the percentages (Tables 3 and 4; Figs. 2–4). The stratigraphy is given in Table 2.

Late Glacial and Early Holocene; Zones PLS 1–9

At the base of the core the values of *Hippophaë* are remarkably high (Zone PLS 1). Since sea-buckthorn is not a good

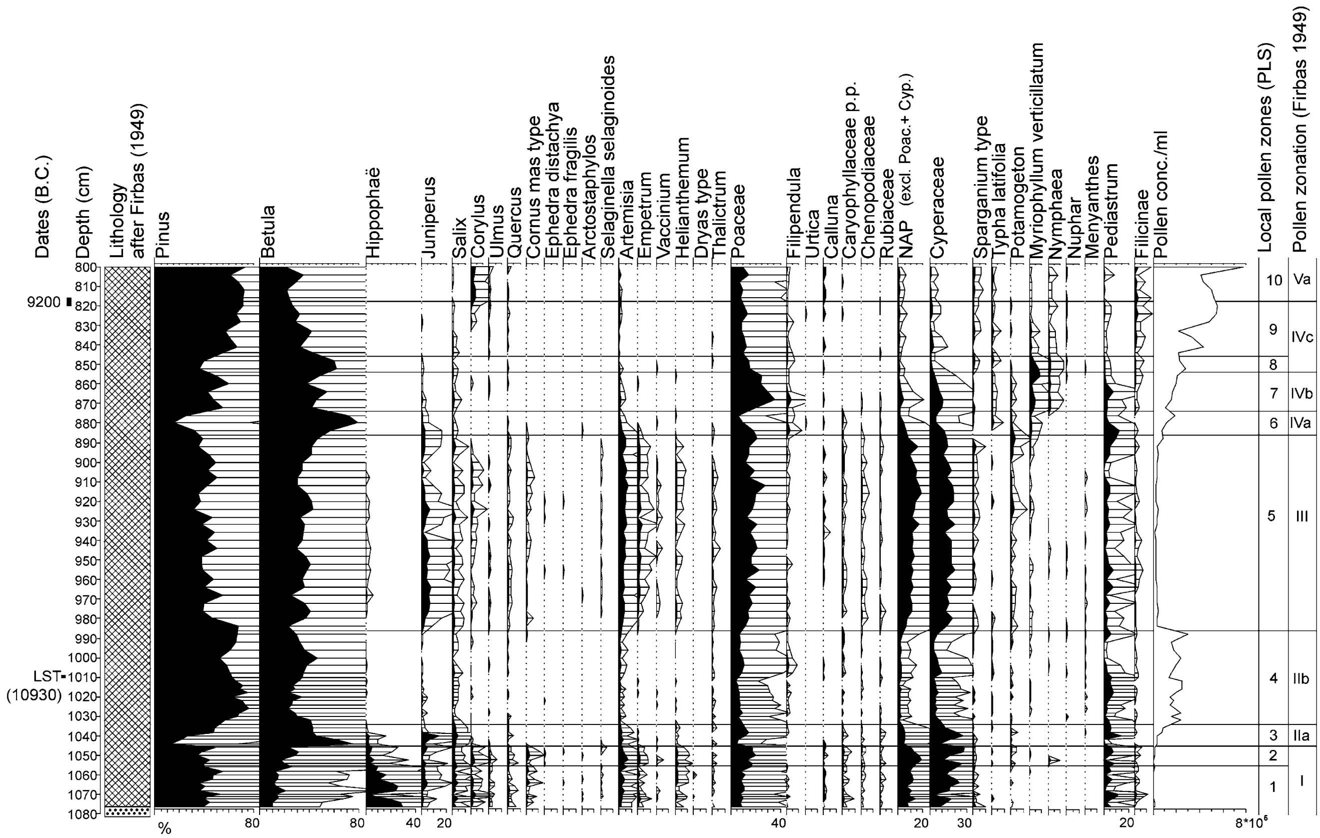

Fig. 2 Pollen diagram for Löddigsee, Late Glacial and Early Holocene

pollen producer, stands of this shrub must have been close to the coring site. A distinct decrease in *Hippophaë* in the two samples at 1070 and 1071 cm is parallel to a change of sediment colour and structure, and a peak in *Pinus* pollen, which must be regarded as being derived from reworked material as a result of erosion. This phase with abundant *Hippophaë* and low values of *Betula* (Meiendorf Interval: Menke 1968; Usinger 1998) is interpreted as the first expansion of shrubs through rising summer temperatures (de Klerk et al. 2001; Wolters 2002). In diagrams from Wilhelmshorst in Brandenburg (Müller 1970) and Endinger Bruch and Reinsberg in Vorpommern (de Klerk et al. 2001; de Klerk 2002) the *Hippophaë* phase is preceded by a phase of open vegetation, which is not present in the Löddigsee profile. The pollen concentration is very low in Zone PLS 1. The NAP values are high, especially of *Artemisia*, *Helianthemum* and *Empetrum*, but also of Poaceae and Cyperaceae. *Selaginella selaginoides* occurs regularly. Woody taxa besides *Hippophaë* are mainly *Betula*, *Juniperus*, *Salix* and the *Cornus mas* type. This pollen type also includes *Cornus suecica* (Beug 2004), which certainly occurs here. Besides most of the *Pinus* pollen grains, the thermophilous taxa such as *Corylus*, *Ulmus* and *Quercus* must also be regarded as being reworked. Towards the end of PLS 1 the high values of *Hippophaë* decrease continuously; either sea-buckthorn grew less frequently in the vegetation, or the stands were farther away from the coring site as a result of expansion of the lake. Around the lake was a scattered reed belt with *Sparganium* and *Typha angustifolia*. Aquatic taxa are rare.

In Zone PLS 2, *Hippophaë* values decrease and Poaceae and other NAP increase slightly. Perhaps a short climatic setback is indicated here, which is more clearly visible in diagrams from Vorpommern, where it is referred to as "Open vegetation phase II" (de Klerk et al. 2001; de Klerk 2002). This cooling phase was also identified in diagrams from western Brandenburg (Wolters 2002); there, however, the signal is weaker than in the Vorpommern area and more comparable to the Löddigsee diagram.

Zone PLS 3 shows a very high peak in *Betula*. Pollen concentration increases while the NAP values (especially *Artemisia*, *Helianthemum* and *Empetrum*) and *Cornus mas* type decrease. *Salix* still occurs frequently and *Juniperus* even increases distinctly, showing that the expanding woodland still had no closed canopy. Brande (1980) attributes this *Betula* phase to the Allerød (Zone IIa after Firbas 1949; Brande 1980), whereas Wolters (2002) classifies it as the Bølling (Zone Ib after Iversen 1954). A third period of open vegetation, which was identified in the Eifel region by Litt

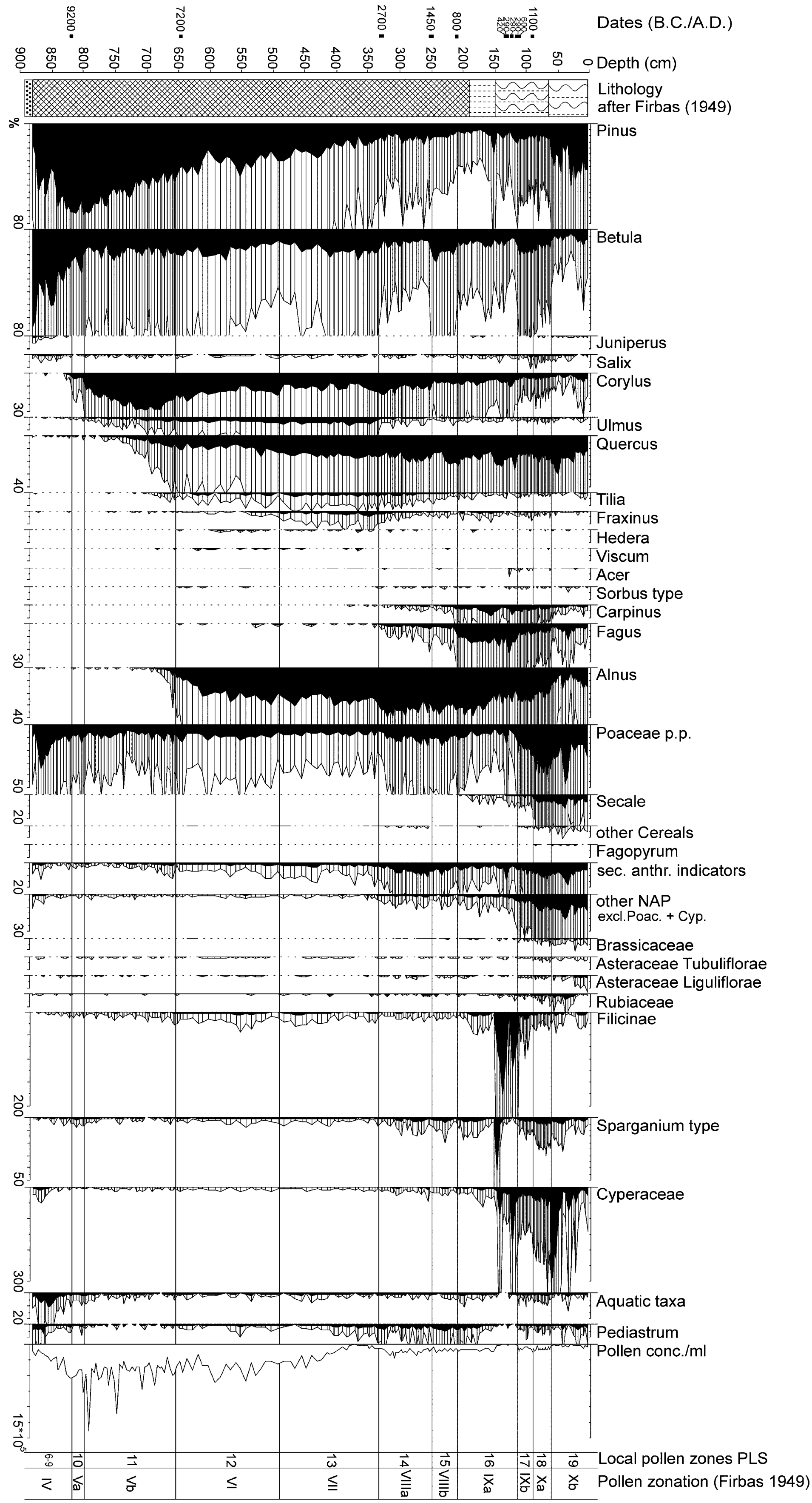

Fig. 3 Pollen diagram for Löddigsee, Holocene

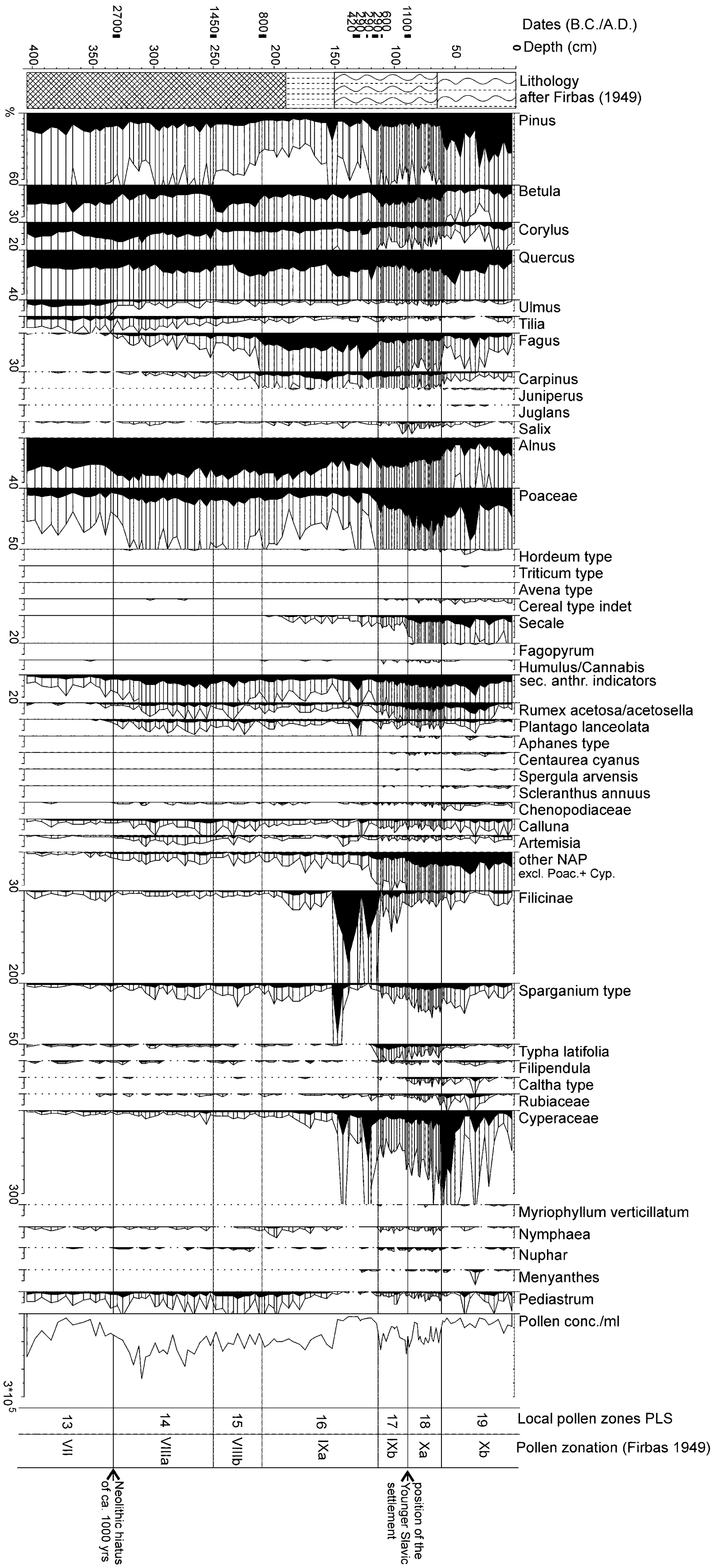

Fig. 4 Pollen diagram for Löddigsee, Middle and Late Holocene, anthropogenic indicators detailed

Table 1 Radiocarbon dates. Those not used for the age model are marked with an asterisk

Lab. code	Depth (cm)	Material dated	C (mg)	Age (B.P.)	Cal age (1σ range)	$\delta^{13}C$ (‰)
KIA 20722*	84–88	Pollen	2.9	1195 ± 29	A.D. 781–785; 785–792; 808–882	−30.09 ± 0.13
KIA 26583	88–92	*Carex rostrata* fruits	4.6	943 ± 26	A.D. 1031–1059; 1086–1122; 1138–1156	−25.03 ± 0.09
KIA 18147	111–112	Peat	5.3	1477 ± 28	A.D. 545–546; 560–620; 633–636	−28.95 ± 0.14
KIA 26584	114–118	*Carex rostrata* fruits, *Menyanthes trifoliata* seeds	3.9	1719 ± 26	A.D. 259–282; 290–298; 321–358	−24.27 ± 0.25
KIA 18148	122–123	Peat	2.4	1757 ± 28	A.D. 241–262; 278–325; 328–336	−25.55 ± 0.11
KIA 18149	129–130	Peat	4.8	1751 ± 28	A.D. 244–262; 277–325; 326–336	−27.83 ± 0.07
KIA 26585	130–134	*Carex rostrata* fruits, *Menyanthes trifoliata* seeds	4.6	1643 ± 33	A.D. 343–371; 379–435	−27.91 ± 0.07
KIA 26586*	186–190	*Carex* fruits	2.5	1737 ± 30	A.D. 248–305; 315–342; 372–377	−26.61 ± 0.09
KIA 18146*	207–209	Pollen	0.8	2913 ± 38	B.C. 1207–1203; 1189–1180; 1154–1142; 1130–1035; 1034–1021	−30.80 ± 0.11
KIA 24714	207–212	Pollen	5.4	2598 ± 20	B.C. 802–790	−28.16 ± 0.09
KIA 24715	248–253	Pollen	1.0	3178 ± 28	B.C. 1493–1476; 1458–1413	−28.69 ± 0.25
KIA 24716	327–333	Pollen	3.4	4132 ± 27	B.C. 2859–2829; 2822–2811; 2749–2723; 2700–2660; 2651–2623	−28.28 ± 0.23
KIA 24717	644–648	Pollen	1.7	8189 ± 40	B.C. 7299–7267; 7261–7247; 7244–7223; 7185–7136; 7130–7115; 7101–7082	−27.69 ± 0.07
KIA 24864	816–820	Pollen	5.2	9736 ± 36	B.C. 9249–9208; 9196–9196	−27.58 ± 0.11

and Stebich (1999) (Zone Ic, Older Dryas, after Iversen 1954) has not so far been found in North-eastern Germany (Wolters 2002; de Klerk 2002), neither is it visible in the Löddigsee diagram.

In Zone PLS 4 *Betula* values decrease again, parallel to a decline in *Juniperus* and *Salix*. *Pinus* values increase, and pine is established as the main constituent of the woodland; this is also reflected in a distinctly higher pollen concentration. NAP values are low. The Laacher See Tephra (LST), deposited during the Allerød at 10,930 cal. B.C. (Brauer et al. 1999), was found at a depth of 1009 cm. The *Betula* peak at 1000 cm also occurs in several pollen diagrams from Brandenburg (Wolters 2002) and the Wendland area, west of the River Elbe (Lesemann 1969). Wolters (2002) showed that in most of these pollen diagrams this *Betula* peak is contemporaneous with the LST deposition and he proposed an interpretation as the Gerzensee oscillation (Eicher 1980). The Löddigsee diagram, however, belongs to those rarer sites (Wolters 2002) where the *Betula* peak clearly lies above the LST.

PLS 5 is characterised by a strong increase in *Juniperus*, and to a lesser extent in *Salix* and the *Cornus mas* type. *Pinus* values, on the other hand, decrease. Pollen of thermophilous taxa (*Corylus*, *Ulmus*, *Quercus*), which occurs regularly, must again be regarded as being reworked. NAP increase distinctly, especially *Artemisia*, *Helianthemum*, *Empetrum* and *Thalictrum*. The pollen concentration is again very low. The zone clearly indicates the opening of the vegetation during the Younger Dryas, more distinct than in some pollen diagrams from the Brandenburg area (e.g. Jahns 2001; Wolters 2002). With a thickness of 1 m the Younger Dryas deposits are similar in thickness to profiles from Northern Vorpommern. There the sediment accumulations were interpreted as a result of more open vegetation than in Brandenburg and consequently stronger erosion (de Klerk 2002). At the top of the zone *Potamogeton* and *Pediastrum* display higher values.

A high *Betula* peak and a decrease in NAP in Zone PLS 6 show the expansion of relatively dense birch woods as a result of the rapid warming at the Younger Dryas/Preboreal transition. The increase in temperatures is also indicated by higher values of the thermophilous *Filipendula* (Iversen 1954) and an expansion of *Typha latifolia*, which requires similarly warm temperatures.

In Zone PLS 7 there is a distinct *Betula* decrease, simultaneous with a strong increase in Poaceae. In Zone PLS 8 a second peak in *Betula* can be seen, whereas Poaceae decline. The second *Betula* maximum is followed by the final development of forest vegetation dominated by pine (Zone PLS 9). In this part of the diagram *Ulmus* and *Quercus* are continuously present. In the Berlin-Brandenburg area, Brande (1980), Wolters (2002) and Jahns (2004) interpret the presence of these thermophilous trees as an indicator of

Table 2 Stratigraphy

Depth (cm)	Sediment
0–15	Mixture of peat and soil
15–59	Poorly decomposed brown peat
59–100	Dark peat
100–152	Poorly decomposed dark peat
152–190	Mixture of coarse detritus mud and peat
190–280	Light brown calcareous mud
280–333	Dark brown calcareous mud
333–335	Layer of mollusc shells
335–400	Light grey calcareous mud
400–875	Grey to brown calcareous mud
875–885	Light grey calcareous mud
885–900	Grey to brown calcareous mud
900–975	Light grey calcareous mud
975–985	Grey to brown calcareous mud
985–1045	Brown calcareous mud
1009–1010	Laacher See tephra
1045–1076	Light grey calcareous mud
1076–1130	Sand

the final warming in the Preboreal period (Zone IVc after Behre 1978). The correlation of the vegetation development of Zones PLS 7 and 8 in the Löddigsee profile with other classifications of the Preboreal oscillations meets with more difficulties. In contrast with most other authors, Usinger (2004) could show not only one, but two periods of climatic deterioration in the Preboreal in the high-resolution diagram from Kubitzbergmoor (Schleswig-Holstein, Germany). The first short period is attributed to lower temperatures, whereas the second one reflects drier conditions. In the Löddigsee diagram, only Zone PLS 7 may be regarded as a climatic setback. The *Betula* decrease shows a renewed opening up of birch woodland. The simultaneously higher *Pinus* values may be due to long-distance transport (Usinger 2004). The increase of Poaceae in this zone could be the result either of open vegetation, as is true in the Younger Dryas, but on the other hand, in the Preboreal it might also reflect an expansion of *Phragmites australis* in a reed belt around the lake (de Klerk 2002). The latter possibility is corroborated by more abundant Cyperaceae at the same time. It is questionable whether the Poaceae peak can be used as an indicator of open vegetation, because the influence of such a reed belt cannot be estimated. Other indicators of a climatic deterioration, such as *Artemisia*, *Empetrum* or *Juniperus* do not change in the same direction. It has proved difficult to trace the Preboreal oscillations in the area of Brandenburg and Southern Mecklenburg. In diagrams from the Berlin-Brandenburg area this period mostly also starts with an expansion of *Betula* (Brande 1980; Wolters 2002); however, in some diagrams *Pinus* prevails at the beginning of the Preboreal (e.g. Böcker et al. 1986; Bittmann and Pasda 1999; Brande 2003). The diagram from Groß Rehberg from the Müritz area in southern Mecklenburg shows the same two distinct *Betula* maxima preceding the final development of pine forest. Other diagrams from this area indicate a final expansion of *Pinus* following only one *Betula* peak at the beginning of the Preboreal (Schoknecht 1996). However, none of all these studies provides such an excellent time resolution as that from Kubitzbergmoor (Usinger 2004) and therefore possibly not every short oscillation is recorded. In the Löddigsee diagram, the *Betula* decline in Zone PLS 7 is interpreted as climatic setback (Zone IVb after Behre 1978). The second *Betula* peak indicates the final climatic improvement and a phase of birch woodland before the pine prevailed at the end of the Preboreal.

Mid and Late Holocene vegetation development; Zones PLS 10–19

In Zone PLS 10 (Early Boreal, Va) *Corylus* values increase and reach a maximum in Zone PLS 11 (Late Boreal, Vb). These values of 30%, are characteristic in the old moraine area of Western Germany and the young moraine area of Brandenburg and Southern Mecklenburg (Lesemann 1969; Schoknecht 1996; Jahns 2000, 2001; Wolters 2002). A date at the beginning of this period yields an age of ca. 9200 B.C. Zone PLS 11 is also characterised by an increase in *Quercus*, *Tilia* and *Ulmus*, whereas *Pinus* decreases continuously. Zone PLS 12 shows the expansion of *Alnus* (Early Atlantic, VI). The first pollen grains of *Fagus* were found from the beginning of this zone onwards. At 646 cm the finding of a ceratohyale from *Perca fluviatilis* proves the existence of this fish species in the lake. The beginning of the zone was dated to ca. 7200 B.C., which is in agreement with the date of 7450 B.C. for the beginning of the Atlantic period from the Rugensee diagram (Dörfler, in press).

The trend of decreasing *Pinus* and high *Quercus* and *Tilia* values continues in Zone PLS 13 (Late Atlantic, VII), which is further characterised by a distinct rise in *Fraxinus*. At the top of this zone the first *Carpinus* pollen grains were found. The uppermost part of the Late Atlantic and the beginning of the Early Subboreal (VIIIa) are not represented in the sediment. Apparently, the coring site was dry at that time. The hiatus is clearly shown in the sediment by a marked change at 335–330 cm. The fine mud changes to a coarse peaty sediment with an accumulation of *Anodonta cygnea* shells and other molluscs in great number, possibly the remains of mollusc shell deposits in shallow water close to a shore. As a result of this hiatus the elm decline, dated to 3850 B.C. in the Rugensee diagram (Dörfler, in press), is absent from the Löddigsee profile and is not the same as that in the 335 cm level.

Sedimentation started again at 330 cm with conspicuously lower values of *Ulmus* and *Fraxinus* (Zone PLS 14, Early Subboreal, VIIIa). The layer 327–333 cm was dated to

Table 3 Local pollen zones PLS of the Late Glacial and Early Holocene, compared to the pollen zones of Firbas 1949 and Brande 1980 and other regions: Döberitzer Heide (Wolters 2002), Vorpommern (de Klerk 2002), Meerfelder Maar (Litt and Stebich 1999)

PLS	Depth (cm)	Zone description	Wolters 2002	Firbas 1949 Brande 1980	de Klerk 2002	Litt and Stebich 1999	Dating Löddigsee
9	818-846	*Pinus-Betula*-Zone with *Corylus*,*Ulmus*, *Quercus*	DH 9 *Pinus-Betula*-Polypodiaceae	IV	Early Holocene *Betula-Pinus* forest phase	IV Preboreal	9200 B.C. at 816-820 cm
8	846-854	*Betula-Pinus*-Zone with *Ulmus*, *Quercus*					
7	854-874	*Pinus-Betula*-Zone	DH 8 *Betula-Pinus-Populus*				
6	874-886	*Betula-Pinus*-Zone, higher pollen conc.					
5	886-986	*Pinus-Betula*-Zone with *Juniperus*, *Artemisia*, *Empetrum*, *Helianthemum*, *Cornus mas* type, *Selaginella selaginoides*, low pollen conc.	DH 7 *Pinus-Juniperus-Artemisia*	III	Open vegetation phase III	III Younger Dryas	
4	986-1034	*Pinus-Betula*-Zone, high pollen conc.	DH 6 *Pinus-Betula* DH 5 *Betula-Pinus* DH 4 *Pinus-Betula*	IIb	Late Glacial *Betula*/*Pinus* forest phase	II Allerød	10,930 B.C. LST at 1009 cm
3	1034-1045	*Betula-Juniperus*-Zone with *Artemisia, Helianthemum*, higher pollen conc.	DH 3 *Betula-Juniperus*	IIa		Ic Older Dryas Ib Bølling	
2	1045-1055	*Betula*-Zone with *Hippophaë*, *Artemisia*, *Empetrum*, *Juniperus*, *Helianthemum*, *Cornus mas* type, higher NAP		I	Open vegetation phase II	Ia Oldest Dryas	
1	1055-1076	*Hippophaë-Betula*-Zone with *Helianthemum*, *Juniperus*, *Artemisia*, *Cornus mas* type, *Empetrum, Selaginella selaginoides*	DH 2 *Betula-Salix* DH 1 *Salix-Hippophaë-Betula*		*Hippophaë*-phase	Meiendorf	

ca. 2700 B.C., which means 1000 years of the Subboreal and an unknown part of the Late Atlantic are missing. However, the first pollen grains of *Fagus* and *Plantago lanceolata* at the top of the recorded part of the Late Atlantic suggest that the major part of that period is included in the profile. *Betula* displays lower values than in the Late Atlantic. The *Pinus* values drop to <10–15%. Apparently pine did not play an important role in the vegetation around the lake any longer, as found in the results from palynological studies in the Wendland, west of the River Elbe (Lesemann 1969). In the north, in the area around Schwerin, pine had already lost its importance in the Atlantic period (Dörfler, in press). *Alnus* occurs more abundantly and *Fagus* and *Carpinus* are continuously present with slowly increasing values. *Acer* and *Sorbus* type, low pollen producers, occur regularly. In this zone permanent human impact is indicated, mainly by continuous and parallel pollen curves for *Rumex* and *Plantago lanceolata*. Cereal pollen occurs only as single grains of *Hordeum*- and *Triticum* type. Distinct settlement phases cannot be differentiated.

The beginning of the following Zone PLS 15 (Late Subboreal, VIIIb) was dated to ca. 1450 B.C. *Corylus* values decline. Simultaneously, the secondary anthropogenic indicators decrease and the *Betula* values increase distinctly. The decrease in *Corylus* may be a result of a reduction in woodland destruction by grazing. As a light-demanding tree *Betula* follows in the secondary woodland succession. This was obviously not the case here, as the *Betula* values remain on a higher level throughout Zone PLS 15 (ca. 650 years) and are reduced only by the subsequent *Fagus* and *Carpinus* expansion in PLS 16. One reason for the high *Betula* values might be a lower lake level with birch trees invading the shore.

In Zone PLS 16 (Early Subatlantic, IXa), a steep *Fagus* increase to >10% and an increase in *Carpinus* to 2% is visible. The date of 800 B.C. for the *Fagus* mass expansion is 800 years earlier than in the Rugensee area, just 50 km northwest of Löddigsee (Dörfler, in press). *Secale* now is continuously present at low values. At 190 cm, a transition from calcareous mud to peat shows the beginning of the terrestrialisation at the coring site and at 150 cm there is a clear change to a mixture of coarse detritus, mud and peat. This process is also reflected in the pollen diagram by a subsequent peak in *Sparganium* type and Cyperaceae. High values of Filicinae could be due to spreading of *Thelypteris palustris* on the fen. Terrestrialisation is also indicated by discontinuous presence of *Nymphaea* pollen grains and of *Pediastrum* algae (Fig. 4). Apparently, the peat accumulated quickly, as the pollen concentration in this part of the profile was very low. Selective corrosion does not seem a likely explanation, as there is no enhancement in the relatively resistant *Pinus* pollen.

In Zone PLS 17 (Early Subatlantic, IXb) *Fagus* and *Corylus* values decline steeply. *Betula* displays higher values, possibly as a reaction to a more open canopy, or as a result of moister conditions at the coring site. A higher lake level is also indicated by the reoccurrence of *Nymphaea* and *Pediastrum*, higher values of *Sparganium* type and *Typha latifolia*, and a decline in Filicinae. The pollen concentration also increases again. The *Fagus* decline may reflect human impact (see below). The secondary anthropogenic indicators, however, do not react conspicuously, although Poaceae increase steeply and the other NAP also occur more frequently.

In Zone 18 (Late Subatlantic, Xa) the Poaceae show nearly their maximum values. *Secale* occurs abundantly and *Fagopyrum* and *Humulus*/*Cannabis* are continuously present. Other cereals, however, were found only in low numbers. Secondary anthropogenic indicators like *Centaurea cyanus* and *Aphanes* type occur regularly and other NAP increase distinctly. Thus, the zone shows the typical signs of land-use in medieval times after the German eastwards expansion that started in A.D. 1147. In the swamp vegetation, *Caltha* and *Menyanthes* grew more frequently, *Menyanthes trifoliata* being also documented by abundant seeds. *Salix* from open woodland or lake margin vegetation is also represented by higher values.

Table 4 Local pollen zones (PLS) and zonation of the Middle and Late Holocene according to Firbas 1949

PLS	Depth (cm)	Zone description	Firbas	Time span
19	0–61	*Pinus-Secale*-Zone	Xb	
18	61–89.5	*Quercus-Alnus-Secale*-Zone with *Fagopyrum*, *Juglans*, *Rumex*	Xa	A.D. 1100 at 88–92 cm
17	89.5–113.5	*Quercus-Alnus-Betula-Secale*-Zone	IXb	ca. A.D. 300–1100
16	113.5–210	*Quercus-Fagus-Carpinus-Alnus*-Zone with *Secale*	IXa	ca. 800 B.C.-A.D. 300
15	210–250	*Quercus-Betula-Alnus*-Zone	VIIIb	ca. 1450–800 B.C
14	250–333	*Quercus-Tilia-Alnus-Plantago lanceolata*-Zone with *Fagus*, *Carpinus*	VIIIa	ca. 2700–1450 B.C
	Hiatus			
13	333–490	*Quercus-Ulmus-Tilia-Fraxinus-Alnus*-Zone	VII	
12	490–654	*Quercus-Ulmus-Tilia-Alnus*-Zone	VI	7200 B.C. at 644–648 cm
11	654–798	*Corylus-Pinus-Betula*-Zone with *Quercus*, *Ulmus*, *Tilia*	Vb	
10	798–818	*Pinus-Betula-Zone* with *Corylus*	Va	9200 B.C. at 816–820 cm

At 62 cm, the stratigraphy changes to less decomposed peat (Zone PLS 19, Late Subatlantic Xb). Perhaps this is because of the creation of ponds for the operation of water mills since high medieval times. A distinct decrease in *Alnus* and *Betula* at 61 cm indicates transformation of birch and alder carrs to moist pastureland. *Pinus*, on the other hand, increases distinctly, either as a result of better habitat conditions after the clearing of the woodland or through long-distance transport in open vegetation. Pollen grains of planted *Juglans* were found more frequently than in PLS 18. *Juniperus* occurs regularly, indicating a pastoral economy in dry places.

Another change in the stratigraphy to darker peat can be observed at 15 cm, which possibly reflects the construction of the so-called "Judengraben", which in 1752 canalised the River Elde.

The Late Neolithic and the Younger Slavic Island settlements in the Löddigsee

The Late Neolithic settlement

The Neolithic settlement is situated at the south-western end of the former island (Fig. 1). According to the archaeological model it was built in a period of low water table and was inhabited until the newly rising lake level led to conditions that were too marshy in the Subboreal. Nowadays the settlement structures are covered by 30 cm of peat. The settlement belongs to the Single Grave and Kugelamphoren Culture and existed according to the radiocarbon dates from 2900–2600 B.C. (Görsdorf 2002). According to the palynological investigation of the archaeological site itself (Kloss 2002), parts of the island were already dry at the end of the Preboreal as a result of a low lake level. During the Boreal and the Atlantic period no organogenic sediment was formed at the later settlement site. In the first part of the Subboreal it was built on top of the dry Preboreal peat. In the cultural layer pollen was preserved. The investigated samples from this layer show almost no anthropogenic indicators. The peat, which covers the cultural layer, shows pollen analytical characteristics of the later Subboreal, indicating marshy conditions for that period (Kloss 2002). Botanical macro remains were not investigated and the archaeological material gives no information about plant husbandry. On the other hand, the animal remains, which were studied intensively, allow interesting conclusions about the economy of the settlement in the Löddigsee. Judging by the large proportion of wild animal remains in the material, the subsistence of the population was based on hunting. Most of the animals were shot in the months between May and September (Becker and Benecke 2002). The results of the archaeozoological investigation in combination with the palynological study of Kloss give the impression that the settlement was just a seasonal hunting station, without agriculture.

The radiocarbon date at 330 cm in the Löddigsee core, just above the shell layer has a 1σ range of 2806–2620 B.C. According to this date, the last part of the settlement is only represented in the sediments from 330–335 cm. Even if cereal processing did not take place in the settlement, single pollen grains of Cereal types and regularly occurring *Plantago lanceolata* indicate an agrarian culture in the surroundings of the lake at the same time. After a short regression, a distinct increase of secondary anthropogenic indicators (mainly *Plantago lanceolata*, *Rumex*, *Calluna* and *Artemisia*) is visible at 310 cm. Poaceae increase slightly. Pollen grains from cereals were detected in very low numbers (*Hordeum* and *Triticum* type according to Beug 2004). This increase of anthropogenic indicators reflects settlement activity in the area from the late to the end of the Neolithic, but it is not possible to specify distinct settlement periods.

The lowering of the lake level from the end of the Preboreal, which can be observed at the archaeological site, finally led to the hiatus in the sediment of the lake at the coring site as mentioned above. During the Boreal, the Early Atlantic and part of the Late Atlantic, when the settlement site was already dry, the pollen diagram shows that there was still open water at the coring site. In the earlier Subboreal, just before the Neolithic settlement was built, the location was not situated on an island, but on a sandy hill, surrounded partly at least by dry ground. The pollen record, however, does not reflect the lowering of the lake level, as for example would an increase of reed taxa.

The interval between the Neolithic and the Slavic settlement period

A decline in the secondary anthropogenic indicators synchronous with an increase in *Betula* is found at 250 cm, with only the values of *Calluna* increasing slightly. The radiocarbon date of ca. 1450 B.C. at this level places this event in the Bronze Age. This trend could be due either to a decrease of population in the area, or to a change of economy with reduced woodland grazing, similar to findings in the Bronze Age in north-western Germany (Behre and Kučan 1994). From 250 to 210 cm, no distinct changes in the intensity of human impact can be deduced from the pollen diagram. From 210 cm onwards *Secale* is represented continuously, although at low values. The date of ca. 800 B.C. at 208 cm would be too early for rye cultivation, which started in Northern Germany in the Roman Iron Age (Behre 1992). Therefore the *Secale* pollen must be attributed to weed rye.

From 250 to 113.5 cm, anthropogenic indicators are present throughout, but no distinct settlement phases are reflected in the diagram. From 188 cm upwards, an increase of *Secale* indicates rye cultivation in the area. One shortlived peak of *Plantago lanceolata* in the two samples 129 and 131 cm can be observed. At 113 cm a *Fagus* decline in combination with an increase in Poaceae, other NAP and, on a smaller scale, in *Secale* and *Humulus*/*Cannabis* may also be due to human impact.

The successive sediment change from mud to fen peat at 190 cm shows the overgrowing of the Löddigsee at the coring site which becomes *Carex* peat at 150 cm. Apparently, a swamp or fen developed, either as a result of lower lake level or as a natural terrestrialisation process. The pollen diagram shows a high peak in *Sparganium* type and in Cyperaceae. Some seeds of *Carex* and *Menyanthes trifoliata* were found in the same layer, as well as of *Najas marina*. As a consequence of further overgrowing pollen grains of aquatic taxa like *Myriophyllum verticillatum*, *Nymphaea* and *Nuphar* and *Pediastrum* algae were no longer found. The pollen concentration is very low from 150 to 119 cm and monolete fern spores show very high values indicating an expansion of *Thelypteris palustris* on the dry fen.

From the horizon 114 cm to 134 cm four dates are available. Two were obtained from peat samples (KIA 18148, 18149), the other two from a mixture of *Carex* and *Menyanthes trifoliate* fruits and seeds (KIA 26584, 26585; Table 2). All four of them provided almost identical ages in the range A.D. 240–435. Obviously, peat accumulated fast in this horizon. At 113 cm a transition to moister conditions is indicated by a decrease in fern spores, increasing values of *Sparganium* type, *Typha latifolia*, *Filipendula*, Rubiaceae, *Caltha* type and the reoccurrence of pollen of aquatic taxa like *Nymphaea*, *Nuphar* and *Myriophyllum verticillatum*.

The Younger Slavic settlement

The Younger Slavic site is situated ca. 400 m north of the Neolithic site. It was constructed in the decade after A.D. 1030. This first settlement was destroyed by force and burned down around A.D. 1050. Between A.D. 1059 and 1065 it was rebuilt and continuously inhabited until it was abandoned without further destruction in the first quarter of the 12th century. After a time of desertion a German settlement was built at the site in the 13th and 14th century, which lasted to the 15th century. The stratigraphy of the excavated area showed that some time before the Slavic settlement the sand bar was flooded due to a higher lake level. Like the Neolithic settlement before it, the Younger Slavic settlement was constructed when the lake level was low. Its fortifications were built on 5 m of fen peat. It is questionable whether the location still was a real island at that time or whether it was surrounded by a swamp (Paddenberg, in press).

In contrast to the Neolithic settlement, the abundant plant remains from the excavation of the Slavic settlement were thoroughly investigated (Alsleben, in press). Large quantities of food stores were carbonised when the first settlement was burned down. The spectrum of cultivated plants is in agreement with finds at other Slavic centres in Germany: rye, barley, oat, bread wheat and millet were the most important cereals, together with pea, lentil, horse bean and linseed which were found in large numbers. Fruit cultivation is indicated by findings of plum stones. Such large quantities of cultivated plants would normally lead to the conclusion that agriculture played an important role in the economy. However, it is noteworthy that although much evidence of cereal processing was found, hardly any agricultural tools such as sickles, scythes or ploughs were present. For this and other reasons the site is interpreted by Paddenberg (in press) as a centre of trade and worship, rather than of agriculture. Perhaps the large food stores were also used as trading goods. The zoological remains have not yet been fully investigated, although bones were found in large numbers. Animal husbandry seems to be indicated to a certain degree. Fishing was not as important as in German times, when the settlement was used as a fishing village.

The ^{14}C date at 111–112 cm gives an Early Slavic Age in a 1σ range of A.D. 545–636. From 112 cm upwards an increase in Poaceae and secondary anthropogenic indicators (mainly *Rumex acetosa*/*acetosella*) is visible. Possibly an extension of agriculture in the area around Löddigsee is reflected here. The earliest pollen grains of *Centaurea cyanus* were found at 103 cm. The ^{14}C date 88–92 cm (KIA 26583) agrees with the time of the Slavic settlement. It is derived from a sample of pure *Carex rostrata* fruits and provides a 1σ age range of A.D. 1031–1156. From 89 cm a distinct increase in *Secale*, *Hordeum* type and *Rumex*, with more frequent occurrences of *Centaurea cyanus*, *Humulus*/*Cannabis*, *Aphanes* type, *Scleranthus annuus*, *Spergula arvensis* and Chenopodiaceae show a major increase of land-use in the area. From 86 cm *Fagopyrum* pollen is present. So far, the ^{14}C-date at 88–92 cm is the closest to that for the beginning of the *Fagopyrum* presence in pollen diagrams from Mecklenburg or Brandenburg. In the "Siedlungskammer Flögeln" in northern Lower Saxony, the first *Fagopyrum* pollen grains appear in the 11th Century (Behre and Kučan 1994), which coincides with the date KIA 26583 at Löddigsee. Pollen analytical evidence for a very early presence of buckwheat is reported for the early Slavic settlement of Gahro in Lower Lusitania, where *Fagopyrum* pollen was found in the moat sediments (Lange et al. 1978), but these sediments were not radiocarbon dated. The current state of research on the presence of buckwheat in Germany suggests an introduction from south-eastern Central Europe in the 13th /14th century. So far macrofossil evidence of this crop exists in northern Germany only from this time onwards (e.g. Wiethold 1995, 1999; Ansorge et al. 2003, in press), thus contradicting the early date at Löddigsee. If the date of shortly after A.D. 1100 is true for the cultivation of *Fagopyrum* in the area around Löddigsee, the question remains open as to whether it belonged to the Younger Slavic settlement or to the rural economy of the subsequent German village. Certainly an attribution to a Slavic husbandry has to be regarded with care until buckwheat cultivation in this period has been established through macrofossils. In the abundant archaeobotanical material from the Slavic settlement in Löddigsee, however, no buckwheat was found (Alsleben, in press). In this respect the finds of *Fagopyrum* by Cyprien et al. (2004) from France need a thorough and critical review.

The *Carex* peat stratigraphy of the core suggests that during the period proposed for the Slavic settlement, the island was not surrounded by a lake but rather by scattered reed beds, fen and swamp. Later on the remains of the Slavic settlement were also covered by peat (Paddenberg, in press).

Neither the Migration Period, the end of the Slavic settlement activities, nor the following period of abandonment and the new colonisation of the site as a small, insignificant fishing village, is reflected in the pollen diagram. Because of this, it must be suggested that, in a similar way to the record of the Neolithic settlement, the anthropogenic indicators in the pollen diagram are derived from agrarian activities and land cultivation in the surrounding area and not from the direct vicinity of the lake. From this viewpoint, the archaeological interpretation of the Younger Slavic settlement on the island as a place of trade and worship, without its own agrarian economy, is of great interest.

Conclusions

The pollen diagram from Löddigsee gives important information on the distribution of the Late Glacial vegetation. Several climatic oscillations, which have been identified in studies from adjacent areas, could also be verified for southern Mecklenburg. The Holocene vegetation development shows characteristics of north-eastern German pollen diagrams (low *Corylus* maximum), but also characteristics of the adjacent western and north-western area, especially as regards the low presence of *Pinus* since the Subboreal and the respective proportions of *Fagus* and *Carpinus* in the woodland in the Early Atlantic.

As to the Late Neolithic settlement on a former island in the Löddigsee, it can be shown that the lake must have been at least partly dry during that period, thus reducing the available information on Late Neolithic husbandry. At the end of the Neolithic and in the Bronze Age, the Pre Roman Iron Age and the Early Slavic period human impact is visible, but with no specific settlement periods. The Younger Slavic settlement was also built during a period of low lake level and was most probably surrounded by a swamp rather than open water. The Younger Slavic agricultural economy is characterised by high values for *Secale* and weeds related to winter crops. The end of the Slavic settlement is not reflected in the diagram. Apparently, agriculture was carried out only at some distance from the lake during both settlement periods on the island.

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