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Macrofossil evidence of early Holocene presence of *Picea abies* (Norway spruce) in NE Poland

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Early Holocene presence of *Picea abies* (Norways spruce) was recorded in NE Poland. Currently it is the westernmost known fossil site of spruce for the Early Holocene (9500–9000 cal. BP) in central-eastern Europe, approximately five thousand years earlier than presumed. For the first time, the occurrence of *P. abies* was documented by the presence of needles, bud scales and seeds. *Picea abies* grew on a peatland developed on a mineral peninsula between lakes Kojle and Perty during a period of low water level, when *Corylus* expanded. The disappearance of *P. abies* is related to a substantial climate change from continental to oceanic, approximately 9400 cal. BP, which resulted in an increase in humidity, higher water levels, and submergence of the peatland inhabited by *P. abies*.

Introduction

Climatic changes during the Holocene resulted in large-scale plant migrations (Birks 1986, Lang 1994). A notable migration is that of *Picea abies* (Norway spruce), one of the most important tree species in the forests of central, north, and north-eastern (NE) Europe. Its current distribution includes the Alps, the Carpathians, Scandinavia, and eastern Europe (Hultén & Fries 1986). A disjunction of the range of *P. abies* occurs in Poland (Zając & Zając 2001): *Picea abies* from the Alpine-Carpathian centre occurs in the southern part of the country, and Scandinavian-Siberian spruce occurs in the NE region.

As the history of the expansion of *P. abies* in Europe is controversial, numerous attempts to determine the direction and time of migration of *P. abies* have been undertaken. Those studies were mainly based on palynological data, supplemented with macrofossil findings (Szafer 1921, Środoń 1967, Lang 1994, Ravazzi 2002, Giesecke & Bennett 2004, Obidowicz *et al*. 2004, van der Knaap *et al*. 2005, Latałowa & van der Knaap 2006, Środoń & Tobolski 2007); more recently, genetic studies have also been conducted (Lewandowski *et al*. 2012, Parducci *et al*. 2012). However, as emphasized by Birks and Birks (2000), macroscopic findings play a very important role in the reconstruction of the migration routes of plants.

NE Poland is a key area for studies on migration and the reasons for the disappearance of plants with regard to changing climate and environmental transformations in the postglacial period, and this is related to the location of the study area. Over thousands of years, this region constituted a migration gate for plants in

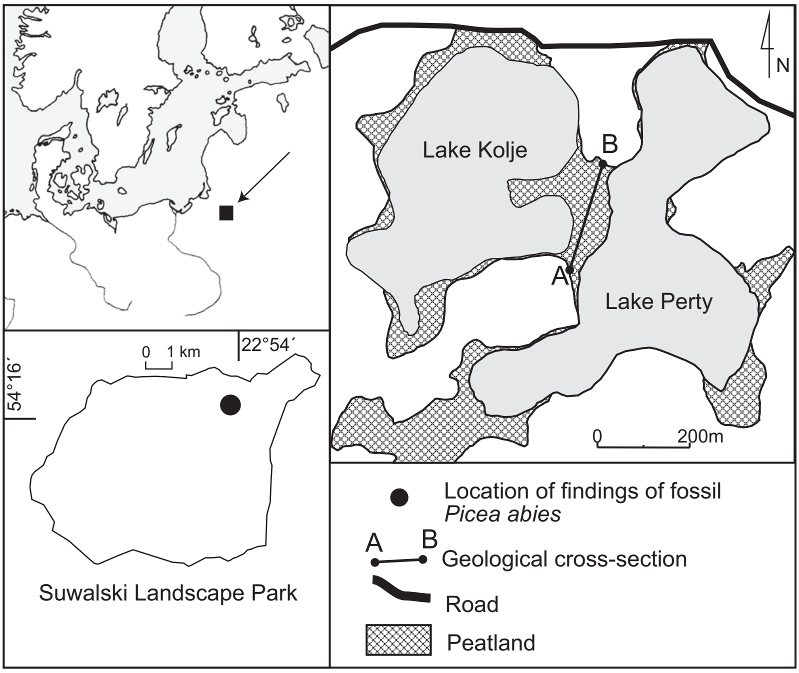

Fig. 1. Location of the study area.

the north–south–north and east–west–east directions. Another specific feature of NE Poland is the variable climate, with both continental and oceanic elements.

This report is a result of more extensive palaeoecological research conducted in NE Poland. To date, the research has revealed the presence of plants currently recognized as not occurring in this part of Europe, such as *Juncus subnodulosus* (Gałka 2009) and *Najas flexilis* (Gałka *et al*. 2012); diminishing, such as *Cladium mariscus* (Gałka & Tobolski 2012); and newly appearing, such as *Sphagnum wulfianum* (Gałka 2009). The history of the development of waterbodies within the context of the occurrence of aquatic plants during the Late Glacial was also determined (Gałka & Sznel 2013).

The objective of the present study was to determine the time and the environmental conditions during the presence of *P. abies* in NE Poland. Current results are the first to show the presence of *P. abies* based on the occurrence of its needles, bud scales, and seeds in this part of Europe. Previous studies suggesting the occurrence of spruce in this area were based on palynological data (Kupryjanowicz 2007, Lauterbach *et al*. 2011).

Material and methods

Study site

The study area is located in NE Poland in the Suwalski Landscape Park (Fig. 1). The modern landscape, which is characterized by numerous kame hills (with a height frequently exceeding 200 m a.s.l.), eskers, and depressions filled with water or biogenic sediments, is formed by the Scandinavian ice sheet. The modern landforms developed during the retreat of the ice sheet and as a result of the related fluvioglacial activity and glaciotectonics (Ber 2000, Krzywicki 2002). The study area is located within the range of a moderate transitional climate with clear continental influence. The mean July temperature is 17 °C and the mean January temperature is –5 °C (Woś 1999). The total mean annual precipitation exceeds 650 mm, with the maximum precipitation occurring in July and minimum precipitation in February. Similar to the climate, the vegetation of NE Poland is notably different from that of other areas in the country. The majority of the forest complexes are mixed *Coryleto-Piceetum* forests and pine–spruce mixed coniferous *Calamagrostio arundinaceae–Piceetum* forests

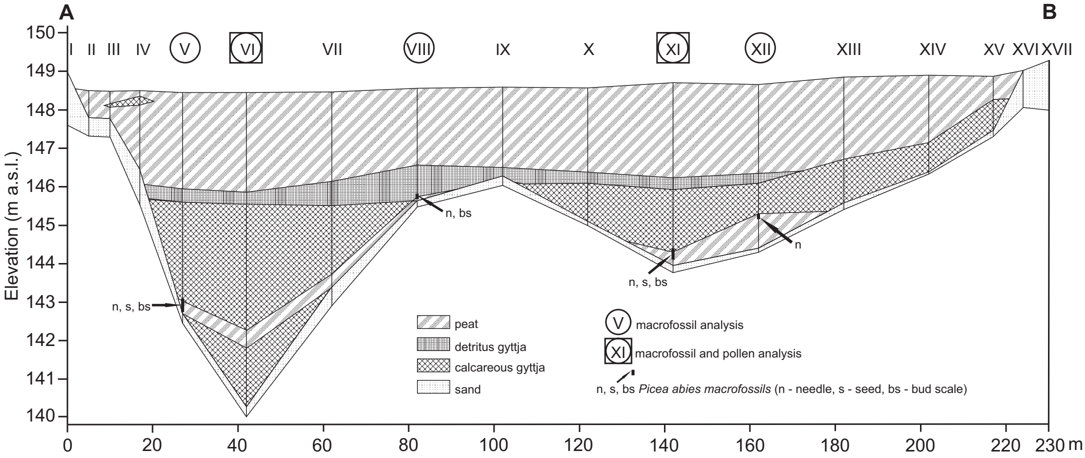

Fig. 2. Geological cross-section A–B (*see* Fig. 1).

(Sokołowski 1973). According to Matuszkiewicz (1991), the study area is located within the area of occurrence of oak–hornbeam forest of the *Carpinion betuli* type of the subboreal vicariant with Norway spruce.

The surrounding area is mainly occupied by pastures to the north and mixed forests dominated by *Pinus sylvestris*, *Picea abies*, *Carpinus betulus*, and *Betula pubescens* to the south. *Alnus glutinosa*, *Phragmites australis*, *Cladium mariscus*, and *Schoenoplectus lacustris* grow along the lake borders. The area between lakes Kojle and Perty is currently occupied by a peatland inhabited by species such as *Pinus sylvestris*, *Picea abies*, *Betula pubescens*, and *Frangula alnus* in addition to *Andromeda polifolia*, *Oxycoccus palustris*, *Sphagnum magellanicum* and *S. palustre*. The northern part of this peat bog was damaged for peat extraction. Currently, the peat pits are undergoing restoration.

The coring was performed using a Russian corer with a diameter of 5 cm and a length of 50 cm. Palaeoecological analyses (plant macrofossils and palynology) were performed on the bottom biogenic sediments deposited on the mineral bedrock sampled from four sites (Fig. 2). Two coring sites in the geological cross-section (Fig. 2) on the peatland between lakes Kojle and Perty have the following locations: sampling site VI) 54°16´26.8´´N, 22°53´43.4´´E and sampling site XI) 54°16´31.22´´N, 22°53´44.98´´E.

Laboratory studies

The lowermost sediments from the four sites were sampled for analyses. Limnic-peat sediment was placed in PVC tubes. In the laboratory, sediments were unpacked, cleaned, and then using a surgical scalpel divided into 1-cm-thick slices. The samples were washed with warm running water on sieves with a 0.25 mm mesh. The volume per sample was approx. 25 cm^3. Selected plant macrofossils were studied under a stereoscopic microscope Nikon SMZ800 under 10–200× magnification and a light microscope. The results were presented as plant macrofossil diagrams prepared using the C2 graphic software (Juggins 2003). Fruits and seeds are given in absolute numbers, while contributions of brown mosses, *Sphagnum* and vegetative parts of vascular plants, e.g. Cyperaceae, are given as percentages of the total volume of a sieved sediment sample. Species identification was done with the help of the following keys: Grosse-Brauckmann (1974), Tobolski (2000), Velichkevich and Zastawniak (2006, 2009) and Hölzer (2010). The names of plant species were used following Mirek *et al*. (2002). The results are based on 1-cm-resolution botanical composition analyses of 226 samples from the four cores.

Palynological analyses, covering 37 samples, were conducted at two sites. Samples of variable resolution were collected; the choice of resolution was based on the distribution in the deposit layers. For palynological analyses, 1 cm^3 of sediment was sampled. Each sample was acetolyzed following modified Erdtman's method with an addition of hydrofluoric acid (Faegri & Iversen 1989). Pollen taxa were identified and counted using a Zeiss AMPLIVAL light microscope (magnifications 400× and 1000×). Samples were counted until a minimum number of 500 tree and herb pollen grains was obtained. There are several samples where fewer pollen grains were counted because of poor preservation, and/or low concentration of pollen. The percentages of sporomorphs in individual spectra were calculated based on individual taxa numbers in relation to the total pollen sum taxa (AP + NAP), excluding local taxa (cryptogams, limnophytes, telmatophytes, and Cyperaceae). The percentages of local pollen taxa and cryptogams were calculated in relation to the pollen sum. The tresults of the palynological analyses are presented in diagrams prepared with the Tilia software (Grimm 1991).

Due to the narrow scope of this report, covering the Early Holocene history of spruce, we present only selected taxa. Complete diagrams will be published in a separate publication on Early Holocene water level fluctuations in the lakes of NE Poland in relation to vegetation development.

In order to determine the age of commencement and termination of the sediment accumulation process in the study area, macrofossils of terrestrial plant species from four samples were selected for AMS radiocarbon dating (Table 1). In two cases, material for dating was sampled from a 1-cm-thick sediment layer. In two other cases, material was sampled from 2-cm- and 2.5-cm-thick layers. The ^{14}C dating was performed in the Poznań Radiocarbon Laboratory. The resulting conventional radiocarbon dates were calibrated with the OxCal 4.1 software (Bronk Ramsey 2009).

Results

Lithostratigraphy

The form and distribution of sediments are presented in a geological cross-section performed for the peatland located between lakes Kojle and Perty (Figs. 1 and 2). To the south, the mineral bedrock, composed of grey sands with gravels, is covered by carbonate gyttja, with an interlayer of strongly decomposed peat of a maximum thickness of 46 cm. In the northern part, the mineral soil is covered by a layer of weakly decomposed peat, mostly constituted by *Sphagnum* and the roots of Cyperaceae. The thickest peat (90 cm) was recorded in core XII. The peat layer in both parts of the cross-section is covered by calcareous gyttja on which detritus gyttja accumulated, though the absence of detritus gyttja is typical of the northern part of the cross-section. It is also significant that detritus gyttja is deposited directly on the mineral bedrock in the central part of the cross-section where a distinct mineral elevation is located. In the Late Glacial and Early Holocene, the mineral elevation between lakes Kojle and Perty was a peninsula overgrown by trees. The limnic sediments are covered with peat, which is thickest at 255 cm in core VI. The bottom part contains herbaceous peat (fine roots of Cyperaceae and *Thelypteris palustris*), whereas the peat deposits are dominated by *Sphagnum* and *Eriophorum vaginatum* in the uppermost part.

According to radiocarbon dating, the accumulation of the peat layer in the southern part of the cross-section (core VI) commenced approximately 10 000 cal. BP (10 191–9781 cal. BP) and ended approximately 9400 cal. BP (9533–9308 cal. BP) (Fig. 2 and Table 1). In the northern part (core XI), the bottom peat was dated at approximately 9500 cal. BP (9542–9438 cal. BP) and the uppermost peat at 9200 cal. BP (9400–9028 cal. BP) (Fig. 2 and Table 1). The synchronization of events concerning the change in the accumulation of peat to gyttja is confirmed by palynological analyses. In both cases, the boundary between peat and the overlying gyttja corresponds with the time of expansion of *Alnus* in the area, i.e., at approximately 9400 cal. BP (Fig. 3). The time of expansion of *Alnus*, around 9400 cal. BP, was also documented at other sites in the Suwalski Landscape Park: Lake Hańcza (Lauterbach *et al*. 2011) and Lake Linówek (M. Gałka unpubl. data). The results of the palynological analyses suggest a clear convergence of the time of development of the peat layer at sites VI and XI, which corresponds with the time of

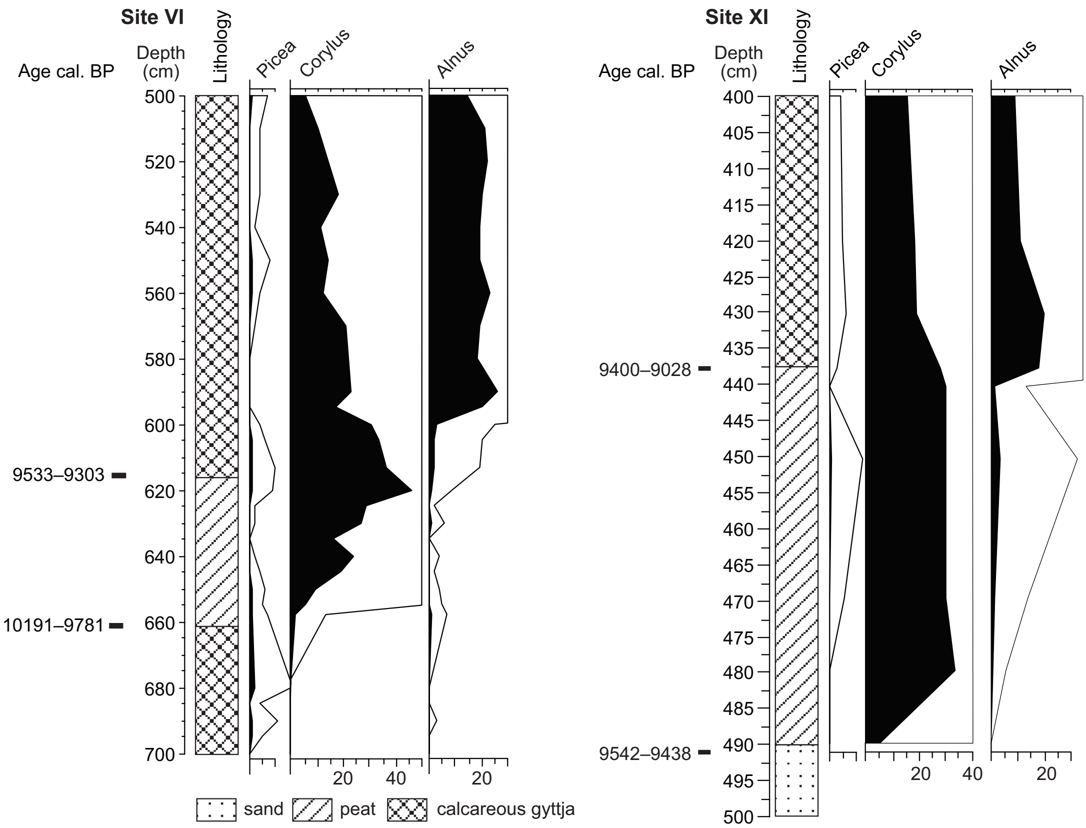

Fig. 3. Pollen percentage diagrams for core VI and XI for the selected taxa. The outline curves are magnified 10 times.

expansion of *Corylus* in the area, i.e., at approximately 10 200 cal. BP (Fig. 3).

Palaeobotanical analyses

Pollen

Site VI

The first occurrence of *Picea* pollen at site VI was recorded at a depth of 680 cm, i.e. in the Younger Dryas. Its contribution amounted to 1.5% (Fig. 3). In the Early Holocene, the contribution of spruce pollen was below 1%. The highest contribution in the Early Holocene pollenwas by *Corylus*. The frequency of its pollen reached a maximum of 45% (at a depth of 620 cm). The second predominating tree from approximately 9400 cal. BP was *Alnus*. The maximum contribution of *Alnus* at a depth of 590 cm amounted to 26%.

Table 1. Radiocarbon dates.

Site [depth (cm)]	Lab. no.	Age (^{14}C date, BP)	Calibrated range 95.4% (cal BP)	Dated material
VI [614.5–615.5]	Poz-37191	8430 ± 50	9533–9308	bud scales of trees
VI [660–662]	Poz-38708	8890 ± 50	10191–9781	unidentified wood
XI [436.5–439]	Poz-38709	8230 ± 50	9400–9028	fruits of *Betula* sp. and needles of *Pinus sylvestris*
XI [492.5]	Poz-38710	8490 ± 50	9542–9438	nut of *Corylus avellana*

Site XI

At site XI, the share of *Picea* pollen was less than 1% (Fig. 3). The predominating component was *Corylus*, with the highest occurrence amounting to approximately 34% (at a depth of 480 cm). At the initial stage of expansion of *Alnus* at this site, its maximum contribution was 19.5% (at a depth of 430 cm).

Macrofossils

Site VIII (Fig. 4)

Needles and bud scales of *Picea abies* were found in the uppermost peat layer deposited on the mineral bedrock and in detritus gyttja. Macrofossils of the following trees were present: *Betula pubescens*, *Pinus sylvestris*, and *Tilia* sp. The peat layer contained the fruits of *Carex* (zone VIII-1). *Cladium mariscus* and *Typha* sp. fossils were recorded in the bottom part of the gyttja layer, determining the period of shallow water. The period of existence of the lake is confirmed by the presence of macrofossils of the aquatic species *Nymphaea alba*, *Nuphar lutea*, and *Najas marina* (zone VIII-2).

Site XI (Fig. 5)

Picea abies fossils (needles, bud scales, and seeds) occurred in the peat deposit (at a depth of 457–468 cm) and at the bottom of the gyttja layer (only needles); a *Corylus avellana* nut was found at the bottom of the peat layer (zone XI-1). *Pinus* sylvestris needles were numerous at a depth of 480 and 479 cm (up to 40). The peat layer developed with a contribution of *Menyanthes trifoliata* and brown mosses. The uppermost layer was dominated by *Sphagnum teres*. The limnic sediments contained the seeds of *Nymphaea alba* and *Cladium mariscus* (zone XI-2) in addition to other seeds.

Site XII (Fig. 5)

The presence of *Picea abies* was confirmed by the occurrence of needles in peat (zone XII-2 and XII-3), and fossils of *Betula pubescens*, *Pinus sylvestris*, and *Tilia* sp. were found. The peat layer developed with the main contribution of *Sphagnum teres* (zone XII-1) and *Sphagnum* sect. *Sphagna* and sect. *Cuspidata* (zone XII-2). Brown mosses also participated in the peat-forming process. The occurrence of *Paludella squarrosa* (zone XII-1) in addition to *Tomentypnum nitens* and *Calliergon stramineum* (zone XII-2) was determined. *Oxycoccus palustris* (zone XII-2) also occurred on the peatland. In the uppermost peat layer, *Cladium mariscus* was represented very abundantly and may constitute evidence of an increase in the habitat's humidity. At a depth of 448 cm, 60 seeds of *Cladium mariscus* (zone XII-3) were found, and the gyttja layer contained the seeds of *Najas marina*, oospores of *Chara* sp., and single seeds of *Cladium mariscus* and *Typha* sp. (zone XII-4).

Discussion

In NE Poland, the first plants occurred after the retreat of the Scandinavian ice sheet, that took place approximately 14 600 cal. BP (Rinterknecht *et al*. 2006). The surfaces of moraines and outwash plains, composed of postglacial tills, gravels, and boulders, were colonized by, among others, *Betula nana*, *Artemisia*, *Juniperus*, and shrubby *Salix*. During the first stage, *Hippophae rhamnoides*, *Helianthemum*, and *Selaginella selaginoides* were also present (Kupryjanowicz 2007, Lauterbach *et al*. 2011, Gałka *et al*. 2013). These plants are resistant to severe climatic conditions and prefer open, sunlit surfaces (Piękoś-Mirkowa & Mirek 2003).

In lakes, the first taxa to appear were *Batrachium* sp., *Potamogeton filiformis*, and *Chara* sp. (Gałka & Sznel 2013), i.e., pioneer species typical of the waterbodies in the area previously occupied by the ice sheet (Fredskild 1992, Birks 2000, Amon *et al*. 2010, Mortensen *et al*. 2011). The migration of trees to the area was possible due to the warming climate and improvement of the soil conditions in the Bølling-Allerød interstadial (Wacnik 2009, Mortensen *et al*. 2011), and the first to appear were *Betula pubescens* and *Pinus sylvestris*. Their macrofossils were recorded in the limnic sediments of the waterbodies in the vicinity of Lake Hańcza (Gałka

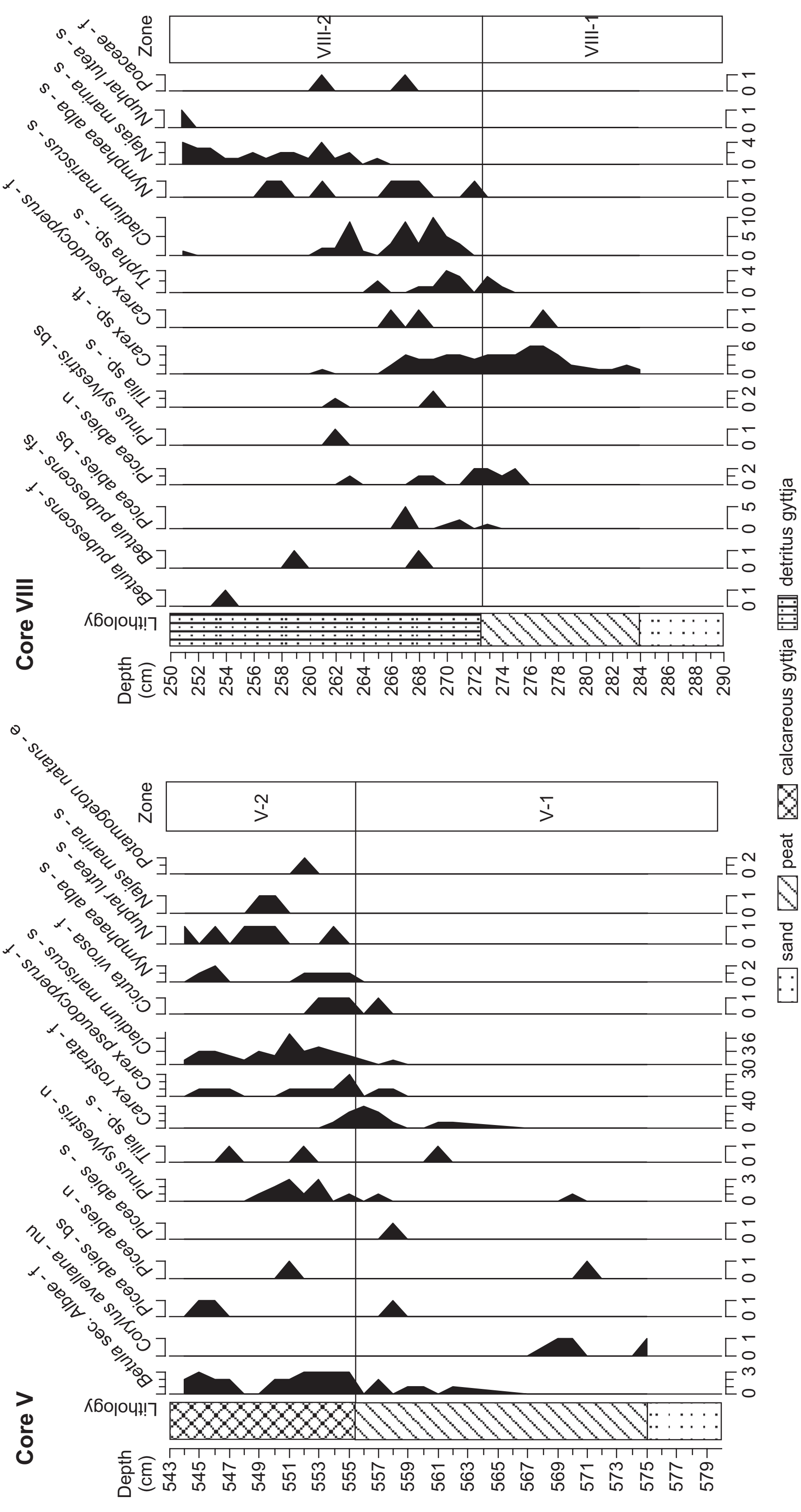

Fig. 4. Diagrams of plant macrofossils illustrating local vegetation changes in the peatland and lakes adjacent to core V (Gałka 2012, selected curves) and VIII. Abbreviations of plant remains: f = fruit, s = seed, oos = oospore, e = endocarp, r = rootlets, n = needle, fs = fruit scale, bs = bud scale, l = leaf, epi = epidermis.

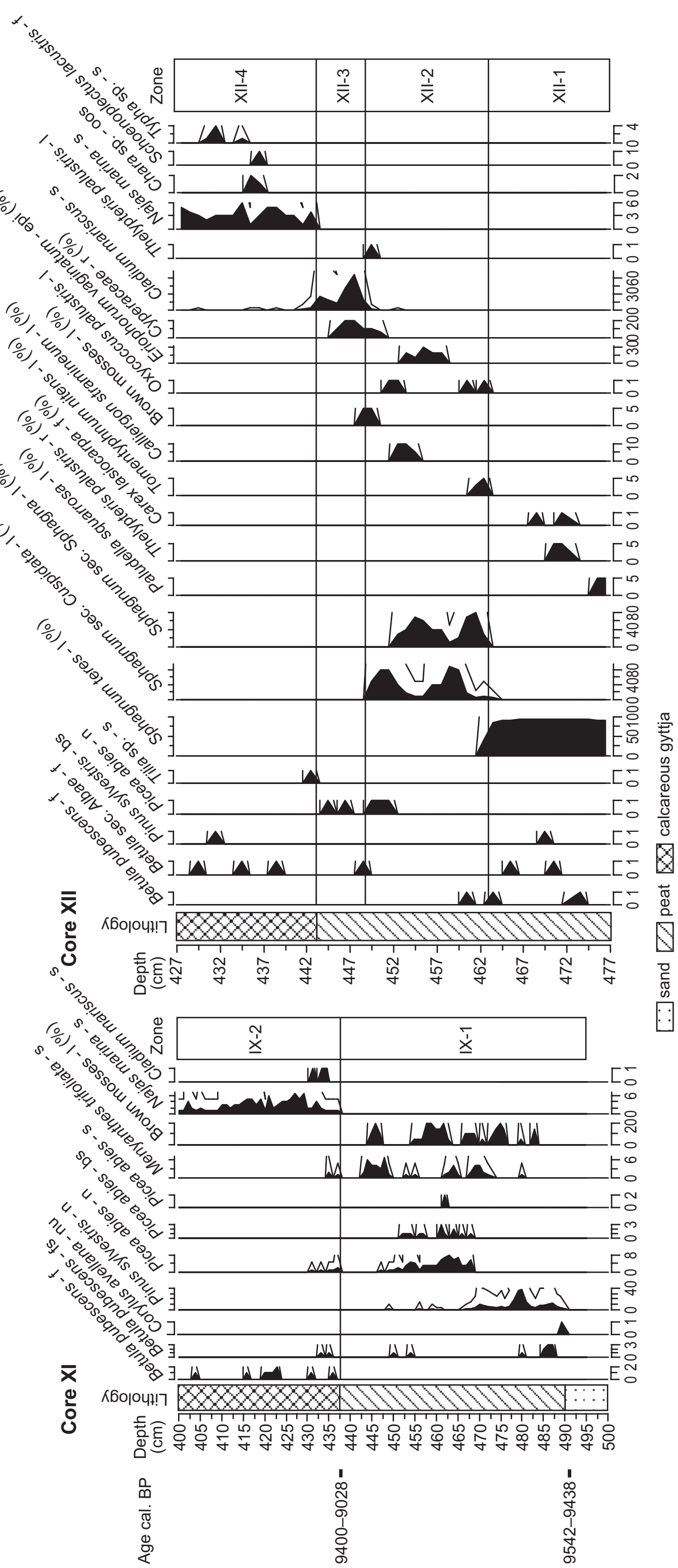

Fig. 5. Diagrams of plant macrofossils illustrating local vegetation changes in the peatlands and lakes adjacent to core XI (selected curves) and XII. Abbreviations of plant remains as in Fig. 3.

& Sznel 2013), in Lake Linówek (Gałka *et al*. 2013), and in the south-western part of Lake Kojle (M. Gałka unpubl. data).

Norway spruce expanded in the area of Poland from two centres: the Carpathian and W Russia centres (Środoń & Tobolski 2007). The expansion of this forest-forming tree in Poland started during the Vistulian Late Glacial in the Carpathian centre (Obidowicz *et al*. 2004), and, according to these authors, its contribution amounted to approximately 10% of the pollen spectra at the turn of the Early Holocene (in the period 11 500–10 700 cal. BP) in the Bieszczady Mountains. Based on the publication of isopollen maps by Rybniček and Rybniková (2002), the contribution reached as much as 20% in the neighbouring Orava (Slovakia).

The results of palynological analyses suggest that *Picea abies* was already present in NE Poland during the Late Glacial. According to Kupryjanowicz and Jurochnik (2009), Norway spruce was present within the area of Lake Wigry from approximately 11 600 cal. BC to approximately 10 500 cal. BC. The pollen curve of the *Picea abies* type during that period ranged from 0.2% to 1.0%, and itscontribution was below 1% at the Hańcza site (approximately 5 km from Lake Kojle; Lauterbach *et al*. 2011). A similar contribution of *P. abies* was recorded for the Lake Linówek site (approximately 7 km from Lake Kojle; M. Gałka unpubl. data). However, despite such a low contribution of Norway spruce, the data may suggest its presence in the area; according to the findings, a *P. abies* contribution of approximately 0.6%–1.0% proves its presence in the vicinity of the study site (Środoń 1967, Giesecke & Bennett 2004, Latałowa & van der Knaap 2006). Nevertheless, because the presence of *Picea* was not confirmed based on macroscopic fossils, it is difficult to unequivocally determine its presence in NE Poland during the Late Glacial. The nearest macroscopically documented site with spruce in the Late Glacial is located in Lithuania, and the presence of *Picea* sp. confirmed by a macroscopic finding (seed) and palynological data was determined for SE Lithuania in the Allerød period (Stančikaitė *et al*. 1998). During the Younger Dryas and Early Holocene (approximately 11 507–10 790 cal. BP), *P. abies* expanded to the north and west of Lithuania, as evidenced by macroremains and pollen (Stančikaitė *et al*. 2008, 2009, Gaidamavičius *et al*. 2011). Segerström and von Stedingk (2003) and Giesecke and Bennett (2004) mentioned a rapid Early Holocene expansion of spruce from Belarus and north Russia to the area of Fennoscandia. Such a rapid expansion of *P. abies* in NE Europe may be related to the glacial refuge of the species in Russia and to the two other refuges: the Carpathian and the south-Alpine (Lang 1994).

Based on the abundant presence of needles, bud scales, and seeds, our findings confirm the presence of *P. abies* in the Early Holocene in NE Poland in the vicinity of lakes Kojle and Perty, making this site the westernmost early-Holocene plant macrofossil finding of *P. abies* in central Europe. According to radiocarbon dating, *P. abies* grew at the study site approximately 9500–9000 cal. BP. Considering the direction and time of expansion of Norway spruce in eastern Europe, as determined by Latałowa and van der Knaap (2006), our finding contributes to the knowledge on the presence of *P. abies* in this part of Europe.

Picea abies grew on a peatland developed on a mineral peninsula between lakes Kojle and Perty and could also occur along the shores of the lakes. *Pinus sylvestris*, *Betula pubescens*, *Corylus avellana* and *Tilia* sp. (most likely *T. cordata*) also occurred in addition to Norway spruce. *Corylus avellana* appeared in the area approximately 10 200 cal. BP, as confirmed by macroscopic (nuts) and palynological analyses (Figs. 3–5), whereas *Tilia* appeared later, approximately 9 200 cal. BP (Lauterbach *et al*. 2011, Gałka unpubl. data).

Picea abies in the study area grew in the vicinity of lakes and on acidic peatland (occurrence of *Sphagnum* mosses), which was undoubtedly favorable for a species that prefers humid soils (Giesecke & Bennett 2004). *Picea abies* also grows on peat, developing a *Sphagno girgensohnii-Piceetum* complex, in NE Poland today (Matuszkiewicz 2001).

The direct cause of its disappearance at the site was an increase in the water level in Lake Kojle–Perty. The peatland colonized by Norway spruce and other trees got submerged, which is clearly visible in the change of sediment. Calcareous gyttjas started to accumulate on peat since approximately 9400 cal. BP (Figs. 2–5). An increase in water level and a change of the habitat from peatland to lake is visible through the appearance of typically aquatic taxa, such as *Najas marina*, *Nuphar lutea*, *Nymphaea alba*, and *Chara* sp. (Figs. 4 and 5). A gradual increase in water level is suggested by the presence of rush vegetation (*Cladium mariscus, Typha* sp., *Cicuta virosa*), which appeared on the partially inundated peatland and later grew in shallow water. The common presence of *Cladium mariscus* is particularly worth mentioning, as that species was one of the first plants to colonize the inundated surface of peatlands.

The increase of water level in the lakes resulted from a radical climate change (increase of the climate humidity) in this part of Europe, occurring between 10 000 and 9000 cal. BP. The climate was rather continental and dry until approximately 9500 cal. BP, yet humid masses of warm and oceanic air intruded after the melting of the ice sheet in Scandinavia (Lauterbach *et al*. 2011). This clearly changed the conditions for plant species. Substantial humidification and further warming of the climate permitted the expansion to the area of plants with higher humidity and temperature requirements. Several species, including *Cladium mariscus* (Meusel *et al*. 1965), *Carex pseudocyperus* (Brinkkemper *et al*. 1987), and *Najas marina* (Bennike *et al*. 2001) considered to be indicators of warm climate appeared, and their current occurrence in Europe suggests their clear preference for an oceanic climate. *Alnus glutinosa* also appeared, and its occurrence in east Europe is substantially limited by the humidity factor (Claessens *et al*. 2010).

The climate changes occurring after 9500 cal. BP suggest that the environmental conditions for Norway spruce were deteriorating. The factors limiting the occurrence of *P. abies* in this part of Europe in the Early Holocene include climate changes and also the disappearance of habitats as a result of higher water tables. *Picea abies*, as a typical continental species, is clearly adapted to a colder climate. The northern limit is in the arctic, just north of 70°N in Fennoscandia (Hultén & Fries 1986). *Picea abies* could not compete with thermophilic trees like *Ulmus, Tilia*, and *Quercus*, which began their dynamic expansion in the area. According to Hoffmann *et al*. (1998), the presence of *Corylus avellana* evidences that the mean temperature of July during that time was 15 °C or higher. Even higher temperatures are suggested by the presence of *Cladium mariscus*: its occurrence indicates a mean minimum July temperature of approximately 16 °C, and a mean minimum January temperature of approximately –4 °C (Wasylikowa 1964). The present occurrence of *C. mariscus* in Latvia, where the eastern boundary of its occurrence is located, is limited to areas where the mean July temperature does not fall below 16.5 °C (Salmina 2004).

The presence of *P. abies* in the area for the remaining part of the Holocene is still an open issue. A massive expansion of *P. abies* in the Suwalski Landscape Park area occurred at approximately 4300 cal. BP (Lauterbach *et al*. 2011, Gałka *et al*. 2013) and was correlated with a substantial climate cooling in NE Europe from approximately 4500 cal. BP on (Heikkilä & Seppä 2003, Seppä & Poska 2004). The mass occurrence of spruce from 4300 cal. BP in the area is confirmed by palynological data and numerous macrofossil findings. At another site in the Suwalski Landscape Park, namely Lake Linówek, an increase in *P. abies* pollen was recorded during that time (approx. 4300 cal. BP) from approximately 1% to 7%, in addition to numerous needles, scales, and seeds (Gałka *et al*. 2013). However, the spruce macrofossils at the Lake Perty and Lake Purwin (approx. 1 km north of Lake Kojle-Perty) were of older age. The age of the *P. abies* needles found in peat on the western shore of Lake Perty was estimated to be 5211–4859 cal. BP (M. Gałka unpubl. data), and the age of bud scales in gyttja at Lake Purwin to be 4959–4646 cal. BP (M. Gałka unpubl. data). In the deposits of the Stare Biele peatland between the Sokołda and Słoja Rivers in the Knyszyńska Forest (approximately 120 km north of our site), the age of Norway spruce needles was dated at approximately 5000 cal. BP (Marek 2000, Kupryjanowicz 2000). Based on the results of the palynological analyses and the curves of the Holocene contribution of *P. abies* from the studied sites, Linówek (Gałka *et al*. 2013), Hańcza (Lauterbach *et al*. 2011), and Wigry (Kupryjanowicz 2007), it appears that *P.*

abies could exist in local isolated islands in the area. Nevertheless, its presence remains uncertain due to the lack of macroscopic findings.

The presence of *P. abies* macrofossils (needles, bud scales, and seeds) in sediments between lakes Kojle and Party proves that Norway spruce was present in NE Poland in the Early Holocene (approximately 9400 cal. BP. Previously, the westernmost known Early Holocene presence of *P. abies* was in west Lithuania.

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