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Flora and vegetation changes on the basis of plant macroremains analysis from an early Pleistocene lake of the Augustów Plain, NE Poland

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ABSTRACT. Lacustrine and fluvio-lacustrine organic sediments from profiles of Czarnucha and Żarnowo (NE Poland) were examined by means of the analysis of plant macroremains. Succession of plant macroremains is conformable with the results of previous palynological studies of profiles indicating that the examined lacustrine series was formed in the Augustovian interglacial (=Bavelian Complex or Cromerian I) and bears a record of warm and cold periods of the interglacial, as well as of periods associated with the Narevian and Nidanian glaciations. A detailed analysis of selected plant macroremains showed the occurrence of several taxa being good indicators of changes of climatic and edaphic conditions. Over ten species were identified as extinct or not nowadays found in the area of Poland.

In diagrams of plant macroremains, the Local Macrofossil Assemblage Zones were distinguished, marked by the occurrence or increase in the number of taxa of a significant quantitative or indicatory value. The taxonomic composition of distinguished zones provided a basis for the reconstruction of the development of vegetation in the basin and its closest surroundings, as well as of changes in climate and fluctuations in water level and trophy.

The presence of macroscopic plant remains with particular climatic requirements, confirms the occurrence of warm and cold periods. Warm periods were marked by the presence of megaspores of *Azolla filiculoides* and *Salvinia natans*, fragments of fruits and spines of *Euryale* cf. *ferox* and *Trapa natans*, as well as fruits of *Scirpus atroviroides* and *Carpinus betulus*. Cold periods were characterized by the appearance of e.g. *Betula nana* and *Selaginella selaginoides*. Both profiles are characterized by an abundant occurrence of species withstanding an increased amount of NaCl in the environment.

KEYWORDS: macroremains of plants, Early Pleistocene, Augustovian interglacial, Augustów Plain, NE Poland

CONTENTS

INTRODUCTION

Lower Pleistocene sediments from the Augustów Plain have been investigated for several years by numerous researchers, both geologists (Ber 1996a, 2000, 2005, Krzywicki 1995, 1998) and palaeobotanists (Janczyk-Kopikowa 1996, 2009, Winter 1998, 2008, 2009, Winter & Janczyk-Kopikowa 2006, Stachowicz-Rybka 2007, 2009). Biogenic Quaternary sediments, found between strata of till, are infrequent in the Pleistocene of Poland. Geologic and cartographic survey, conducted in the 1990s by the Polish Geological Institute in its works on map sheets of the Detailed Geological Map of Poland at a scale of 1:50 000 (Ber 1997, 1998, 2009, Krzywicki 1995, Kacprzak & Lisicki 1999, 2000, Ber & Włodek 2001, Ber et al. 2002), provided many new materials for palaeobotanical and lithological-petrographic studies as well as other data on the Pleistocene of north-eastern Poland (Janczyk-Kopikowa 1996, Ber 1996a, 2000, Lisicki 2003, Winter & Lisicki 2005).

Several full-drillcore boreholes, penetrating the Quaternary sediments and reaching the Tertiary and older deposits, were drilled on the Augustów Plain at sites of Szczebra, Kalejty, Sucha Wieś, Janówka, Komorniki, Zielone Królewskie, Gawrych Ruda, and Domuraty. Lower parts of the sediments beared thick lacustrine and boggy sediments, underlayed by till, directly overlying sediments of an older bed-rock.

Results of detailed palynological analyses performed on these organic lacustrine series in profiles from Szczebra (Janczyk-Kopikowa 1996) enabled the assignment of the sediments to an interglacial stage, named as the Augustovian, from the area of its occurrence. In the Augustovian interglacial, two climatic optima, a cooler first one and a warmer second one, related to different climatic ranks, were distinguished. Initially, Janczyk-Kopikowa (1996) correlated the younger warm period with the Pastonian stage, distinguished by West (1980a, b) in England, and with the Cromerian IV stage, distinguished in the Netherlands by Zagwijn (1985, 1996). At present, on the basis of both palaeobotanical and palaeomagnetic studies, confirming the occurrence of the Brunhes-Matuyama boundary in profiles from Szczebra and Czarnucha at the depth of 112.8 m (Nawrocki 1997, 2009), the age of sediments is related to the Marine Isotope Stage 21. The top parts of the Augustovian succession should be correlated with the Cromerian I (Waardenburg), according to the Dutch stratigraphy (Zagwijn 1996), while its basal parts – with the Bavelian Complex (Ber et al. 2009).

In Eastern Europe, the three climatic periods of the Augustovian are likely to correspond to the middle and upper period of the Belorussian Rogachevian complex. In Belarus, the Korchevian interglacial is considered the oldest one (Velichkevich et al. 2001, Yelowicheva 2009). However, it is rather of an interstadial type and is likely to be an equivalent of the Domuraty interstadial. According to Mamakowa and Ryłowa (2007), the Korchevian succession represents the Mogilevian (=Ferdynandovian 1) interglacial, however, its correlation with the Augustovian I cannot be excluded.

In Ukraine, this stratigraphic position comprises the middle and younger fossil soils of the Shirokino complex 2 and 3, separated by a readable gap in pedogenic processes (Lindner et al. 2004).

Palynologically documented Augustovian strata, found on the Augustów Plain, were recorded at the sites of Szczebra (Janczyk-Kopikowa 1996), Kalejty (Winter 2001), Janówka, Sucha Wieś (Ber et al. 2002), Komorniki (Khursevich et al. 2004), Czarnucha (Lisicki & Winter 2005, Winter 2009), Żarnowo (Winter & Janczyk-Kopikowa 2006, Winter 2009), and on the Suwałki Lakeland at the site of Zielone Królewskie (Janczyk-Kopikowa 1995). The most complete pollen succession of this interglacial is recorded in profiles of Kalejty and Żarnowo (Winter 2001, 2009). It is more complete than the succession of Szczebra, formerly considered as stratotypical (Ber 1996a, b, 2000, Ber et al. 1998, Janczyk-Kopikowa 1996, Nitychoruk et al. 2000, Winter 2001).

Following Krzywicki (1998), the mineral sediments of the Augustovian interglacial are also found in the profiles of Ateny, Blizna and Małowiste.

According to results of palynological studies of lacustrine sediments of the Augustovian interglacial (Janczyk-Kopikowa 1996, Winter 2001, 2003), the sediments represent two warm climatic periods at the rank of interglacials: an older one, denoted as the Augustovian I, and a younger one, denoted as the Augustovian II, separated by a cooling – the Augustovian I/II (Lindner et al. 2004). According to the outline of palynostratigraphy, Mamakowa (2003) assumes that the Augustovian succession represents two distinct interglacials: interglacial 1 (older) and interglacial 2 (younger), separated by a cold fluctuation, which is marked by the development of steppe-like and tundra communities, and therefore could be ranked as a glaciation-stadial. Such a conception of division was based on palynological data from the profile of Kalejty, located close to Augustów and studied by Winter (2001).

According to the stratigraphic scheme for north-eastern Poland, sediments of the Augustovian interglacial in the Augustów Plain are overlain by the succession of Domuraty (Winter & Lisicki 2005), correlated with an interstadial in the Sanian 1 glaciation or between the Nidanian and Sanian glaciations, which corresponds with the Malopolanian interglacial (Lindner 1992, Lindner et al. 2004). Although the succession is discontinuous, its characteristic features enable its distinction from other long pollen sequences of Poland – the Augustovian and Ferdynandovian succession.

Sediments of the Mazovian interglacial were palynologically documented in profiles of Augustów (Borówko-Dłużakowa 1972), Gawrych Ruda (Janczyk-Kopikowa 1995) and Krzyżewo (Janczyk-Kopikowa 1996) at the Ełk Lakeland. The site of Gawrych Ruda is worth particular consideration, due to the record of three series of lacustrine organic sediments, one of which was associated with the close of the second warm period of the Augustovian interglacial, and the remaining two – with the Mazovian interglacial (Janczyk-Kopikowa 1996).

Up to now, no organic deposits with a palaeobotanical record of the Eemian interglacial were found in the Augustów Plain. However, lacustrine sediments representing this interglacial are described from three sites located in the Suwałki Lakeland: Szwajcaria (Borówko-Dłużakowa & Halicki 1957, Ber 1973a), Błaskowizna (Borówko-Dłużakowa 1965, 1966, Ber 1973b), and Smolniki (Andrzejeszczak 1971, Borówko-Dłużakowa 1971). They sedimented in small lakes and hollows of glacier uplands in the period of the Wartanian glaciation.

Considering the area of the Augustów Plain and the Biebrza River valley, numerous papers discussed the development of present day peats (Świt 1991) and investigations on the genesis of peat bogs in the Augustovian Sandur and the Biebrza ice-marginal valley (Żurek 1975, 1984, 1991).

The aim of this thesis was to reconstruct the flora and succession of vegetation in lacustrine and swamp communities of a Lower-Pleistocene basin, as well as in communities of its closest surrounding, on the basis of a detailed analysis of plant macroremains from both profiles.

STUDY AREA

LOCATION OF THE INVESTIGATED SITES

The borehole in Czarnucha was drilled 4.5 km to the south-east of Augustów and 1.5 km to the south of Lake Sajno, while the borehole in Żarnowo was drilled 6 km to the south-west of Augustów. The boreholes are at a distance of 15 km in straight line from each other (Fig. 1).

Both drillings are located in the macroregion of the Lithuanian Lakeland, mesoregion of the Augustów Plain, and microregion of the Augustovian Hills, where sands are accompanied by outcrops of till and peaty thaw lakes (Kondracki 2000).

GEOMORPHOLOGY OF THE STUDY AREA

The Augustów Plain is an extensive area, with a poorly diversified morphology of a sandur surface extending from the vicinity of Suwałki, at the height of ca 190 m, and declining to ca 120 m in the area of Augustów. From the north, the sandur borders on the moraines of the East Suwałki Lakeland, from the west – the West Suwałki Lakeland, and from the south – the Biebrza Basin. In Poland, it covers the area of ca 1170 km^2 (Kondracki 2000).

The northern part of the plain was formed by waters of a melting ice-sheet of the Leszno-Pomeranian stadial of the Vistulian glaciation, while the central and southern part bears fluvioglacial sediments accompanied by limnoglacial sediments: fine-grained silty sand and ice-dammed sediments. The monotonous landscape is enhanced by "islands" of a small area but diversified landform (kames, eskers

Fig. 1. Location of the investigated sites and other localities of the Augustovian interglacial

and drumlins) originating from the Leszno-Pomeranian stadial and most likely also from older stadials of the Vistulian glaciation (Ber 1996a).

Geological studies revealed, that in Pleistocene the Augustów Plain was a low in which fluvioglacial sedimentation occurring in shallow basins was the dominant process. Landform features of the Augustów Plain were also determined by the geological structure of its older bed-rock and, to a smaller extent, by accumulatation and glacitectonic activity of the ice-sheet in the Leszno-Pomeranian stadial (Krzywicki & Lisicki 1993, Ber 1989, 2000, 2009).

GEOLOGICAL DESCRIPTION OF THE EXAMINED PROFILES

Lacustrine sediments examined from both profiles directly overlie the till of the Narevian glaciation and are overlain by sediments of the Nidanian glaciation. (Kacprzak & Lisicki 1999, Ber & Włodek 2001). In the Czarnucha profile, the tills of the Narevian glaciation appear to belong to two complexes, however, they actually represent only one thrust of the ice-sheet, 7.5 m in thickness, and are correlated with the younger thrust (Gronkowska-Krystek 2000). The sediments overlie Lower-Palaeocene deposits developed as grey quartz-glauconite limy sandstones, overlying greenish-grey sandy marls bearing glauconite and fauna.

Lacustrine and fluvial, boggy sediments, 32.1 m in thickness, overlying the deposits of the Narevian glaciation and associated with the Augustovian interglacial, bear a 2.5 m thick ice-dammed (interstadial) series in their basal part. The series of lacustrine sediments is overlain by till, 1.4 m in thickness and representing the Nidanian glaciation. Overlying interstadial sediments are likely to represent a fragment of lacustrine sediments of the Domuraty series.

Large amounts of sandy sediments found in Czarnucha profile indicate its origin from a littoral zone of an extensive basin, in which the sandy material, fluvial or deltaic, was accumulated in cooler periods. Periodically, the basin was overgrown and peat beds were formed (Ber 2009).

In the profile from Czarnucha, according to Kacprzak and Lisicki (1999), the till of the Nidanian glaciation is overlain by five strata of tills representing three glaciations: Odranian (1 stratum), Wartanian (2 strata) and Vistulian (2 strata). Particular glacial strata are separated mainly by fluvioglacial sediments.

In the Żarnowo profile, sediments of the Narevian glaciation are 2.5 m in thickness and overlie glauconite sand, clay, rock and marl of the Upper Eocene.

Tills of the Narevian glaciation are overlain by organic lacustrine sediments, 33 m in thickness. Their sedimentation was likely to occur in the same extensive lacustrine-boggy basin marked by periodic flows. Temporarily, the environment of the basin could have been reducing due to a high concentration of sulphides.

Interglacial sediments are overlain by tills of the Nidanian glaciation. In the profile from Żarnowo, the till of the Nidanian glaciation is overlain by a bed of silty-clayey sediments, associated with the Ferdynandovian interglacial. It is overlain by a till of the Sanian 2 glaciation, fluvial sand associated with the Mazovian interglacial, and eventually – by a till of the Liviecian glaciation. Subsequent beds are represented by sediments bearing sandy silt, fluvioglacial sand, clay and loam of the Odranian, Wartanian, and Vistulian glaciations (Gronkowska-Krystek 2000).

PRESENT DAY CLIMATE, SOIL AND VEGETATION

According to records from meteorological stations in Suwałki and Sejny, the area of the Augustów Plain is controlled by the most continental-like climatic conditions in Poland. This area, in comparison with the other parts of Poland, shows the greatest number of frosty days, with a mean daily temperature below –15°C., On the average 4 very frosty and 34 quite frosty, and 23 hot days, with a maximum temperature of 25–30°C, are recorded in a year. In comparison with other parts of Poland, the region is marked by the maximum number of days with a quite frosty weather and a heavy cloud cover. The mean January temperature in Suwałki in the period of 1951–1980 amounted to –5.3°C, while the mean July temperature – to 16.9°C (Woś 1999).

The mean annual rainfall in the period of 1951–1980 amounted to 578 mm, 358 mm of which fell in the vegetation period, lasting only 180–190 days (Woś 1995).

In the Suwałki Region, spring begins three weeks later than in the south-west Poland, that is ca at the 11[th] of March. Thermic summer begins in the first ten days of June and lasts for 2.5–3 months. Mean annual temperature amounts to ca 6°C on average, however, it frequently fluctuates (e.g. –5.2°C in 1997 and –7,7°C in 1998). The annual amplitude of temperature is relatively high and attains ca 20°C.

Soils of the study area are diversified. The soil cover forms a complex of zonal podsols and brown soils. Lessive, semihydrogenic and hydrogenic soils (peaty, gyttia, and gley soil) occur occasionally.

Rusty soil and podsol, with sandur sand and boulder sand in bed-rock, are most abundant and cover nearly the entire surface of the Augustów Plain, from the Wigry Lake to Augustów.

The western part of the Augustów Plain is covered by brown soil, mainly with till (often marked by chalky xenoliths) and less frequently with loamy sands and clays in bedrock. Typical brown soils are frequently of a neutral reaction.

Lessive soil, found near the typical brown soils form small patches to the east of the Wigry Lake and to the south of Augustów. Their bed-rock bears till and sand overlying loam. Lessive soil, similarly as brown soil, are classified into soils of good quality.

Gyttja soil represent a specific type of soil developed from various post-lacustrine sediments (Uggla 1969a,b). They are typical of lakeland landscapes, form natural water retention reservoirs and affect the climate and water conditions of the surrounding areas. They are accompanied by peaty soil of low peat bogs which frequently become wastelands due to their drying up (Bednarek & Prusinkiewicz 1999).

According to the geobotanical regionalization of Poland (Szafer 1972) the investigated sites are located in the Augustów Landscape region, classified into the Suwałki-Augustów syntaxonomical region.

The most frequent forest habitat type of this region is the fresh mixed forest, found in large areas, less frequently forming patches in other habitats. It grows on soil developed from sand and fluvioglacial (sandur) gravel with fluvioglacial crust, as well as from accumulated moraine, esker, kame and boulder sand. Therefore, as forest overgrow various types of soil, different plant associations may be distinguished. The upper forest floor of the tree stand is formed by pine and *Picea*, accompanied by *Quercus* and occasionally by *Betula*, with an admixture of *Populus trmula*, *Tilia*, and *Carpinus*. The lower forest floor comprises mostly spruce accompanied by oak. Other trees occur singly and occasionally. The undergrowth is composed of *Euonymus europea*, *E. verrucosa*, *Rhamnus*, *Sambucus nigra*, *S. racemosa*, *Ribes alpinum*, *Pyrus*, *Crataegus*, *Viburnum*, and other taxa.

The second forest habitat type, when considering the frequency of occurrence, is the fresh mixed coniferous forest, found mostly in habitats covered by sand and fluvioglacial (sandur) gravel.

Alder tree stands occur mainly in the south part of the Puszcza Augustowska Forest (Augustów Primeval Forest). Alder forest found in poorer habitats and on peats are marked by an admixture of *Betula pubescens* and *Pinus*, while occurring in more rich habitats include also *Fraxinus* (Szafer 1972).

The very small proportion of pedunculate oak in more rich habitats, as well as the occurrence of *Tilia parvifolia*, instead of *Carpinus*, in oak-hornbeam forest, what is ecologically justified by the proximity of the range boundary of hornbeam occurence (Zaręba 1978), should also be taken into consideration

MATERIAL AND METHODS

Organic sediments from Czarnucha and Żarnowo, 32.1 and 33.0 m in thickness, respectively, were examined by means of analysis of macroscopic plant remains. Sampling conducted for the purposes of the analysis was, in both profiles, strictly correlated with sampling for pollen analysis. Material for the analysis of plant macroscopic remains was sampled from 10 cm long segments. Samples for pollen analysis were taken from the middle of these segments. In most cases, the analysis was conducted for every second sample. Depths of the samples taken for carpological studies are marked in diagrams.

From the Czarnucha profile, 128 samples were analysed, while from the Żarnowo profile 137. All samples were macerated with the use of 10% solution of KOH and detergents (in strongly compacted silts.) The sediment, always of a constant volume for a given site (Czarnucha 200 ml, Żarnowo 150 ml), was soaked in water for ca 24 h. and subsequently boiled with addition of KOH. After the sediment was boiled to a pulp, it was subjected to wet-sieving on a sieve with the meshes diameter of 0.2 mm. Material remaining on the sieve was sorted out under a binocular magnifying glass. All plant remains qualifying for identification were segregated with a fine brush and placed in a mixture of glycerine, water and ethyl alcohol in the ratio of 1:1:1, with an addition of thymol. Before determining, the remains were rinsed in a mixture of ethyl alcohol and water. For further storage, the determined material was dried and transferred to separate small "boxes".

The isolated plant remains: megaspores, seeds, fruits, fruit scales, needles, thorns, and other vegetative parts were, if the material was preserved in a sufficiently good condition, determined to the rank of species.

Qualitative and quantitative results of the identification are presented in diagrams showing the number of remains, grouped in 14 zones. In the diagrams, the determined taxa were categorized into the following groups: trees and shrubs, plants typical of fresh and humid habitats, plants of wet habitats, plants of boggy habitats, swamp plants, aquatic plants, and others. Within the groups, taxa were arranged in a stratigraphic order. The diagrams, in the form of histograms, were plotted with the POLPAL software for Windows (Walanus & Nalepka 1999). Local Macrofossil Assemblage Zones (L MAZ) were distinguished in the diagrams, on the basis of visual analysis.

The determined macroremains are stored in the Palaeobotanical Museum of the W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków, Poland.

LITHOLOGICAL PROFILE OF SEDIMENTS FROM CZARNUCHA

Depth [m]	Description of sediment
93.4–94.2	laminated sandy silt
94.2–95.4	fine-grained sand, locally silty and with thin humic intercalations
95.4–96.2	clayey silt bearing: gravel, 1.5-cm-diameter dropstones and plant detritus
96.2–96.4	fine-grained silty sand with fine clayey laminations
96.4–96.7	clayey silt with thin humic intercalations
96.7–96.9	peaty silt passing into peat
96.9–97.1	clayey silt with thin humic intercalations
97.1–98.1	sandy silt
98.1–98.3	fine-grained silty sand
98.3–98.9	sandy-clayey silt
98.9–99.0	clayey silt with plant detritus and remains of shells
99.0–99.1	silt with plant detritus and infrequent remains of shells
99.1–99.3	sandy silt with plant detritus and shells
99.3–99.7	silty sand with single grits
99.7–99.8	clayey silt with single mollusc shells and dispersed plant detritus
99.8–100.1	silt
100.1–100.4	sandy silt
100.4–101.0	clayey silt
101.0–102.4	sandy till, passing into sandy-clayey at the top
102.4–102.8	clayey silt with single shells
102.8–102.9	peat
102.9–103.1	sandy silt penetrated by plant matter including peat interbeddings
103.1–103.2	peat
103.2–103.4	sandy silt penetrated by organic matter
103.4–103.6	shiny dy
103.6–104.3	sandy silt with fine vivianite concretions and plant detritus
104.3–112.6	fine-grained sand and very fine sand, locally silty or laminated with clay
112.6–112.8	mixed-grained sand with silt interbeddings containing plant remains
112.8–113.8	clayey silt with vivianite, locally comprising accumulations of plant matter
113.8–114.0	silty sand
114.0–114.4	very fine sand with laminas of humic matter
114.4–114.7	clayey silt with an admixture of humic matter
114.8–114.9	peaty clay
114.9–115.0	peaty-sandy silt with a single occurrence of shell detritus
115.0–115.2	brown sandy silt with clusters of clayey silt with plant matter and mollusc shells
115.2–116.1	clayey-sandy silt with plant matter
116.1–116.5	clayey silt with accumulations of shells
116.5–117.1	clayey silt with accumulations of plant detritus
117.1–119.6	clayey silt, locally clayey-sandy silt; at the depth of 117.7–117.9 m accumulated remains of mollusc shells
119.6–120.7	sandy silt with plant detritus
120.7–121.0	peaty silt with mollusc shells at the basal part
121.0–123.3	silty sand
123.3–124.0	sandy silt
124.0–124.1	sandy silt with plant matter and shell detritus
124.1–124.3	peaty silt passing into peat
124.3–124.4	silt with peaty interbeddings
124.4–125.1	sandy silt
125.1–125.5	peaty sandy silt; the proportion of peat decreases towards the top of the layer
125.5–126.1	compacted peat
126.1–126.8	fine-grained sand
126.8– 28.1	fine-grained clayey sand
128.1–29.0	silty sand laminated with sand
129.0–130.35	sandy silt

LITHOLOGICAL PROFILE OF SEDIMENTS FROM ŻARNOWO

Depth [m]	Description of sediment
113.1–114.0	clayey-sandy silt with dispersed plant detritus
114.0–114.6	clayey-sandy silt
114.6–115.0	compact fine-grained sand with silty interbeddings
115.0–115.2	fine-grained silty sand
115.2–115.5	clayey silt with plant detritus
115.5–115.8	fine-grained silty sand
115.8–116.1	laminated clayey silt
116.1–116.3	slightly laminated silty sand
116.3-117.0	slightly laminated clayey silt

117.0–118.0	sandy silt, with peat locally developed, bearing detritus of plants and of mollusc shells
118.0–118.7	sandy-clayey silt laminated with peaty clayey silt
118.7–120.4	sandy-clayey silt typified by rusty marks and bearing precipitations of vivianite
120.4–121.1	clayey silt with dispersed plant matter
120.1–123.0	clayey silt with detritus of plants and of mollusc shells
123.0–123.8	clayey silt with detritus of mollusc shells and of plants
123.8–124.5	clayey silt
124.5–125.4	silty-sandy silt with a clay lamination with plant detritus and dropstones occurring in the upper part
125.4–125.6	silty clay with an admixture of sand, bearing detritus of plants and of mollusc shells
125.6–126.2	silty clay with very fine detritus of plants and of mollusc shells
126.5–127.0	clayey silt with detritus of plants and of mollusc shells
127.0–127.3	sandy silt with detritus of plants and of mollusc shells
127.3–127.7	detritus gyttja abundant in detritus of mollusc shells and of plants
127.7–128.0	clayey silt with detritus of plants and of mollusc shells
128.0–129.5	clayey silt with a slight admixture of sand and infrequent mollusc detritus
129.5–129.9	clayey silt with humic matter and detritus of mollusc shells
129.9–131.0	clayey silt with thick plant detritus and detritus of mollusc shells
131.0–131.4	sandy silt with detritus of mollusc shells; laminar stratification displayed at the basal part
126.2–126.5	peaty clayey silt with detritus of mollusc shells
131.4–131.9	fine-grained silty sand with infrequent occurrences of thick detritus of plants and of mollusc shells
131.9–132.4	sandy-clayey silt with detritus of mollusc shells
132.4–133.2	clayey silt with clusters of brown clay
133.2–134.9	clayey silt laminated with grey clay at the top
134.9–136.6	clayey silt with detritus of mollusc shells and of plants
136.6–137.6	detritus gyttja
137.6–138.0	fine-detritus, clayey-sandy gyttja
138.0–138.1	sandy silt with detritus of mollusc shells
138.1–139.1	peaty coarse-detritus gyttja
139.1–139.6	detritus gyttja with detritus of mollusc shells
139.6–140.0	silt with fine detritus of mollusc shells
140.0–140.3	highly compacted peat with silty interbeddings
140.3–140.6	peaty detritus gyttja with detritus of mollusc shells
140.6–140.9	humic sandy silt
140.9–141.5	humic, medium-grained silty sand with fragments of wood
141.5–142.8	mixed-grained silty sand with thick detritus of plants and of mollusc shells
142.8–143.4	gray, mixed-grained silty sand with thick detritus of plants and 10 mm diameter gravel

TAXONOMIC COMPOSITION OF FOSSIL PLANT REMAINS

Floras of Czarnucha and Żarnowo include taxa of higher plants, determined on the basis of seeds, fruits, megaspores, endocarps, wood and other remains, and comprising species nowadays found in the area of Poland and absent in the present day Polish flora, as well as extinct species.

From 128 samples studied from the Czarnucha profile, 156 taxa were identified, including 116 determined to the rank of species, 10 approximately to the rank of species (cf.), 30 to the rank of genus, 6 to the rank of section, and 3 to the rank of family. The identified species comprised 13 extinct ones and 7 species not found in the present day Polish flora, 5 of which were determined for the first time from the Pleistocene of Poland.

From 137 samples studied from the Żarnowo profile, 158 taxa were identified, including 119 determined to the rank of species, 10 approximately to the rank of species (cf.), 29 to the rank of genus, 5 to the rank of section, and 3 to the rank of family. The identified species comprised 15 extinct ones and 6 species not found in the present day Polish flora, 7 of which were determined for the first time from the Pleistocene of Poland.

Names of vascular plants determined in the investigated material follow mainly Mirek et al. (2002). In the taxonomical list (Tab. 1) families and species within families are arranged in an alphabetical order.

Macroscopic plant remains were identified with the use of keys, atlases (Beijerinck 1947, Berggren 1969, Kats et al. 1965, Nilsson & Hjelmquist 1967), and other studies and publications. However, the determining was based mainly on the reference collection of present day seeds and fruits and collections of fossil floras housed in the Department of Palaeobotany, W. Szafer Institute of Botany, Polish Academy of Sciences in Kraków.

Identification of endocarps of the genus *Potamogeton* and of other problematic taxa was carried out under the guidance of Prof. Dr. F. Yu. Velichkevich, at the Institute of Geological Sciences, National Academy of Sciences, Minsk, Belarus, and W. Szafer Institute of Botany, Polish Academy of Sciences in Kraków. The identification of *Carex* remains from the Czarnucha profile was verified by K. Rybniček, PhD, at the

Table 1. Taxonomic list of floras from Czarnucha and Żarnowo

List of used abbreviations: **s** – seed, **f** – fruit, **en** – endocarp, **mgs** – megaspore, **n** – needle, **ep** – epicarp, **ds** – dwarf shoot, **t** – tegmen, **c** – capsule, **th** – thorn, **sn** – spine, **pr** – perianth, **co** – cone, **fsc** – scale, **st** – sclerotia, **w** –wood, **ws** – wing of seed, **o** – oospore, **ssc** – seed scale, ⊗ – species not occurring in contemporare flora of Poland, † – extinct species

Taxa	CZARNUCHA		ŻARNOWO	
	Type of remains	Number of specimens	Type of remains	Number of specimens
CHAROPHYTA				
Characeae				
Chara sp. div.	**o**	249	**o**	944
MYCOTA				
Hyphomycetes				
Cenococcum geophilum Fr.	**st**	129	**st**	541
PTERIDOPHYTA				
Azollaceae				
⊗ *Azolla filiculoides* Lam. foss.	**mgs**	732	**mgs**	1552
Salviniaceae				
Salvinia natans (L.) All.	**mgs**	674	**mgs**	605
Selaginellaceae				
⊗ *Selaginella helvetica* (L.) Spring	**mgs**	11	**mgs**	27
Selaginella selaginoides (L.) P.Beauv. ex Schrank & Markt.	**mgs**	3	**mgs**	6
† *Selaginella* cf. *tetraedra* Wieliczk.	—	—	**mgs**	2
Selaginella sp.	—	—	**mgs**	2
SPERMATOPHYTA				
CONIFEROPHYTINA				
Pinaceae				
Abies sp.	**n / w**	2 / 2	**n / w**	1 / 2
Larix sp.	**n**	128	**s / n**	1 / 19
Picea sp.	s / n	1 / 9	**s / n**	1 / 2
Pinus sylvestris L.	**s / w**	1 / 6	**s / w**	5 / 8
Pinus sp.	**ds**	2	**n / ds**	9
Larix sp./ *Picea* sp.	**w**	2	**w**	7
Pinaceae undiff.	**n**	17	**n / co**	7 / 1
Cupressaceae				
Juniperus communis L.	**N / s**	1 / 1	**n / s**	1 / 1
MAGNOLIOPHYTINA				
Aceraceae				
Acer sp.	**ws**	1	—	—
Alismataceae				
Alisma plantago-aqatica L.	**s**	176	**s**	220
†*Alisma plantago-minimum* (Nikit.) Dorof. ex Wieliczk.	**s**	10	**s**	11
Sagittaria sagittifolia L.	**s**	22	**s**	19
Apiaceae				
Cicuta virosa L.	**f**	11	**f**	14
Oenanthe aqatica L.	**f**	282	**f**	202
Araceae				
Calla palustris L.	**f**	1	**f**	1
Asteraceae				
Bidens tripartita L.	**f**	42	**f**	45
Bidens sp.	**f**	1	**f**	5
Carduus crispus L.	**f**	2	**f**	3
Cirsium arvense L.	**f**	3	**f**	3
Eupatorium cannabinum L.	**f**	1	—	—
Senecio aquaticus L.	**f**	1	—	—
Senecio sp.	—	—	**f**	1
Asteraceae undiff.	**s**	47	**s**	39
Betulaceae				
Alnus glutinosa (L.) Gaertn.	**f**	31	**f**	32
Alnus incana (L.) Moench	**f**	7	**f**	8
Alnus cf. *incana* (L.) Moench	—	—	**f**	3
Alnus sp.	**f / co / w**	3 / 67 / 12	**f / co / w**	15 / 15 / 27

Table 1. Continued

Taxa	CZARNUCHA		ŻARNOWO	
	Type of remains	Number of specimens	Type of remains	Number of specimens
Betula sect. *Albae*	**f / fsc**	227 / 14	**f / fsc**	419 / 41
Betula humilis Schrank	**f / fsc**	37 / 9	**f / fsc**	64 / 11
Betula nana L.	**f / fsc**	24 /14	**f / fsc**	50 / 17
Betula cf. *nana* L.	—	—	**f**	8
Betula sp.	**f / fsc / w**	26 / 4 / 1	**f / fsc / w**	27 / 16 / 4
Carpinus betulus L.	—	—	**f**	2
Brassicaceae				
Rorippa palustris (L.) Besser	**s**	31	**s**	133
Brassicaceae undiff.	—	—	**s**	2
Callitrichaceae				
Callitriche sp.	**s**	25	**s**	187
Cannabaceae				
Humulus lupulus L.	**f**	2	**f**	3
Caprifoliaceae				
Sambucus nigra L.	—	—	**f**	2
Ceratophyllaceae				
Ceratophyllum demersum L.	**f**	6	**f**	25
Ceratophyllum sp.	—	—	**f**	3
Chenopodiaceae				
Chenopodium album L..	**s**	2	**s**	16
Chenopodium hybridum L.	**s**	7	**s**	120
Chenopodium polyspermum L.	**s**	18	**s**	61
Chenopodium sp.	**s**	18	**s**	44
Cyperaceae				
Carex acutiformis Ehrh.	**f**	4	—	—
†*Carex blysmoides* Dorof.	—	—	**f**	1
Carex canescens L.	**f**	7	—	—
Carex cf. *canescens* L.	**f**	5	—	—
Carex elata All.	**f**	103	**f**	4
Carex elongata L.	**f**	3	—	—
Carex gracilis Curtis	**f**	93	**f**	9
Carex cf. *gracilis* Curtis	**f**	3	—	—
Carex nigra Reichard	**f**	24	—	—
†*Carex paucifloroides* Wieliczk.	**f**	279	**f**	116
†*Carex* cf. *paucifloroides* Wieliczk.	—	—	**f**	1
Carex pseudocyperus L.	**f**	38	**f**	14
Carex riparia Curtis	**f**	7	—	—
Carex cf. *riparia* Curtis	**f**	1	—	—
Carex rostrata Stokes	**f**	80	—	—
Carex cf. *rostrata* Stokes	**f**	1	—	—
Carex sylvatica Huds.	**f**	6	—	—
Carex vesicaria L.	**f**	27	—	—
Carex cf. *vesicaria* L.	**f**	10	—	—
Carex sect. *Acutae*	**f**	49	—	—
Carex sect. *Flavae*	**f**	5	—	–8
Carex sp. div. 3-sided	**f**	220	**f**	248
Carex sp. div. 2-sided	**f**	1258	**f**	1219
Carex sp.	**f / ep**	53 / 14	**f / ep**	1/ 2
Cyperus fuscus L.	—	—	**f**	55
⊗ *Cyperus glomeratus* L.	**f**	174	**f**	82
Eleocharis acicularis (L.)Roem. & Schult.	**f**	4	**f**	6
Eleocharis palustris (L.) Roem. & Schult.	**f**	468	**f**	236
Eleocharis cf. *palustris* (L.) Roem. & Schult.	**f**	3	—	—
†*Eleocharis praemaximoviczii* Dorof.	**f**	24	**f**	116
Eleocharis sp.	**f**	3	—	—
Schoenoplectus lacustris (L.) Palla	**f**	136	**f**	224
Schoenoplectus tabernaemontani (C.C. Gmel.) Palla	**f**	4	**f**	1
Schoenoplectus sp.	**f**	3	—	—
Scirpus sylvaticus L.				

Table 1. Continued

Taxa	CZARNUCHA		ŻARNOWO	
	Type of remains	Number of specimens	Type of remains	Number of specimens
†*Scirpus atroviroides* Dorof.	**f**	270	**f**	226
†*Scirpus kreczetoviczii* Wieliczk.	**f**	26	—	—
Elatinaceae				
Elatine hydropiper L.emend. Oeder	**f**	68	**f**	149
†*Elatine hydropiperoides* Dorof. & Wieliczk.	**f**	6	**f**	104
Ericaceae				
Vaccinium uliginosum L.	—	—	**s**	1
Haloragaceae				
Myriophyllum spicatum L.	**en**	14	**en**	6
Myriophyllum cf. *spicatum* L.	**en**	1	**en**	2
Myriophyllum verticillatum L.	**en**	4	**en**	4
Myriophyllum sp.	**en**	1	**en**	1
Hippuridaceae				
Hippuris vulgaris L.	s	34	**s**	61
Hydrocharitaceae				
Hydrocharis morsus-ranae L.	**s**	3	**s**	9
Stratiotes aloides L.	—	—	**s**	2
†*Stratiotes brevispermus* Wieliczk.	—	—	**s**	1
†*Stratiotes* cf. *goretskyi* Wieliczk.	**s**	1	—	—
Stratiotes sp.	**s / sn**	7 / 86	**s / sn**	32 / 149
Iridaceae				
Iris pseudacorus L.	—	—	**s**	1
Juncaceae				
Juncus sp.	**s**	4	**s**	8
Juncaginaceae				
Triglochin maritimum L.	**f**	5	**f**	11
Lamiaceae				
Lycopus europaeus L.	**f**	75	**f**	71
†*Lycopus* sp. exot.	**f**	1	**f**	—
Lycopus sp.	**f**	2	**f**	2
Mentha aquatica L.	**f**	67	**f**	132
Stachys palustris L.	**f**	7	**f**	45
Stachys sp.	**f**	1	**f**	4
Lemnaceae				
Lemna minor L.	**s**	8	**s**	1
Lemna trisulca L.	**s**	54	**s**	74
Menyanthaceae				
Menyanthes trifoliata L.	**s**	159	**s**	101
Najadaceae				
Najas marina L.	**s**	17	**s**	46
Najas minor All.	**s**	27	**s**	186
⊗ *Najas tenuissima* (A.Br.)Magnus	**s**	1	—	—
Najas sp.	**s**	1	—	—
Nymphaeaceae				
⊗ *Euryale* sp.	**s/ sn**	8/1	**sn**	2
Nuphar sp.	—	—	**s**	1
Nymphaea cf. *alba* L.	**s**	10	**s**	12
†*Nymphaea cinerea* Wieliczk.	**s**	3	—	—
Plantaginaceae				
Plantago media L.	**s**	2	—	—
Poaceae				
Poaceae gen.div.	**s**	2	**s**	134
Polygonaceae				
Polygonum amphibium L.	—	—	**f**	1
Polygonum aviculare L.	**f**	2	**f**	1
Polygonum lapathifolium L.	**f**	18	**f**	9
Polygonum sp.	**f**	1	**f**	4
Rumex acetosa L.	f	1	—	—
Rumex hydrolapathum Huds.	**f**	1	—	—

Table 1. Continued

Taxa	CZARNUCHA		ŻARNOWO	
	Type of remains	Number of specimens	Type of remains	Number of specimens
Rumex maritimus L.	**f / pr**	113 / 205	**f / pr**	27 / 368
Rumex sp.	—	—	**f**	5
Potamogetonaceae				
Potamogeton crispus L.	**en**	4	**en**	4
Potamogeton cf. *crispus* L.	**en**	1	—	—
†*Potamogeton dvinensis* Wieliczk.	**en**	5	**en**	1
Potamogeton filiformis Pers.	**en**	6	**en**	6
Potamogeton friesii Rupr.	**en**	2	**en**	1
Potamogeton gramineus L.	**en**	41	**en**	18
Potamogeton lucens L.	**en**	1	—	—
Potamogeton natans L.	**en**	18	**en**	9
Potamogeton cf. *natans* L.	**en**	8	—	—
Potamogeton nodosus Poir.	**en**	6	**en**	5
Potamogeton panormitanus Biv.	**en**	14	**en**	19
†*Potamogeton panormitanoides* Dorof.	**en**	1	**en**	4
Potamogeton pectinatus L.	**en**	17	**en**	35
Potamogeton perfoliatus L.	**en**	13	**en**	29
†*Potamogeton perforatus* Wieliczk.	—	—	**en**	1
Potamogeton polygonifolius Pourr.	**en**	2	—	—
Potamogeton pusillus L.	**en**	5	**en**	69
Potamogeton rutilus Wolfg.	**en**	52	**en**	1
Potamogeton cf. *rutilus* Wolfg.	**en**	4	—	—
Potamogeton trichoides Cham. & Schltdl.	—	—	**en**	4
⊗ *Potamogeton vaginatus* Turcz.	**en**	2	**en**	7
⊗ *Potamogeton* cf. *vaginatus* Turcz.	—	—	**en**	1
Potamogeton sp. div.	**en**	83	**en**	73
Primulaceae				
Lysimachia thyrsiflora L.	—	—	**s**	1
Ranunculaceae				
Batrachium sp.	**f**	69	**f**	209
Caltha palustris L.	**f**	21	—	—
Ranunculus acris L.	—	—	**f**	1
Ranunculus flammula L.	**f**	36	**f**	12
†*Ranunculus gailensis* E.M. Reid	**f**	85	**f**	88
†*Ranunculus* cf. *gailensis* E.M. Reid	**f**	2	—	—
⊗ *Ranunculus gmelinii* DC.	**f**	1	**f**	8
Ranunculus lingua L.	**f**	11	**f**	51
Ranunculus repens L.	**f**	4	—	—
Ranunculus reptans L.	**f**	1	—	—
Ranunculus sceleratus L.	**f**	1506	**f**	1559
Ranunculus sp.	**f**	11	**f**	4
Thalictrum flavum L.	**f**	7	**f**	27
Thalictrum lucidum L.	**f**	2	**f**	7
Thalictrum minus L.	**f**	5	**f**	2
Thalictrum simplex L.	—	—	**f**	12
Thalictrum sp.	**f**	8	—	—
Rosaceae				
Comarum palustre L.	**s**	47	**s**	9
Filipendula ulmaria (L.) Maxim.	**s**	9	**s**	3
Filipendula sp.	—	—	**s**	1
Potentilla anserina L.	**s**	13	**s**	40
Potentilla supina L.	**s**	11	**s**	17
Potentilla sp.	**s**	60	**s**	88
Rubus idaeus L.	**s**	4	**s**	9
Rubus sp.	**s**	2	**s**	5
Salicaceae				
Salix sp.	**c / w**	41 / 48	**w**	41
Silenaceae				
Stellaria palustris Retz.	**f**	5	**f**	5

Table 1. Continued

Taxa	CZARNUCHA		ŻARNOWO	
	Type of remains	Number of specimens	Type of remains	Number of specimens
Silenaceae sp. div.	—	—	**f**	10
Solanaceae				
Solanum dulcamara L.	**f**	4	**f**	20
Solanum sp.	—	—	**f**	2
Sparganiaceae				
Sparganium emersum Rehmann	f	6	**f**	4
⊗ *Sparganium* cf. *hyperboreum* Laest.	**f**	1	—	—
Sparganium minimum Wallr.	**f**	4	**f**	2
Sparganium sp.	**f**	4	**f**	6
Trapaceae				
Trapa sp.	**f /th**	36/11	**th**	2
Typhaceae				
†*Typha aspera* Dorof.	—	—	**t**	30
Typha sp.	**t**	511	**t**	413
Urticaceae				
Urtica dioica L.	**f**	436	**f**	2021
⊗*Urtica* cf. *laetevirens* Maxim.	**f**	7	**f**	52
†*Urtica* cf. *thunbergiana* Siebold & Zucc.	—	—	**f**	31
Urtica sp.	**f**	1	—	—
Valerianaceae				
Valeriana officinalis L.	**f**	3	—	—
Violaceae				
Viola palustris L.	**s**	2	**s**	2
Viola sp.	**s**	2	**s**	2
Zannichelliaceae				
Zannichellia palustris L.	**s**	334	**s**	2029

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REMARKS ON SELECTED SPECIES

The detailed analysis of plant macroremains from both sites revealed that most of the determined taxa are known from Polish Pleistocene floras or are nowadays cosmopolitan. The list of determined taxa includs: extinct species, species absent in the present day flora of Poland, and indicator species of a clear climatic and environmental significance, all described and illustrated in detail below.

SELAGINELLACEAE

Selaginella selaginoides (L.) P. Beauv. ex Schrank & Mart.

Fig. 2

Material. Czarnucha: 3 megaspores, Żarnowo: 6 megaspores

Description. Megaspores 0.40–0.50 mm in diameter, oblate-spheroidal, with a three-radial scar. The height of the scar rays gradually decreases from the centre to the periphery of the megaspore. Surface of apical part bears a sculpture of minute rounded tubercles, visible between the scar rays. Basal part uniformly rounded, with a small shallow pit at the centre. Perisporium thin, elastic, dark grey, mat or finely lustrous.

Note. Occurs in the Augustovian interglacial I/II in the Czarnucha profile and in the Nidanian glaciation in the Żarnowo profile.

Fig. 2. *Selaginella selaginoides* (L.) P.Beauv.ex Schrank & Markt. (Żarnowo) × 80

E c o l o g y. Found in damp meadows, peat-bogs, on rocks, and among mosses in swampy places. Widespread in the Central and West Europe, European Russia and North America.

F o s s i l o c c u r r e n c e. Belongs to arctic-boreal species occurring in stadial and periglacial sediments. Among Vistulian floras of Poland, determined at sites of Witów (Wasylikowa 1964), Zator (Koperowa & Środoń 1965), Kępno (Rotnicki & Tobolski 1965), Kraków (Mamakowa 1970), Nowa Huta (Mamakowa & Środoń 1977), and in cold periods of profiles related to interglacials of Ferdynandów (Janczyk-Kopikowa 1975), Stanowice (Sobolewska 1977), Imbramowice (Mamakowa 1989), and Konieczki (Nita 1999). In Belorussian floras the species is very well represented (Velichkevich 1973).

Selaginella cf. ***tetraedra*** Wieliczk.

Fig. 3

M a t e r i a l. Żarnowo: 2 megaspores

D e s c r i p t i o n. Megaspores 0.3 mm in diameter. Specimens are flattened, however, still display a slightly pyramidal shape. Convex part pressed inwards. Surface mostly smooth or infrequently with rounded tubercles. Faces of the tetrahedron flat or slightly convex, descending towards the basal part. Perisporium thin, elastic, yellow-grey, mat.

N o t e. Found in the Żarnowo profile in the Augustovian interglacial II and in the interstadial segment of the Nidanian glaciation. Extinct species, described from East European floras. Determined for the first time from Pleistocene floras of Poland.

E c o l o g y. Occurrence of the species in warm periods of the interglacial is likely to indicate relatively high temperature requirements.

F o s s i l o c c u r r e n c e. In Lithuania described from the Butenai (Mazovian) interglacial (Velichkevich 1980) and from the Eopleistocene flora of Daumantai-1 (Velichkevich et al. 1998), while in Belarus from the Belovezhian (Ferdynandovian) interglacial at the site of Nizhinsky Row and from the Alexandrian (Mazovian) interglacial at the sites of Ruba (Velichkevich 1982), Verkhov'e-1 (Velichkevich 1977a) and Verkhov'e-2 (Velichkevich 1977b).

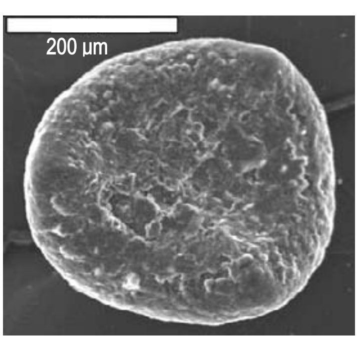

Fig. 3. *Selaginella* cf. *tetraedra* Wieliczk. (Żarnowo) SEM

SALVINIACEAE

Salvinia natans (L.) All.

Fig. 4

M a t e r i a l. Czarnucha: 674 megaspores, Żarnowo: 605 megaspores

D e s c r i p t i o n. Megaspores 0.35–0.60 × 0.30–0.55 mm, ellipsoidal, rarely ovoid. Apex with a three-radial scar, blunt, indistinctly separated from the body of megaspore with a circular band (Fig. 4a,b). Perisporium thick, from pale cream to brown. Surface bearing a sculpture of minute rounded tubercles clustered in groups. (Fig. 4c,d).

N o t e. In both profiles the species is accompanied by *Azolla filiculoides* and is most abundant in the Augustovian interglacial II. Megaspores of *Salvinia natans* are described as typically white, pale grey or cream, while

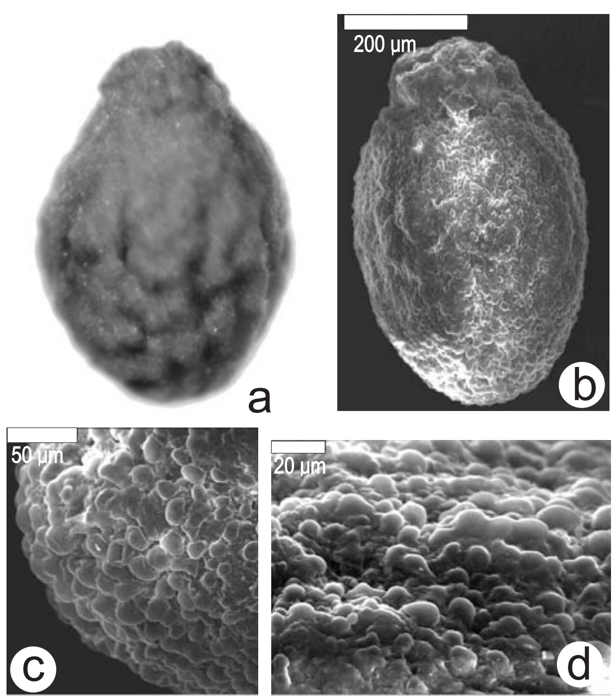

Fig. 4. **a** – *Salvinia natans* (L.) All. (Czarnucha) × 80, **b** – (Żarnowo) SEM, **c, d** – details of surface, SEM

specimens found in both floras were mostly very dark, nearly brown. The reason for such preservation is unknown.

Ecology. Fern, characterized by high temperature and light requirements, frequently forming unbroken carpets, typical of pleuston communities, on the water surface (similarly as *Azolla*) of old riverbeds and standing or very slow-flowing waters. A nearly cosmopolitan species.

Fossil occurrence. Found in interglacial, less frequently in interstadial floras of early Pleistocene. In Poland described from the Mazovian interglacial in Maków Mazowiecki (Gołąbowa 1957), Stanowice (Sobolewska 1977) and Konieczki (Nita 1999) and from the Eemian interglacial in Imbramowice (Mamakowa 1989).

AZOLLACEAE

Azolla filiculoides Lam. foss.

Fig. 5

Material. Czarnucha: 732 megaspores, Żarnowo: 1551 megaspores

Description. Megaspores mean size 0.38–0.45 × 0.32–0.36 mm, with a structure typical of the species. The upper conical part consists of three ovoid floats located in a circular band surrounding the megaspore. The band separates the apical part from the hemispherical basal part, marked by numerous rounded tubercles.

Note. In both profiles, some megaspores were attached to discoid massulae, provided with anchor-shape glochidia, keeping the megaspores in compact clusters. The species is most abundant in the climatic optima of the Augustovian interglacial I and II and is also found in Augustovian interglacial I/II.

Ecology. *Azolla filiculoides* is a aquatic fern occurring in California, South America and Mexico, its northern range of distribution extends nearly to Alaska. It is considered a thermophilous species, however, resistant to freezing into thin layers of ice formed on the surface of basin. In late spring it frequently forms dense, monospecies pleuston layers on the lake surface.

Fossil occurrence. In the Pleistocene of Poland, recorded from the Mazovian interglacial

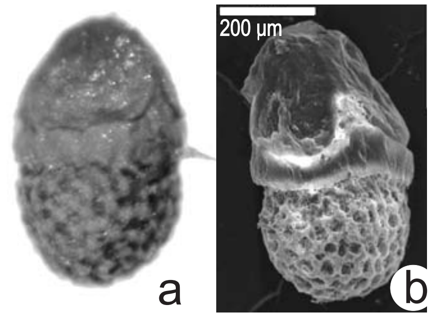

Fig. 5. a – *Azolla filiculoides* Lam. foss. (Czarnucha) × 80, **b** – (Żarnowo) SEM

at the site of Stanowice (Sobolewska 1977) and from the Eemian interglacial at the site of Imbramowice (Mamakowa 1989). Described also from the Pliocene and Pleistocene of Western (Florschütz 1938, Folieri 1970–1971, Mai & Walther 1988, Aalto et al. 1996, Field 1992) and Eastern Europe (Nikitin 1957, Dorofeev 1963, Velichkevich 1982, 1986, Velichkevich & Zastawniak 2003).

TYPHACEAE

Typha aspera Dorof.

Fig. 6

Material. Żarnowo: 30 tegmens.

Description. Tegmens mean size 1.1–1.3 × 0.2–0.3 mm, oblong, occasionally slightly swollen at the basal part, frequently slightly curved. Apex truncate and closed by the rarely preserved micropyle disc marked by a short, centrally placed subulate style. Base gradually tapered and furnished with a mamillary stalk. Surface pale brown, lustrous.

Note. Recorded in the Żarnowo profile in all cold periods. An extinct species determined for the first time by Dorofeev (1971, 1982) in the

Fig. 6. *Typha aspera* Dorof. (Żarnowo) SEM

Pliocene flora of Kholmech in Belarus. Species determined for the first time in Pleistocene floras of Poland.

Ecology. Fossil species probably of similar ecological requirements as the present day *Typha latifolia*, found on loamy grounds, in eutrophic waters, and on peaty, strongly shallowed lake shores. However, its occurrence in cool periods of the Augustovian succession is also likely to serve as indicator of lower temperature requirements.

Fossil occurrence. Described from the Pliocene flora of Kholmech (Dorofeev1982, Velichkevich & Zastawniak 2003). In Pliocene floras of Belarus, determined also by Yakubovskaya (1982,1984).

POTAMOGETONACEAE

Potamogeton dvinensis Wieliczk.

Fig. 7

Material. Czarnucha: 5 endocarps, Żarnowo: 1 endocarp

Description. Endocarps mean size 2.8–3.3 × 2.3–2.4 mm, broad, nearly rounded to irregularly elliptical, narrow and slightly concave in their lower part and marked by a strongly convex dorsal margin in their upper part. Lid narrow, keeled, occasionally reaches the style-base with its edge. Style rather thick, short pointed, ventrally positioned. Stalk small, inserted laterally at the obliquely truncate base. Faces flat, with a broad, shallow central depression whose mouth opens out on to the central margin in its lower third. Surface rough, mat, marked by a spongy structure.

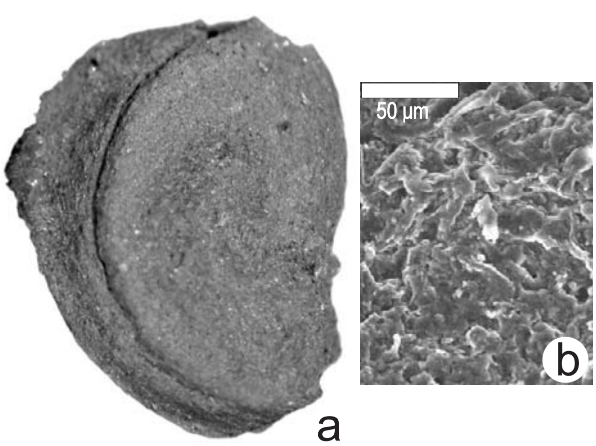

Fig. 7. a – *Potamogeton dvinensis* Wieliczk. (Czarnucha) × 20, **b** – details of surface, SEM

Note. Recorded in the Augustovian interglacial I and II in both profiles. Extinct species.

Ecology. Mostly associated with the present day *Potamogeton distinctus* A. Benn, found in Eastern Asia, particularly in Korea and Japan, usually in small basins with eutrophic water.

Fossil occurrence. Described in Belarus from the Alexandrian (Mazovian) interglacial at the site of Verkhov'e-1 (Velichkevich 1977a), and from the Mogilevian (Ferdynandovian) interglacial at the site of Smolensky Brod (Velichkevich 1978). In Poland determined for the first time from the Mazovian interglacial at the site of Konieczki (Nita 1999).

Potamogeton nodosus Poir.

Fig. 8

Material. Czarnucha: 6 endocarps, Żarnowo: 5 endocarps

Description. Endocarps mean size 3.0–3.2 × 2.1–2.2 mm, ovoid. Ventral part slightly convex, faintly tapered at the margin. Lid keeled, broad, with a pointed tip not reaching the style-base. Style thick, rather long, ventrally positioned. Faces convex, without a central depression, often with a mamillate wart at the base of both faces of the endocarp. Walls of endocarp thick, firm. Surface finely rough.

Fig. 8. *Potamogeton nodosus* Poir. (Czarnucha) × 20

Note. At the Czarnucha site, determined from the Augustovian interglacial II, and at the Żarnowo site from the Augustovian interglacial I. Species described from different parts of the world under various names: *P. americanus* Cham. & Schlecht. and *P. richardii* Solms in Africa, *P. thunbergii* Cham. & Schlecht. in

Southern Africa, P. *fluitans* Roth. in Europe, and *P. ferrugineus* Hagstr. in South America.

E c o l o g y. Widespread in areas controlled by moderate, subtropical and tropical climate. Frequently found in slow-flowing waters. Endocarps of the species are likely to float on the water surface for a long time thanks to air spaces placed in the pericarp.

F o s s i l o c c u r r e n c e. Described from the Middle Pleistocene of south-eastern England (Aalto et. al. 1996), as well as from the Alexandrian (Mazovian) interglacial, Mikulian (Eemian) interglacial (Velichkevich 1982) and Korchevian interglacial (Velichkevich 1986) in Belarus.

Potamogeton panormitanoides Dorof.

Fig. 9

M a t e r i a l. Czarnucha: 1 endocarp, Żarnowo: 4 endocarps

D e s c r i p t i o n. Endocarps mean size 1.4–1.5 × 2.1–2.2 mm, asymmetrically ovoid. Ventral margin convex, stalk short and narrow, style thin, centrally positioned, of various lengths. Dorsal margin uniformly convex, with a narrow, slightly keeled or rounded lid. Faces weakly convex or flat, with a small central depression which may be lacking.

N o t e. In both profiles recorded from the Augustovian interglacial I, while in the Żarnowo profile additionally from the Nidanian glaciation. Extinct species determined for the first time in Russia at a Middle-Pleistocene site of Neznanovskiye Vysyelki (Dorofeev 1986), while in Poland from the Mazovian interglacial at the site of Konieczki (Nita 1999).

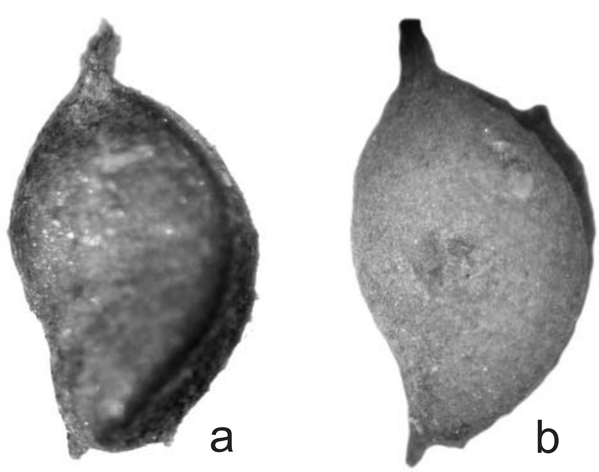

Fig. 9. a – *Potamogeton panormitanoides* Dorof. (Czarnucha) × 30, **b** – (Żarnowo) × 30

E c o l o g y. A species most similar to extant *Potamogeton panormitanus*, currently not found in the area of Poland. Inhabits eutrophic or brackish shallow waters and loamy or muddy grounds. Displays a low sensitivity to fluctuations in water level (Podbielkowski & Tomaszewicz 1982).

F o s s i l o c c u r r e n c e. Determined from the Mazovian interglacial at the site of Konieczki (Nita 1999) and Ciechanki Krzesimowskie (Velichkevich et al. 2004). Among floras of Eastern Europe, recorded from the Belovezhian interglacial at the site of Motol (Velichkevich et al. 1993) and from the Mazovian interglacial at the site of Krukenichi (Velichkevich 1982) and at many other sites.

Potamogeton pectinatus L.

Fig. 10

M a t e r i a l. Czarnucha: 5 endocarps, Żarnowo: 11 endocarps

D e s c r i p t i o n. Endocarps mean size 2.8–3.2 × 1.9–2.6 mm, ovoid, flat, massive. Ventral margin slightly convex, occasionally nearly straight. Lid short, blunt, with a flat keel, not reaching the style-base. The shoulder is large,

Fig. 10. *Potamogeton pectinatus* L. (Żarnowo) × 20

approximately half as long as the lid or nearly equal to the radius of the endocarp, straight or slightly convex, rounded at the edge. Faces slightly convex or flattened, with a broad and shallow central depression. Style small, often inconspicuous, continuing the ventral margin. Stalk small, inserted laterally at base.

Note. Found in both profiles, in both warm and cold periods.

Ecology. Species of a very broad ecological amplitude, occurring mostly in eutrophic, occasionally in slightly saline, waters. Grows in standing and slow-flowing waters, on loamy, sandy-muddy and peaty grounds. Most frequently found in shallow basins in the zone of aquatic vegetation, rarely enters swamps.

Fossil occurrence. Occurs abundantly in interglacial floras, characteristic species of pre- and post-optimal phases of interglacials. In Poland described from the interstadial flora of Tarzymiechy (Środoń 1954), from the Eemian interglacial at the site of Imbramowice (Mamakowa 1989) and from the Mazovian interglacial at the site of Stanowice (Sobolewska 1977), while in Belarus from the Belovezhian interglacial (lower optimum of the Ferdynandovian interglacial) at the site of Motol (Velichkevich et al. 1993) and from the Mogilevian interglacial (upper optimum of the Ferdynandovian interglacial) at the site of Smolensky Brod (Velichkevich 1978) and at many other sites.

Potamogeton perforatus Wieliczk.

Fig. 11

Material. Żarnowo: 1 endocarp

Description. Endocarp 2.5 × 2.1 mm, broadly ovate in outline, flat. Ventral margin unequally sigmoid, slightly keeled in its upper half. Lid narrow, keeled, with a pointed top reaching the style-base. Style short, centrally sited. Faces flat with a large comma-shaped central hole.

Note. Found in the Żarnowo profile in the Augustovian interglacial I. Extinct species, very similar to the extant *P. perfoliatus*, also polymorphic. Described mostly from the Lower Pleistocene, however, recorded also in younger interglacials.

Fig. 11. *Potamogeton perforatus* Wieliczk. (Żarnowo) × 20

Ecology. Likely to have similar ecological requirements as *P. perfoliatus* which is a species found in boreal and circumpolar climate.

Fossil occurrence. Described from the Eopleistocene flora of Slave-2 (Velichkevich 1973) and Daumantai-1 (Velichkevich et al. 1998), similar in age, where the endocarps of the species occur exceptionally abundantly. Recorded also in older interglacials of the East European Lowland (Velichkevich 1982). Not found in the Mazovian interglacial, when it was most likely replaced with the present day *Potamogeton perfoliatus.*

ZANNICHELLIACEAE

Zannichellia palustris L.

Fig. 12

Material. Czarnucha: 334 seeds, Żarnowo: 2029 seeds

Description. Seeds mean size 1.7–2.5 × 05–0.8 mm (excluding style and stalk), flat, slightly curved, elliptical in outline, with a short stalk, marked by a longitudinal crack dividing the fruit into two lobes, one of which is tipped with a long style. Base rounded, with a rather thick, flattened, slightly curved stalk which is shorter than the fruit breadth. Dorsal margin slightly or strongly toothed. Wall surface indistinctly celled, uneven, grey-brown, faintly lustrous.

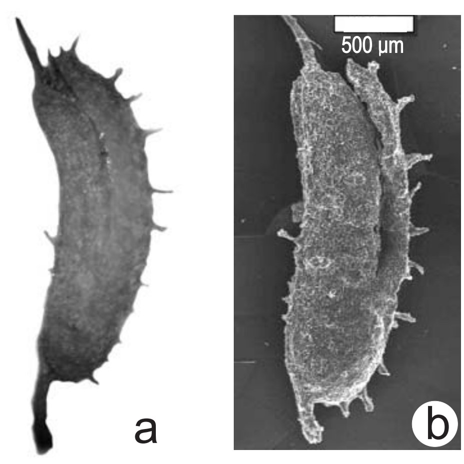

Fig. 12. a – *Zannichellia palustris* L. (Żarnowo) × 20, **b** – (Czarnucha) SEM

N o t e. In both profiles, recorded mostly in the Augustovian interglacial I and Augustovian interglacial I/II.

E c o l o g y. *Zannichellia palustris* inhabits mainly extremely eutrophic or slightly saline waters, standing or slow-flowing, greatly increasing their temperature in the summer. Grows in lakes and rivers, at different depth of littoral shallows.

F o s s i l   o c c u r r e n c e. In Poland described from the Eemian flora of Horoszki (Granoszewski 2003) and from the Mazovian flora of Konieczki (Nita 1999, 2009), while in the East – from the Likhvinian (Mazovian) interglacial at the site of Rudakov Rov (Velichkevich 1982). Fruits usually occur occasionally, except from the Korchevian and Augustovian interglacial, where they are found abundantly.

NAJADACEAE

Najas minor All.

Fig. 13

M a t e r i a l. Czarnucha: 17 seeds, Żarnowo: 186 seeds

D e s c r i p t i o n. Seeds mean size 1.8–2.9 × 0.6–0.8 mm, narrow, lanceolate in outline (Fig. 13a). Apex subacute, slightly inclined towards the raphe. Base unilaterally rounded or obliquely truncate. Testa thin, resilient. Surface cells form a net-like pattern, with their longer axes pointed towards the shorter axis of the seed and arranged in conspicuous, longitudinal rows, forming slightly elevated lines (Fig. 13b,c).

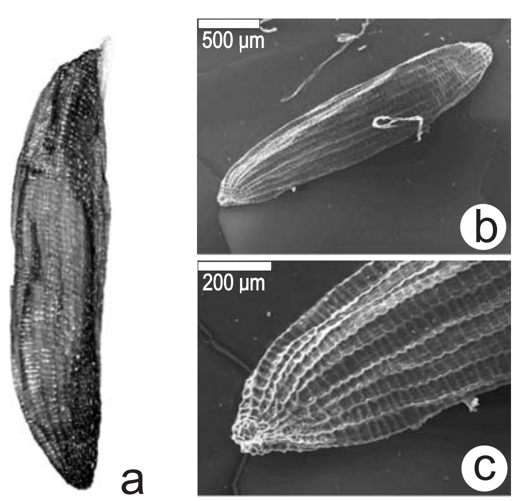

Fig. 13. a – *Najas minor* All. (Żarnowo) × 20, **b** – (Żarnowo) SEM, **c** – details of surface

N o t e. In both profiles, most abundant in the Augustovian interglacial II. In the Żarnowo profile recorded also from the Augustovian interglacial I, however, less frequently.

E c o l o g y. Aquatic plant. Frequently forms underwater fields, single plants are found rarely. Growing on strongly eutrophicated sites with muddy or muddy-sandy ground. Characteristic species of the *Parvopotamo-Zannichellietum* association (Matuszkiewicz 2001). At present, occurs mainly in Asia, Africa, middle and southern Europe, and in the basin of the Mediterranean Sea, in areas of moderately warm climate.

F o s s i l   o c c u r r e n c e. Present in numerous Pleistocene and Holocene floras of Poland and Europe.

Najas tenuissima (A. Br.) Magnus

Fig. 14

M a t e r i a l. Czarnucha: 1 seed

D e s c r i p t i o n. Seed 2.5 × 0.4 mm, narrowly elliptic in outline, apex and base rounded. Surface smooth, lustrous, light to dark brown. Surface with conspicuous, rectangular cells,

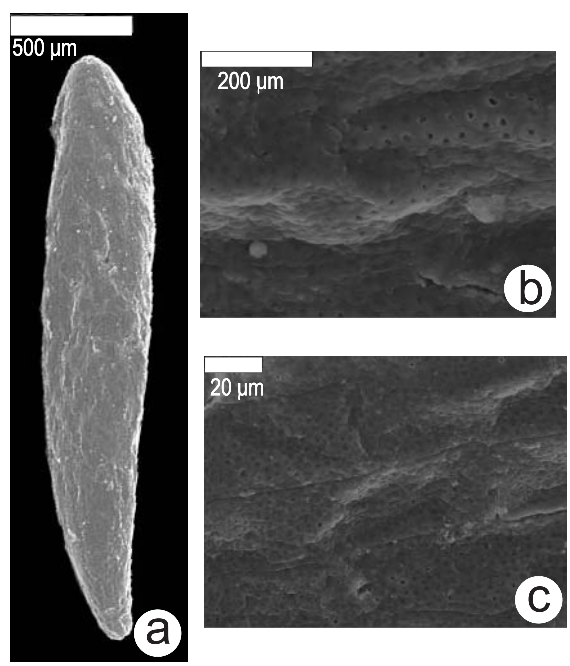

Fig. 14. a – *Najas tenuissima* (A. Br.) Magnus, (Czarnucha) SEM, **b, c** – SEM, details of surface

from nearly square to clearly elongated in outline, thin-walled and arranged in fairly regular rows. (Fig. 14 a). Cells arranged parallel to the longer axis of the seed with their longer axes, and marked by numerous minute pores (Fig. 14b,c). Testa thin, resilient, two-layered.

Note. Determined from the Czarnucha profile from the Augustovian interglacial I/II. Not found in the present day flora of Poland.

Ecology. Occurs rather infrequently in lakes of eastern Europe and Finland.

Fossil occurrence. From the Pleistocene of Poland, determined from the Mazovian interglacial at the site of Ciechanki Krzesimowskie (Brem 1953) and at the site of Styków (Wąs 1956), of an uncertain stratigraphic position. Described from the Pleistocene of Belarus (Kats & Kats 1960) and in Russia, from the areas of Novochopersk (Niktin & Dorofeew 1953) and Yaroslavsk (Gorłowa 1960). Seeds of *N. tenuissima* were also identified by West and Wilson (unpublished data), from a Cromerian stage of an unspecified chronostratigraphic position (Godwin 1975). Palaeobotanical studies indicate that the taxon occurred in various interglacials and was widely spread in the past (Tralau 1962.)

JUNCAGINACEAE

Triglochin maritimum L.

Fig. 15

Material. Czarnucha: 5 fruits, Żarnowo: 11 fruits

Description. Fruits 3.8–3.9 × 1.0–1.1 mm, longitudinally elongated, trigonal in cross-section, base obliquely truncate. Apex abruptly narrowed to the short and thick style, dorsally inclined, ending in the stigma. The outer face of the fruit larger, elongated and rounded. Two remaining faces smaller, flat, slightly curved. Walls usually thin, resilient, semitransparent. Surface distinctly longitudinally striate, brown.

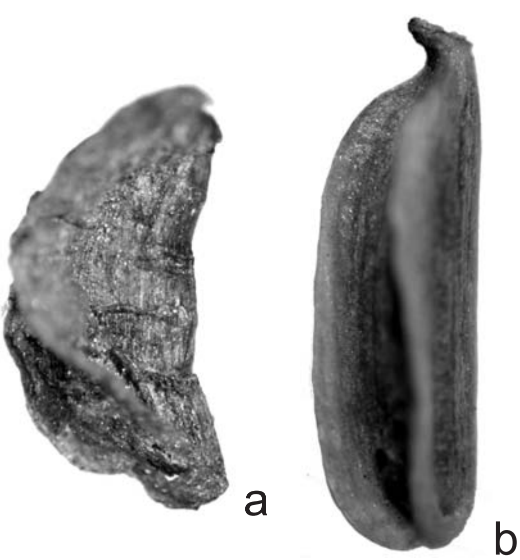

Fig. 15. a – *Triglochin maritimum* L. (Czarnucha) × 20, **b** – present day specimen × 20

Note. Recorded from the Nidanian glaciation in profiles from Czarnucha and Żarnowo and from the Narevian glaciation in the Czarnucha profile.

Ecology. Found in the north, at seashores and, infrequently, on solonchak-like soils and on sphagnum-peat bogs. Occurs in middle Europe, Caucasus, Siberia, and Mongolia.

Fossil occurrence. In fossil floras of Poland, determined for the first time from the site of Gołków near Warsaw, in the frame of verification of unpublished material of M. Brem, (housed in the Palaeobotanical Museum, W. Szafer Institute of Botany, Polish Academy of Sciences). From the site, 10 fruits of *Triglochin maritimum* were determined by F. Yu. Velichkevich. In floras of Eastern Europe described from Povolzhe and Prikame by Kipiani and Kolbutov (1961).

ALISMATACEAE

Alisma plantago-minimum (Nikit.) Dorof. ex Wieliczk.

Fig. 16

Material. Czarnucha: 10 seeds, Żarnowo: 11 seeds

Description. Seeds mean size 1.0–1.2 × 0.5–0.7 mm, asymmetric. Micropylar arm shorter and narrower, with a rounded apex and fragment of style occasionally preserved. Chalazal arm slightly broader and longer, gradually broadening towards base. Surface black, shining, with elongate cells arranged along the seed (Fig. 16a,b). Differs mostly in size from *Alisma plantago-aquatica* (Fig. 16c,d).

Note. In both profiles, most frequently found in the Augustovian interglacial I and the Nidanian glaciation. An extinct species, usually related to *Alisma orientale* (Sam.) Juz., occurring in China and Japan, or to the North American *A. triviale* Pursh.

Ecology. Ecological conditions preferred by the species probably resembled those of *Alisma*

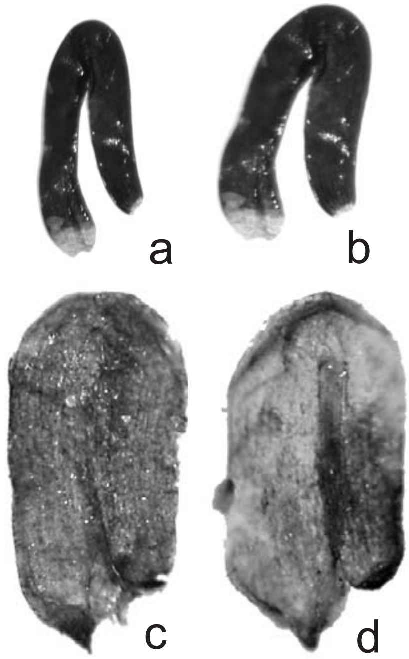

Fig. 16. a, **b** – *Alisma plantago-minimum* (Nikit.) Dorof. ex Wieliczk. (Żarnowo) × 50, **c**, **d** – *Alisma plantago-aquatica* L. (Czarnucha) × 40

plantago-aquatica, most frequently found in eutrophic habitats of shallow waters, and even on lakeshores and in terrestrial areas.

Fossil occurrence. Described mainly from Pliocene and less frequently from older interglacials of Pleistocene in Central Russia (Dorofeev 1979) and Belarus (Dorofeev 1986a, Velichkevich 1990).

HYDROCHARITACEAE

Stratiotes cf. ***brevispermus*** Wieliczk.

Fig. 17

Material. Żarnowo: 1 seed.

Description. Seed 7.4 × 2.9 mm, broad and comparatively short. Apex regularly rounded and slightly dorsally inclined. Base abruptly narrowed to a very short, inconspicuous neck, ventrally deflected at an acute or even right angle to the seeds axis. Keel massive, regular. Surface distinctly celled, with elongate cells arranged in distinct rows. Testa very thick at the keel and comparatively thin on the central face.

Note. The general structure, size, and the length-to-width ratio indicate that the *Stratiotes* seed recorded in the flora of Żarnowo can be assigned to an extinct species, *Stratiotes brevispermus* Wieliczk. When considering its size, it is similar to a Pliocene species, *S. intermedius* (Hartz) Chandler. A new species in the Pleistocene of Poland, determined from the Żarnowo profile in the cold period preceding the first warm period.

Ecology. Ecological requirements of the species were likely to resemble the ones of the extant *Stratiotes aloides*, however, the occurrence of remains in the cooler period of the Augustovian interglacial is likely to suggest lower temperature requirements or a continental climate with very warm summers and cold winters.

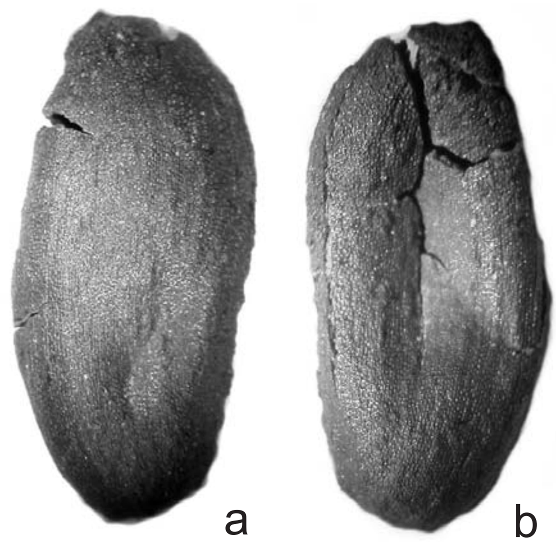

Fig. 17. a, **b** – *Stratiotes* cf. *brevispermus* Wieliczk. (Żarnowo) × 10, a dorsal and ventral view

Fossil occurrence. For the first time determined from the Belovezhian interglacial in the flora of Kosteshi (Velichkevich 1979). Described also from older Lithuanian interglacials (Velichkevich et al. 1998).

Stratiotes cf. ***goretskyi*** Wieliczk.

Fig. 18

Material. Czarnucha: 1 seed

Description. Seed 8.6 × 3.0 mm, elongate, slightly sigmoid, somewhat twisted, cylindrical in the centre. Apex rounded, base narrowed into a neck. Keel massive, irregular in outline. Surface furnished with minute tubercles arranged in distinct rows.

Note. Recorded from the Augustovian interglacial II in the Czarnucha profile. Extinct species, closely related to a Pliocene taxon, *Stratiotes brevispermus*. From the Pleistocene floras of Poland determined for the first time.

Fig. 18. *Stratiotes* cf. *goretskyi* Wieliczk. (Czarnucha) × 10

Ecology. Conditions advantageous for the occurrence of this species were likely to resemble the ones of *Stratiotes aloides.*

Fossil occurrence. In Belarus recorded at the sites of Korchevo (Velichkevich 1982) and Dvorets (Velichkevich 1990).

CYPERACEAE

Carex paucifloroides Wieliczk.

Fig. 19

Material. Czarnucha: 279 fruits, Żarnowo: 116 fruits

Description. Fruits mean size 2.0–2.6 × 0.8–1.2 mm, bilateral, elongate, narrowly elliptical in outline, swollen in the middle or below. Apex abruptly narrowed and passing into a cylindricalor subulate style. Dorsal face flat or slightly concave, ventral one slightly convex, sometimes with a flattened longitudinal rib.

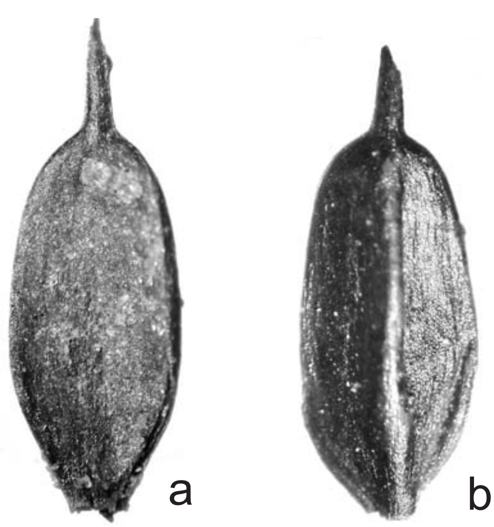

Fig. 19. a, **b** – *Carex paucifloroides* Wieliczk., (Czarnucha) × 20

Note. Abundant in both profiles, particularly in the Augustovian interglacial II of the Czarnucha profile. In the Żarnowo profile, found frequently in the Augustovian interglacial I and II. Extinct species, described from the Upper Pliocene flora of Dvorets in Belarus (Velichkevich 1990.)

Ecology. Species most similar to the extant *Carex pauciflora*, found in raised bogs, peaty meadows and on lakeshores in Sudetes and Carpathians.

Fossil occurrence. In Poland, determined from several sites representing the Mazovian interglacial, e.g. Ciechanki Krzesimowskie and Maków Mazowiecki (Mamakowa & Velichkevich 1993), in Belarus from numerous sites representing the Korchevian, Belovezhian, and Alexandrian interglacial (Velichkevich 1974, 1979, 1982, 1990), while in Lithuania in the flora of Snajgupele (Velichkevich 1974). Recorded also from the Upper Pliocene in Germany (Mai & Walther 1988, Gümbel & Mai 2004).

Cyperus glomeratus L.

Fig. 20

Material. Czarnucha: 174 fruits, Żarnowo: 82 fruits

Description. Fruits mean size 1.0–1.1 × 0.25–0.30 mm, linear, sometimes slightly swollen at the lower part, thin-walled, with a sculpture characteristic for the species. Irregularly trigonal in cross-section. Ribs narrow and with rounded edges. Apex gradually tapering, rounded, with a short, cylindrical style. Base slightly narrowed, horizontally truncate, often slightly curved (Fig. 20a,b,e,f). Surface with thin, variously shaped, however, generally undulate cells, visible in SEM pictures. Centre of each cell marked by a rounded tubercle (Fig. 20c,d).

Note. Particularly abundant in the Augustovian interglacial II of both sites, less frequently found in the first warm period. Nowadays not found in the area of Poland. Recorded

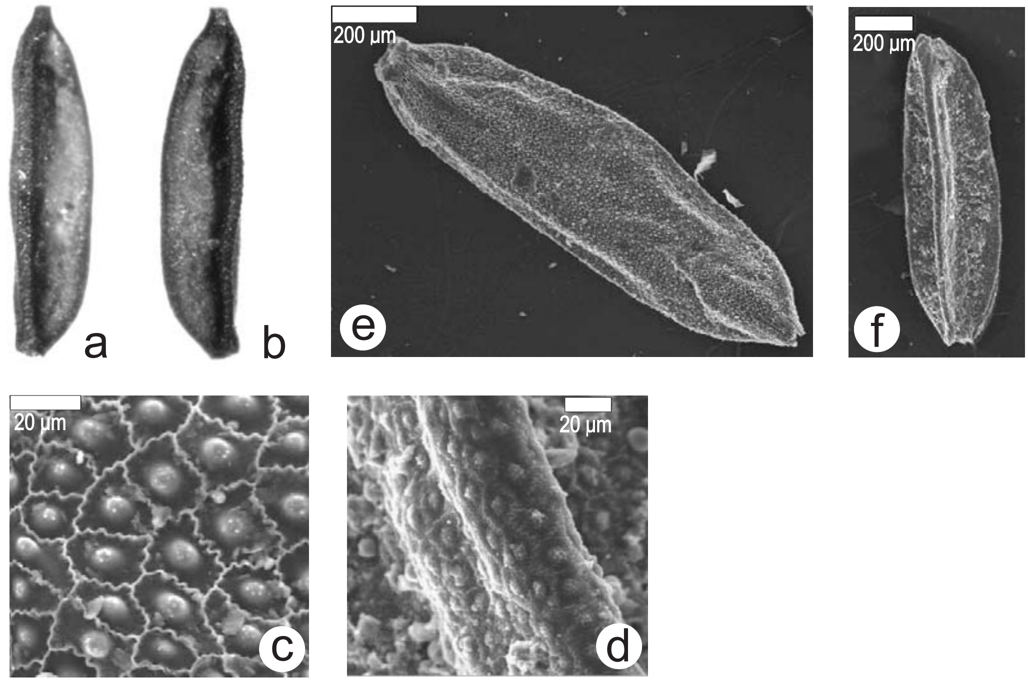

Fig. 20. a, **b** – *Cyperus glomeratus* L. (Czarnucha) × 40, **c**, **d** – (Żarnowo) SEM, details of surface, **e** – (Czarnucha), SEM; **f** – (Żarnowo) SEM

in southern Europe up to Caucasus, as well as in Iran, Uzbekistan, northern China, Japan and Siberia (Stankow & Taliew 1949).

Ecology. Inhabits riverbanks, nowadays often also rice fields.

Fossil occurrence. Described from numerous Pliocene and Pleistocene localities (Dorofeev 1963, Velichkevich 1973, 1982).

Eleocharis praemaximoviczii Wieliczk.

Fig. 21

Material. Czarnucha: 24 fruits, Żarnowo: 115 fruits

Description. Fruits mean size 0.9–1.1 × 0.5–0.6 mm, ovate, trigonal in cross-sections, with a flat, irregular base of stylopodium and subulate style at apex. Base narrow and horizontally truncate. Walls thin, usually deformed (Fig. 21a–d). Surface covered with minute, very narrow cells arranged in longitudinal rows, which, when observed under a small magnification, make a fine striation.

Note. Remains of the species were found in both profiles, particularly in the Żarnowo profile, mostly in the Augustovian interglacial I, however also in the Nidanian glaciation of the Czarnucha profile. Extinct species, occurring in Middle-Eastern Europe since Pliocene until Middle Pleistocene. Initially, nuts of this taxon, recorded from Pliocene and Early-Middle Pleistocene floras, were determined as *Eleocharis pseudoovata*, despite no similarity to biconvex nuts of the present day *E. ovata*

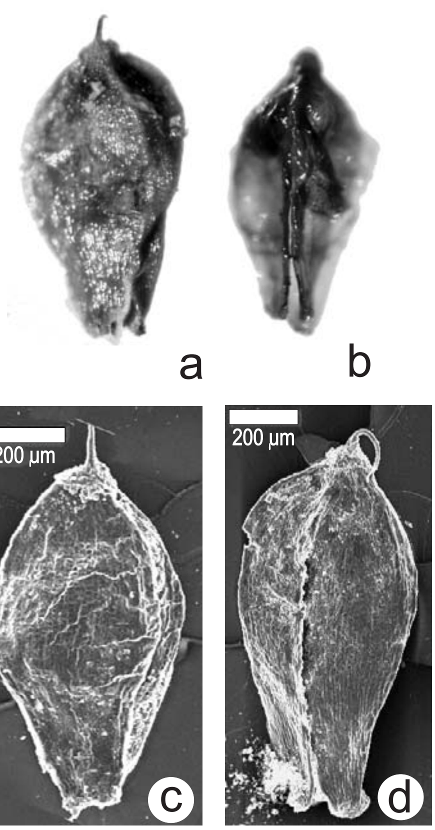

Fig. 21. a, **b** – *Eleocharis praemaximoviczii* Wieliczk. (Czarnucha) × 40, **c**, **d** – (Żarnowo) SEM

(Velichkevich 1973, 1982). However, according to Dorofeev (1986a), the extinct species shows greater similarity to *E. maximoviczii* Süsserl, and therefore should be distinguished as another extinct taxon, *E. praemaximoviczii*.

Ecology. Presumably, the ecological requirements of the species were similar to the extant *Eleocharis ovata*, most frequently found on riverside alluvia, shores, old river beds and in temporarily exposed muddy bottoms of basins.

Fossil occurrence. In Poland described from the Mazovian interglacial at the site of Konieczki (Nita 1999, 2009), in Lithuania from the Kemėnai interglacial at the site of Vindžiūnai (Velichkevich et al. 1998), while in Belarus from the Pliocene flora of Dvorets (Velichkevich 1990). Recorded also from the Pleistocene of Germany (Gümbel & Mai 2004.)

Scirpus atroviroides Dorof.

Fig. 22

Material. Czarnucha: 270 fruits, Żarnowo: 226 fruits

Description. Fruits mean size 0.8–1.0 × 0.50–0.55 mm, obovate, irregularly trigonal. Margins narrow and rounded. Dorsal face broader than each of the two ventral ones. Style short, thick, circular in cross-profile (Fig. 22a–c). Surface minute-celled, shining. Under the SEM the surface cells appear variously shaped, with thin, undulate walls (Fig. 22f).

Note. In both investigated sites, occurred most abundantly in the Augustovian interglacial II, however, was also occasionally recorded in the Augustovian interglacial I. Extinct species. The shape of both nuts and surface cells of *Scirpus atroviroides* indicate its close relationship to *Scirpus atrovirens* (Fig. 22d,e). *Scirpus atroviroides* is most frequently found in interglacial periods since Late Pliocene and serves as indicator of a moderately warm climate.

Ecology. Nowadays, *Scirpus atrovirens* is found in North America, with its range of occurrence extending from the Great Lakes to Florida and inhabits mostly humid hollows and shores of ponds, lakes drainage channels and canals.

Fossil occurrence. *Scirpus atroviroides* was described by Dorofeev (1986a). In Poland fruits of the species occur abundantly in the Mazovian flora of Konieczki (Nita 1999). In the western part of the East European Plain, it is recorded from floras of different age, since the Late Pliocene (Velichkevich & Zastawniak 2003) until the Middle Pleistocene. In the area of Lithuania it was described from the Eopleistocene flora of Daumantai-1 (Velichkevich et al. 1998).

Scirpus kreczetoviczii Wieliczk.

Fig. 23

Material. Czarnucha: 26 fruits

Description. Fruits mean size 4.0–4.4 × 1.8–2.2 mm, irregularly trigonal, ovate. Walls very thick, massive. Ribs bluntly rounded, often marked by a deep crack starting from the base. Style short, pyramidally ended. Surface smooth, dark brown to black. (Fig. 23a,b).

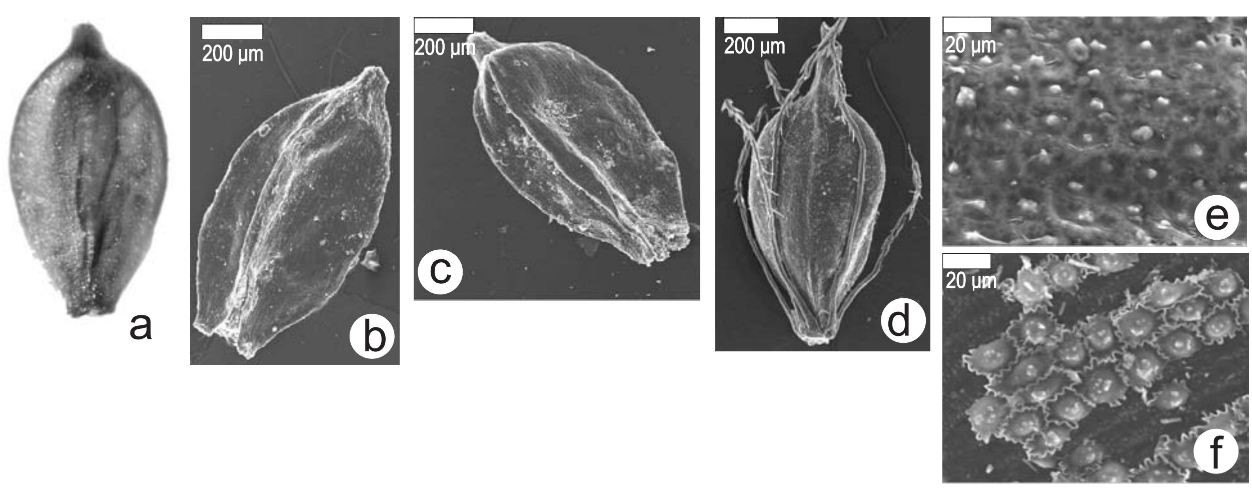

Fig. 22. a – *Scirpus atroviroides* Dorof. (Czarnucha) × 40, **b**, **c** – (Żarnowo) SEM, **d** – *Scirpus atrovirens* Muhl. (present day specimen) SEM, **e** – SEM details of surface, **f** – *Scirpus atroviroides* Dorof. SEM details of surface

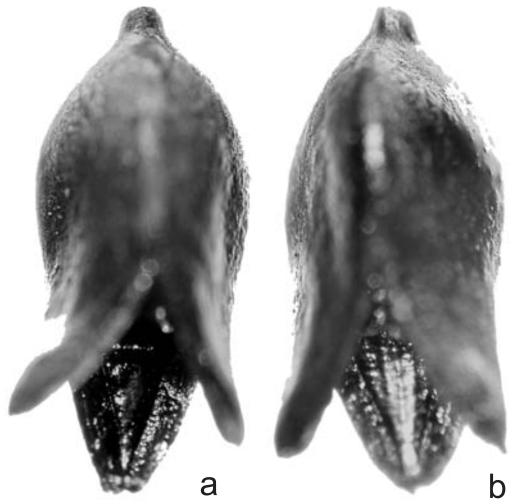

Fig. 23. a, **b** – *Scirpus kreczetoviczii* Wieliczk. (Czarnucha) × 15, a dorsal and ventral view

N o t e. Recorded exclusively in the Czarnucha profile in the Augustovian interglacial II. Specimens recorded from the flora of Czarnucha are distinctly larger than ones described by Velichkevich (1982) from the flora of Kosteshi. Extinct species, not formerly described from the Pleistocene floras of Poland.

E c o l o g y. Climatic requirements of the fossil species are unknown, as it does not have an unequivocal equivalent in the present day flora. Morphologically the nuts are most similar to the ones of *Bolboschoenus maritimus*, found on shores of standing or slow-flowing waters and in slightly salinized or strongly eutrophic habitats.

F o s s i l o c c u r r e n c e. Species determined for the first time from the Belovezhian (formerly Shklovian) interglacial in the flora of Kosteshi described by Velichkevich (1979) from the Lower Pleistocene of western Belarus. Very characteristic for the Korchevian interglacial, in which it is found exceptionally abundantly (Velichkevich 1982). Recorded also from the stage of Kemėnai in Lithuania (Velichkevich et al. 1998).

URTICACEAE

Urtica cf. ***laetevirens*** Maxim.

Fig. 24

M a t e r i a l. Czarnucha: 7 seeds, Żarnowo: 52 seeds

D e s c r i p t i o n. Seeds mean size 1.1–1.2 × 0.7–0.8 mm, ovate in outline, lower half swollen. Apex blunt, base with an indistinct stalk (Fig. 24a-c). Surface dark brown, minute-celled (Fig. 24d).

N o t e. In both profiles the taxon occurs in the Augustovian interglacial II, however, in the Żarnowo profile it is most abundant in the Augustovian interglacial I and Augustovian interglacial I/II. Seeds of the present day *Urtica dioica*, in comparison with the described ones, are smaller and elongated, swollen in the middle. Exotic seeds of *Urtica* determined from both profiles resemble mostly the *Urtica laetevirens* Maxim., nowadays found in Korea.

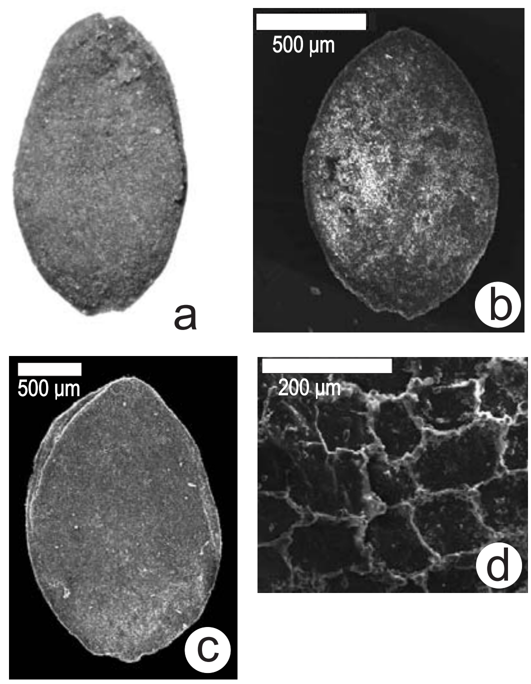

Fig. 24. a – *Urtica laetevirens* Maxim. (Czarnucha) × 30, **b, c** – (Żarnowo) SEM, **d** – details of surface, SEM

F o s s i l o c c u r r e n c e. Seeds of *Urtica* typified by the above-described shape were determined by Dorofeev (1977) as *Urtica* sp. 1 from the flora of Simbugino, as *Urtica dioica* var. 2 from the site of Yarkovo, and as *Urtica dioica* var.3 from the sites of Nizhnaya Boyarshchina and Samostrzelniki (Dorofeev 1963).

NYMPHACEAE

Euryale sp.

Fig. 25

M a t e r i a l. Czarnucha: 8 fragments of seeds, 1 spine. Żarnowo: 2 spines

D e s c r i p t i o n. Eight thick-walled fragments of seeds, with a characteristic pitted surface (Fig. 25a–c), as well as 3 spines (Fig. 25i,k), preserved only as terminal fragments, with a distinct sculpture visible in SEM pictures (Fig. 25j,l,m), were determined. Fragments of seeds were identified on the basis of their sculpture and wall structure. Spines from the Żarnowo profile were compared with the ones determined as *Euryale ferox* (Fig. 25f–h), from the site of Stanowice, by Sobolewska (1970). Sculpture of spines recorded in Żarnowo and Stanowice seems very similar in SEM pictures.

N o t e. Remains of *Euryale* cf. *ferox* were determined from the Augustovian interglacial II in both profiles and from the Augustovian interglacial I in the Żarnowo profile. Comparison between the sculpture of the present day seed (Fig. 25d,e) and the one recorded at the site of Czarnucha seems likely to indicate that the fossil remains represent *E. ferox*. However, the lack of a complete seed, or at least a fragment including the operculum and hilum, makes the determination uncertain. In the Pleistocene of Belarus, one more extinct species, *E. bielarussica* Wieliczk. (Velichkevich 1979), was described. In their general outline, its seeds resemble *E. ferox*, however, the species differ in the structure of operculum. It cannot be excluded that floras of Czarnucha and Żarnowo comprise *E. bielarussica* instead of the present day *E. ferox*, however, again due to missing complete seeds, the issue remains unresolved.

E c o l o g y. Nowadays *Euryale ferox* is found in the tropical and subtropical areas of south-eastern Asia (India, China, Japan, Korea, and south-east Siberia). The mean July temperature required for the occurrence of this species amounts to 21°C, however in extreme conditions it tolerates decreases in temperature

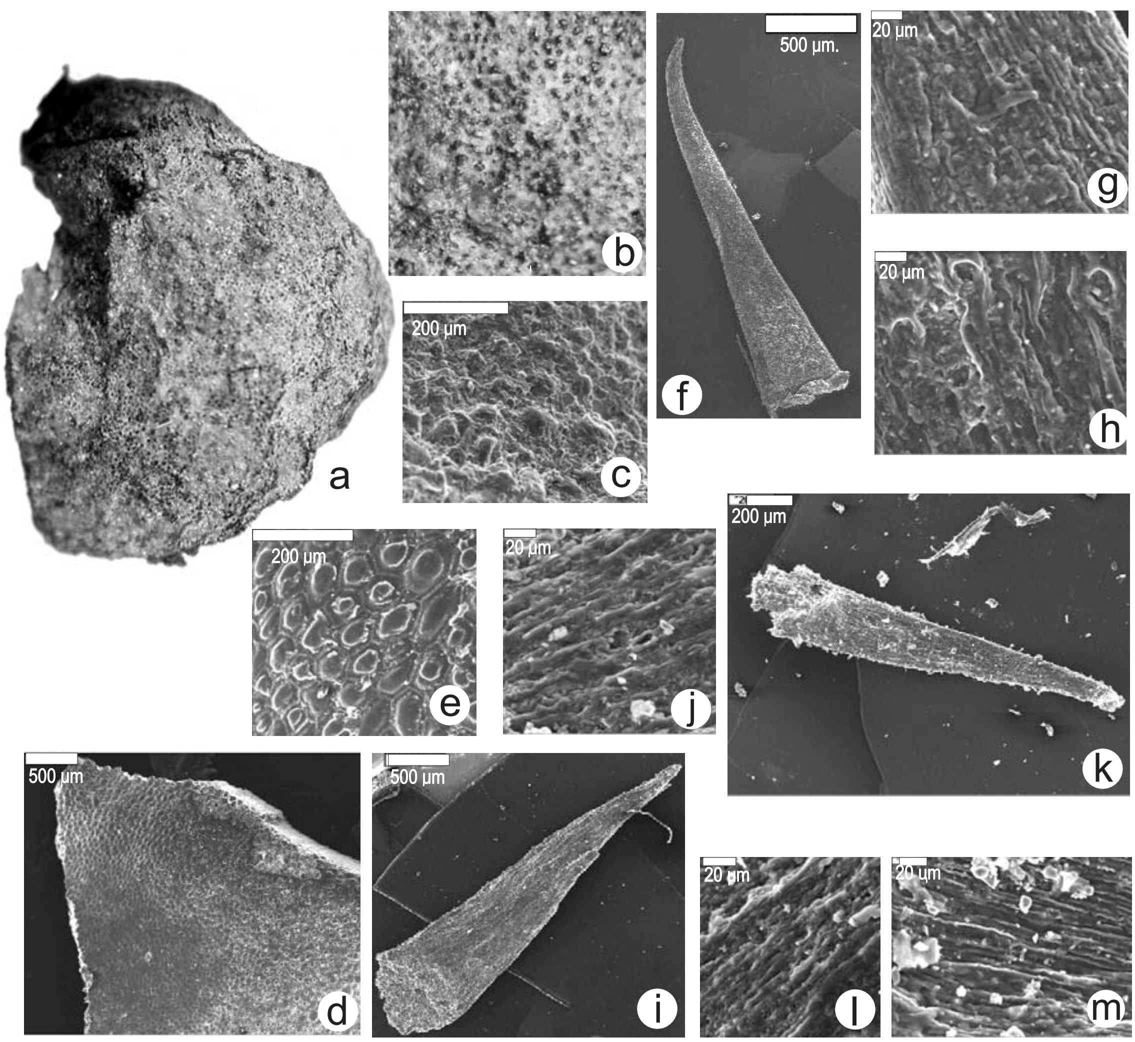

Fig. 25. a. *Euryale* sp. fragment of seed (Czarnucha) × 10**, b**. details of surface × 30, **c.** details of surface SEM, **d** – *Euryale ferox* Salisb. fragment of a present day seed SEM, **e** – details of surface of a present day seed, SEM, **f** – *Euryale* sp., spine (Stanowice by Rybnik) SEM, **g**, **h** – details of surface, SEM, **I** – spine (Żarnowo), **j** – details of surface, SEM, **k** – spine (Żarnowo), **l**, **m** – details of surface, SEM

down to even –18°C. It is resistant to great differences in temperature, recorded particularly in very hot summers and frosty winters (Sobolewska 1977).

F o s s i l o c c u r r e n c e. In Poland, described for the first time from the sediments representing the Mazovian interglacial at the site of Stanowice (Sobolewska 1970, 1977). Up to now, in the Pleistocene of Europe, fossil remains of *Euryale ferox* were described from the Mazovian (Holsteinian) interglacial in Germany and determined by Gripp and Beyle (1937). Recently the species was described from the Lower Pleistocene of south-east England (Aalto et al. 1996). *Euryale* was also identified from the Tegelen in the Netherlands (Reid & Reid 1907, 1915), as *E. europea* and *E. limburgensis*, as well as from the Likhvinian interglacial in Russia (Sukatscheff 1908), as *Euryale.*

Nymphaea cinerea Wieliczk.

Fig. 26

M a t e r i a l. Czarnucha: 10 seeds

D e s c r i p t i o n. Seeds 2.5–2.7 × 2.0–2.1 mm, thin-walled, broadly elliptical. Apex usually destroyed, operculum not preserved in the studied specimens. Surface cells rectangular, from nearly square to transversely elongate in relation to the seed axis, with intensely undulate walls. Testa soft, grey-brown. Seeds smaller than the ones of *Nymphaea alba. Nymphaea cinerea*, and *N. alba* frequently coexist in fossil floras, however, *N. alba* is more widely spread.

N o t e. In the Czarnucha profile, determined from the Augustovian interglacial II and from an interstadial in the Nidanian glaciation. One of most important diagnostic features of *Nymphaea* species is the anatomical structure of testa, visible in transverse section (Velichkevich 1973). However, such anatomical studies require comparisons between mature and well preserved seeds, not found in the material from Czarnucha.

E c o l o g y. Ecological requirements of *Nymphaea cinerea* were likely to resemble those of the *N. alba*.

F o s s i l o c c u r r e n c e. Extinct species, recorded since the Middle Pliocene until the ande of Pleistocene, characteristic for floras of the Lower and Middle Pleistocene (Velichkevich

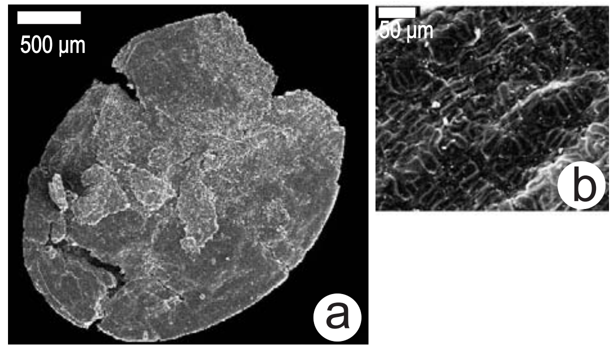

Fig. 26. a – *Nymphaea cinerea* Wieliczk., (Czarnucha), SEM, **b** – details of surface, SEM

1973, 1982). In Poland determined from the Mazovian floras from the sites of Nowiny Żukowskie, Ciechanki Krzesimowskie and Stanowice (Mamakowa & Velichkevich 1993, Velichkevich & Mamakowa 2003, Velichkevich et al. 2004). In Lithuania described from the corresponding Butenai (Mazovian) interglacial (Riškienė 1979).

RANUNCULACEAE

Ranunculus gmelini DC.

Fig. 27

M a t e r i a l. Czarnucha: 1 fruit, Żarnowo: 8 fruits

D e s c r i p t i o n. Fruits 1.4 × 1.1 mm, irregularly rounded, slightly biconvex, one margin strongly thickened. Surface uneven, divided into a central part and rim. Central part indistinctly minute-celled. Fruits very similar to those of *Ranunculus sceleratus*, which are, however, smaller, evenly thickened at margins, and with a convex central part marked by more or less distinct transverse ridges.

N o t e. Determined in both profiles from the Augustovian interglacial I/II and in the

Fig. 27. *Ranunculus gmelinii* DC. (Żarnowo) × 40

Żarnowo profile additionally from the Nidanian glaciation. Grows in North America, not found in the present day flora of Poland.

Ecology. Arctic-boreal species usually occurring in tundra and woody tundra floras, mainly on wetlands, riverbanks, and lakeshores.

Fossil occurrence. Determined for the Middle and Upper Pleistocene of Eastern Europe at the sites of Minichi, Krukenichi and Panfilovo (Velichkievich 1982) as well as of Verkhov'e-1 (Velichkievich 1977a). In the Pleistocene of Poland, described from Vistulian sites of Ściejowice, Brzeziny and Białka Tatrzańska (Velichkievich & Mamakowa 1999).

Ranunculus gailensis E.M.Reid.

Fig. 28

Material. Czarnucha: 85 seeds, Żarnowo: 88 seeds

Description. Seeds mean size 0.6–0.8 × 0.5–0.6 mm, asymmetrically elliptical or almost circular. Surface divided into a central part and rim, indistinctly minute-celled (Fig. 28d). Rim unevenly thickened, however, narrower than in a similar species, *R. sceleratus*. Central part marked by indistinct ridges.

Note. In both profiles, most abundant in the Augustovian interglacial I. Extinct species, determined for the first time in western Siberia (Nikitin 1948), very often described from fossil floras of eastern Europe as *Ranunculus sceleratoides* Nikit. ex Dorof.

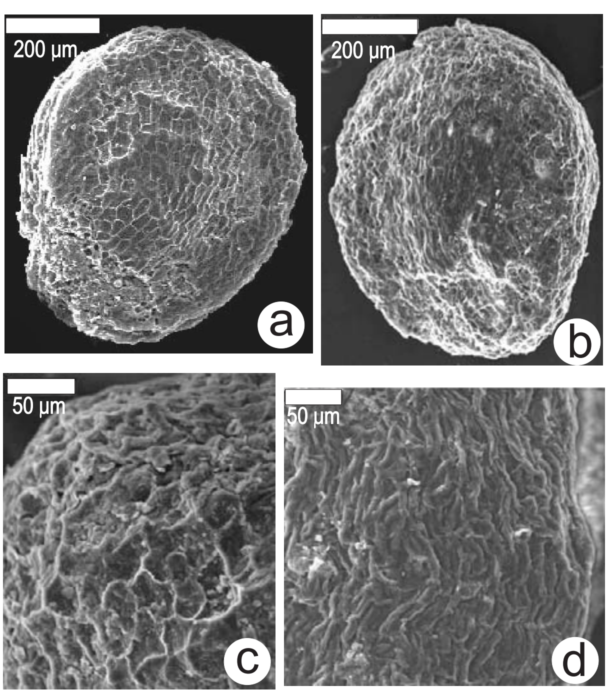

Fig. 28. a, **b** – *Ranunculus gailensis* E.M. Reid. (Żarnowo), SEM, **c**, **d** – details of surface, SEM

Ecology. Ecological requirements of the species probably resembled the ones of *Ranunculus sceleratus*, a holarctic species inhabiting shores and bottoms of basins with standing or slow-flowing waters.

Fossil occurrence. Determined from the Oligocene of Siberia (Dorofeev 1974), Miocene and Pliocene of Europe (Mai 2004, Mai & Walther 1988) and Pleistocene of Belarus (Yakubovskaya 1973, Velichkevich 1990).

ELATINACEAE

Elatine hydropiperoides Dorof. & Wieliczk.

Fig. 29

Material. Czarnucha: 6 seeds, Żarnowo: 104 seeds

Description. Seeds of a characteristic hooked shape, 0.5–0.6 × 0.1–0.2 mm with the micropylar arm longer than the chalazal one (Fig. 29a–c), differ this species from the extant *Elatine hydropiper* (Fig. 29d), however, the differences are frequently not clearly seen. *E. hydropiperoides* is marked by a lower number of celles on surface of the seed than in *E. hydropiper*. Moreover, the number of cells found in the lateral margin is nearly two times smaller in the fossil species. The seeds differ also in the degree of twist, sculpture of margins and thickness of cell walls. Seeds of *E. hydropiper* are rounded-pyramidal in cross-profile.

Note. Extinct species, in both profiles most frequently recorded in the Augustovian interglacial I and in the interstadial in the Nidanian glaciation.

Ecology. Requirements of *Elatine hydropiperoides* were likely to resemble the ones of *E. hydropiper*, classified within the holarctic element and Eurosiberian subelement, which is, in Europe, found mainly in the eastern, middle and northern part of the continent. Most widely spread in the southern part of the Scandinavian Peninsula. Grows in alluvial communities developing on riverbanks and lakeshores. Occurs in dried bottoms of basins in late summer or early autumn.

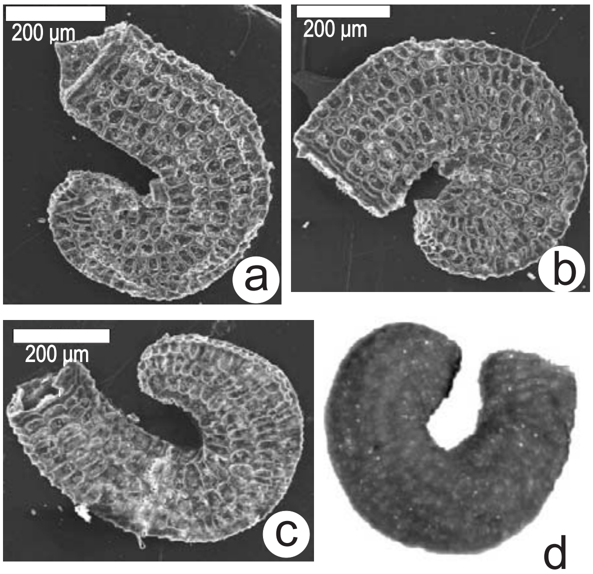

Fig. 29. **a** – **c** *Elatine hydropiperoides* Dorof. & Wieliczk. (Żarnowo) SEM, **d** – *Elatine hydropiper* L. (Czarnucha) × 80

Fossil occurrence. In the Pleistocene, described from the "Korchevian type" floras (Velichkevich 1982). In Lithuania determined from the Eopleistocene floras of Slave-2 and Daumantai-1 (Velichkevich et al. 1998).

DESCRIPTION OF MACROSCOPIC FLORA OF THE AUGUSTOVIAN INTERGLACIAL AND ITS RELATION TO FLORAS OF OTHER INTERGLACIALS

Analysis of the macroscopic floras from the sites of Czarnucha and Żarnowo enabled the distinction of an assemblage of species characteristic from the Augustovian interglacial in north-eastern Poland.

The forest flora of the Augustovian interglacial, similarly as floras of the Korchevian interglacial in Belarus and the Kemėnai in Lithuania, is marked by only infrequent remains of trees and shrubs. It comprises infrequent needles and fragments of wood of *Abies*, recorded for the first and second warm period of the interglacial what confirms the range of occurrence of fir in north-eastern Poland. The second warm period was marked by the occurrence of *Carpinus betulus*, characteristic of the period according to the pollen succession of the Augustovian interglacial. Sediments of an interstadial in the Nidanian glaciation were marked by a wing of seed of *Acer*. The most abundantly found taxa included *Betula* sect. *Albae*, *Alnus glutinosa* (Pl. 1, fig.3), *A. incana*, *Alnus*, and *Salix* (Pl. 1, fig.4), accompanied by less frequent *Larix*, *Pinus sylvestris*, *Picea* (Pl. 2, fig.2), and *Juniperus communis*.

In the aquatic flora, megaspores of *Azolla filiculoides* and seeds and spines of *Euryale* cf. *ferox*, so far recorded in Poland only from the Mazovian interglacial, were identified. Species characteristic from the Augustovian interglacial include numerous extinct species such as *Stratiotes* cf. *goretskyi*, *S.*cf. *brevispermus*, *Potamogeton perforatus*, *P. panormitanoides*, *P. dvinensis*, *Carex paucifloroides*, *Scirpus atroviroides*, *S. kreczetoviczii*, *Ranunculus gailensis*, *Eleocharis praemaximoviczii*, *Elatine hydropiperoides*, *Alisma plantago-minimum*, *Typha aspera*, and *Selaginella* cf. *tetraedra*, as well as species not found in the present day flora of Poland such as *Cyperus glomeratus*, *Urtica* cf. *laethevirens*, and *U.*cf. *thunbergiana*. The Augustovian flora is also marked by an exceptional abundance of *Salvinia natans* and *Zannichellia palustris*.

The floras from Czarnucha and Żarnowo are characterized by the occurrence of an Asiatic element, represented by *Eleocharis praemaximoviczii*, *Urtica* cf. *laethevirens*, *U.* cf. *thunbergiana*, *Euryale*, and *Potamogeton dvinensis*, as well as by a North American element, represented by *Azolla filiculoides* and *Scirpus atroviroides*.

Both analyzed floras are dominated by nowadays occurring species, however, the appearance of numerous extinct species, described from the Upper Pliocene and Lower Pleistocene floras of Belarus and Lithuania, as well as of several other taxa not found in the present day flora of Poland, support the assignment of the sediments to the Lower Pleistocene.

The composition of plant macroremains characteristic of the Belovezhian and Mogilevian interglacials, conformable with the complete Ferdynandovian succession in Poland, are similar to the Augustovian interglacial. Apart from species regarded as characteristic from the Augustovian interglacial, the Belovezhian and Mogilevian interglacials bear the remains of *Azolla pseudopinnata*, *Brasenia borysthenica*, *Potamogeton sarjanensis*, *Euryale bjelorussica*, and *Pilularia borysthenica.* In Poland, macroscopic plant remains representing the Ferdynandovian interglacial (Janczyk-Kopikowa 1975) were examined exclusively at the site of Ferdynandów and comprise e.g. *Brasenia purpurea*, *Isoëtes lacustris*, and

Zannichellia palustris. Extinct species were not recorded at the site.

Macroscopic remains of trees determined from floras of the Mazovian (=Alexandrian) interglacial, described from numerous sites in Poland and Europe, are marked by the occurrence of *Abies alba*, *Taxus baccata*, and *Picea* sect. *Omorica*. Among aquatic plants significant from the Mazovian interglacial, the following species were determined: *Azolla filiculoides*, *Euryale ferox*, *Caulinia goretskyi*, *Aldrovanda dokturovskyi*, and *Brasenia borystenica* var. *heterosperma*. Moreover, according to the present day studies, within the Pleistocene glacials only this interglacial is characterized by the appearance of *Aracites interglacialis.*

Macrofloras of the Eemian (=Muravian) interglacial are devoid of extinct species and, when considering their composition, most closely related to the Holocene floras. Species characteristic from this interglacial, however, not found in the present day flora of Poland, are *Aldrovanda vesiculosa*, *Dulichium spathaceum*, *Brasenia holsatica* (=*B. schreberi*), and *Picea obovata*.

Potamogeton sukaczevii is a characteristic species from the Early Vistulian,.

MACROFOSSIL ASSEMBLAGE ZONES

In the diagrams plotted for macroscopic plant remains of Czarnucha and Żarnowo profiles, the Macrofossil Assemblage Zones, numbered from the base to the top of profiles and described as Cza MAZ 1-14 (Tab. 2, Fig. 30) and Żar MAZ 1-14 (Tab. 3, Fig. 31), were distinguished.

Boundaries of the zones were determined on the basis of appearance, disappearance, increase or decrease in the number of taxa of a significant quantitative or indicative value.

The distinction was conducted on the basis of occurrence of one or several most abundant or characteristic and diagnostic taxa in the zone. Consequently, the zones were named after such taxa. Unnamed zones do not contain such taxa or comprise only ones found infrequently.

Table 2. Local Macrofossil Asemblage Zones of the Czarnucha profile

L MAZ	Depth (m)	Description of zone
Cza MAZ-1 Sporadic plant remains	130.35–126.25	The zone comprises 12 samples including 4 empty ones. Only single specimens of *Potamogeton panormitanus*, *Potamogeton*, *Chenopodium*, *Typha*, *Alisma plantago-aquatica*, *Betula nana*, *Rumex maritimus*, *R. acetosa*, *Polygonum*, and *Carex canescens* were determined. The upper boundary of the zone is marked by an abundant appearance of many taxa.
Cza MAZ-2 *Azolla filiculoides–Betula* sect. *Albae–Scirpus atroviroides*	126.25–124.45	The zone comprises 11 samples and is marked by a numerous occurrence of remains of trees and shrubs. *Betula* sect. *Albae* attains its maximum values. *B. nana*, *B. humilis*, and woods of *Salix* are also abundant. *Larix*, *Pinus sylvestris*, *Juniperus communis*, and *Rubus idaeus* were determined as well. Remains of plants typical of humid habitats: *Scirpus atroviroides*, *Ranunculus sceleratus*, *Urtica dioica*, *Carduus crispus*, *Potentilla supina*, *Rumex maritimus*, *Polygonum lapathifolium*, and *Mentha aquatica* are also very numerous. Abundant remains of boggy and swamp plants, particularly representing the Cyperaceae (*Carex* sp. div and *Eleocharis palustris)*, accompanied by *Menyanthes trifoliata*, *Sparganium emersum*, *Typha*, and *Ranunculus lingua*. Among aquatic plants – numerous *Zannichellia palustris*, *Salvinia natans*, *Lemna trisulca* and *Potamogeton* sp. div, accompanied by very frequent megaspores of *Azolla filiculoides.* The upper boundary of the zone was outlined above a decrease in the amount of remains of trees and *Azolla filiculoides*, *Urtica dioica*, and *Ranunculus sceleratus*, however it precedes the increase in the proportion of *Typha*
Cza MAZ-3 *Typha–Lycopus europaeus*	124.45–122.05	The zone comprises 15 samples. Decreased number and variability of remains of trees and shrubs, a wood of *Abies* determined. Still frequent remains of terrestrial plants, particularly of *Urtica dioica*, *Ranunculus sceleratus*, and *Scirpus atroviroides*. *Typha*, *Sagittaria sagitifolia*,and *Lycopus europaeus* are numerous at the basal part. Among aquatic plants – abundant *Azolla filiculoides* foss and *Zannichellia palustris*. Various species of *Potamogeton* are found, however represented only by infrequent endocarps. The upper boundary of the zone is outlined below an increase in the number of *Ranunculus sceleratus*, *Urtica dioica*, and *Carex paucifloroides.*

Table 2. Continued

L MAZ	Depth (m)	Description of zone
Cza MAZ-4 *Ranunculus sceleratus–Urtica dioica*	122.05–119.45	The zone comprises 16 samples. *Ranunculus sceleratus* and *Urtica dioica* attain their maximum values. Remains of trees and shrubs disappear towards the top of zone. Single remains of *Betula humilis*, *B.* sect. *Albae*, *Larix*, and wood fragments of *Salix*. Relatively abundant *Selaginella helvetica*, *Potentilla*, and *Bidens tripartita*. Swamp plants represented, particularly in the middle of the zone, by *Eleocharis palustris*, *Typha*, and *Alisma plantago-aquatica*. Among aquatic plants – abundant remains of *Zannichellia palustris*, *Batrachium*, *Azolla filiculoides*, and *Chara* sp. div. The upper boundary of the zone was outlined above a decrease in the number of *Ranunculus sceleratus*, *Urtica dioica*, *Zannichellia palustris*, and *Azolla filiculoides.*
Cza MAZ-5 *Rumex maritimus–Thalictrum minus*	119.45– 118.25	The zone comprises 8 samples and is marked by only infrequent plant remains. No trees and shrubs. Relatively numerous *Rumex maritimus*, *Urtica dioica*, *Chenopodium*, *Potentilla* and *Thalictrum minus*. *Carex paucifloroides* relatively abundant at the basal part. Remains of aquatic and swamp plants are infrequent. The upper boundary of the zone outlined below a readable increase in the proportion of *Oenanthe aquatica*, *Elocharis palustris*, and *Lemna trisulca*.
Cza MAZ-6 *Carex paucifloroides–Oenanthe aquatica–Eleocharis palustris–Ranunculus sceleratus*	118.25– 117.25	The zone comprises 8 samples. The basal part is marked by the dominance of: *Carex paucifloroides*, *Oenanthe aquatica*, *Elocharis palustris*, *Ranunculus sceleratus*, and *Lemna trisulca*, number of which decreases towards the top and eventually the taxa disappear. Single *Betula* sect. *Albae* and Coniferae, accompanied by *B. nana* and *Salix. Urtica latevirens* as a taxon characteristic for the zone. Among aquatic plants, significant proportions of *Salvinia natans*, *Lemna trisulca*, *Najas marina*, and *Najas minor*. The upper boundary of the zone was outlined below the initial increase in *Azolla filiculoides*, *Salvinia natans*, *Cyperus glomeratus*, and *Scirpus atroviroides*.
Cza MAZ-7 *Azolla filiculoides – Salvinia natans–Euryale – Cyperus glomeratus*	117.25–115.85	The zone comprises 8 samples. Among trees, *Abies*, *Picea* and *Alnus glutinosa* are recorded again. *Cyperus glomeratus*, *Scirpus atroviroides*, *Carex paucifloroides*, *Schoenoplectus lacustris*, *Typha*, *Azolla filiculoides*, and *Salvinia natans* attain their maximum values. Proportions of *Oenanthe aquatica* and *Eleocharis praemaximoviczii* are also significant. Remains of *Euryale*, *Stratiotes* cf. *goretskyi*, *Trapa natans*, *Scirpus kreczetoviczii*, *Potamogeton nodosus*, and *Myriophyllum spicatun* occur exclusively in this zone. The upper boundary of the zone was outlined on the basis of a decrease in the number of *Azolla filiculoides*, *Salvinia natans*, *Scirpus atroviroides*, and *Cyperus glomeratus*.
Cza MAZ-8 *Zannichellia palustris–Batrachium*	115.85–115.05	The zone comprises 5 samples including an empty one and is marked by a decrease in the number and variability of plant remains. *Alnus*, *Picea*, and a fragment of wood of *Salix* were determined. Among other remains, aquatic plants, dominated by *Zannichellia palustris*, *Batrachium*, and *Chara* sp. div., are the most numerous. *Azolla filiculoides* and *Salvinia natans* are far less abundant than in the preceding zone. The upper boundary of the zone is marked by a reincrease in the number and variability of remains of trees and shrubs and occurrence of *Carex* sp. div.
Cza MAZ-9 *Larix–Betula nana–Rumex maritimus*	115.05– 114.05	The zone comprises 6 samples including an empty one and is marked by an increase in the number and variability of remains of trees and shrubs, including *Alnus glutinosa*, *A. incana*, *Betula nana*, *B. humilis*, *B.* sect. *Albae*, *Larix*, *Picea*, *Pinus*, and wood of *Salix*. Among herbaceous plants, *Rumex maritimus* and *Carex* sp. div. 2-sided are exceptionally numerous, while among swamp plants – *Elatine hydropiper*, *Hippuris vulgaris*, and *Eleocharis palustris*. Aquatic plants, except from *Chara* sp. div., diminish. The upper boundary of the zone is marked by the disappearance of remains of trees, shrubs, *Carex* sp. div., *Rumex maritimus* and other.
Cza MAZ-10 Rare of macrofossil plant remains	114.05– 112.85	The zone comprises 8 samples including 4 empty ones and is marked by an impoverishment of the composition and number of remains of most taxa, some of which completely disappear. No trees and shrubs are found. Among herbaceous plants only single *Lysimachia* and *Urtica dioica.* Only swamp and aquatic plants, like *Typha*, *Alisma plantago-aquatica*, *Azolla filiculoides*, and *Salvinia natans*, are well represented. The upper boundary of the zone is marked by the reoccurrence of remains of trees and increase in the proportion of remains of other plants.

Table 2. Continued

L MAZ	Depth (m)	Description of zone
Cza MAZ-11 *Ranunculus sceleratus–Alisma plantago aquatica*	112.85– 112.35	The zone comprises 5 samples including an empty one and is marked by a slight increase in the number and variability of plant remains. Remains of trees, e.g. *Betula* sect. *Albae* and *Acer*, reappear. Frequent *Ranunculus sceleratus*. Among swamp plants, numerous *Alisma plantago-aquatica* and *Typha*, while among aquatic plants – *Azolla filiculoides* and *Lemna trisulca*. The upper boundary of the zone was not distinguished. The zone is overlain by a nearly 6-m-thick sand bed devoid of organic matter.
Cza MAZ-12 Sporadic plant remains	106.65– 105.85	The zone comprises 13 samples, including only two ones bearing remains – of *Eupatorium cannabinum* and *Potentilla* The upper boundary of the zone is marked by a 2-m-thick sand bed devoid of plant remains.
Cza MAZ-13 *Carex* sp. div.–*Azolla filiculoides–Salvinia natans*	103.65– 102.45	The zone comprises 8 samples with remains of boggy and aquatic plants as dominant ones. Among trees and shrubs, *Betula* sect. *Albae*, *B. humilis*, and *B. nana* were determined. Abundant *Carex* sp. div and aquatic plants like *Azolla filiculoides* and *Salvinia natans*. Numerous *Potamogeton* species (*P. gramineus*, *P. filiformis*, *P. natans*, and *P. rutilus*) and *Nymphaea* cf. *alba*. The upper boundary of the zone is marked by a 1.5-m-thick bed of boulder loam.
Cza MAZ-14 Sporadic plant remains	100.85– 100.15	The zone comprises 6 samples including 2 empty ones. Fragments of wood of *Pinus sylvestris* and single *Polygonum aviculare*, *Plantago media*, *Alisma plantago-aquqtica*, and *Batrachium* were recorded. The upper boundary of the zone is marked by the appearance of sands devoid of macroscopic plant remains.

Table 3. Local Macrofossil Asemblage Zones of the Żarnowo profile

L MAZ	Depth (m)	Description of zone
Żar MAZ-1 Sporadic plant remains	143.75– 142.75	The zone comprises 4 samples. Single boxes of *Salix* and fragments of wood of *Larix/Picea* and *Salix*. Among herbaceous plants, *Ranunculus sceleratus*, *Urtica dioica*, *U.* cf. *laetevirens* and, *U.* cf *thunbergiana* were determined. Among aquatic plants, single *Zannichellia palustris*, *Stratiotes*, and *Chara* sp. div. The upper boundary of the zone was outlined below the appearance of e.g. *Schoenoplectus lacustris*, *Carex paucifloroides*.
Żar MAZ-2 *Alnus glutinosa– Schoenoplectus lacustris–Urtica laetevirens*	142.75– 140.35	The zone comprises 11 samples, including an empty one, and is marked by the appearance of remains of *Alnus glutinosa*, *Alnus* and *Larix.* Among herbaceous plants, *Urtica dioica*, *U.* cf. *laetevirens*, *U.* cf. *thunbergiana*, *Cyperus glomeratus*, *Carex paucifloroides*, and *Cicuta virosa* are relatively abundant. Among swamp plants, *Schoenoplectus lacustris*, *Stachys palustris*, *Typha*, *Alisma plantago-aquatica*, and *Lycopus europaeus* are frequent. Aquatic plants include several *Potamogeton* sp. div., *Salvinia natans*, *Stratiotes aloides*, *S.* cf. *brevispermus*, abundant *Stratiotes*, and *Ceratophyllum demersum.* The upper boundary of the zone was outlined below the increase in the proportion of *Zannichellia palustris*, *Ranunculus sceleratus*, and *Urtica dioica.*
Żar MAZ-3 *Urtica dioica–Ranunculus sceleratus–Zannichellia palustris*	140.35– 138.55	The zone comprises 10 samples and is marked by a significant increase in the number and variability of plant remains. Occurrence of *Betula sect. Albae*, *Pinus sylvestris*, *Pinus*, *Larix*, *Alnus*, *Sambucus nigra*, and *Abies.* Herbaceous plants are dominated by *Urtica dioica* and *Ranunculus sceleratus*, accompanied by frequent *Rumex maritimus*, *Scirpus atroviriodes*, *Ranunculus gailensis*, *Mentha aquatica*, *Bidens tripartita*,and *Carex* sp. div. Remains of *Cicuta virosa*, *Solanum dulcamara*, and *Carex pseudocyperus* were determined at the basal part. The number and variability of remains of swamp plants, including *Typha*, *Alisma plantago-aquatica*, *Eleocharis palustris*, and *E. praemaximoviczii*, increases. Aquatic plants are dominated by *Zannichellia palustris* and *Chara* sp. div. Taxa such as *Batrachium* and *Potamogeton pusillus* are numerous as well. The upper boundary of the zone was outlined above a rapid decrease in values for *Zannichellia palustris* and *Chara* sp. div. and below an abundant occurrence of *Azolla filiculoides* and *Carex* sp. div. 2-sided, accompanied by a increase in the proportion of *Ranunculus sceleratus* and *Urtica dioica.*

Table 3. Continued

L MAZ	Depth (m)	Description of zone
Żar MAZ-4 *Betula sect. Albae–Azolla filiculoides–Urtica dioica*	138.55– 136.35	The zone comprises 12 samples and is marked by an increase in the number and variability of trees and shrubs, e.g. *Betula* sect. *Albae*, *B. nana*, *B. humilis*, *Alnus glutinosa*, *Alnus*, *Larix*, *Pinus sylvestris*, and *Salix*, wood of which was determined. Among herbaceous plants, abundant *Urtica dioica* and *Ranunculus sceleratus* and relatively numerous Poaceae and *Scirpus atroviriodes*. Among peat plants, *Carex* sp. div. 2-sided is the dominant one. *Carex paucifloroides* and *Menyanthes trifoliata* are frequent as well. The zone is marked by a great number and variability of remains of swamp and aquatic plants. Aquatic plants are dominated by *Azolla filiculoides* accompanied by numerous *Najas minor*, *Ceratophyllum demersum*, *Batrachium*, and *Zannichellia palustris. Euryale* was determined. Particularly abundant *Cenococcum geophilum*, found at the basal part. The upper boundary of the zone was outlined above a decrease in the number of fruits of Carex sp. div. 2-sided, *Azolla filiculoides*, and *Urtica dioica*.
Żar MAZ-5 *Eleocharis palustris–Rumex maritimus*	136.35–134.35	The zone comprises 11 samples. Remains of swamp plants, including *Eleocharis palustris*a, *Oenanthe aquatica*, *Typha*, *Alisma plantago-aquatica*, *Elatine hydropiper*,and *E. hydropiperoides*, are the most frequent ones. Among peat plants, abundant *Carex paucifloroides*, *Menyanthes trifoliata*, and *Carex* sp. div. Among aquatic plants, numerous *Azolla filiculoides*, *Salvinia natans*, and *Zannichellia palustris*, and a single occurrence of *Najas marina* and *Trapa.* Other herbaceous plants included *Rumex maritimus*, *Urtica dioica*, *Potentilla*, *Rorippa palustris*, *R. gailensis*, and *Scirpus atroviriodes*. Trees and shrubs represented by *Betula* sect. *Albae*, *B. humilis*, *B. nana*, *Larix*, and fragments of wood of *Salix.* The upper boundary of the zone is marked by a gap in the occurrence of *Azolla filiculoides*, *Salvinia natans*, *Zannichellia palustris*, and remains of many herbaceous plants.
Żar MAZ-6 *Ranunculus sceleratus–Potentilla*	134.35–132.35	The zone comprises 10 samples. Impoverishment of the composition and number of some taxa, eventually disappearing. Among trees and shrubs, *Betula* sect. *Albae*, *B. humilis*, *B. nana*, *Larix*/*Picea*, and *Salix* is found. Herbaceous plants are represented by abundant *Ranunculus sceleratus* and *Potentilla*. Among peat plants, infrequent *Carex* sp. div. and *Menyanthes trifoliata.* Among swamp and aquatic plants, *Typha. Alisma plantago-aquatica*, *Lemna trisulca*, and *Stratiotes* are recorded. The upper boundary of the zone is marked by an increase in the proportion of *Zannichellia palustris* and *Chara* sp. div.
Żar MAZ 7 *Zannichellia palustris–Chara* sp. div.–*Selaginella helvetica*	132.35–129.75	The zone comprises 13 samples and is marked by an increase in the variability and number of plant remains, in comparison with the preceding zone. *Salix*, *Pinus sylvestris*, *Larix*, *Picea*, *Betula* sect. *Albae*, *B. nana* and *B. humilis* were determined. Herbaceous plants are represented by *Urtica dioica*, *Rumex maritimus*, *Rorippa palustris*, *Selagonella selaginoides*, *Potentilla anserina*, and *Selaginella helvetica* a taxon characteristic for the zone. Among peat plants, frequent *Carex* sp. div. Among aquatic plants, abundant *Zannichellia palustris* and *Chara* sp. div., accompanied by numerous *Azolla filiculoides*, *Salvinia natans*, *Batrachium*, and Potamogeton sp. div. Swamp plants are represented by *Alisma plantago-aquatica*, *Eleocharis palustris*, and *Typha.* The upper boundary of the zone is marked by a decrease of *Zannichellia palustris* and *Chara* sp. div. and disappearance of *Batrachium*.
Żar MAZ-8 *Salvinia natans–Typha –Carex paucifloroides*	129.75–127.55	The zone comprises 12 samples. Its middle part is dominated by *Salvinia natans*, *Typha*, *Carex paucifloroides*, *Cyperus glomeratus*, and *Urtica dioica*. Abundance of the taxa decreases towards the top of the zone. Frequent *Ranunculus sceleratus*, *Rumex maritimus*, *Selaginella helvetica*, and *Potentilla anserina*. Among trees, single *Betula* sect. *Albae* and *Pinus.* The upper boundary of the zone is marked by the reoccurrence of *Azolla filiculoides*, *Salvinia natans*, *Najas marina*, and *N. minor.*
Żar MAZ-9 *Azolla filiculoides–Salvinia natans–Euryale–Carpinus betulus*	127.55–126.15	The zone comprises 7 samples. *Carpinus betulus*, *Picea*, *Alnus glutinosa*, *A. incana*, and fragments of wood of *Abies* occur exclusively in this zone. Significant proportion of remains of plants typical of humid habitats: *Cyperus glomeratus*, *C. fuscus* and *Urtica dioica.* Among aquatic plants, abundant *Azolla filiculoides* and *Salvinia natans*, accompanied by numerous *Zannichellia palustris*, *Najas marina*, *N. minor.* and *Euryale.* Among swamp plants, only *Typha* and *Eleocharis praemaximoviczii* are abundant. The upper boundary of the zone is marked by a decrease of *Azolla filiculoides* and *Salvinia natans* and disappearance of *Cyperus glomeratus* and *Najas marina*.

Table 3. Continued

L MAZ	Depth (m)	Description of zone
Żar MAZ-10 *Lemna trisulca–Menyanthes trifoliata–Abies*	126.15–123.15	The zone comprises 15 samples. Moderate amount of remains within each ecological group. Among trees and shrubs, *Alnus glutinosa* and *Alnus*, fragments of wood of *Salix*, and, exclusively in this zone, *Abies*, were found. Herbaceous plants are represented by *Rumex maritimus*, *Scirpus atroviroides*, *Urtica dioica*, and *Ranunculus acris.* Among peat plants, *Menyanthes trifoliata* is found, while among swamp plants – *Typha*, *Alisma plantago-aquatica*, and *Oenanthe aquatica*. Remains of aquatic plants: *Lemna trisulca*, *Nymphaea* cf. *alba*, and *Stratiotes* are most numerous at the basal part of the zone. *Azolla filiculoides*, *Salvinia natans*, and *Zannichellia palustris* occur infrequently, however continuously. The upper boundary of the zone was outlined below the reappearance of *Rorippa palustris* and *Elatine hydropiperoides* and the abundant occurrence of *Chenopodium hybridum.*
Żar MAZ-11 *Rumex maritimus–Rorippa palustris–Callitriche*	123.15–120.15	The zone comprises 15 samples. Great variability of plant remains. Among trees and shrubs, single *Betula* sect. *Albae*, *B. humilis*, *B. nana*, *Larix*, *Picea*, and wood of *Salix* were determined. Among herbaceous plants, the most abundant taxa are *Rumex maritimus*, *Rorippa palustris*, *Chenopodium hybridum*, *Ch. polyspermum*, *Chenopodium*, and *Potenilla anserina*, accompanied by *Selaginella helvetica* and *S. selaginoides. Triglochin maritimum* was determined exclusively in this zone. Among swamp plants, numerous *Typha*, *Alisma plantago-aquqtica*, *Eleocharis palustris*, *Hippuris vulgaris*, *Elatine hydropiperoides*, and *E. hydropiper.* Aquatic plants are represented by abundant *Callitriche* and numerous *Batrachium*, *Stratiotes*, and *Chara* sp. div. Taxa like *Azolla filiculoides*, *Salvinia natans*, and *Zannichellia palustris* are infrequent in the zone. The upper boundary of the zone is marked by the disappearance of *Callitriche* and *Stratiotes*.
Żar MAZ-12 Rare of macrofossil plant remains	120.15–117.15	The zone comprises 11 samples, including 2 empty ones. A general impoverishment of the composition and number of taxa, involving the disappearance of many taxa. Apart from *Rubus* and fragments of wood of *Alnus*, the zone is devoid of remains of trees and shrubs. Remains of herbaceous plants occur at the basal part and are represented by *Rorippa palustris*, *Mentha aquatica*, *Ranunculus sceleratus*, and *Rumex maritimus.* Swamp and aquatic plants: *Alisma plantago-aquatica*, *Lemna trisulca*, *Typha*, and *Stratiotes* are also numerous at the base of the zone. The upper boundary of the zone is marked by the reoccurrence of trees and an increase in the variability of remains typical of other ecological groups.
Żar MAZ-13 *Betula humilis–Betula nana–Zannichellia palustris*	117.15–115.15	The zone comprises 3 samples, including an empty one. Very numerous *Betula nana*, *B. humilis* and *B*. sect. *Albae*, accompanied by a single occurrence of *Alnus glutinosa*. Among herbaceous plants, *Rorippa palustris*, Poaceae, *Ranunculus sceleratus*, *Rumex maritimus*, *Bidens tripartita*, and *Scirpus atroviroides*, as well as *Selaginella selaginoides*, were determined. Among swamp plants, *Typha*, *T. aspera*, *Alisma plantago-aquatica*, and *Oenanthe aquatica* are found. The group of aquatic plants diminishes. *Zannichellia palustris* is still frequent, however, Potamogeton sp. div., *Najas marina*, and *Chara* sp. div. are recorded only as single occurrences. The upper boundary of the zone is marked by the disappearance of aquatic and swamp plants as well as of most other plants.
Żar MAZ-14 Sporadic plant remains	115.15–113.15	The zone comprises 3 samples. *Larix* and wood fragments of *Salix* and *Alnus* were found in the zone. Herbaceous plants are represented by *Selaginella selaginoides*, *Potentilla anserina* and *Ranunculus.* Only infrequent Carex sp. div. 2-sided and *Chara* sp. div., which is an example aquatic plants, were recorded. The upper boundary of the zone is marked by the end of the series of organic sediments.

CORRELATION OF LOCAL MACROFOSSIL ASSEMBLAGE ZONES

The basal part of organogenic sediments from both Czarnucha and Żarnowo profiles is represented by lacustrine and lacustrine-fluvial series, bearing sandy sediments, marked by only infrequent plant remains and correlated with the Narevian glaciation. The bottom part is overlain, at the depth of 125.85 m in

Fig. 30. Diagram plotted for plant macrofossils from the Czarnucha profile

Fig. 31. Diagram plotted for plant macrofossils from the Żarnowo profile

the Czarnucha profile and 143.05 m in the Żarnowo profile, by sediments of the Augustovian interglacial, in which, on the basis of both examination of macroscopic plant remains and palynological analysis (Winter 2008, 2009), two warm periods were distinguished (Augustovian interglacial I and II), separated by a cold period (Augustovian interglacial I/II). The interglacial sediments are overlain by sediments of the Nidanian glaciation (Tab. 4).

NAREVIAN GLACIATION

Both Cza MAZ-1 and Żar MAZ-1 zones, found at the bases of profiles, may be assigned to the Narevian glaciation. They differ in thickness, but are both marked by only occasional occurrences of plant remains of taxa such as *Betula nana* and *Larix*, as well as *Ranunculus sceleratus* (Pl. 1, fig. 15), *Chara* sp. div., and *Zannichellia palustris*.

AUGUSTOVIAN INTERGLACIAL I

Zones Żar MAZ-2 and Żar MAZ-3 of the Żarnowo profile have no equivalents in the Czarnucha profile. They bear mainly remains of plants surrounding the shore of the basin as well as of swamp and aquatic ones, particularly of *Chara* sp. div. and *Zannichellia palustris.* The zones are considered to represent the initial period of the interglacial despite the abundant occurrence of remains and the variability of species, as they are devoid of remains of plants with high temperature requirements. They represent the protocratic stage of the interglacial.

Zones Cza MAZ-2 and Żar MAZ-4 are marked by numerous tree remains, particularly *Betula*

Tabele 4. Correlation of Local Macrofossil Asemblage Zones of Czarnucha and Żarnowo profiles

CZARNUCHA PROFILE	ŻARNOWO PROFILE	Stratigraphy (Winter 2008, 2009)	
Cza MAZ-14 Sporadic of macrofossil plant remains **Cza MAZ-13** *Carex* sp. div.*–Azolla filiculoides –Salvinia natans* **Cza MAZ-12** Rare of macrofossil plant remains **Cza MAZ-11** *Ranunculus sceleratus–Alisma plantago–aquatica* **Cza MAZ-10** Rare of macrofossil plant remains **Cza MAZ-9** *Larix–Betula nana–Rumex maritimus*	**Żar MAZ-14** Sporadic of macrofossil plant remains **Żar MAZ-13** *Betula humilis–Betula nana–Zannichelia palustris* **Żar MAZ-12** Rare of macrofossil plant remains **Żar MAZ-11** *Rumex maritimus–Rorippa palustris–Callitriche*	Nidanian gaciation	
Cza MAZ-8 *Zannichellia palustris–Batrachium* **Cza MAZ-7** *Azolla filiculoides–Salvinia natans–Euryale–Cyperus glomeratus* **Cza MAZ-6** *Carex paucifloroides –Oenanthe aquatica–Eleocharis palustris–Ranunculus sceleratus*	**Żar MAZ-10** *Lemna trisulca–Menyanthes trifoliata–Abies* **Żar MAZ-9** *Azolla filiculoides– Salvinia natans–Euryale–Carpinus betulus* **Żar MAZ-8** *Salvinia natans–Typha–Carex paucifloroides*	Augustovian II	Augustovian interglacial
Cza MAZ-5 *Rumex maritimus –Thalictrum minus.* **Cza MAZ-4** *Ranunculus sceleratus –Urtica dioica.*	**Żar MAZ-7** *Zannichellia palustris–Chara* sp. div.*–Selaginella helvetica* **Żar MAZ-6** *Ranunculus sceleratus –Potentilla*	Augustovian I/II	
Cza MAZ-3 *Typha–Lycopus europaeus* **Cza MAZ-2** *Betula* sect. *Albae–Scirpus atroviroides*	**Żar MAZ-5** *Eleocharis palustris – Rumex maritimus* **Żar MAZ-4** *Betula* sect. *Albae–Azolla filiculoides–Urtica dioica* **Żar MAZ-3** *Urtica dioica–Ranunculus sceleratus–Zannichellia palustris* **Żar MAZ-2** *Alnus glutinosa–Schoenoplectus lacustris–Urtica latevirens*	Augustovian I	
Cza MAZ-1 Sporadic of macrofossil Plant remains	**Żar MAZ-1** Sporadic of macrofossil plant remains	Narevian glaciation	

sect. *Albae* and *B. humilis*, and of herbaceous plants, such as *Urtica dioica* and *Ranunculus sceleratus.* Zones are typified by an increase in the proportion of remains of thermophilous plants, such as *Azolla filiculoides*, *Salvinia natans*, *Scirpus atroviroides*, and *Lemna trisulca*. In the Żarnowo profile, *Cyperus glomeratus* and *Euryale* were additionally recorded. From the taxonomic composition it may be concluded, that in the Żarnowo profile the warm period I of the Augustovian interglacial was characterized by the development of communities slightly more thermophilic than those from Czarnucha, or, what is even more likely, that the Czarnucha profile lacks in the part of sediments likely to bear a record of the warm period I. Such a view is confirmed by the results of palynological analysis (Winter 2009) as well as by the clastic development of sediments of this segment of the core.

Zones Cza MAZ-3 and Żar MAZ-5 should be categorized in the close of the warm period I of the interglacial. Although the remains of plants typical of warm interglacial periods are still relatively numerous, the gradual diminishing of plant communities and a low frequency of remains in both profiles indicate the deterioration of climatic conditions. The Czarnucha profile comprises remains of thermophilous species, like *Abies*, *Trapa*, and *Azolla filiculoides*, however, accompanied by indicators of cool climate, such as *Betula humilis*, *B. nana*, *Larix*, and *Ranunculus gailensis*. Additionally, in both profiles the vegetation of this period indicates slightly different edaphic conditions.

AUGUSTOVIAN INTERGLACIAL I/II

In zones Cza MAZ-4 and Cza MAZ-5, as well as in Żar MAZ-6 and Żar MAZ-7, the lacustrine vegetation diminishes, and the occurrence of *Thalictrum minus* in Czarnucha as well as of remains of *Betula nana* and *B. humilis* and wood fragments of *Larix/ Picea* in Żarnowo, indicate the deterioration of climate. The results of pollen analysis of the Czarnucha profile (Lisicki & Winter 2004, Winter 2009) confirm the prevalence of boreal climate.

AUGUSTOVIAN INTERGLACIAL II

In Czarnucha profile, this interglacial period is represented by zones Cza MAZ-6, Cza MAZ-7 and Cza MAZ-8, with the warmest period falling in Cza MAZ-7. In Żarnowo profile, the warm period II is represented by zones Żar MAZ-8, Żar MAZ-9 and Żar MAZ-10, with the warmest period falling in Żar MAZ-9.

Zones bearing a record of the warmest part of the warm period II of the Augustovian interglacial at the investigated sites differ in the successions of macroscopic remains. Czarnucha is marked by the simultaneous occurrence of abundant megaspores of *Azolla filiculoides* and *Salvinia natans*, accompanied by seeds of *Euryale*. Plant communities are most abundant and diversified in the entire interglacial. In Żarnowo, the warming is evidenced only by the occurrence of infrequent, however, indicative taxa such as *Carpinus betulus*, *Salvinia natans*, and *Euryale*.

The period subsequent to the climatic optimum is represented by zones Cza MAZ-8 and Żar MAZ-10 and is marked by similar events in both profiles. A decrease is recorded in the frequency of plant remains and the number of taxa with high climatic requirements.

NIDANIAN GLACIATION

The cold stadial period is represented by zones Cza MAZ-9, Cza MAZ-10, Cza MAZ-11 and Cza MAZ-12 in the Czarnucha profile and by Żar MAZ-11and Żar MAZ-12 in the Żarnowo profile and is distinguished by a lack of remains of plants with high temperature requirements. The occurring taxa are e.g. *Salix*, *Chenopodium*, *Ranunculus sceleratus*, and *Typha* (Pl. 2, fig. 16). It seems likely that sediments of zones Cza MAZ-11 and Cza MAZ-12 were redeposited, what is confirmed by the type of vegetation and sediment, as well as by the results of pollen analysis. Redeposited Tertiary spores were found abundantly in the zones (Winter 2008, 2009). Redeposition of pollen may indicate the supply of allochtonic material to the basin as a result of erosion and solifluction processes.

In the Nidanian glaciation, the profile from Czarnucha comprises an interstadial-like zone, Cza MAZ-13, characterized by a very high proportion of remains of thermophilous plants such as *Azolla filiculoides* and *Salvinia natans*, however, accompanied by *Betula nana* and *B. humilis*.

In the Żarnowo profile, this zone is most likely to correspond to Żar MAZ-13, which does not bear remains of plants of higher temperature requirements, but, in comparison with the closest zones, is marked by an increase in the frequency of remains.

In both profiles, in zones Cza MAZ-14 and Żar MAZ-14, the sediment passes into a more sandy one, with a low content of organic matter and only occasional occurrence of plant remains. Taxa determined from this period indicate unfavourable temperature conditions, however accompanied by good light conditions. Taxa found in this period include e.g. *Plantago media*, *Selaginella selaginoides*, *Larix*, and *Potentilla anserina* (Pl. 2, fig. 9).

REMARKS ON ECOLOGICAL CONDITIONS AND DEVELOPMENT OF VEGETATION IN THE PALAEOLAKES OF CZARNUCHA AND ŻARNOWO

NAREVIAN GLACIATION

Cza MAZ-1 (130.35–126.25 m)
Żar MAZ-1 (143.75–142.75 m)

In both profiles, segments assigned to the zones comprise mainly sands and clayey sands, marked by a low content of organic matter and accompanied by locally occurring silty sands bearing thick plant detritus and gravel. The sediments are likely to represent the close of the Narevian glaciation.

Due to a very low frequency of macroscopic plants remains, a detailed reconstruction of changes in lacustrine and waterside vegetation was not possible. The occurrence of sclerotia of *Cenococcum geophilum*, as well as the type of the sediment, indicate that the lake was in its initial stage of development, and the surrounding vegetation did not form a dense cover.

Humid habitats were overgrown by communities of dwarf shrub tundra including *Betula nana*, while slightly drier, open areas were marked by the appearance of *Rumex acetosa*, *Chenopodium*, and *Polygonum*. Boggy sites were inhabited by *Rumex maritimus* and *Ranunculus sceleratus*, nowadays found mostly on shores of strongly eutrophicated basins. Humid habitats, abundant in nitrogen, were overgrown by various species of nettle. In the littoral, a belt of swamps comprising *Typha* and *Alisma plantago-aqatica* was formed. Aquatic vegetation was represented by single specimens of *Potamogeton*, *Zannichellia palustris*, *Stratiotes*, and *Chara*.

In the Żarnowo profile, sediments closing the zone bear remains of fragments of wood of *Larix/Picea* and remains of *Salix*, providing basis for the assumption that surroundings of lake were already entered by first trees and shrubs.

Only the occasional occurrence of plant remains, as well as the presence of gravel in the sediment, evidence strong fluvioglacial processes and lack of a dense plant cover, which are typical of cold glacial periods. Although the basin was in its initial stage of development, the degree of its eutrophication must have already been relatively high, what is indicated by the occurrence of e.g. *Zannichellia palustris*, *Rumex maritimus* (Pl.2, fig. 6), and *Urtica dioica*.

AUGUSTOVIAN INTERGLACIAL I

Żar MAZ-2 (142.75–140.35 m)

The proceeding improvement in climatic conditions was evidenced by an increase in the content of organic matter and calcium carbonate in the sediment. The younger part of the zone is marked by the appearance of detritus-calciferous gyttjas.

Such changes are accompanied by a rapid development of vegetation in the lake and its surroundings. Among trees, alder became locally dominant in humid habitats and in areas bordering on swamps. Various habitats were also marked by the occurrence of pine. Wet habitats, located closer to the lake, were overgrown by willow scrubs, what is evidenced by the occurrence of remains of *Salix.* Drier sites were overgrown by shrubs of *Rubus.* Humid habitats, rich in nitrogen, were still marked by the presence of nettle. Lack of a dense plant cover is indicated by the occurrence of heliophilous *Polygonum* and *Chenopodium*.

In the younger part of the zone, in wet and eutrophic habitats as well as in drying up waterside habitats, a community of therophytes came into being, represented by species characteristic of present day syntaxa classified in Bidentetea tripartiti, such as *Bidens tripartita* (Pl. 2, fig. 3), *Rumex maritimus*, *Ranunculus sceleratus*, and *Rorippa palustris.* The boundary with the swamp was most likely overgrown by abundant *Mentha aquatica* (Pl. 1, fig. 2), as well as by *Solanum dulcamara* (Pl. 2, fig. 4) and *Cyperus glomeratus*.

Border of swamp communities were the origin of peat *Carex* species (2- and 3-sided) as well as of *Menyanthes trifoliata* (Pl. 2, fig. 10) and *Cicuta virosa*. *Lycopus europaeus* was found in various habitats and communities.

Exceptionally numerous fruits of *Schoenoplectus lacustris*, found particularly in the younger part of the zone, suggest the existence of a community similar to the present day *Scirpetum lacustris* association, usually growing on sandy, loamy or sandy-gravel grounds, and covering large areas of eu- and mesotrophic basins. This community forms the first belt of swamp vegetation bordering on aquatic communities. It was probably accompanied by a belt of a typical swamp, what is confirmed by the occurrence of remains of *Typha*, *Stachys palustris*, *Oenanthe aquatica* (Pl. 2, fig 18), *Alisma plantago-aquatica*, and *Sparganium emersum* (Pl. 1, fig. 7).

Communities of aquatic plants included species characteristic for the present day Potamion alliance (Matuszkiewicz 2008), such as *Potamogeton trichoides*, *P. nodosus*, *P. natans*, *P. perfoliatus*, *P. rutilus*, and *Ceratophyllum demersum.*

Shallow coves of the lake were likely to be inhabited by *Stratiotes*, including *Stratiotes* cf. *brevispermus*, which is an extinct species with its ecological requirements probably resembling the ones of the extant *Stratiotes aloides.* A pleuston community with *Salvinia natans* appeared on the lake surface.

The Żarnowo profile most probably includes the complete warm period I of the Augustovian interglacial. Vegetation characteristic for zone Żar MAZ-2 is of an initial type, what suggests the beginning of its development, resulting from an improvement in climatic conditions following the Narevian glaciation. The improvement of climate is evidenced by the occurrence of species characteristic for the climatic optimum of the interglacial, including aquatic plants such as *Potamogeton trichoides*, *P. nodosus*, *Ceratophyllum demersum* (Pl. 1, fig. 16), and *Salvinia natans*, as well as terrestrial plants such as *Cyperus glomeratus*, which is nowadays found in warmer areas of Europe.

Żar MAZ-3 (140.35–138.55 m)

Sediment is more carbonate than in the preceding zone and is formed mostly of detritus gyttja, containing abundant plant remains and mollusc shells.

Landscape of the lake surroundings became enriched with tree birches and thermophilous trees and shrubs, what is evidenced by the presence of seeds of *Sambucus nigra* and fragments of wood of *Abies*. The occurrence of *Abies* was already recorded in the younger period of the Augustovian interglacial I in the Czarnucha profile.

Zone Żar MAZ-3 is marked by an exceptional abundance of plant macroremains, with the dominance of several species. Nitrophilous habitats were absolutely dominated by *Urtica dioica*. Heliophilous species such as *Thalictrum minus* (Pl. 2, fig. 12), *T. simplex*, *Chenopodium album*, and *Potentilla anserina* were very numerous. The occurrence of such plant species indicates a lack of dense groups of trees and shrubs in the surroundings of the lake.

Periodic fluctuations in the water level are evidenced by an exceptionally abundant occurrence of fruits of *Ranunculus sceleratus* and *Rumex maritimus*, species nowadays found in the *Rumicetum maritimi* association, overgrowing the most eutrophicated shores of lakes and ponds. Moreover, identification of numerous taxa of herbaceous plants, such as *Scirpus atroviroides*, *Humulus lupulus*, *Thalictrum lucidum*, *T. flavum*, and *Ranunculus gmelinii*, representing various communities and wet habitats, suggests a diversity of waterside communities, although the species were recorded only as occasional specimens.

Peaty habitats or ones bordering on swamps, particularly in the younger part of the zone, were overgrown by *Menyanthes trifoliata*, *Comarum palustre*, *Cicuta virosa*, *Ranunculus flammula*, as well as by various species of *Carex* (2- and 3-sided, *Carex paucifloroides*). Their occurrence serves as evidence for the existence of peat bogs (low or transition ones) or peaty soils on shores and in humid hollows.

Swamp communities become a more important part of landscape. Abundance of remains of *Typha*, *Schoenoplectus lacustris*, *Hippuris vulgaris* (Pl. 2 fig. 11), *Alisma plantago-aquatica*, *Eleocharis palustris* (Pl. 2, fig. 15), as well as of *Mentha aquatica* and *Lycopus europaeus* (Pl. 1, figs 10, 11) , may be associated with the presence of communities similar to the present day typical swamps. Shallow, calm coves were marked by the growth of *Elatine hydropiper.*

A distinct increase of water eutrophication or salinity resulted in the prevalence of *Zannichellia palustris* in aquatic communities. Its proportion, however, gradually decreases in the younger part of the zone. Simultaneously to *Zannichellia palustris*, an increase was recorded for *Chara* sp. div., accompanied by several *Potamogeton* species, including *Potamogeton natans*, *P. perfoliatis*, and halophilous *P. pectinatus.* All the above-mentioned species were likely to form communities similar to ones representing the present day *Parvopotamo-Zannichellietum* (Matuszkiewicz 2008).

The diversity of species and abundance of plant remains indicate a proceeding strong eutrophication of the presumably shallow basin, affected by frequent seasonal fluctuations in the water level.

Cza MAZ-2 (126.25–124.45 m)
Żar MAZ-4 (138.55–136.35 m)

Sediments associated with the Narevian glaciation in the Czarnucha profile are not overlain by any sediments corresponding to the initial period of the Augustovian interglacial I, namely the protocratic stage and the older part of the mesocratic stage, following Iversen (1958), Tobolski (1976), and Dzięciołowski and Tobolski (1982). Zone Cza MAZ-2 represents rather the close of the younger period of the Augustovian interglacial I. Such an assignment is supported by the results of analysis of macroscopic plant remains, as well as by comparisons between the results of pollen analysis obtained from the profile of Czarnucha (Lisicki & Winter 2004, Winter 2009), the Augustovian profile of Szczebra (Janczyk-Kopikowa 1996), and profiles of Kalejty (Winter 2001, Lisicki & Winter 2004) and Żarnowo (Winter 2008).

Zone Cza MAZ-2 was marked by a rapid change in the type of sediment. Clayey sands found at the basal part passed into peats and peaty sandy silts at the top part. In zone Żar MAZ-4, detritus-calciferous gyttja is the dominant sediment. The amount and diversity of macroscopic remains determined in the zones indicate that plant communities were varied in the surroundings of the lake, as well as in the lake itself.

The lake was surrounded mainly by birches (*Betula* sect. *Albae*). The number of identified remains representing this genus is likely to suggest that it formed a tree stand of a greater density, in which birches were accompanied by pine, larch and, in habitats of a higher humidity, by alder. Patches of tundra vegetation with *Betula nana*, *B. humilis*, and *Salix* were an important component of the landscape in the surroundings of the lake. The younger part of zone Cza MAZ-2 was marked by the appearance of *Juniperus communis*.

Nitrophilous habitats were still dominated by *Urtica dioica*. Heliophilous species, represented by *Chenopodium hybridum*, *Ch. polyspermum*, *Thalictrum simplex*, *Potentilla anserina*, as well as by Asteraceae and Poaceae, were found abundantly. In habitats of a higher eutrophication, a community similar to the present day *Rumicetum maritimi*, including *Rumex maritimus* and *Ranunculus sceleratus*, retained its prevalence. Wetlands or muddy, drying up parts of lakeshores were most likely inhabited by communities comprising *Bidens tripartita* and *Rorippa palustris.*

The appearance of numerous species of trees and herbaceous plants in the surroundings of the basin may have resulted from the decline of its water level. Gradual shallowing of the lake appears to be evidenced by the abundant occurrence of fruits of *Carex* sp. 2- and 3-sided, likely to originate from peat habitats or communities similar to swamps of the Magnocaricetea class, presence of which is supported by the appearance of remains of *Menyathes trifoliata* and *Comarum palustre.*

Swamp communities were still an important part of landscape. The zone of swamps was likely to include communities similar to the present day typical swamps, comprising *Typha*, *Schoenoplectus lacustris*, *Hippuris vulgaris*, *Alisma plantago-aquatica*, *Eleocharis palustris*, *Oenanthe aquatica*, and *Lycopus europaeus.* Swamp communities with *Schoenoplectus lacustris* were gradually passing into ones typical of open waters. Communities including *Eleocharis palustris*, *Oenanthe aquatica*, and *Hippuris vulgaris* were found close to habitats of shallow, calm waters, grown also by *Elatine hydropiper*, *E. hydropiperoides*, and *Sagittaria sagittifolia* (Pl. 2, fig. 17).

The proportion of *Zannichellia palustris* and *Chara* gradually declines in communities of aquatic vegetation. The species are replaced with *Azolla filiculoides*., *Lemna trisulca*, and *Salvinia natans*, all forming a pleuston community. Abundant pleuston communities, developing on the surface, limited the circulation of water and caused a strong overshadowing, resulting in dying out of numerous plants found at greater depth or rooted in the bottom of basins.

Important components of aquatic communities included *Najas minor* (Pl. 1, fig. 12), *N. marina*, *Batrachium* (Pl. 1, fig. 14), *Ceratophyllum demersum*, *Potamogeton perfoliatus*, *P. pusillus*, *P. natans*, and the extinct *P. dvinensis.* Presumably, the species, accompanied by *Zannichellia palustris*, formed an association similar to the present day *Parvopotamo-Zannichellietum* in insolated and calm coves. *Euryale*, not found in the present day flora of Poland and serving as indicator of higher summer temperatures and lower winter temperatures, occurred only occasionally in zone Żar MAZ-4.

The increase in content of organic matter in the sediment, the occurrence of remains of *Betula* sect. *Albae* (indicating a mean July temperature of 12–13°C) and *Solanum dulcamara* (nowadays found in areas of minimum July temperatures of 13°C; Kolstrup 1980), however accompanied by an increase in the proportion of heliophytes being indicators of cooler climate (*Betula nana*, *B. humilis*, *Selaginella selaginoides*, and *Rorippa palustris*), evidences the continental features of climate and deterioration of temperature conditions.

It should be noticed that conclusions based on studies of macroremains of terrestrial plants are contradictory to results of analyses of macroremains of aquatic plants. Aquatic vegetation did not respond to the deterioration of climate. The lake was still inhabited by *Salvinia natans*, *Lemna trisulca*, *Ceratophyllum demersum*, and *Euryale*, occurrence of which indicates minimum July temperatures likely to attain 21°C.

Exceptionally frequent sclerotia of *Cenococcum geophilum*, found in zone Żar MAZ-4, serve as evidence for the occurrence of intensive solifluction processes, associated with the lack of a dense plant cover, in the surroundings of basin. Remains of *Zannichellia palustris*, *Triglochin maritimum*, and *Strariotes* , found abundantly in the zones, suggest an advanced shallowing and eutrophication of the basin as well as a low salinity of its waters.

Cza MAZ-3 (124.45–122.05 m)
Żar MAZ-5 (136.35–34.35 m)

The decrease in number of remains of trees and shrubs, as well as the gradual change in the type of sediment, passing, towards the top of zone, from silts marked by a high content of organic matter into silts with an admixture of sand, indicates a slight deepening of the basin and, most likely, the withdrawal of communities of trees and shrubs into areas more distant from the lakeshore. Remains of tree birches and common pine, as well as of spruce, larch and fir, are still recorded, suggesting that birch-pine forest, which appeared already in the preceding zone, was retained in the surroundings of the basin. Occurrence of fir in the area was previously under discussion and the origin of its pollen grains was related to long-distance transport. However, the presence of *Abies*, recorded as a fragment of wood in zone Cza MAZ-3, correlates with the pollen curve of this species (Winter 2009). This evidences the actual occurrence of the species in the area at the close of the Augustovian interglacial I.

Similarly as in preceding zones, the terrestrial herbaceous vegetation surrounding the lacustrine basin is represented by numerous species. *Urtica dioica* is still relatively abundant, however its proportion has rapidly decreased. *Ranunculus sceleratus* and *Rumex maritimus*, found in extremely eutrophic habitats of periodically emerged lakeshores, were gradually withdrawn. Vegetation of humid habitats comprised various species of *Potentilla*, e.g. *Potentilla anserina*, *P. supina*, and *Potentilla* sp. div., accompanied by *Plantago media* and *Selaginella helvetica* (Pl. 1, fig. 1). Plants typical of open habitats were represented by *Rorippa palustris*, *Chenopodium hybridum*, and *Ch. polyspermum*, all characterized by high light requirements and indicating a relatively low density of tree stands surrounding the lake.

Thermophilous species, such as *Scirpus atroviroides* and *Cyperus glomeratus*, both alien to the present day flora of Poland and accompanied by *Juncus*, were still quite frequent in wet habitats. *Mentha aquatica* and *Ranunculus gailensis* also occurred abundantly.

Peaty areas may have been the sites of development of swamps of the Magnocaricetea class, including *Menyathes trifoliata*, *Comarum palustre*, *Carex riparia*, *Carex gracilis*, and *Carex paucifloroides.* The occurrence of tegmens of *Typha* and remains of *Oenanthe aquatica*, *Alisma plantago-aquatica*, *Lycopus* *europaeus*, and *Hippuris vulgaris* indicate for the presence of a belt of swamps similar to the present day typical swamps.

Shallow sites, sheltered from waves, were likely to be overgrown by *Elatine hydropiper* and *E. hydropiperoides.* Communities resembling low swamps comprised *Sagittaria sagittifolia* and *Sparganium emersum*, accompanied by an extinct species, *Scirpus kreczetoviczii*. In the present day flora, its closest equivalent is *Bolboschoenus maritimus*, most frequently found in slightly saline or strongly eutrophic waters.

The aquatic flora is distinctly diminished – a decrease is recorded for both the frequency and diversity of remains. From minor amounts of megaspores of *Salvinia natans* and *Azolla filiculoides* it may be concluded, that the significance of pleuston communities was noticeably decreased. Among macrophytes, the appearance of numerous species, such as *Potamogeton natans* (Pl. 1, fig. 13), *P. crispus*, *P. pusillus*, *P. panormitanoides*, *P. filiformis*, and *P. pectinatus*, as well as of *Myriophyllum spicatum* (Pl. 2, fig. 14) and *M. verticillatum*, was recorded. The occurrence of *Zannichellia palustris*, *Scirpus kreczetoviczii*, and *Potamogeton pectinatus* in aquatic vegetation indicates a very strong eutrophication of waters or their low salinity. Remains of *Rumex maritimus* and *Ranunculus sceleratus* indicates that the surroundings of basin were marked by high trophy as well.

The gradual diminishing of vegetation and disappearance of organic matter from the sediment, observed towards its top part, both suggest that the described zones represent the close of the Augustovian interglacial I. The appearance of *Ranunculus gmelinii*, as a holarctic species, nowadays occurring in Scandinavia (Wasylikowa 1964), evidences a gradual deterioration of temperature conditions. At the close of interglacials aquatic vegetation shows a delayed response for the deterioration of temperature conditions in comparison with terrestrial vegetation (cf. Iversen 1954, 1964, Szafer 1954, Wasylikowa 1964). This fact should be the explanation for only slight changes in the composition of aquatic vegetation, and in part also of the swamp vegetation, in comparison with the preceding zones. The composition of aquatic flora indicates a slight decline of the water level in the basin.

AUGUSTOVIAN INTERGLACIAL I/II

Cza MAZ-4 (122.05–119.45 m)
Żar MAZ-6 (134.35–132.35 m)

The zones were not characterized by distinct changes in the sediment. Silts, marked by minor amounts of humic matter at the top part, were still depositing.

Trees were noticeably withdrawn from the area. Remains of birches, willows and *Rubus idaeus* (Pl. 2, fig. 5), still found at the base of the zone, occur only occasionally at its top part. However, such an observation was not recorded for wet and humid habitats, vegetation of which, with only small changes in its composition, was present in zones Cza MAZ-2 and Żar MAZ-3.

Communities of herbaceous plants are still dominated by *Urtica dioica*, *Potentilla*, and *Ranunculus gailensis*, accompanied by occasionally found *Potentilla supina* (Pl. 2,fig. 8), *P. anserina*, and *Polygonum aviculare*. This indicates that the lake was still surrounded by open, nitrophilous habitats. Sites of a higher insolation were likely to be dominated by communities similar to ones representing Bidentetea tripartiti, including *Bidens tripartita*, *Rorippa palustris*, and *Ranunculus sceleratus.* The younger parts of both zones were marked by a higher proportion of heliophilous vegetation, comprising *Chenopodium album*, *Selaginella helvetica*, *S. selaginoides*, and Asteraceae undiff.

In comparison with the preceding period, the number of peat-bog plants has significantly decreased, however, the occurrence of *Carex elata*, *C. paucifloroides*, *C. riparia*, and *Menyanthes trifoliata*, accompanied by *Lycopus europaeus* in habitats close to the swamp, evidences the existence of small patches of low peat-bogs and swamps of the Magnocaricetea class in the surroundings of lake. Communities resembling typical swamps were still present in the littoral, however, in a diminished form, represented only by single remains of *Typha*, *Alisma plantago-aquatica*, *Eleocharis palustris*, *Hippuris vulgaris*, and *Sagittaria sagittifolia*.

Pleuston communities comprising *Azolla filiculoides* and *Salvinia natans* began to disappear in the younger part of the zone, to completely disappearance at its top. Shallow parts of the lake with standing water, and, most likely, also the zone of swamps of a low density, could have been inhabited by a community resembling the present day *Hydrocharietum morsus-ranae*. This is indicated by the occurrence of remains of *Hydrocharis morsus-ranae* and *Stratiotes*, as well as of *Potamogeton pusillus* (Pl. 2, fig. 13), *P. rutilus*, *P. filiformis*, and *Callitriche* (Pl. 1, figs 8, 9).

The presence of seeds of *Zannichellia palustris* evidences the strong eutrophication of water, confirmed by the appearance of communities including *Najas marina* and *N. minor* in the waterside shallows. The nearly continuous occurrence of *Zannichellia palustris* in the Czarnucha profile is likely to indicate a constant presence of habitats marked by fluctuations in the water level, resulting in a high content of mineral salts.

Cza MAZ-5 (119.45–118.25 m)
Żar MAZ 7 (132.35–29.75 m)

The zones are marked by a change in the sediment, passing from an organic one into a sandy silt bearing minor amounts of humic matter.

Zone Cza MAZ-5 is typified by a complete disappearance of remains of trees and shrubs, while the corresponding zone from Żarnowo – by the occurrence of *Betula* sect. *Albae*, *B. humilis*, *B. nana*, and *Salix*. Apart from the above-mentioned taxa, the forest communities were reentered by larch, spruce and common pine. Vegetation of wet and humid habitats was clearly diminished in comparison with the preceding zone. *Urtica dioica*, *Potentilla*, *Chenopodium*, *Thalictrum flavum*, and *T. lucidum* were still the dominant species. Heliophytic communities comprised *Selaginella selaginoides* and *Carduus crispus* (Pl. 2, fig. 7), *Selaginella helvetica*, *Potentilla anserina*, *Chenopodium polyspermum*, and *Thalictrum simplex* were still found. Muddy, drying up parts of lakeshores or wetlands were probably overgrown by small patches of communities with *Rorippa palustris*. Sites of the highest eutrophication were characterized by a reincrease in the surface of a community similar to the present day *Rumicetum maritimi*, what is evidenced by the occurrence of relatively frequent remains of *Rumex maritimus* and *Ranunculus sceleratus*.

Peaty habitats, as well as ones close to the swamp, were dominated by *Cicuta virosa* and *Carex paucifloroides*. The occurrence of *C. paucifloroides* suggests the presence of communities similar to raised bogs, while *Cicuta virosa* is frequently found in swamps of the Magnocaricetea class. Peat habitats at the edge of swamp communities were composed mainly of sedges, *Carex* (2- and 3-sided), *C. pseudocyperus*, and *Menyanthes trifoliata*.

Significance of swamp communities, after their impoverishment due to a deterioration of climate in the first period of the Augustovian interglacial I/II, reincreases. Abundant remains of *Typha*, *Alisma plantago-aquatica*, *Eleocharis palustris*, *Hippuris vulgaris*, and *Oenanthe aquatica*, accompanied by less frequent remains of *Sagittaria sagittifolia* and *Ranunculus lingua* (Pl. 1, fig. 5), all found in zone Żar MAZ-7, may be associated with communities similar to the present day typical swamps. Shallow, calm coves were marked by the occurrence of *Elatine hydropiper*. Communities of macrophytes were characterized by the domination of *Zannichellia palustris* and increase in the proportion of *Chara*. The presence of *Zannichellia palustris* indicates eutrophic conditions of water and, most likely, its low salinity. *Potamogeton* species, e.g. *Potamogeton pusillus*, *P. perfoliatis*, and *P. pectinatus*, as well as *Myriophyllum spicatum* and *M. verticillatum*, were found frequently. Aquatic communities included also *Callitriche* and *Batrachium*.

The presence of aquatic and swamp communities, nearly continuous though slightly variable in proportion and composition in the periods of Agustovian interglacial I and I/II, suggests that the water level and ecological conditions of the littoral remained almost unchanged in the area for a very long time. Such conditions provided the opportunity for the preservation of such aquatic and swamp communities throughout nearly the entire Agustovian interglacial. Considering the constant accumulation of sediment, both organic and mineral, the lake basin would have eventually been filled with sediments. As swamp and aquatic communities survived and the water level was marked by only slight fluctuations, a constant and gradual decline of the lake bottom may have occurred due to deposition of sediments or tectonic movements (Ber 2009).

The withdrawal of trees and shrubs, as well as the presence of diminished open communities, indicate unfavourable climatic conditions for the development of vegetation. The lack of a dense plant cover resulted in an increase in solifluction processes, indicated by the greater amount of *Cenococcum geophilum* in the sediment. The type of vegetation, described on the basis of analysis of macroscopic remains, changes in sediment, as well as the results of pollen analysis, bearing a record of high percentage values for herbaceous vegetation and of a decline or disappearance of curves for thermophilous trees (Lisicki & Winter 2004, Winter 2009), provide the basis for the assumption that zone Cza MAZ-5 is at least of a stadial type.

The subsequent gradual return of numerous species of trees, as well as of swamp and aquatic plants, particularly at the close of the Augustovian interglacial I/II in zone Żar MAZ-7, suggests a gradual warming of climate and, most likely, also an increase in its humidity, advantageous to the development of vegetation typical of humid habitats.

Despite occasional occurrences of remains of thermophilous plants among aquatic vegetation, zones Cza MAZ-5 and Żar MAZ-7 should be described as of a stadial type, as the species may have been retained in small groups due to a delayed response of water habitats to the deterioration of climate. The zones mark out the boundary between the two warm periods of Augustovian interglacial I and Augustovian interglacial II.

Climate controlling the close of the Augustovian interglacial I was gradually, but distinctly deteriorating. All trees, except for *Larix*, were withdrawn from the youngest part of the zone and replaced with plants typical of open habitats, including *Thalictrum minus*, *Chenopodium*, and *Potentilla*. Their occurrence indicates a minimum temperature of the warmest month not falling below 10°C (Mamakowa 1997). However, the zone still abounds in remains of aquatic and swamp plants, many of which evidence mean July temperatures amounting to at least 15°C (*Rumex maritimus*; Tobolski 1991) or even to 17°C (*Salvinia natans*).

It seems likely that the trends observed for aquatic and terrestrial vegetation at the close of the Augustovian interglacial I support the general hypothesis of a delayed response of aquatic vegetation, compared with the terrestrial one, to the coolings occurring at the close of interglacials (Iversen 1954, 1964, Szafer 1954, Wasylikowa 1964). However, it should be also emphasized that aquatic plants respond very quickly to the improvement in climatic conditions after cold periods and serve as early indicators of changes in temperature.

AUGUSTOVIAN INTERGLACIAL II

Cza MAZ-6 (118.25–117.25 m)
Żar MAZ-8 (129.75–127.55 m)

At the beginning of the Augustovian interglacial II, remains of trees were not frequent. Occurrence of occasional remains of *Betula nana* and *B.* sect. *Albae*, as well as of *Pinus* and *Salix*, indicates the presence of forests of a low density in the area.

Composition of communities of wet and humid habitats remained almost unchanged. Habitats of a high humidity and abundant in nitrogen were still overgrown mainly by *Urtica dioica* and *U. laetevirens*. Vegetation typical of fresh and humid habitats comprised various species of *Potentilla*, e.g. *Potentilla anserina* and *P. supina*, as well as *Chenopodium*, and *Selaginella helvetica*, all characterized by high light requirements, confirming the relatively low density of plant cover surrounding the lake. At periodically exposed lakeshores, communities resembling the present day Bidentetea tripartiti (Matuszkiewicz 2008), including *Rumex maritimus* and *Ranunculus sceleratus*, were still an important part of landscape. The reoccurrence, so far infrequent, of fruits of thermophilous *Cyperus glomeratus* and *Scirpus atroviroides*, alien to the present day flora of Poland, evidences a gradual improvement in temperature conditions, as well as an increase in the humidity of climate. Significance of *Mentha aquatica* and *Ranunculus gailensis* decreases.

Vegetation of peat habitats was changed only slightly in comparison with the preceding zone. Sedges, including *Carex* (2- and 3-sided), *Carex paucifloroides*, *C. pseudocyperus*, and *Comarum palustre*, were still found.

A similar observation was recorded for swamp communities, undoubtedly predominated by *Typha*, *Eleocharis palustris* and *Oenanthe aquatica*. *Typha* and *Eleocharis palustris* coexisted in typical swamps, however, when considering the fact that remains of *Eleocharis palustris* appear suddenly and abundantly at the basal part of the zone, and afterwards rapidly disappear, it may be assumed that the taxa formed monospecies communities of a transitional type. In shallow parts of the lake (up to 0.5 m), communities resembling the present day *Oenantho-Rorippetum* (Matuszkiewicz 2008), which is an association known to disappear suddenly after existing throughout several vegetation seasons, may have been formed. Such types of communities are frequently damaged by rapid flows or an increase in the water level. Mono-species clusters of plants were also likely to be formed by *Eleocharis palustris*. At present, such communities are found in the outer belt of swamp vegetation. Very numerous fruits of the species, as well as the occurrence of mollusc shells in the sediment, indicate that the ground must have been abundant in calcium carbonate. Species like *Hippuris vulgaris*, *Alisma plantago-aquatica*, and *Sagittaria sagittifolia*, characteristic of typical swamps, were still relatively abundant. *Elatine hydropiper* and *E. hydropiperoides* were relatively frequent as well.

Aquatic communities were marked by significant changes. A pleuston community with *Salvinia natans* and *Azolla filiculoides*, enriched with a relatively high proportion of *Lemna trisulca*, reincreased its area. Coves of a high insolation and sheltered from waves were most likely sites of development of communities similar to the present day *Parvopotamo-Zannichellietum* association (Matuszkiewicz 2008), including *Zannichellia palustris*, *Najas marina*, *N. minor*, *Potamogeton perfoliatus*, and *Chara*, suggesting a high eutrophication and salinity of waters. In zone Cza MAZ-6, the community comprised also *Potamogeton pectinatus* and *P. vaginatus.* The lake surface was likely to be covered by communities of a Nymphaeion type, including *Nymphaea alba* and *Potamogeton crispus.*

Above a sample marked by a high number of megaspores of *Salvina natans*, zone Żar MAZ-8 is devoid of remains of aquatic plants. An intensive development of a pleuston community, dominated by *Salvina natans* and likely to resemble the present day *Salvinietum natansis* (Matuszkiewicz 2008), may have limited the circulation of air in the water and shadowed its depths, therefore hindering the photosynthesis of other aquatic plants. In extreme situations, communities with *Salvina natans* as the most important component are likely to cover the entire surface of the lacustrine basin. Such conditions are evidenced by the abundant occurrence of remains of *S. natans*, accompanied by a simultaneous diminishing of remains of other aquatic plants (Mamakowa 1989). Climate characterizing this part of warm period II of the Augustovian interglacial (Augustovian II) was gradually improving. Interpretation of the disappearance of nearly all plant remains from the zones, suggesting the withdrawal of plants from the closest surroundings of the lake, is unclear. Only birch and pine were retained. The exceptional abundance of megaspores of *Salvinia natans* indicates that the minimum July temperatures attained even 17°C (Mamakowa 1997).

The return of thermophilous aquatic species in the zone serves as evidence for a gradual warming of climate and, most likely, also an increase in its humidity, advantageous to the development of vegetation typical of wet habitats.

Results of pollen analysis performed for this segment of profile (Lisicki & Winter 2004, Winter 2009) indicate the spreading of birch-pine forests, as well as, in the younger part, of alder forests and thermophilous forests including high proportions of *Quercus* and *Ulmus*, accompanied by *Carpinus* at the end of the period.

Cza MAZ-7 (117.25–115.85 m)
Żar MAZ-9 (127.55–126.15 m)

The change in the type of sediment, passing, towards the top of the zone, from detritus-calciferous gyttjas into silts bearing large amounts of organic matter, evidences a slight deepening of the basin in comparison with the preceding zone.

Tree birches (*Betula* sect. *Albae*) were still growing near the lake, but in forest communities surrounding the basin fir, alder and *Rubus idaeus* appeared. The zones are marked by exclusively occurring nuts of *Carpinus betulus*, indicating the presence of forests comprising hornbeam. This macroscopic observation is conformable with results of palynological studies, showing a significant frequency of this thermophilous tree in forest communities in warm period II (Janczyk-Kopikowa 1996, Winter 2001, 2003, 2009, Lisicki &Winter 2004).

Habitats of a high humidity and amount of nitrogen were still overgrown by *Urtica dioica*, *U.* cf. *laetevirens*, and *Urtica* cf. *thunbergiana*, fresh habitats – also by *Polygonum lapathifolium* and *Selaginella helvetica*, humid habitats – by very numerous *Cyperus glomeratus*, *C. fuscus*, and *Scirpus atroviroides*, while sites slightly closer to swamps – also by *Mentha aquatica* and *Lycopus europaeus.* Drier areas were inhabited by *Senecio aquatilis* and *Polygonum lapathifolium* (Pl. 1, fig. 6).

Cyperus glomeratus is a species alien to the present day flora of Poland and is currently found in warmer regions of Europe, including the Mediterraneanarea, Turkey and Iran. The warm climate was likely to be marked by the occurrence of the extinct *Scirpus atroviroides*, with the North American *Scirpus atrovirens* as its equivalent found in the present day flora. The most abundant presence of these species in zone Cza MAZ-7 indicates a climate warmer than the present day one.

Similarly as in the preceding zones, exposed lakeshores were overgrown by communities resembling *Rumicetum maritimi* (Matuszkiewicz 2008). Zone Cza MAZ-7 is characterized by exceptionally frequent remains of the extinct *Carex paucifloroides*, most closely related to the extant *Carex pauciflora.* At present, the species is mainly found in communities of a raised-bog type (Sphagnetalia magellanei). At the edges of swamp communities peat species were growing such as *Carex gracilis*, *C. rostrata*, *C. acutiformis*, *C. pseudocyperus*, as well as *Comarum palustre* and *Cicuta virosa*.

Typical swamps, slightly diminished in the zone, were undoubtedly still dominated by *Typha* accompanied by *Alisma plantago-aquatica*, *A. plantago-minimum, Sparganium emersum*, *Sagittaria sagittifolia*, and the extinct *Scirpus kreczetoviczii*, which is most frequently found in slightly saline or strongly eutrophic waters.

In shallow parts of the lake (up to 0.5 m), a community resembling *Oenantho-Rorippetum* developed. *Eleocharis palustris*, very numerous in the preceding zone, disappeared, while an abundant appearance was recorded for *Schoenoplectus lacustris*, nowadays often forming monospecies clusters. Accompanied by *Typha*, it may have formed a community similar to the present day *Scirpo-Phragmitetum* (Podbielkowski, Tomaszewicz 1982). The boundary between swamps and open water was marked by the occurrence of *Schoenoplectus lacustris*. The end of the zone was marked by the reoccurrence of *Elatine hydropier*, likely to grow in shallow, calm coves.

In the lake, the expansion of a pleuston community with *Salvinia natans* and *Azolla filiculoides*, accompanied by *Lemna trisulca*, attained its maximum extent. Such communities are likely to cover even entire water basins and therefore limit the circulation of air and access to light in deeper parts of water. Such conditions, indicated by high frequency of remains of *Salvinia natans* and *Azolla filiculoides*, should result in a decrease in the proportion of other remains of aquatic plants. However, such a situation did not occur in both examined zones, what is evidenced by a significant number of *Zannichellia palustris*, likely to be found in insolated and calm coves, where it was accompanied by *Najas minor*, *Potamogeton perfoliatus*, *P. pusillus*, *P. natans. P. trichoides*, *P. pectinatus*, and *P. crispus*, all most likely forming an association resembling the present day *Parvopotamo-Zannichellietum* (Matuszkiewicz 2008).

The presence of *Trapa natans* suggests a likely development of a community similar to the *Trapetum natansis* association (Matuszkiewicz 2008) or a community classified in the Nymphaeion alliance (Matuszkiewicz 2008). The occurrence of such communities is indicated by the presence of seeds of *Nymphaea cinerea*, *Ceratophyllum demersum*, *Myriophyllum spicatum*, *Batrachium*, as well as of *Euryale*, representing the Nymphaeaceae family and frequently forming monospecies compact clusters or found as a component of communities of a Nymphaeion type (Matuszkiewicz 2008). Numerous remains of *Stratiotes* and *Hydrocharis morsus-ranae* serve as evidence for the existence of a community resembling the present day *Hydrocharietum morsus-ranae*, found in shallow, standing parts of the lake, and most likely also in swamps of a low density. Presence of such a community indicate the shallowing of the lake by the accumulation of organic sediments.

Vegetation characterizing zones Żar MAZ-9 and Cza MAZ-7 represents the warmest period of the Augustovian interglacial II. The occurrence of nuts of *Carpinus betulus*, as well as the abundance and diversity of aquatic plants, particularly of *Euryale*, *Salvinia natans*, *Azolla filiculoides*, *Ceratophyllum demersum*, and *Trapa natans*, suggests minimum temperatures of the warmest month attaining 21°C, while the temperatures of winter months may have been lower than the present day ones, as nowadays *Euryale ferox* withstands temperatures falling to –18°C. Numerous occurrence of aquatic vegetation, as well as the appearance of *Cyperus glomeratus* and *Scirpus atroviroides* among terrestrial vegetation, evidence the increasing humidity of climate.

The exceptionally abundant vegetation characterizing the zones is conformable with the climatic optimum distinguished in pollen diagrams from Czarnucha and Żarnowo (Lisicki & Winter 2004, Winter 2008, 2009). Pollen diagrams representing the close of the climatic optimum are marked by an alder-spruce period, indicating distinct changes in regional vegetation, resulting from a cooling of climate. However, the aquatic vegetation of zones conformable with the alder-spruce period was not affected by such changes. Therefore, at the end of the interglacial, conditions of the lake were still favourable for the survival of thermophilous vegetation.

Cza MAZ-8 (115.85–115.05 m)
Żar MAZ-10 (126.15–123.15 m)

Sediment of the zones is not marked by noticeable changes. Silts were still depositing, however, they comprised less plant detritus that in the preceding zones.

The surroundings of lake were covered by forest communities with tree birches, fir, alder, and willow. Spruce appeared as well.

Herbaceous plant communities were distinctly reduced. The zone comprises only occasional remains of *Urtica dioica*, *Rumex maritimus*, and *Ranunculus sceleratus*, previously dominating in habitats abundant in nitrogen and of a strong eutrophication. *Scirpus atroviriodes*, *Thalictrum lucidum*, *Cyperus fuscus*, and *Mentha aquatica* were relatively frequent in humid habitats.

The appearance of *Thalictrum minus*, *Chenopodium hybridum*, *Ranunculus acris*, and *Selaginella* cf. *tetraedra*, which is an extinct species characteristic of Lower-Pleistocene floras of Belarus and Lithuania, was recorded. Czarnucha profile is devoid of remains of peat plants, while the Żarnowo profile is marked by the occurrence of remains of *Menyanthes trifoliata*, fruits of *Carex elata* and *Lycopus europaeus*, as well as of *Carex* (2- and 3-sided) and *Carex paucifloroides*.

The gradual withdrawal of vegetation from wet, humid, and peat habitats suggests the declining water level.

Swamp and aquatic communities diminish as well. The belt of typical swamp nearly disappears. The existence of its small patches is indicated by the occurrence of single remains of *Typha*, *Oenanthe aquatica*, *Schoenoplectus lacustris*, *Sparganium emersum*, *Lycopus europaeus*, and *Alisma plantago-minimum*.

The lake is still marked by the presence of pleuston communities, however most likely found only as small patches, including *Salvinia natans*, *Azolla filiculoides*, and *Lemna trisulca*, which were most frequent at the basal part of the zone. Increase in the number of *Zannichellia palustris*, as well as the presence of *Najas marina*, *N. minor*, *Myriophyllum spicatum*, *Potamogeton perfoliatus*, and *P. pusillus*, suggest that the littoral comprised habitats of a variable water level, in which a community similar to *Parvopotamo-Zannichellietum* (Matuszkiewicz 2008) was likely to spread.

Zone Cza MAZ-8 is characterized by a gradual deterioration of climatic conditions following the temperature optimum recorded in preceding zones. The water level of the lake was likely to gradually decline, what is evidenced by the withdrawal of numerous species typical of wet, humid and aquatic habitats, as well as by the increase in the proportion of *Cenococcum geophilum*, which attains its maximum values in a stratum of sediment bearing an admixture of clastic material, what indicates a slightly intensified solifluction. The zone represents the close of the Augustovian interglacial II.

NIDANIAN GLACIATION

Cza MAZ-9 (115.05–114.05 m)
Żar MAZ-11 (123.15–120.15m)

Due to the decline of water level in the lake, accompanied by its gradual shallowing and overgrowing, numerous species of trees entered habitats bordering on the basin. The deterioration of climate resulted in the return of *Betula nana* and *B. humilis*, abundant remains of which, accompanied by remains of *Salix*, serve as evidence for the appearance of patches of tundra vegetation in the lake surroundings. The basin may have been surrounded by birch forests (frequent remains of *Betula* sect. *Albae*) comprising larch, pine and spruce. Habitats of a higher humidity, bordering on the swamp, were overgrown by *Alnus glutinosa* and *A. incana*.

Strongly eutrophicated habitats were most likely marked by the reincrease in the proportion of communities comparable with the present day *Rumicetum maritime* (Matuszkiewicz 2008), what is indicated by the occurrence of exceptionally numerous remains of *Rumex maritimus* and relatively frequent remains of *Ranunculus sceleratus*. Sites of a higher insolation were likely to be dominated by communities resembling Bidentetea tripartite (Matuszkiewicz 2008), including *Bidens* and *Rorippa palustris*, which is the most abundant species in the zones. Nowadays it is found in areas of a minimum temperature of the warmest month attaining ca 10°C.

The zones are characterized by a distinct increase in the frequency of heliophilous vegetation, comprising *Chenopodium hybridum*, *Ch. polyspermum*, Asteraceae undiff., *Selaginella helvetica*, and *S. selaginoides*, as well as *Potentilla anserina* and *P. supina*. In comparison with the preceding zone, the number of remains of peat plants slightly decreased, however the occurrence of *Menyanthes trifoliata*, *Comarum palustre*, *Carex elata*, and *C. paucifloroides* indicates the existence of low peat bogs and swamps of the Magnocaricetea class (Matuszkiewicz 2008) in the lake surroundings.

Swamp plants comprised taxa recorded exclusively in this zone, such as *Caltha palustris* and *Rumex hydrolapathum*, which is a halophilous species.

Shallow, calm coves were most likely grown by relatively abundant *Elatine hydropiper* and *E. hydropiperoides*, while the belt of swamps was predominated by *Eleocharis palustris* and *Hippuris vulgaris*, which is found today in areas of a minimum July temperature attaining 10° C (Wasylikowa 1964) and is known to appear as one of first plants at the beginning of the Late Glacial in Great Britain and Scandinavia (Wasylikowa 1964).

In the aquatic environment, *Chara*, preferring habitats abundant in calcium carbonate, was the most important component. Small patches of pleuston communities, including *Salvinia natans*, *Azolla filiculoides*, and *Lemna trisulca*, were probably present. *Zannichellia palustris*, *Potamogeton panormitanus*, *P. rutilus*, and *Myriophyllum spicatum* were found as well. *Batrachium* and *Callitriche*, as well as *Stratiotes* and *Hydrocharis morsus-ranae*, which are known to be involved in the overgrowing and shallowing of water basins, were particularly numerous.

The abundant occurrence of heliophytes in zone Żar MAZ-11, accompanied by the diminshing participation of trees and shrubs, evidences the successive and distinct deterioration of climate. The lack of a dense plant cover resulted in intensified solifluction processes, indicated by a reincrease in the proportion of *Cenococcum geophilum*.

Cza MAZ-10 (114.05–112.85 m)
Żar MAZ-12 (120.15–117.15 m)

The zones bear a record of the Nidanian glaciation, marked by the withdrawal of vegetation from all terrestrial habitats, as well as by a distinctly limited development of aquatic vegetation. Surroundings of the lake were overgrown by rare heliophilous plants comprising *Rubus idaeus*, *Chenopodium hybridum*, *Selaginella helvetica*, and *Rorippa palustris*, as well as *Mentha aquatica*, which was relatively frequent in habitats of a higher humidity.

The zones are nearly devoid of remains of vegetation typical of wet, humid and peat habitats. Habitats of a high humidity and eutrophication were marked by occasional occurrences of *Ranunculus sceleratus*, *R. gailensis,* and *Bidens*. Peat bogs close to the belt of swamps were overgrown by *Carex paucifloroides*, *Menyanthes trifoliata*, and *Comarum palustre*. Swamp vegetation was represented by minor amounts of *Typha*, *Alisma plantago-aquatica*, and *Eleocharis palustris*.

Despite a noticeable impoverishment of terrestrial vegetation, indicating the deterioration of climatic conditions, the aquatic vegetation was still, though only occasionally, marked by the occurrence of indicators of warm climate, such as *Azolla filiculoides* and *Lemna trisulca*, coexisting with boreal indicators, represented by *Potamogeton filiformis.* Among aquatic plants, the presence of *Zannichellia palustris*, *Stratiotes*, and *Callitriche* was recorded as well.

Disappearance of macroscopic plant remains from the sediments of the zone evidences a significant deterioration of climate and serves as a distinct indicator of the first stadial period of the Nidanian glaciation.

Cza MAZ-11 (112.85–112.35 m)
Cza MAZ-12 (106.65–105.85 m)

Zones Cza MAZ-11 and Cza MAZ-12 are generally very poor in plant macroremains. Their sediment bears a high proportion of coarse fraction. Following Ber (2009), the sediment is of a fluvial or deltaic type, characteristic of the littoral zone. In the top part of zone Cza MAZ-11, a wing of fruit of *Acer* and remains of *Ceratophyllum demersum*, *Scirpus kreczetoviczii*, *Salvinia natans*, *Azolla filiculoides*, and *Lemna trisulca* were determined. Maximum values of the taxa occur in the optimum of Augustovian interglacial II. From the type of sediment, developed as mixed-grained sands, marked by interbeddings of silts with plant remains, and as silty sands, it may be concluded that plant remains found in the zones were redeposited. Moreover, they are not represented by any equivalent in the Żarnowo profile. The zones may be assigned to the stadial period of the Nidanian glaciation.

Cza MAZ-13 (103.65–102.45 m)
Żar MAZ-13 (117.15–115.15 m)

Both zones bear a record of a successive change in climate. In the Czarnucha profile, the complex of sands, several meters in thickness, is overlain by beds of silts and peats, while in the Żarnowo profile – by clayey silts representing the interstadial period of the Nidanian glaciation.

Patches of tundra vegetation with *Betula nana* and *B. humilis* must have been an important part of landscape. Tree birches, accompanied by only occasional *Alnus glutinosa* and *Picea*, appeared as well. The taxonomic composition of trees and shrubs suggests that communities overgrowing the lakeshore were most likely of a low density.

Eutrophic habitats were marked by the redevelopment of a community similar to *Rumicetum maritime* (Matuszkiewicz 2008), including *Rumex maritimus* and *Ranunculus sceleratus.* Heliophilous vegetation comprised *Chenopodium*, *Selaginella selaginoides*, *S. helvetica*, *Potentilla anserina*, *Viola palustris*, *Cirsium palustre*, and *Potentilla.* Small patches of communities with *Bidens tripartita* and *Rorippa palustris* were also likely to occur.

In the Czarnucha profile, the presence of fruits of *Carex elata*, *C. gracilis*, *C. rostrata*, *C. vesicaria*, and *C. riparia*, as well as of exceptionally abundant fruits of *Carex* 2- and 3-sided, accompanied by *Menyanthes trifoliata* and *Comarum palustre*, serves as evidence for the occurrence of various communities, categorized in sedge and boggy meadows and sedge swamps, in the surroundings of lake.

Swamp communities, including *Typha aspera*, *Alisma plantago-aquatica*, *Oenanthe aquatica*, *Eleocharis palustris*, and *Ranunculus lingua* were redeveloped.

The cold stadial period was followed by an exceptionally rapid spread of aquatic vegetation, showing a response to the improvement in climate. The lake was once again the site of development of plentiful pleuston communities including *Salvinia natans*, *Azolla filiculoides*, and *Lemna trisulca*. *Zannichellia palustris* and various *Potamogeton* species, recorded only as single occurrences and represented by *P. perfoliatus*, *P. pusillus*, *P. panormitanoides*, *P. pectinatus*, and *P. vaginatus*, appeared temporarily, however numerously, in the lake. The above-mentioned species, as well as *Najas marina*, indicate that littoral habitats were marked by a fluctuating water level. They may have been overgrown by a community similar to the *Parvopotamo-Zannichellietum* association (Matuszkiewicz 2008). In the Czarnucha profile, abundant endocarps of *Potamogeton gramineus* evidence the occurrence of a community resembling the present day *Potamogetonetum graminei* (Matuszkiewicz 2008). The community was most likely to inhabit shallow, up to 0.5 m deep parts of the lake with a sandy or sandy-muddy ground. *Nymphaea cinerea*, *Nymphaea* cf. *alba*, *Myriophyllum verticillatum*, *Potamogeton rutilus*, *P. natans*, and *P. pusillus* were the likely components of communities of a Nymphaeion alliance, nowadays found on muddy grounds in shallow parts of the lake (Podbielkowski & Tomaszewicz 1982).

The reappearance of plants with higher temperature requirements, as well as the occurrence of *Salvinia natans* and *Najas marina*, suggest a minimum July temperature attaining ca. 17°C (Mamakowa 1997), while the presence of heliophytes associated with a cooler climate (*Betula nana*, *B. humilis*, *Selaginella selaginoides* and *Rorippa palustris*) indicates a minimum temperature of the warmest month not falling below 10°C (Mamakowa 1997).

Cza MAZ-14 (100.85–100.15 m)
Żar MAZ-14 (115.15–113.15 m)

Silts bearing a large admixture of sand comprised fragments of wood of *Pinus sylvestris*, infrequent fruits of *Betula* sect. *Albae* and *Larix*, as well as single remains of *Selaginella* *selaginoides*, *Potentilla anserina*, *Polygonum aviculare*, *Ranunculus*, and *Plantago media*, as plants representing herbaceous vegetation typical of open sites. Among swamp and aquatic plants, *Alisma plantago-aquqtica* and *Batrachium* survived in the basin, most likely in minor amounts. Such a noticeable impoverishment of both the quantity and quality of plant remains, accompanied by the appearance of a coarse fraction of sand in the sediment, evidences the initiation of solifluction processes and a rapid deterioration of climate. A similar conclusion may be drawn on the basis of increase of *Cenococcum geophilum*. The changes serve as a convincing indicator of a subsequent stadial in the Nidanian glaciation.

STRATIGRAPHIC CORRELATION WITH LOWER PLEISTOCENE FLORAS OF BELARUS AND LITHUANIA

Nowadays, Lower Pleistocene floras of Czarnucha and Żarnowo have no equivalents, in terms of age, described from the area of Poland. For this reason, they were correlated with floras of the Korchevian interglacial in Belarus and with the Lithuanian stage of Kemėnai. With respect to the taxonomic composition of macroscopic plants remains, the Augustovian interglacial may be also related to the Daūmantai – an Eopleistocene stage distinguished in Lithuania (Tab. 5)

Sediments of the Korchevian interglacial are underlain by tills representing the oldest Belorussian glaciation, the Narevian glaciation, and are overlain by glacial deposits of the Yasielda glaciation (Velichkevich et al. 2001). The "Korchevian type" floras were described from the sites of Korchevo (Velichkevich 1986), Chimy (Velichkevich & Rylova 1988) and Postolovo (Velichkevich et al. 1993).

At the site of Korchevo, the Korchevian interglacial is represented by lacustrine sediments, 25 m in thickness. Since their examination in 1974, they have been repeatedly studied by geologists and palaeobotanists (Vozniachuk et al. 1977, 1978, Velichkevich 1996, Mamakowa & Rylova 2007).

Macroscopic floras of the "Korchevian type" comprise species recognized as characteristic of the Augustovian interglacial (Tab. 5) as well as additional taxa such as *Carex rostrata-pliocenica*, *Brasenia*, *Caulinia antiqua*, *Aldrovanda borysthenica*, and *A. zusii.* When considering taxa of a stratigraphic significance for the Augustovian floras, the Korchevian ones are devoid of *Euryale*, *Typha aspera*, and *Selaginella tetraedra.*

The site of Chimy is located in the area of Rogachzev. Its interglacial sediments: gyttja, peat and humic sands were investigated by means of pollen analysis (Rylova) and examination of macroscopic plant remains (Velichkevich & Rylowa 1988). The Korchevian age of this flora is indicated by the occurrence of species such as *Carex rostrata-pliocenica*, *Potamogeton perforatus*, *P.* cf. *panormitanoides*, *Scirpus kreczetoviczii*, and *Ranunculus sceleratoides* (= *Ranunculus gailensis*).

At the site of Postolovo (Velichkevich et al. 1993), the determined macroscopic plant remains included species typical of Early Pleistocene, such as *Potamogeton perforatus*, *P. pseudorutilus*, *P. praemaackianus*, *Caulinia paleotenuissima*, *Scirpus atroviroides*, and *Eleocharis praemaximoviczii.*

In the area of Lithuania, sediments representing the oldest glaciation, the Kalvai glaciation, are overlain by ones of the stage of Kemėnai. In the stage of Kemėnai, the sites of Vindžiūnai Šumskas and Padvarionys were subjected to analysis of macroscopic plants remains (Velichkevich et al. 1998).

Tills assigned to the Kalvai glaciation overlie sediments of the Eopleistocene stage of Daūmantai, represented by sites of Daūmantai-1 and Šlavé-2, both studied by Velichkevich (1982).

The stage of Kemėnai, similarly as the Augustovian interglacial, is marked by two warm periods, distinguished on the basis of palynological studies by Kondratiene (1996). The older and warmer period was recorded in sediments of Vindžiūnai, while the younger and cooler period – at the sites of Padvarionys and Šumskas. Flora of Vindžiūnai, considered to have developed in the older and warmer period, included *Potamogeton trichoides* (Velichkevich 1982) and lacked in tree remains – only one fragment of a needle of *Larix* was determined. Complex of macroremains recorded at this site comprised seven extinct species: *Ranunculus* cf. *sceleratoides* (= *R. gailensis*), *Azolla interglacialis*, *Potamogeton dvinensis*, *P. perforatus*, *P.*cf. *parvulus*, *Elatine hydropiperoides*,

Tabele 5. Occurrence of extinct taxa and ones characteristic for the Lower Pleistocene of Poland, Belarus and Lithuania

Taxa	Poland	Belarus	Lithuania	
	Augustovian interglacial	Korchevian interglacial	Formation Kemėnai	Formation Daūmantai
PTERIDOPHYTA				
Azolla filiculoides foss.	+			
Azolla interglacialis		+	+	+
Azolla pseudopinnata				+
Pilularia borysthenica		+		
Pilularia pliocenica				+
Salvinia aphtosa				+
Salvinia natans	+			
Selaginella borysthenica		+		
Selaginella reticulate		+		
Selaginella tetraedra	cf. +			+
SPERMATOPHYTA				
MAGNOLIOPHYTINA				
Aldrovanda borysthenica		+		
Aldrovanda zusii		+		
Alisma plantago-minimum	+			+
Brasenia sp.		+		
Carex paucifloroides	+	+	+	
Carex rostrata-pliocenica		+	+	
Caulinia antique		+		
Caulinia palaeotenuissima		+		+
Cyperus glomeratus	+			
Dulichium arundinaceum		+		
Elatine hydropiperoides	+		+	+
Eleocharis praemaximowiczii	+	+	+	
Eleocharis pseudoovata				+
Euryale sp.	+			
Hypericum tertiaerum				+
Myriophyllum cf. *subspicatum*				+
Potamogeton dvinensis	+	+	+	
Ranunculus gailensis (=*R. sceleratoides*)	+	+	cf. +	+
Potamogeton panormitanoides	+	cf. +		
Potamogeton parvulus		+	cf. +	
Potamogeton perforatus	+	+	+	+
Potamogeton. praemaackianus		+	+	+
Potamogeton pseudorutilus		+	+	
Potamogeton trichoides	+		+	
Scirpus atroviroides	+	+	+	
Scirpus kreczetoviczii	+	+	+	
Scirpus torreyi		+		
Stratiotes brevispermus	cf. +		cf. +	
Stratiotes goretskyi	cf. +	+		
Trapa natans	+			
Typha aspera	+			
Urtica cf. laetevirens	+			
Urtica platyphylla		+		
Urtica cf. *thunbergiana*	+			
Zannichellia palustris	+			

and *Eleocharis praemaximowiczii* (Velichkevich et al. 1998.)

Complex of macroscopic remains determined for sediments of the Padvarionys site, regarded as deriving from the younger period, was devoid of clearly thermophilous taxa. Within extinct species of a stratigraphic significance, the occurrence of *Potamogeton pseudorutilus*, *Stratiotes* cf. *brevispermus*, and *Ranunculus* cf. *sceleratoides* was recorded.

Flora of Šumskas also originates from the younger and cooler period of Kemėnai and includes seven characteristic extinct species: *Stratiotes* cf. *brevispermus*, *Potamogeton pseudorutilus*, *P. dvinensis*, *P. perforatus*, *P.* cf. *praemaackianus*, *Carex rostrata-pliocenica*, and *Ranunculus* cf. *sceleratoides* (= *R. gailensis.*)

Stratigraphy of sediments from the Eopleistocene sites of Šlave-2 and Daūmantai is still under discussion. On the basis of pollen analysis, Kondratiene (1996) assigned them to the Early Pleistocene. Kiselene (2002) also recognized them as representing the Early Pleistocene, however, Velichkevich et al. (1998), in reference to macroscopic studies, related them to the Eopleistocene.

Characteristic species of these floras comprise: *Azolla interglacialis*, *Pilularia pliocenica*, *Salvinia aphtosa*, *Selaginella tetraedra*, *Potamogeton perforatus*, *Potamogeton praemaackianus*, *Myriophyllum* cf. *subspicatum*, *Ranunculus sceleratoides* (= *R. gailensis*), and *Alisma plantago-minimum.*

The complex of species determined from macroscopic plant remains at sites of Czarnucha and Żarnowo, typical of the Augustovian interglacial, is conformable, in terms of age, with the Early Pleistocene floras of surrounding countries.

CONCLUSIONS

1. The analysis of macroscopic plant remains was performed for the first time from Lower-Pleistocene sediments in the area of Poland.

2. In the Czarnucha profile, 156 taxa were determined, including seven ones not found in the present day flora of Poland and 13 extinct species, five of which were identified for the first time from the Pleistocene of Poland.

In the Żarnowo profile, 158 taxa were determined, including six ones not found in the present day flora of Poland and 15 extinct species, seven of which were identified for the first time from the Pleistocene of Poland.

3. In diagrams plotted for macroscopic plants remains from the sites of Czarnucha and Żarnowo, 14 Local Macrofossil Assemblage Zones were distinguished. Zones of the two profiles were correlated with each other and assigned to stratigraphic stages. The following stages were distinguished: Narevian glaciation, Augustovian interglacial I and Augustovian interglacial II (separated by a cold period, Augustovian interglacial I/II), and the Nidanian glaciation, most likely marked by two warmings of an interstadial type (Table 4).

Narevian glaciation

Due to a low frequency of macroremains, a detailed reconstruction of vegetation changes was not possible. The occurrence of *Cenococcum geophilum* and the type of sediment indicate that the lake was at its initial stage of development and the vegetation lacked in a dense plant cover. Humid sites were overgrown by communities of dwarf shrub tundra with *Betula nana*, while slightly drier, open areas – by *Rumex acetosa*, *Chenopodium*, and *Polygonum*. Periodically exposed lakeshores were inhabited by *Rumex maritimus* and *Ranunculus sceleratus*. Close of the period is marked by the appearance of first trees and shrubs (*Larix*/*Picea* and *Salix*) in the lake surroundings.

Augustovian interglacial I

Zones Żar MAZ-2 and Żar MAZ-3 from the Żarnowo profile have no equivalents in the Czarnucha profile, which is devoid of sediments representing the older period of Augustovian interglacial I. The zones, in spite of an abundant occurrence of remains and the variability of species, should be considered as the initial period of the interglacial as they are devoid of taxa with high temperature requirements. The waters are marked by a high eutrophication or salinity and are dominated by *Zannichellia palustris* and *Potamogeton pectinatus.* Proportion of *Chara* sp. div. increases. The basin was most likely shallow and was characterized by periodic fluctuations in the water level.

Zones Cza MAZ-2 and Żar MAZ-4 are marked by a deterioration of temperature conditions and a climate displaying continental properties, indicated by the occurrence of *Betula* sect. *Albae* and *Solanum dulcamara*, both suggesting a mean July temperature 12–13°C, and the simultaneous existence of heliophyte communities, including *Betula nana*, *B. humilis*, *Selaginella selaginoides*, and *Rorippa palustris*. However, conclusions based on the composition of aquatic vegetation suggest minimum July temperatures attaining at least 17°C, and most likely even 21°C (*Salvinia natans*, *Lemna trisulca*, *Ceratophyllum demersum*, and *Euryale*)

Close of the Augustovian interglacial I is marked by the appearance of a holarctic species, *Ranunculus gmelinii*, indicating a gradual deterioration of temperature conditions. Composition of aquatic flora evidences a slight decline of the water level in the basin.

Augustovian interglacial I/II

Lack of trees and the occurrence of poor communities typical of open habitats, including *Thalictrum minus*, *Betula nana*, and *B. humilis*, resulted in intensified solifluction processes and changes in the composition of sediment. From the composition of herbaceous vegetation it may be concluded that the period was at least of a stadial type. Thermophilous plants, retained due to a delayed response of the aquatic environment to the cooling of climate, are found occasionally among aquatic vegetation.

Augustovian interglacial II

The warmest period of the Czarnucha profile is observed in zone Cza MAZ-7, while of the Żarnowo profile – in zones Żar MAZ-9-11.

The climatic optimum is marked by a simultaneous appearance of *Azolla filiculoides* and *Salvinia natans*, the occurrence of *Ceratophyllum demersum*, *Trapa natans*, and *Euryale*, as well as by the most luxuriant development of vegetation in the entire interglacial. The exceptional development of aquatic vegetation, accompanied by the appearance of *Cyperus glomeratus* and *Scirpus atroviroides* among terrestrial vegetation, evidences an increase in the humidity of climate. At the end of the period, communities with *Hydrocharis morsus-ranae* and *Stratiotes* are likely to indicate the shallowing of lake by the deposition of organic sediments. Infrequent, however indicative presence of *Carpinus betulus* is conformable with the results of pollen analysis.

The optimum is followed by a decrease in the frequency of plant remains and in the number of species with high temperature requirements.

Nidanian glaciation

In both profiles the period is marked by several fluctuations in climatic conditions. Remains of plants with high temperature requirements nearly disappear, except for zone Cza MAZ-13, typified by interstadial features and a high proportion of thermophilous plants such as *Azolla filiculoides* and *Salvinia natans*, coexisting with *Betula nana* and *B. humilis*.

In the Żarnowo profile, zone Żar MAZ-13 is devoid of plants of high temperature requirements, however the frequency of remains increases in comparison with the closest zones. Remains of *Betula nana*, *B. humilis*, and *B.* sect. *Albae* are found abundantly and are accompanied by a fruit of *Alnus glutinosa*.

In the uppermost zones plant remains occur only occasionally. Those determined for this period indicate unfavourable temperature conditions, however also good light conditions. The identified species comprise *Plantago media*, *Selaginella selaginoides*, and *Potentilla anserina*, as well as *Larix* among trees.

4. An assemblage of species characteristic from the Augustovian interglacial was distinguished. It comprises the following taxa: *Azolla filiculoides*, *Salvinia natans*, *Euryale* cf. *ferox*, *Euryale*, *Stratiotes* cf. *goretskyi*, *S.* cf. *brevispermus*, *Potamogeton perforatus*, *P. panormitanoides*, *P. dvinensis*, *Carex paucifloroides*, *Zannichellia palustris*, *Scirpus atroviroides*, *S. kreczetoviczii*, *Cyperus glomeratus*, *Ranunculus gailensis*, *Eleocharis praemaximoviczii*, *Trapa natans*, *Elatine hydropiperoides*, *Alisma plantago-minimum*, *Typha aspera*, *Selaginella* cf. *tetraedra*, *Urtica* cf. *laetevirens*, and *U.* cf. *thunbergiana*.

5. Sediments of the investigated sites abound in species withstanding an increased content of NaCl in the environment, particularly *Zannichellia palustris*, recorded mainly in the Augustovian interglacial I and I/II. Among plants resistant to increased amounts of salt, *Triglochin maritimum*, *Najas marina*, *Schoenoplectus tabernaemontani*, *Rumex hydrolapathum*, *Potamogeton pectinatus*, *P. perfoliatus*, and *P. filiformis* were also determined.

6. Floras of Czarnucha and Żarnowo are the only Lower Pleistocene floras described from the area of Poland. For this reason, they were correlated with floras known from sites representing the Korchevian interglacial in Belarus. „Korchevian type" floras, apart from comprising species regarded as characteristic from the Augustovian interglacial, include taxa

such as *Carex rostrata-pliocenica*, *Brasenia Caulinia antiqua*, *Aldrovanda borysthenica*, and *A. zussii.*

7. In Lithuania, the Augustovian interglacial is most closely related, in terms of age, to the floras of Kemėnai, which, apart from taxa listed as characteristic of the Augustovian interglacial, include *Potamogeton trichoides*, *P. pseudorutilus*, *P. praemaakianus*, *Carex rostrata-pliocenica*, *Typha* ex gr. *Pliocenica*, *Pilularia pliocenica*, and *Salvinia aphtosa.*

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REFERENCES

AALTO M.M., COOPE G.R., CURRANT A.P., MC GLADE J.M., PEGLAR S.M., PREECE R.C., TURNER C., WHITEMAN C.A. & WRAYTON R.C. 1996. Early Middle Pleistocene fossiliferous sediments in the Kesgrave Formation at Broomfield, Essex, England. In: Turner Ch. (ed.), Proceedings of the SEQS Cromer Symposium Norwich (United Kingdom) 3–7 September 1990: 83–119. Balkema, Rotterdam Brookfield.

ANDRZEJESZCZAK B. 1971. Nowe stanowisko interglacjału eemskiego w północno-wschodniej Polsce (summary: New locality in the Eemian Interglacial in northeastern Poland). Przegl. Geogr., 43(4): 587–596.

BEDNAREK R. & PRUSINKIEWICZ Z. 1999. Geografia gleb. Wyd. Naukowe PWN, Warszawa.

BEIJERINCK W. 1947. Zadenatlas der Nederlandische flora. H. Veenman & Zonen, Wageningen.

BER A. 1973a. Stratygrafia i rozwój czwartorzędu Pojezierza Suwalskiego. Przewodnik 45 Zjazdu Pol. Tow. Geol. Na Ziemi Suwalsko-Augustowskiej: 75–111. Wyd. Geol. Warszawa.

BER A. 1973b. Sytuacja geologiczna stanowisk interglacjału eemskiego na Pojezierzu Suwalskim (summary: The geological setting of the Eemian Interglacial sites in the Suwałki Lakeland). Przegl. Geol., 21(7): 363–366.

BER A. 1989. Morfogeneza Pojezierza Suwalskiego i Równiny Augustowskiej. Stud. Mater. Ocean., 56. Geologia Morza: 191–207.

BER A. 1996a. Sytuacja geologiczna jeziornych osadów piętra augustowskiego w Szczebrze koło Augustowa oraz osadów jeziornych interglacjał mazowieckiego w Krzyżewie (summary: Geological situation of

Augustovian (Pastonian) Interglacial Lake sediments at Szczebra near Augustów and Mazovian Interglacial organogenic sediments at Krzyżewo). Biul. Państw. Inst. Geol., 373: 35–48.

BER A. 1996b. Geological-floristic setting of the Augustovian (Pastonian, Bavelian?) interglacial lake sediments of Szczebra, near Augustów (NE Poland): 19–20. In: Geological history of the Baltic Sea. Abstract volume. Vilnius, Lithuania.

BER A. 1997. Objaśnienia do Szczegółowej mapy geologicznej Polski 1:50 000, ark Augustów 147. Central Geological Archives, Polish Geological Institute-National Research Institute, Warszawa.

BER A. 1998. Objaśnienia do Szczegółowej mapy geologicznej Polski 1:50 000, ark. Wieliczki 146. Central Geological Archives, Polish Geological Institute-National Research Institute, Warszawa.

BER A. 2000. Plejstocen Polski północno-wschodniej w nawiązaniu do głębszego podłoża i obszarów sąsiednich (summary: Pleistocene of north-eastern Poland and neighbouring areas against crystalline and sedimentary basement). Prace Państw. Inst. Geol., 170: 1–89.

BER A. 2009. Litologia i sytuacja geologiczna osadów interglacjału augustowskiego z profili Sucha Wieś – Pojezierze Ełckie i Czarnucha – Równina Augustowska (summary: Lithology and geological position of the Augustovian Interglacial deposits from Sucha Wieś – Ełk Lakeland and Czarnucha – Augustów Plaine). Biuletyn PIG, 435: 3–22

BER A. & WŁODEK M. 2001. Objaśnienia do Szczegółowej Mapy Geologicznej Polski 1:50 000, ark. Woźna Wieś. Central Geological Archives, Polish Geological Institute-National Research Institute, Warszawa.

BER A., JANCZYK-KOPIKOWA Z. & KRZYSZKOWSKI D. 1998. A new interglacial stage in Poland (Augustovian) and the problem of the age the oldest Pleistocene till. Quatern. Sc. Rev., 17: 761–773.

BER A., LISICKI S. & WINTER H. 2009. Stratygrafia dolnego plejstocenu północno-wschodniej polski na podstawie badań osadów jeziornych z profili Sucha Wieś – Pojezierze Ełckie i Czarnucha – Równina Augustowska w nawiązaniu do obszarów Rosji, Litwy i Białorusi (summary: Lower Pleistocene stratigraphy of northeastern Poland on the basis of studies of lake deposits from the Sucha Wieś – Ełk Lakeland and Czarnucha – Augustów Plain sections with reference to the areas of Russia, Lithuania and Belarus). Biuletyn PIG, 435: 23–36.

BER A., LISICKI S., WINTER H., JANCZYK-KOPIKOWA Z., MARCINIAK B. NAWROCKI J. NITYCHORUK J., SKOMPSKI S. & STACHOWICZ-RYBKA R. 2002. Stratygrafia dolnego plejstocenu Polski NE na podstawie badań osadów jeziornych z profilów: Sucha Wieś i Czarnucha (Równina Augustowska) w nawiązaniu do Rosji, Litwy i Białorusi. Central Geological Archives, Polish Geological Institute-National Research Institute, Warszawa.

BERGGREN G. 1969. Atlas of seeds and small fruits of Northwest-European plant species with morphological descriptions. Part 2. Cyperaceae. Swedish Nat. Sci. Res. Council, Stockholm.

BORÓWKO-DŁUŻAKOWA Z. 1965. Ekspertyza palinologiczna dotycząca jedenastu próbek z profilu Błaskowizna. Central Geological Archives, Polish Geological Institute-National Research Institute, Warszawa.

BORÓWKO-DŁUŻAKOWA Z. 1966. Orzeczenie dotyczące 14 próbek profilu Ia we wsi Błaskowizna, ark. Olecko. Central Geological Archives, Polish Geological Institute-National Research Institute, Warszawa.

BORÓWKO-DŁUŻAKOWA Z. 1971. Kopalna flora interglacjału eemskiego w Smolnikach koło Suwałk (summary: The buried Eem Interglacial flora at Smolniki near Suwałki) Przegl. Geogr., 43(4): 591–600.

BORÓWKO-DŁUŻAKOWA Z. 1972. Opracowanie palinologiczne dziewiętnastu próbek z Augustowa. Central Geological Archives, Polish Geological Institute-National Research Institute, Warszawa

BORÓWKO-DŁUŻAKOWA Z. & HALICKI B. 1957. Interglacjały Suwalszczyzny i terenów sąsiednich (summary: Interglacial sections of the Suwałki region and of the adjacent territory). Acta Geol. Polon., 7: 361–401.

BREM M. 1953. Flora interglacjalna z Ciechanek Krzesimowskich (summary: Interglacial *flora* from *Ciechanki Krzesimowskie* by Łęczyca). Acta Geol. Polon., 3: 475–480.

DOROFEEV P.I. 1963. Novye dannye o pleystotsenovykh florakh Belorusi i Smolenskoy oblasti (New data of the Pleistocene floras of Belarus and Smolensk district) : 5–180. In: Sukachev V.N. (ed.), Materialy po istorii flory i rastitelnosti SSSR (Materials of the history of the flora and vegetation of the USSR), 4. Izdat. Akad. Nauk SSSR., Moskva-Leningrad. (in Russian).

DOROFEEV P.I. 1971. O pliotsenovoy flore der. Kholmech na Dnepre (On the Pliocene flora of vill. Kholmech on the Dnieper). Dokl. Akad. Nauk SSSR, 200(4): 917–920. (in Russian).

DOROFEEV P.I. 1974. Ranunculaceae: 104–107. In: Takhtajan A.L. (ed.), Iskopaemye tsvetkovye rasteniya SSSR, 1 (Fossil flowering plants ofd the USSR, 1). Izdat Nauka, Leningrad. (in Russian).

DOROFEEV P.I. 1977. Simbuginskaya flora (Flora of Simbugino): 35–83. In: Goretsky G.I. (ed.), Fauna i flora Simbugino. Izdat. Nauka, Moskva. (in Russian).

DOROFEEV P.I. 1979. O pliotsenovoy flore s. Dan'shino na Donu (On the pliocene flora of the vill. Dan'shino on the Don): 87–94. In: Raskatov G.I. (ed.), Problemy Antropogena tsentralnykh rayonov Russkoy platformy (The problems of the Antropogene of central districts of the Russian platform). Izdat Voronezh. Univ., Voronezh. (in Russian).

DOROFEEV P.I. 1982. K sistematike tretichnykh *Typha* (On the taxonomyof the Tertiary *Typha*): 5–26. In: Velichkevich F.Yu. (ed.), Paleokarpologicheskie issledovaniya kaynozoya (The palaeocarpological investigation of the Cenozoic). Izdat. Nauka i Tekhnika, Minsk. (in Russian.

DOROFEEV P.I. 1986a. O pliotsenovoy flore der. Dvorets na Dnepre (On the Pliocene flora of village Dvorets on the Dnieper): 44–71. In: Takhtajan A.L. (ed.), Problemy paleobotaniki (The problems of palaeobotany). Izdat. Nauka, Leningrad. (in Russian).

DOROFEEV P.I. 1986b. Iskopaemye *Potamogeton* (Fossil *Potamogeton*). Izdat. Nauka, Leningrad. (in Russian).

DYAKOWSKA J. 1952. Roślinność plejstoceńska w Nowinach Żukowskich (summary: Pleistocene flora of Nowiny Żukowskie on the Lublin Upland). Biul. Inst. Geol., 67: 115–181.

DZIĘCIOŁOWSKI W. & TOBOLSKI K. 1982. Czwartorzędowe cykle klimatyczno-ekologiczne a ewolucja gleb. Roczn. Glebozn., 33(1/2): 201–211.

FIELD M.H. 1992. *Azolla tegeliensis* Florschütz from the early Pleistocene of the British Isles. Geol. Mag., 129(3): 363–365.

FLORSCHÜTZ F. 1938. Die beiden *Azolla*– Arten des niederländischen Pleistozäns. Recueil des Travaux Botaniques Néerlandais, 35: 932–945.

FOLIERI M. 1970–71. *Azolla filiculoides* Lam. in the Lower Pleistocene of central Italy. Annali di Botanica, 30: 177–182.

GODWIN H. 1975. The history of the British Flora. Cambridge Univ. Press, London.

GOŁĄBOWA M. 1957. Roślinność interglacjalna z Makowa Mazowieckiego. (summary: Interglacial vegetation from Maków Mazowiecki). Biul. Inst. Geol., 118: 91–107.

GORŁOWA R.N. 1960. O sovremiennom i proshlom rasprostranenii *Najas tenuissima* A.Br. Byull. Mosk. ob-va ispyt. prirody, 60.

GRANOSZEWSKI W. 2003. Late Pleistocene vegetation history and climatic changes at Horoszki Duże, eastern Poland: a palaeobotanical study. Acta Palaeobot. Suppl., 4: 3–95.

GRIPP K. & BEYLE M. 1937. Das Interglazial von Billstedt (Öjendorf) Mitt. Geol. Staatsinstitut Hamburg, 16: 19–36.

GRONKOWSKA-KRYSTEK B. 2000. Szczegółowa mapa geologiczna Polski w skali 1:50 000, ark. Sztabin. Badania petrograficzno-litologiczne osadów czwartorzędowych. Central Geological Archives, Polish Geological Institute-National Research Institute, Warszawa.

GÜMBEL F. & MAI D.H. 2004. Neue Pflanzenfunde aus dem Tertiär der Rhön. Teil 2. Mitteil.Museum Naturk. Berlin, Geowiss. Reihe 7: 175–220

IVERSEN J. 1954. The late-glacial flora of Denmark and its relation to climate and soil. Danm. Geol. Unders., 2(80): 87–119.

IVERSEN J. 1958. The bearing of glacial and interglacial epochs on the formation and extinction of plant taxa. Uppsala Univ. Årsskr., 6: 210–215.

IVERSEN J. 1964. Plant indicators of climate, soil and other factors during the Quaternary. In: Dylik J. (ed.) Report of the 6th INQUA Congress 2: 421–428, Łódź.

JANCZYK-KOPIKOWA Z. 1975. Flora interglacjału mazowieckiego w Ferdynandowie (Summary: Flora of the Mazovian Interglacial at Ferdynandów). Biul. Inst. Geol., 290: 5–94.

JANCZYK-KOPIKOWA Z. 1995. Stratygrafia plejstocenu Polski NE na podstawie roślinności. Central Geological Archives, Polish Geological Institute-National Research Institute, Warszawa.

JANCZYK-KOPIKOWA Z. 1996. Ciepłe okresy w mezoplejstocenie północno-wschodniej Polski (summary: Temperate stages of the Mesopleistocene in northeastern Poland). Biul. Państw. Inst. Geol., 373: 49–66.

JANCZYK-KOPIKOWA Z. 2009. Analiza pyłkowa międzymorenowych osadów z profilu Sucha Wieś, Pojezierze Ełckie, północno-wschodnia Polska (summary: Pollen analysis of intermoriane deposits from the Sucha Wieś section, Ełk Lakeland, Northeastern Poland) Biul. Państw. Inst. Geol., 373: 37–46.

KATS N.Ya. & KATS S.V. 1960. Iskopaemaya flora i rastitelnost' mezhlednikovykh otlozheniy u Zhidovshchizny pod Grodno. Byull. Komiss. po izuch. chetvertichn. perioda (AN SSSR), 25: 35–49.

KATS N.Ya., KATS S.V. & KIPIANI M.G. 1965. Atlas i opredelitel' plodov i semyan vstrechayushchikhsya v chetviertichnykh otlozheniyach SSSR (Atlas and keys of fruits and seeds occuring in the Quaternary deposits of the USSR). Izdat. Nauka, Moskva. (in Russian).

KACPRZAK L. & LISICKI S. 1999. Szczegółowa mapa geologiczna Polski 1:50 000, ark. Sztabin (186). Central Geological Archives, Polish Geological Institute-National Research Institute, Warszawa.

KACPRZAK L. & LISICKI S. 2000. Objaśnienia do SMGP 1:50 000 – ark. Sztabin. Central Geological Archives, Polish Geological Institute-National Research Institute, Warszawa.

KHURSEVICH G., NITA M., BER A., SANKO A. & FEDENYA S. 2004. Palaeoenvironmental and climatic changes during the Early Pleistocene recorded in the lacustrine-boggy-fluvial sediments at Komorniki, NE Poland. Proceedings of the Workshop “Reconstruction of Quaternary palaeoclimate and palaeoenvironments and their abrupt changes”. Pol. Geol. Inst. Special Papers, 16(2005): 35–44.

KIPIANI M.G. & KOLBUTOV A.D. 1961. Novye dannye po stratigrafii plejstotsenovykh otlozheny Povolzh'ya i Prikam'ya. In: Materialy Vsesoyuznovo soveshchaniya po izucheniyu chetvertichnogo perioda. T. 2.: Izdat. Akad. Nauk SSSR.

KISIELIENE D. 2002. Palaeocarpological complexes of Lithuania Quaternary and their stratigraphical significance. Abstract of doctoral dissertation. Inst. of Geol. and Geography, Vilnius.

KONDRACKI J. 2000. Geografia regionalna Polski. Wyd. Naukowe PWN, Warszawa.

KONDRATENE O. 1996. Stratygrafiya i paleografiya kvartera Litvy po paleobotanicheskim dannym (summary: The Quaternary stratigraphy and palaeogeography of Lithuania based on pslaeobotanical studies). Academia, Vilnyus.

KOLSTRUP E. 1980. Climate and stratigraphy in northwestern Europe between 30,000 BP and 13,000 BP, with special reference to the Netherlands. Meded. Rijks Geol. Dienst, 32/15: 181–253.

KOPEROWA W. & ŚRODOŃ A. 1965. Pleniglacial deposits of the Last Glaciation at Zator. Acta Palaeobot., 6(1): 3–32.

KRZYWICKI T. 1995. Szczegółowa mapa geologiczna Polski 1:50 000, ark. Augustów Stacja. Central Geological Archives, Polish Geological Institute-National Research Institute, Warszawa

KRZYWICKI T. 1998. Szczegółowa mapa geologiczna Polski 1:50 000, ark Augustów Stacja (148). Central Geological Archives, Polish Geological Institute-National Research Institute, Warszawa.

KRZYWICKI T. & LISICKI S. 1993. Czwartorzęd Pojezierza Suwalskiego: 59–89. In: Juskowiak O. (ed.), Przewodnik 64 Zjazdu Polskiego Towarzystwa Geologicznego na Ziemi Suwalskiej, 9–12 września 1993. Państw. Inst. Geol., Warszawa.

LILPOP J. 1929. Flora utworów międzylodowcowych w Olszewicach (summary: The flora of interglacial formation in Olszewice near Tomaszów). Spraw. Kom. Fizjogr. PAU, 64: 57–75.

LILPOP J. 1932. Flora utworów międzylodowcowych w Olszewicach pod Tomaszowem Mazowieckim - profil zupełny (summary: The flora of interglacial formation in Olszewice near Tomaszów in central Poland – complete profile). Spraw. Kom. Fizjogr. PAU, 66: 81–88.

LINDNER L. 1992. Stratygrafia (klimatostratygrafia) czwartorzędu: 441–613. In: Lindner L. (ed.), Czwartorzęd. Osady, metody badań, stratygrafia. Wyd. Pol. Agencji Ekol. S.A., Warszawa.

LINDNER L., GOŻIK P., JEŁOWICZEWA J., MARCINIAK B. & MARKS L. 2004. Główne problemy klimatostratygrafii czwartorzędu Polski, Białorusi i Ukrainy. (Summary: Main problems of climatostratigraphy of the Quaternary in Poland, Belarus and Ukraine). In: Kostrzewski A. (ed.), Geneza, litologia i stratygrafia utworów czwartorzędowych. Wyd. Nauk. UAM Poznań, vol. 4, Seria Geografia 68: 243–258.

LISICKI S. 2003. Litotypy i litostratygrafia glin lodowcowych plejstocenu dorzecza Wisły (summary: Lithotypes and lithostratigraphy of tills of the Pleistocene in the Vistula drainage basin area, Poland). Prace PIG, 177: 1–105.

LISICKI S. & WINTER H. 2004. Rewizja pozycji stratygraficznej osadów dolnego i środkowego plejstocenu północno-wschodniej Polski (summary: Revision of stratigraphy of the Lower and Middle Pleistocene sediments of North-eastern Poland): 259–283. In: Kostrzewski A. (ed.), Geneza, litologia i stratygrafia utworów czwartorzędowych. Wyd. Nauk. UAM, Poznań,vol.4, Seria Geografia, 68: 259–283.

LISICKI, H. WINTER, T. & KRZYWICKI. 2000. Rewizja Pozycji stratygraficznej osadów dolnego i środkowego plejstocenu Polski północno-wschodniej. Central Geological Archives, Polish Geological Institute-National Research Institute, Warszawa. 1–48.

MAI D.H. 2004. Die miozänen und pliozänen Floren aus Nordostbranderburg und Südwest-mecklenburg. Palaeontographica,. B, 269: 1–130.

MAI D.H. & WALTHER H. 1998. Die pliozänen Floren von Thüringen, Deutsche Demokratische Republik. Quartärpaläontologie, 7: 55–297.

MAMAKOWA K. 1970. Late-Glacial and Early-Holocene vegetation from the territory of Kraków (Poland). Acta Palaeobot., 11(1): 3–12.

MAMAKOWA 1989. Late Middle Polish Glaciation, Eemian and Early Vistulian vegetation at Imbramowice near Wrocław and the pollen stratigraphy of this part of the Pleistocene in Poland. Acta Palaeobot., 29(1): 11–176.

MAMAKOWA K. 1997. Compiling, entering and processing of Polish data relating to the last interglacial – scientific raport no 2. Archives of the W. Szafer Institute of Botany Polish Academy of Sciences, Kraków.

MAMAKOWA K. 2003. Plejstocen. In: S. Dybova-Jachowicz, A. Sadowska (eds.) Palinologia : 235–266. Instytut Botaniki im. W. Szafera PAN, Kraków

MAMAKOWA K. & ŚRODOŃ A. 1977. O pleniglacjalnej florze z Nowej Huty i osadach czwartorzędu doliny Wisły pod Krakowem (summary: On the pleniglacial flora from Nowa Huta and Quaternary deposits of the Vistula valley near Cracow). Roczn. Pol. Tow. Geol., 47(4): 485–511.

MAMAKOWA K. & VELICHKEVICH F.Yu. 1993. Exotic plants in the floras of the Mazovian (Alexandrian) Interglacial of Poland and Belarus. Acta Palaeobot., 33(2): 305–319.

MAMAKOWA K. & RYLOWA T.B. 2007. The interglacial from Korchewo in Belarus in the light of new palaeobotanical studies. Acta Palaeobot., 47(2): 425–453.

MATUSZKIEWICZ W. 2001. Przewodnik do oznaczania zbiorowisk roślinnych Polski. Wyd. Naukowe PWN, Warszawa.

MATUSZKIEWICZ W. 2008. Przewodnik do oznaczania zbiorowisk roślinnych Polski. Wyd. Naukowe PWN, Warszawa.

MIREK Z., PIĘKOŚ-MIRKOWA H., ZAJĄC A. & ZAJĄC M. 2002. Flowering plants and Pteridophytes of Poland. A checklist (Krytyczna llista roślin naczyniowych Polski). W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

NAWROCKI J. 1997. Wyniki badań paleomagnetycznych 5 prób z profilu Kalejty (Równina Augustowska). Central Geological Archives, Polish Geological Institute-National Research Institute, Warszawa.

NAWROCKI J. 2009. Wyniki badań paleomagnetycznych osadów jeziornych z profilu Czarnucha–Równina Augustowska, północno-wschodnia Polska (summary: The results of palaeomagnetic investigations of lacustrine deposits from the Czarnucha section – Augustów Plain, northeastern Poland). Biuletyn PIG, 435: 69–74

NIKITIN P.A. 1948. Pliotsenovye flory s reki Obi v rayonie Tomska (Pliocene floras from Ob river near Tomsk). Dokl. Akad. Nauk SSSR, 61(6): 1103–1106. (in Russian).

NIKITIN P.A. 1957. Pliotsenovye i chetvertichnye flory Voronezhkoy oblasti (Pliocene and Quaternary fkoras from Voronezh district). Izdat. Akad. Nauk SSSR, Moskva-Leningrad.(in Russian).

NIKITIN P.A. & DOROFEEV P.I. 1953. Chetvertichnaya flora rayona Novokhoperska. Byull. Komiss. po izuch. chetvertichn. perioda (AN SSSR), 17: 22–23.

NILSSON O. & HJELMQUIST H. 1967. Studies on the nutlet structure of South Scandinavian Species of *Carex*. Botaniska Notiser, 120: 460–485.

NITA M. 1999. Mazovian Interglacial at Konieczki near Kłobuck (Silesian-Cracovian Upland). Acta Palaeobot., 39(1): 89–135.

NITA M. 2009. Stratygrafia pyłkowa i historia roślinności interglacjału mazowieckiego i starszej części zlodowacenia liwca na obszarze zachodniej i środkowej części Wyżyn Polskich (summary: Pollen stratigraphy and vegetation history during the Mazovian Interglacial and the older part of Liviecian Glaciation in the western and central parts of Polish Uplands). Prace Nauk. Uniw. Śląskiego, 2658: 1–158.

NITYCHORUK J., BER A., HOEFS J., KRZYWICKI T., SCHNEIDER J. & WINTER H. 2000. Interglaziale Klimaschwankungen in Nordost-Polen – palynologische und isotope-geochemische Untersuchungen an organischen Seesedimenten. Eiszeitalter u. Gegenwart, 50: 86–94.

PAWŁOWSKA S. 1972. Charakterystyka statystyczna i elementy flory polskiej129–206. In: Szafer W. & Zarzycki K. (eds.) Szata roślinna Polski, vol. 1:. Państw. Wyd. Naukowe, Warszawa.

PIECH K. 1932. Das Interglazial in Szczerców (östlich v. Wieluń – Wojewodschaft Łódź). Rocznik Pol. Tow. Geol., 8(2): 51– 132.

PODBIELKOWSKI Z. & TOMASZEWICZ H. 1982. Zarys hydrobotaniki. Państw. Wyd.. Naukowe, Warszawa.

REID C. & REID E.M. 1907. The flora of Tegelen-sur-Meuse near Venloo, in the province of Limburg. Versl. Kon. Akad. Wetensch. Sect. 2., 13(6): 1–26.

REID C. & REID E.M. 1915. The Pliocene floras of the Dutch-Prussian border. Meded. Rijkskopsp. Delfstoffen. 6: 1–178.

RIŠKIENĖ M. 1979. Merkinės tarpledynmečio flora. Geografinis metraštis, 16: 98–106.

ROTNICKI K. & TOBOLSKI K. 1965. Pseudomorfozy wieloboków z lodem szczelinowym i stanowisko tundry w peryglacjalnym basenie sedymentacyjnym ostatniego zlodowacenia w Kępnie. Bad. Fizjogr. Pol.. Zach., 15: 93–146.

SOBOLEWSKA M. 1970. *Euryale ferox* Salisb. in the Pleistocene of Poland. Acta Palaeobot., 11, 1: 13–22.

SOBOLEWSKA M. 1977. Roślinność interglacjalna ze Stanowic koło Rybnika na Górnym Śląsku (summary: Interglacial vegetation of Stanowice near Rybnik (Upper Silesia). Acta Palaeobot., 18(2): 3–17.

SOBOLEWSKA M., STARKEL L. & ŚRODOŃ A. 1964. Młodoplejstoceńskie osady z florą kopalną w Wadowicach (summary: Late-Pleistocene deposits with fossil flora at Wadowice –West Carpathians). Folia Quaternaria, 16: 1–64.

STACHOWICZ-RYBKA R. 2005. Reconstruction of climate and environment in the Augustovian Interglacial on the basis of select plant macrofossil taxa., Pol. Geol. Inst., Special Papers 16: 127–132.

STACHOWICZ-RYBKA R. 2007. Charakterystyka zbiorowisk jeziornych na podstawie dwóch stanowisk interglacjału augustowskiego (Characteristics of lake communities on the basis of two sites of the Augustovian Interglacial). Prace Kom.Paleogeogr. Czwartorzędu PAU, 5: 41–45.

STACHOWICZ-RYBKA R. 2009. Stratygrafia makroszczątków roślin ze stanowiska Czarnucha – Równina Augustowska, północno-wschodnia Polska (summary: Stratigraphy of macroscopic plant remains from Czarnucha section – Augustów Plain, northeastern Poland). Biul. PIG, 435: 97–108

STANKOV S.S. & TALIEV V.I. 1949. Opredelitel vysshikh rasteny evropeyskoy chasti SSSR (Keys of vascular plants of the European part of the USSR). Izdatestvo Sovetskaya Nauka,, Moskva. (in Russian).

STASZKIEWICZ J. & WÓJCICKI J. 1979. Analiza biometryczna rodzaju *Trapa* L. z Polski (Biometrical analysis of Trapa L. nuts from Poland). Fragm. Flor. Geobot., 25(1): 33–59.

SUKATSCHEFF W. 1908. Über das Vorkommen der Samen von *Euryale ferox* Salisb. in einer interglazialen Ablagerung in Russland. Berichte Deutsch. Bot. Gesell., 26: 132–137.

SZAFER W. 1954. Plioceńska flora okolic Czorsztyna` i jej stosunek do plejstocenu (summary: Pliocene flora from the vincinity of Czorsztyn – West Carpathians – and its relationship to the Pleistocene). Prace Inst. Geol., 11: 5–238.

SZAFER W. 1972. Kraina: Suwalsko-Augustowska. In: W. Szafer & K. Zarzycki (eds.), Szata roślinna

Polski, vol.. 2: 176–178. Państw. Wyd. Naukowe, Warszawa.

SZAFER W., TRELA J. & ZIEMBIANKA M. 1931. Flora interglacjalna z Bedlna koło Końskich (Zusammenfassung: Die interglaziale Flora von. Bedlno bei Końskie). Rocznik Pol. Tow. Geol., 7: 402–414.

ŚRODOŃ A. 1954. Flory plejstoceńskie z Tarzymiechów nad Wieprzem (summary: Pleistocene floras from *Tarzymiechy* on the river Wieprz). Biul. Inst. Geol., 69: 5–78.

ŚRODOŃ A. & GOŁĄBOWA M. 1956. Plejstoceńska flora z Bedlna (summary: Pleistocene flora of Bedlno (Central Poland)). Biul. Inst. Geol., 100: 7–44.

ŚWIT J. 1991. Budowa, geneza i rozwój torfowisk pradolinnych Biebrzy. Zesz. Probl. Podst. Nauk Roln., 372: 185–217.

TOBOLSKI K. 1976. Przemiany klimatyczno-ekologiczne w okresie czwartorzędu a problem

zmian we florze (summary: Climatic-ecological transformations in the Quaternary and the problem of changes in the flora). Phytocoeonosis 5(3/4): 187–197.

TOBOLSKI K. 1991. Biostratygrafia i paleoekologia interglacjału eemskiego i zlodowacenia Wisły rejonu konińskiego (summary: Biostratigraphy and palaeology of the Eemian Interglacial and the Vistulian glaciation of the Konon region) : 45–87. In: Stankowski W. (ed.), Przemiany środowiska geograficznego obszaru Konin-Turek. Wyd. Uniw. A. Mickiewicza, Poznań.

TOBOLSKI K. 2000. Przewodnik do oznaczania torfów i osadów jeziornych. Wyd. Nauk. PWN, Warszawa.

TRALAU H. 1962. *Najas tenuissima* (A.BR.) Magnus during the Late Cainozoic period in Europe. Bot. Notiser, 115: 421.

TROELS-SMITH J. 1955. Characterization of consolidated sediments. Danm. Geol. Unders., 4, 3(10): 1–73.

UGGLA H. 1969a. Gleby gytiowe Pojezierza Mazurskiego. I. Ogólna charakterystyka gleb gytiowo-bagiennych i gytiowo-murszowych. Zesz. Nauk. WSR, 25(702): 563–582.

UGGLA H. 1969b. Gleby Pojezierza Mazurskiego. II. Właściwości fizyczne, chemiczne i biologiczne gleb gytiowo-bagiennych i gytiowo-murszowych. Zesz. Nauk. WSR, 25(703): 584–606.

VELICHKEVICH F.Yu. 1973. Antropogenovye flory Belorussii i smezhnykh oblastey (Antropogene floras of Belarus and adjacent regions). Izdat. Nauka i Tekhnika, Minsk. (in Russian).

VELICHKEVICH F.Yu. 1974. Flora razreza Snaygupele bliz g. Druskininkay. Doklady AN BSSR, 18(6): 549–552.

VELICHKEVICH F.Yu. 1977a. Novye dannye o flore Verkhov'e-1 na Zapadnoy Dvine (New data of the flora of Verkhov'e-1 on the West Dvina river).. Doklady Akad. Nauk BSSR, 21(3): 258–261. (in Russian).

VELICHKEVICH F.Yu. 1977b. O srednepleystotsenovoy flore Verkhov'e-2 v Vitebskoy oblasti (On the Middle Pleistocene flora of Verkhov'e-2 in Vitepsk region). Doklady Akad. Nauk BSSR, 21(6): 558–561. (in Russian).

VELICHKEVICH F.Yu. 1978. O semennoy flore razreza Yakhny na Zapadnoy Dvine. Doklady AN BSSR, 22(10): 938–941.

VELICHKEVICH F.Yu. 1979. Istorya pleistotsenovoy flory sredney polosy Vostochno-Evropeyskoy ravniny (The history of Pleistocene flora of intermediary area of the East-European Plain): 79–121. In: Goretsky G.I. & Grichuk V.P. (eds.), Sovetskaya Paleokarpologiya. Izdat. Nauka, Moskva.

VELICHKEVICH F.Yu. 1980. O semennoy flore razreza Butenay na r. Shvyantoye (On the seed.flora of the Butenai on the river Shviantoi): 133–138. In: Problemnye voprosy geologii neogena i antropogena Belorussii.(The problematical questions of the Antropogene and Neogene geology of Belarus). Izdat. Nauka i Tekhnika, Minsk. (in Russian).

VELICHKEVICH F.Yu. 1982. Pleystotsenovye flory lednikovykh oblastey Vostochno-Evropeyskoy Ravniny (The Pleistocene floras of glacial areas of the East-European Plain). Izdat. Nauka i Technika, Minsk. (in Russian).

VELICHKEVICH F.Yu. 1986. O rannepleystotsenovoy flore razreza Korchevo na Novogrudskoy Bozvyshennosti (The Early Pleistocene interglacial flora from the Korchevo exposure within the Novogrudok Upland). Doklady Akad. Nauk BSSR, 30(3): 255–258. (in Russian).

VELICHKEVICH F.Yu. 1990. Pozdnepliotsenovaya flora Dvortsa na Dnepre (The Late Pleistocene flora of Dvorets on the Dnieper River). Izdat. Nauka i Tekhnika, Minsk.

VELICHKEVICH F.Yu. & MAMAKOWA K. 1999. Taxonomic revision of the collections of plant macrofossils from some localities of Poland now referred to the Vistulian Glaciation. Acta Palaeobot., 39(1): 29–87.

VELICHKEVICH F.Yu. & MAMAKOWA K. 2003. Revision of plant macrofossils from the Mazovian interglacial locality Nowiny Żukowskie (SE Poland). Acta Palaeobot., 43(1): 61–76.

VELICHKEVICH F.Yu. & RYLOVA T.B. 1988. O novoy nakhodke rannepleystotsenovoy flory na yugo-vostoke Belorussii (On the new finding of the Early Pleistocene flora in the South-East of Belaruss) . Doklady Akad. NaukN BSSR, 32(11): 1014–1017. (in Russian).

VELICHKEVICH F.YU. & ZASTAWNIAK E., 2003. The Pliocene flora of Kholmech, south-eastern Belarus and its correlation with other Pliocene floras of Europe. Acta Palaeobot., 43(2): 137–259.

VELICHKEVICH F.Yu, KONDRATIENE O. & KISIELIENE D. 1998. The new data on Early Pleistocene paleocarpological complexes in Lithuania. Geologija, Vilnius, 25: 92–101.

VELICHKEVICH F.Yu., MAMAKOWA K. & STUCHLIK L. 2004. Revision of some Mazovian interglacial macrofossil floras of Poland. Acta Palaeobot., 44(1): 93–104.

VELICHKEVICH F.Yu., MAMAKOWA K. & STUCHLIK L. 2005. Revision of some plant macrofossil collections from the Eemian interglacial deposits of central and western Poland. Acta Palaeobot., 45(1): 107–115.

VELICHKEVICH F.Yu, RYLOVA T.B., SANKO A.F. & FEDENYA V.M. 1993. Berezovskiy stratorayon pleystotsena Belarusi (Berezovski strato region of the Pleistocene of Belarus). Nauka i Tekhnika, Minsk. (in Russian)

VELICHKEVICH F.Yu., DERYUGO G.V., ZERNITSKAYA V.P., ILKEVICH G.I., LEVITSKAYA R.I., LITVINYUK G.I.., MATVEEV A.V., NAZAROV V.I., SAN'KO A.F., RYLOVA T.B., KHURSEVICH G.K. & YAKUBOVSKAYA T.V. 2001. Chetvertichnaya sistema – kvarter (Quaternary formation): 325–386. In: Makhnach A.S., Garetskiy R.G., & Matveev A.V. (eds.), Geologiya Belarusi (Geology of Belarus). Institut Geologicheskikh Nauk NAN Belarusi, Minsk. (in Russian).

VOZNYACHUK L.N., MAKHNACH N.A., MOTUZKO A.N., VELICHKEVICH F.Yu., YAKUBOVSKAYA T.V., ZUS M.E., KALINOVSKI P.F., RUNETS E.P., SAN'KO A.F. 1977. Nizhneplejstotsenovye otlozheniya d. Korchevo na novogrudskoy vozvyshennosti v Belorussii i ikh stratigraficheskoye paleogeograficheskoye znachenie. (The Lower Pleistocene deposits of village Korchevo on the Novogrudok Upland in Belarus and their stratigraphic and palegegraphicsignificance). Doklady Akad. Nauk BSSR, 21(11): 1025–1028. (in Russian).

VOZNYACHUK L.N., MAKHNACH N.A., MOTUZKO A.N., VELICHKEVICH F.YU., YAKUBOVSKAYA T.V., ZUS M.E., KALINOVSKI P.F., RUNETS E.P. & SANKO A.F. 1978. Novye dannye po paleogeografii rannego pleystotsena lednikovoy oblasti Vostochno-Evropeyskoy ravniny. (New data ojn the paleogeography of the Early Pleistotsene of glacial area of the East-European Plain). Doklady Akad. Nauk SSSR, 239(1): 154–157. (in Russian).

WALANUS A. & NALEPKA D. 1996. POL-PAL, Palynological Data Base. User's Guide (1994). W. Szafer Institute of Botany, Pol. Acad. Sci., Kraków.

WASYLIKOWA K. 1964. Roślinność i klimat późnego glacjału w środkowej Polsce na podstawie badań w Witowie koło Łęczycy (summary: Vegetation and climate of the Late-Glacial in Central Poland based on investigations made at Witów near Łęczyca). Biul. Perygl. 13: 261–417.

WĄS 1956. Nowe stanowisko interglacjału i gliny zwałowej. Przegl. Geol., 4: 323–325.

WEST R.G. 1980a. Pleistocene forest history in East Anglia. New Phytol., 85.

WEST R.G. 1980b. The pre-glacial Pleistocene of the Norfolk and Suffolk coasts. Cambridge Univ. Press.

WINTER H. 1998. Nowe spojrzenie na stratygrafię plejstocenu środkowego na obszarze Polski północno-wschodniej jako wynik badań palinologicznych. W materiałach z V Konferencji "Stratygrafia Plejstocenu Polski", Iznota 1–4 września 1998.

WINTER H. 2001. Nowe stanowisko interglacjału augustowskiego w połnocno-wschodniej Polsce (summary: New profi le of Augustowski Interglacial in north-eastern Poland): 439–450. In: Kostrzewski A. (ed.), Geneza, litologia i stratygrafi a utworow czwartorzędowych, Vol. 3, Ser. Geografi a, 64. Wyd. Univ. Adam Mickiewicz, Poznań.

WINTER H., 2003. Analiza palinologiczna jako podstawa do odtworzenia roślinności i klimatu interglacjału augustowskiego i interstadiału z Domurat. W materiałach z I Polskiej Konferencji Paleobotaniki Czwartorzędu, Białowieża 22–24 maja 2003.

WINTER H. 2004. Climatic variability and reconstruction of palaeoenviroments inferred from Early Pleistocene long pollen sequences (North-Eastern Poland). W materiałach z Konf. „Reconstruction of Quaternary palaeoclimate and palaeoenvironments and their abrupt changes", 29 Sept.– 2 Oct. 2004, Białowieża, Poland: 44–45.

WINTER H. 2008. Zapis palinologiczny zmian roślinności i klimatu interglacjału augustowskiego w profilu Żarnowo (Równina Augustowska, północno-wschodnia Polska). (Summary: Palinological record of vegetation and climate changes of Augustovian Interglacial at the Żarnowo Site (Augustów Plain, northeastern Poland). Przegl. Geol., 56: 1011–1018.

WINTER H. 2009. Sukcesja pyłkowa z profilu Czarnucha (Równina Augustowska) i jej znaczenie dla stratygrafii dolnego plejstocenu północno-wschodniej Polski. (summary: A pollen succession from from Czarnucha section (Augustów Plain) and its significance for the Lower Pleistocene stratigraphy of northeastern Poland). Biuletyn PIG, 435: 109–120.

WINTER H. & JANCZYK-KOPIKOWA Z. 2006. Zapis palinologiczny sukcesji augustowskiej w profilach Polski północno-wschodniej (Palinological record of Augustovian pollen succession in profile of northeastern Poland). Prace Komisji Paleogeografii Czwartorzędu PAU, 4: 103–109.

WINTER H. & LISICKI S. 2005 Sukcesja pyłkowa z Domurat (Wzgórza Sokólskie) i jej znaczenie dla plejstocenu Polski pólnocno-wschodniej. (summary: A pollen succesion from Domuraty (Sokólskie Hills) and its signification for the Pleistocene of NE Poland). Biuletyn PIG, 416: 115–131.

WINTER H. & STACHOWICZ-RYBKA R. 2002. Changes of environment recorded in the Lower Pleistocene sediments from the Czarnucha section (NE Poland) based on palaeobotanical data: 251–252. In: Book of abstracts 6th European Paleobotany-Palynology Conference Athens, August 29 – September 2. 2002.

WOŚ A. 1995. Zarys Klimatu Polski. Bogucki Wydawnictwo Naukowe, Poznań.

WOŚ A. 1999. Klimat Polski. Wydawnictwo Naukowe PWN, Warszawa.

YAKUBOVSKAYA T.V. 1973. Novye isledovaniya mazhlednikovykh otlozheny ud. Prinemanskaya (b. Zhidovshchizna) bliz g. Grodno: 21–34. In: Materialy po paleogeografii i geokhimii antropogena Belorussii. Nauka i Tekhnika, Minsk.

YAKUBOVSKAYA T.V. 1982. Pliotsenovye flory Belorusskovo Podneprov'ya (Pliocene floras of Byelorussian Podnieprovye): 34–61. In: Velichkevich F.Yu. (ed.), Paleokarpologicheskie issledovaniya kaynozoya (Plaeocarpological investigations of Cenozoic). Nauka i Tekhnika, Minsk. (in Russian).

YAKUBOVSKAYA T.V. 1984. Ocherk neogena i rannevo antropogena Poneman'ya (Skech of Neogene ans Early Antropogene of the Poneman'e). Nauka i Tekhnika, Minsk. (in Russian).

YELOVICHEVA Y.K. 2008. History of the formation of the flora of Belarus (by palynological data). Acta Geogr. Siles., 3: 47–59.

ZAGWIJN W.H. 1985. An outline of Quaternary stratigraphy of the Netherlands. Geologie en Mijnbouw, 64: 17–24.

ZAGWIJN W.H. 1996. The Cromerian Complex Stage of the Netherlands and correlation with other areas in Europe. In: Turner Ch. (ed.) The Early Middle Pleistocene in Europe: 145–172. Balkema, Rotterdam-Brookfield.

ZARĘBA R 1978. Puszcze, bory i lasy Polski. Państw. Wydawn. Rolnicze i Leśne, Warszawa.

ZARZYCKI K., TRZCIŃSKA-TACIK H., RÓŻAŃSKI W., SZELĄG Z., WOŁEK J. & KORZENIAK U. 2002. Ecological indicator values of vascular plants of Poland (Ekologiczne liczby wskaźnikowe roślin naczyniowych Polski). W. Szafer Institute of Botany, Pol. Acad. of Sciences, Kraków.

ŻUREK S. 1975. Geneza zagadnienia Pradoliny Biebrzy. Prace Geograficzne Inst. Geogr. Przestrz. Zagosp. PAN, 110.

ŻUREK S. 1984. Relief, geologic structure and hydrography of the Biebrza ice-marginal valley. Pol. Ecol. Stud., 10: 3–4.

ŻUREK S. 1991. Budowa, geneza i rozwój torfowisk sandru augustowskiego. Zesz. Probl. Podst. Nauk Roln., 372.

PLATES

Plate 1

1. *Selaginella helvetica* (L.) Spring, megaspore, × 40
2. *Mentha aquatica* L., fruit, × 40
3. *Alnus glutinosa* L., fruit, × 20
4. *Salix* sp., capsule, × 20
5. *Ranunculus lingua* L., fruit, × 40
6. *Polygonum lapathifolium* L., fruit, × 20
7. *Sparganium emersum* Rehmann, fruit, × 20

8, 9. *Callitriche* sp., seed, × 20

10, 11. *Lycopus europaeus* L., fruit, × 20

12. *Najas minor* All., seed, × 20
13. *Potamogeton natans* L., endocarp, × 20
14. *Batrachium* sp., fruit, × 20
15. *Ranunculus sceleratus* L., fruit, × 40
16. *Ceratophyllum demersum* L., fruit, × 30

Phot. R. Stachowicz-Rybka

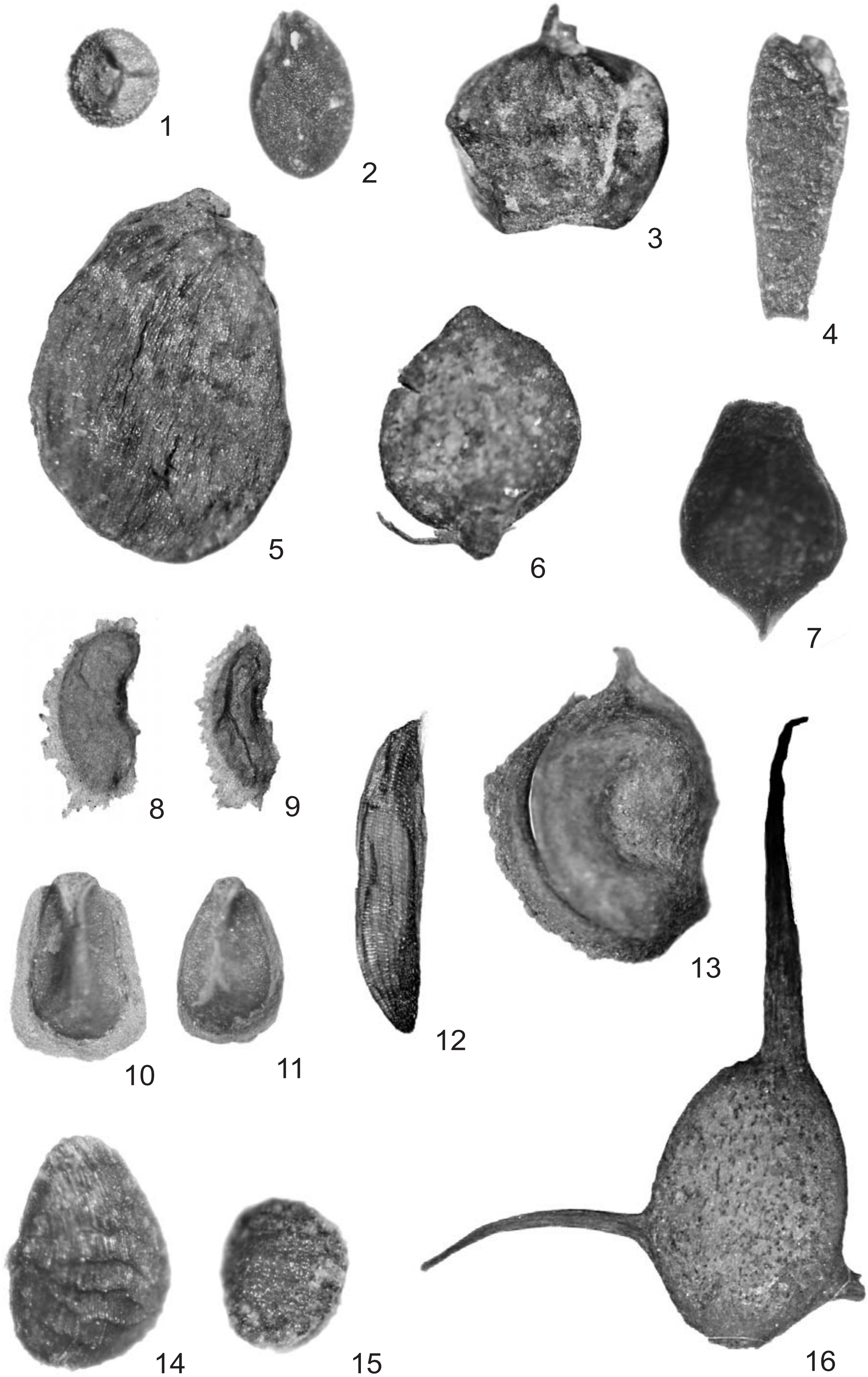
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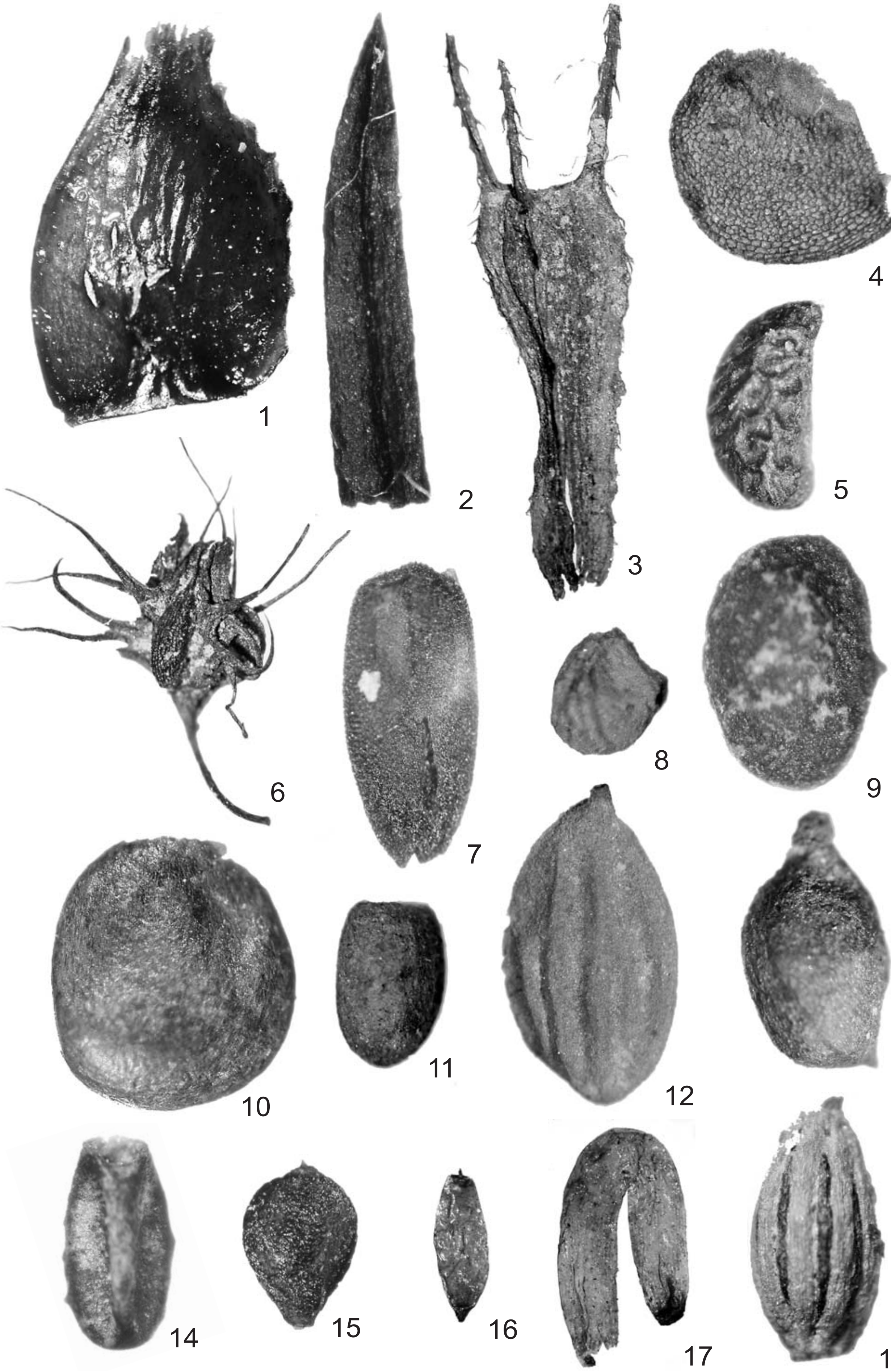
Plate 2

1. *Acer* sp., wing of seed, × 10
2. *Picea* sp. needle, × 20
3. *Bidens tripatita* L., fruit, × 20
4. *Solanum dulcamara* L., fruit, × 20
5. *Rubus idaeus*, seed, × 20
6. *Rumex maritimus* L., perianth, × 20
7. *Carduus crispus* L., fruit, × 20
8. *Potentilla supina* L., seed, × 30
9. *Potantilla anserina* L., seed, × 30
10. *Menyanthes trifoliata* L., seed, × 20
11. *Hippuris vulgaris* L., seed, × 20
12. *Thalictrum minus* L., fruit, × 20
13. *Potamogeton pusillus* L., endocarp, × 20
14. *Myriophyllum spicatum* L., fruit, × 20
15. *Eleocharis palustris* L., fruit, × 40
16. *Typha* sp., tegmen, × 40
17. *Sagittaria sagittifolia* L., fruit, × 20
18. *Oenanthe aquatica* L., fruit, × 20

Phot. R. Stachowicz-Rybka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