Bulletin of Geography – **Physical Geography Series**
No 4/2011: 21–46
https://www.doi.org/10.2478/bgeo-2011-0002

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COMPREHENSIVE PALAEOBOTANICAL STUDIES OF LACUSTRINE-PEAT BOG SEDIMENTS FROM THE MAZOVIAN/ HOLSTEINIAN INTERGLACIAL AT THE SITE OF NOWINY ŻUKOWSKIE (SE POLAND) – PRELIMINARY STUDY

Abstract: The environmental variability during the Mazovian/Holsteinian interglacial is better understood thanks to the results of multidisciplinary palaeobotanical studies. The perfectly preserved and abundant material from Nowiny Żukowskie in SE Poland has been the subject of numerous palaeobotanical analyses. The results both of initial pollen analysis and of the examination of plant macroremains provide a detailed view of changes in the palaeoenvironment of this area during the Mazovian/Holsteinian interglacial. Originally, the water basin was mostly the habitat of plants indicative of low trophy. The frequent occurence of swamp plants evidences a change in hydrological and climatic conditions consistent with the intra-interglacial climatic oscillation. In the subsequent part of the optimum, an expansion of swamps with *Aracites interglacialis* and *Dulichium arundinaceum* was recorded. The development of a peat bog overgrown by i.a. *Sphagnum* sp., *Eriophorum vaginatum*, and *Andromeda polifolia* was also observed. The growth of swamp and peat vegetation resulted in the nearly complete disappearance of aquatic vegetation, apart from species typical of the climatic optimum of the Mazovian/Holsteinian interglacial: *Brasenia borysthenica* and *Aldrovanda dokturovskyi.* The close of the interglacial was marked by the intensive development of peat bog and swamp communities with *Carex rostrata*, *Menyanthes trifoliata*, and *A. interglacialis*. The intensive increase in the number of *A. interglacialis* during the period described as the "birch oscillation" supports the hypothesis of noticeable changes in hydrological conditions at that time. The end of the described period is typified by a deterioration of climatic conditions, indicated by the increase in values for *Betula humilis*, *B. nana*, and *Juniperus communis*.

Key words: Mazovian/Holsteinian interglacial, pollen analysis, plant macroremains, palaeoenvironment, SE Poland.

Introduction

The study of past interglacials in Poland has been a frequent and extremely significant source of information on the palaeoenvironment and palaeoclimatic changes in central Europe. The study of the Mazovian/Holsteinian interglacial has focused almost strictly on pollen analysis and stable Carbon and Oxygene Isotopic Dating. However, it permits numerous correlations with result of study from central and western Europe (de Beaulieau et al. 2001, Geyh & Müller 2005, 2007, Koutsodendris 2011). To better understand environmental variability during the Mazovian/Holsteinian interglacial it is important to conduct a multidisciplinary palaeobotanical study. This may result in detailed information about palaeoenvironmental changes.

Nowiny Żukowskie is located in the northern part of the Lublin Upland, surrounded by the Polesie Region (in the north) and by the eastern end of the Central Polish Lowlands, all these areas being abundant in Pleistocene organic sediments.

For years these sediments have been subjected to both geological and palaeobotanical studies (i.a. Dyakowska 1952, Brem 1953, Sobolewska 1956, Janczyk-Kopikowa 1981, 1983, Pidek 2003). Nowiny Żukowskie is one of the earliest sites to be identified and examined in this area. The first geological studies of this site were performed in the 1950s (Rühle 1952). Pollen analysis and plant macroremains analysis of material obtained in this survey were carried out by Dyakowska (1952). On the basis of these studies, the age of sediments from Nowiny Żukowskie was estimated to the Mazovian/Holsteinian interglacial, and Szafer (1953) considered the site to be a stratotype for this period due to the presence of a complete and undisturbed sequence of lacustrine sediments and perfectly preserved plant material.

In the 60 years since, great progress has been made in research methods used in palaeobotany. In 2005, the drilling was repeated at a site adjacent to the borehole from 1950 in order to sample material to enable the identification of palynostratigraphic zones.

Location and deposits description of the study area

Nowiny Żukowskie is a small locality situated ca. 23 km to the south-east of Lublin, in the northern part of the Lublin Upland (Fig. 1). The site is situated in lowland marked by Quaternary sediments, underlayed by a Neogene limestone-silica rock of as much as 30 m in thickness (Rühle 1952).

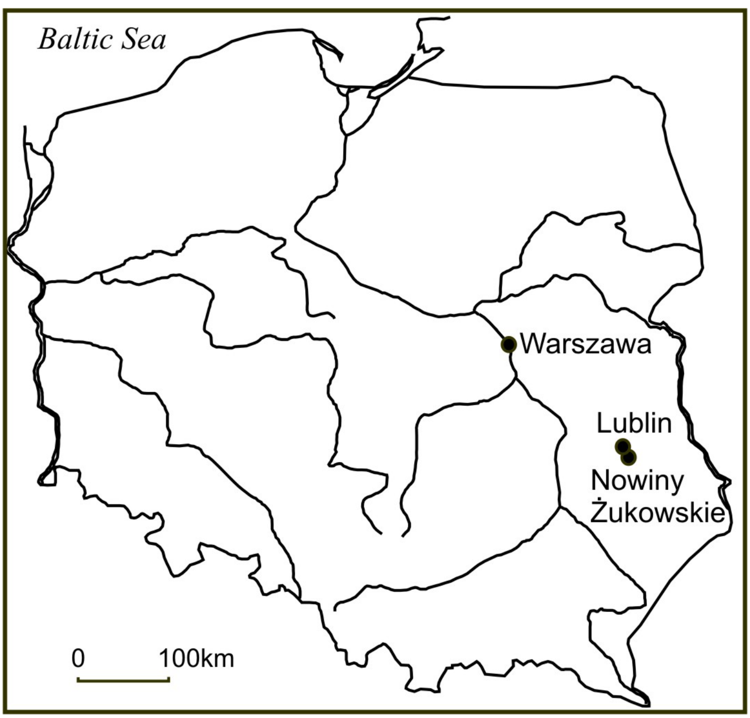

Fig. 1. Location of the Nowiny Żukowskie site

Lacustrine Pleistocene sediments from Nowiny Żukowskie (Rühle 1952) are overlain by sand with thin layers of clay and silt, and are devoid of organic remains and classified into the oldest interglacial (= Ferdynandovian interglacial?). The overlying stratum, 0.9 m in thickness, contains sand with gravels and cobbles of crystalline rocks (= Sanian 2 glaciation). Such sediment types suggest that this lacustrine basin originates from the South Polish glaciations (Sanian 1 glaciation). Most likely it formed as a depression which became the site of gradual lacustrine sedimentation, as indicated by the presence of thick clay and silt. Interbeddings of sand and gravel evidence the occurrence of quick down flows or flows of water at that time. The lack of organic remains (other than traces of plant detritus) indicates that the prevailing conditions were most likely not advantageous to the development of vegetation in the waters and surroundings of the basin. Therefore, the process may be described as cool sedimentation.

Sediments representing the period of the Pleistocene termed the Cracovien glaciation (= Sanian 2 glaciation) by Rühle (1952) directly overlie the sediments of the oldest interglacial. They comprise coarse- and fine-grained sands with gravel. The overlying lacustrine sediments composed of silt, peat with a layer of woods (ca. 6 m in thickness), and clayey silt (at the top part) represent the Mazovian/Holsteinian interglacial.

The last layer of lacustrine origin is composed of silts, with an admixture of sand, cobbles and fragments of sandstones, assigned to the Cracovien glaciation (= Liviecian glaciation, Middle Polish glaciations; ca. 7 m in thickness) by Rühle. The surface of the profile bears yellow-brown loam with an admixture of sand and a high content of loesses and loess-like silt.

History of studies and chronostratigraphy brief

Investigations of the Nowiny Żukowskie site were initiated by Rühle (1952), who, in his works on the Detailed Geological Map of Poland, discovered interglacial lacustrine and peat bog sediments in a well belonging to a local resident.

Floral studies of the material were performed by Dyakowska (1952), who analysed the macroscopic plant remains and pollen of 49 samples and concluded that the examined sediment is to be classified within the Mazovien 1 interglacial (= Mazovian interglacial, Great interglacial, Holsteinian) as well as within the accompanying close of the Late glacial

(South Polish glaciation, Sanian 2, Elsterian) and that it belongs to a series of early glacial sediments (transgression of the Middle Polish glaciation of Varsovien 1 = Liviecian glaciation, Saalian). Within the interglacial series, Dyakowska distinguished a subarctic period dominated by pine-birch forests, then a period of temperate climate predominated by spruce forests giving way to fir-hornbeam forests, and finally a second subarctic period with a prevalence of birch-pine forests with larch.

Szafer (1953) considered Nowiny Żukowskie, with their undisturbed profile, the model site for the Mazovian/Holsteinian interglacial, and therefore of great importance for the stratigraphy of the Polish Pleistocene.

Macroscopic plant remains from Nowiny Żukowskie, first studied by Dyakowska (1952) and presently stored in the Palaeobotanical Museum of the Institute of Botany at the Polish Academy of Sciences in Kraków, were repeatedly examined by Velichkevich and Mamakowa (Mamakowa & Velichkevich 1993 a, b, Velichkevich & Mamakowa 2003). The results completed our knowledge of the composition of macroscopic flora of the Mazovian/Holsteinian interglacial in the study area. At the site, the authors recorded the occurrence of, among others, *Aracites interglacialis* Wieliczk., (being a taxon of an unknown botanical classification and found exclusively in the Mazovian/Holsteinian interglacial) as well as numerous other taxa, not included in the previous analysis by Dyakowska.

Within the Lublin province, palynological analyses were also conducted for many other sites at which the Mazovian/Holsteinian interglacial was recorded. These were the sites of, among others: Krępiec (Janczyk-Kopikowa 1981), Ciechanki Krzesimowskie (Brem 1953), Rokitno (Janczyk-Kopikowa 1983), Syrniki (Sobolewska 1956), and Brus (Pidek 2003). Nevertheless, complete profiles representing the Mazovian/Holsteinian interglacial and accompanying glaciations are found infrequently in this area.

The Podlasie region, located to the north, is also abundant in sediments of the Mazovian/Holsteinian interglacial, recorded mainly in the area of Biała Podlaska (Krupiński 1984–1985), Grabanów (Krupiński 1995a), Ossówka (Krupiński 1995b), Woskrzenice (Bińka, Nitychoruk 1995), Kaliłów (Bińka, Nitychoruk 1996), Wilczyn (Bińka et al. 1997), and several other sites (Krupiński 2000) are also located in this region.

The correlation of the Mazovian/Holsteinian interglacial with the plant succession of other sites of the same age in eastern and western Europe and MIS (Marine Isotope Stage) can be found in Tab. 1.

Tab. 1. Chronostratigraphy and Marine Isotope Stage in Mazovian/Holsteinian interglacial in Europe

Chrono-stratigraphical units	Poland, Nowiny Żukowskie (Ber et al. 2007, Lindner & Marks 2008)	W Europe, Germany (Ber et al. 2007, Lindner & Marks 2008)	The Alps (Lindner 1991, Mojski 1993)	E Europe, Russia & Ukraine (Lindner et al. 2004, 2006)	Marine Isotope Stage (MIS) (Lee et al. 2004, Nitychoruk et al. 2006, Koutsodendris et al. 2011)
glaciation	Liviecian (a part of Odranian)	Saalian	Riss (pre-Riss)	Dnieperian	10
interglacial	Mazovian	Holsteinian	Mindel – Riss	Likhvinian	11 (9?)
glaciation	Sanian 2	Elsterian	Mindel	Orelian	12

Material and methods

All 79 samples meant for pollen analysis (119 in the entire profile) were acetolized according to Erdtman's method (1960). Samples meant for analysis of plant macroremains (74 samples) were taken every 5 cm, in strict correlation with ones meant for pollen analysis. All samples were subjected to maceration using a 10% solution of KOH and detergents. 150 ml of sediment was soaked in water for ca. 24h and then boiled with an addition of KOH. After the sediment was boiled to a pulp, the samples were subjected to wet sieve analysis using a 0.2 mm-mesh sieve. The material remaining on the sieve was sorted under a magnifying binocular glass. All plant remains qualifying for identification were isolated and placed in a mixture of glycerine, water and ethyl alcohol in ratio of 1:1:1, with an addition of thymol. The determined material was stored in separate small "boxes". The isolated plant remains were determined to the rank of species, as far as was possible, considering the state of preservation of the material (Stachowicz-Rybka 2011).

Qualitative and quantitative results of identification were presented in an shorted pollen diagram, in which 8 Local Pollen Assemblage Zones (L PAZ) were distinguished, and in an valorised diagram plotted for plant macroremains, in which 6 Local Macrofossil Assemblage Zones (L MAZ) were distinguished. The diagrams were plotted with the POLPAL software for Windows (Walanus & Nalepka 1999).

Results and discussion

The results of palynological analyses (Fig. 2) (detailed description of L PAZ: Hrynowiecka-Czmielewska 2010) and of the study of plant macroremains (Fig. 3) provided a detailed description of numerous changes in the palaeoenvironment in the area of Nowiny Żukowskie from the beginning to the end of the Mazovian/Holsteinian interglacial.

NŻ05 MAZ-1 Carex rostrata – Potamogeton natans – P. rutilus

The water basin in Nowiny Żukowskie was surrounded by relatively dense boreal birch-pine forests with a noticeable admixture of *Larix*. Dominance of birches indicates that the mean July temperature attained at least 12–13°C. Taxa like *Betula nana*, *B. humilis*, and *Juniperus* indicate the recent prevalence of cool climate. The mean temperature of the warmest month, being optimum for *Juniperus*, amounts to ca. 8°C (Isarin & Bohncke 1999). Communities of herbaceous plants, mainly with Poaceae and Cyperaceae, as well as with Apiaceae and *Thalictrum*, were still often present.

Initially after its formation, the basin was overgrown by a rather poor species composition of phytocenoses, including *Potamogeton natans*, *P. pectinatus*, *P. filiformis*, *P. rutilus*, and *Myriophyllum spicatum. Myriophyllum spicatum* develop in mean July temperatures of ca. 10–13°C (Kolstrup 1980), similarly to *Nuphar lutea*. The occurrence of *Potamogeton* species, known to prefer waters of a moderate depth, and particularly of *P. pectinatus*, which is at its best in very shallow waters (Moss 1983) but can exceptionally grow in very clear waters of up to 10 m in depth (Kantrud 1990), suggests that the basin was relatively shallow. The low content of *P. filiformis* in phytocenoses evidences that the waters of the lake were cool and mesotrophic (Velichkevich & Zastawniak 2006; Kolstrup 1979; Matuszkiewicz 2001) as well as very clear and marked by the presence of $CaCO_3$ (Bennike et al. 1994) and pH exceeding 7 (Lang 1994). The mesotrophic type of the water basin is confirmed also by the appearance of *P. rutilus*, known to prefer such conditions (Preston & Croft 1997). Swamps of the older part of the zone, inhabited mainly by *Phragmites australis* and *Carex rostrata*, were poorly developed. Peat bogs with *Scheuchzeria palustris* developing on the lakeshore were most likely of an initial type. The entry of i.a. *Carex lasiocarpa* and the formation of communities with *Scheuchzeria palustris* and *Andromeda polifonia* indicates a gradual decrease in pH.

The younger part of the zone is characterized by an increase in forestation. The development of the belt of swamp (marked by an enrichment of species composition) and of the peat-bog (typified by the appearance of *Andromeda polifolia*) was also recorded. The growth of swamps with *Schoenoplectus lacustris* and the spreading of diversified communities of nympheids comprising *Nymphaea alba*, *N. candida*, and *Nuphar lutea* serve as evidence of the progressive shallowing of the basin. The occurrences of *Nuphar lutea* indicate that mean temperatures recorded during the warmest month must have exceeded 13–14°C, as this species is not frequently found in cooler areas (Iversen 1954, Kolstrup 1980). The physico-chemical properties of waters were also affected by gradual changes. The development of the peat bog and the occurrence of *Comarum palustre*, which does not tolerate calcium carbonate and is typical i.a. of shores surrounding acidic waters (Kłosowski & Kłosowski 2006), accompanied by the disappearance of phytocenoses formed by *Potamogeton filiformis*, suggests that the decrease in pH is likely to have been associated with the dystrophication of the basin. This trend is confirmed by the presence of *Nymphaea candida*, presently attaining its optimum in humotrophic basins poor in calcium (Kłosowski & Kłosowski 2006). As a result of such alterations in the conditions of waters, the basin was inhabited by a growing population of *Isoëtes lacustris*.

The occurrence of diaspores of i.a. *Ranunculus sceleratus* and *Potentilla repens* suggests that, at least locally, the shores of the shallow basin were flat and boggy, or only periodically flooded due to seasonal changes in the water level.

The variability of ecological requirements of terrestrial plants represented in the macroremains of this part of the zone indicates that the basin was surrounded by a remarkable mosaic of habitats, from fertile and humid tall herb communities with *Urtica dioica*, to thermophilous communities with *Fragaria vesca* and *Potentilla alba*, typical of dry areas. Such a mosaic of habitats in a small area suggests a diversified landform in the vicinity of the basin, and the presence of inclined slopes marked by a surface flow which supplied the basin with the seeds of plants typical of dry habitats.

The end of the zone is typified by a gradual deepening of the basin, confirmed by i.a. the withdrawal of most nympheids and communities with Schoenoplectus lacustris and the regression of swamps. The deepening of the basin is likely to have resulted in the subsequent decrease in pH and, presumably, also in the trophy (Tab. 2), which in turn initiated the intensive development of phytocenoses with *Isoëtes lacustris*.

Sediment was formed by silty gyttja.

Tab. 2. Summarizes the major changes in the lake conditions during the Mazovian/Holsteinian interglacial in the Nowiny Żukowskie basin with regard to L MAZ.

L MAZ		Depth (m)	PH	Depth of the basin	Climate changes	Trophy of the basin
NŻ05 MAZ-1		12.1 – 11.255	> 7, decrease	qutie shallow, shallowing	boreal, temperate cool	Mezo- to dystrophy
NŻ05 MAZ-2		11.205 – 10.655	< 7	deepening	temperate warm	Dys- to humotrophy
NŻ05 MAZ-3		10.605 – 10.405	< 7	shallowing	temperate warm intra-interglacial oscillation	Mezo- to eutrophy
NŻ05 MAZ-4		10.455 – 10.105	< 7	peat bog	temperate warm	Humotrophy
NŻ05 MAZ-5		10.055 – 9.705	< 7	peat bog	warm-up climatic optimum	Humotrophy
NŻ05 MAZ-6	NŻ05 MAZ-6a	9.655 – 9.555	< 7, increase	deepening	temperate warm, gradually cooling	Mezotrophy
	NŻ05 MAZ-6b	9.505 – 9.205	< 7	shallowing	temperate warm, gradually cooling	Oligo- to humotrophy
	NŻ05 MAZ-6c	9.155 – 9.055	< 7	shallow water basin	gradually cooling	Mezo- to eutrophy
	NŻ05 MAZ-6d	9.005 – 8.405	> 7	deepening	boreal, temperate cool	Mezotrophy

NŻ05 MAZ-2 *Isoëtes lacustris – Potamogeton natans*

The improving climatic conditions and increasing humidity were advantageous to the development of forests with high proportions of *Fraxinus*, *Ulmus*, and *Tilia*. *Tilia platyphyllos* requires a mean July temperature of at least 17°C (Zagwijn 1996). The mean temperature of the coldest month already did not fall below –1.5°C (Iversen 1944). *Picea* became dominant in the landscape and shaded the sites of abundant occurrence of *Taxus baccata*. However, in the closest surroundings of the basin (and most likely due to an increase in the water level) the growth of forests was noticeably limited, as evidenced by the only infrequent occurrence of macroscopic tree remains. The intensive development of forests with *Picea abies* indicates that winters of that period were cool, with a mean January temperature even below –3°C, while summers were not very warm, with a maximum July temperature of 17.7–18°C (Zagwijn 1996). *Picea*, which has a competitional advantage when growing in climates with a rapid transition between winter and summer (Dahl 1998), suggests increased seasonality during this zone. *Taxus baccata* is sensitive to severe and prolonged frost (Tallantire 2002, Thomas & Polwart 2003). These shadow-tolerant taxa grow below *Picea* crowns. In this part of the climatic optimum, the temperature of the warmest month could have amounted to 19–20°C or even 21°C (Krupiński 1995a).

They are represented by *Alnus glutinosa*, forming small patches of riparian forest and accompanied by nitrophylous species such as *Sambucus nigra* and *Urtica dioica.* The lowest trophy and greatest lack of calcium carbonate were recorded in the waters of the basin in this zone (Tab. 2). In such conditions, phytocenoses with *Isoëtes lacustris* attained their optimum growth. In the body of waters they were accompanied only by the infrequent *Caulinia flexilis*, while the occurrence of nympheid communities was limited to the littoral. Swamp communities disappeared almost completely, and formed only small phytocenoses, comprising mainly *Phragmites australis*. Peat bogs adjacent to the basin were also poorly developed. Their species composition was impoverished and dominated by leafy mosses (sapric peat composed of plant detritus, not qualifying for determination, and moss peat).

The disappearance or diminishing of dry habitats, covered by i.a. *Fragaria vesca*, was also observed, which supports the hypothesis of a considerable increase in humidity.

At the end of this zone *Taxus baccata* went into decline, suggesting a cooling (Geyh & Muller 2005, Koutsodendris et al. 2010) and drying climate (Hrynowiecka-Czmielewska 2010).

Sediment was formed by silty gyttja.

NŻ05 MAZ-3 *Carex gracilis – Schoenoplectus lacustris – Nuphar lutea*

Picea was still dominant in the landscape. Climatic changes featured a notable decrease in temperature and humidity. The close of the zone was marked by a noticeable increase in the amount of *Pinus sylvestris* and *Betula alba*, as well as by the appearance of *Larix* and even *Betula humilis* (intra-interglacial climatic oscillation). These regressive phases have been described at numerous sites in central and northwestern Europe, i.a. in England (Coxon 1985, Thomas 2001), Germany (Müller 1974, Diehl & Sirocko 2007) and Poland (Krupiński 1995, Bińnka & Nitychoruk 1995, 1996; Bińnka et al. 1997, Nitychoruk et al. 2005, Hrynowiecka-Czmielewska 2010, Tab. 3).

The mechanisms responsible for the regressive phase in vegetation development have remained unclear, but probably it is relative to orbital forcing (Koutsodendris 2010). In the zone, the basin was again affected by gradual shallowing, as documented by the development of phytocenoses with *Schoenoplectus lacustris* and by the expansion of nympheids (*Nuphar lutea*, *Nymphaea alba*, *N. candida*, and *N. cinera*). Swamps, represented mainly by *Carex gracilis* and *C. rostrata*, were gradually restored. Peat bogs surrounding the basin were also well developed and marked by the appearance of *Eriophorum vaginatum*, accompanying such species as *Scheuchzeria palustris* and *Andromeda polifolia*. The high frequency of *Menyanthes trifoliata* suggests the presence of a quagmire, likely to have been formed by the peat bog and entering the water surface. The zone is marked by the appearance of *C. gracilis* in the swamps and the expansion of nympheids (including mainly *Nymphaea alba*, known to prefer meso- to eutrophic waters; Kłosowski & Kłosowski 2006), accompanied by the disappearance of phytocenoses with *Isoëtes lacustris*, which all serve as evidence of an increasing water trophy (Tab. 2). Nevertheless, the waters of the basin were most likely still of a rather low pH and were devoid of carbonates, as indicated i.a. by the presence of *N. candida*. Due to the development of peat bogs and high content of *Picea* and *Pinus* in the tree stands of the catchment, the basin may have also been subjected to gradual dystrophication.

Tab. 3. Correlation of characteristic vegetation sequence in northern Germany (Geyh et al. 2005), Regional Pollen Assemblage ones (R PAZ) and pollen periods after Krupiński (2000) with L PAZ and pollen periods in NŻ05 profile. E.G. – Elstarian Galciation

<table>
<tr><td colspan="3">N-Germany. Characteristic vegetation sequence (Geyh et al. 2005)</td><td colspan="3">E -Poland. Regional Pollen Assemblage Zones (R PAZ) & pollen periods by Krupiński (2000)</td><td colspan="4">Nowiny Żukowskie. L PAZ & pollen periods (Hrynowiecka-Czmielewska 2010, changed)</td></tr>
<tr><td>MM14</td><td>Pinus dominated and thermophilous trees were nearly absent</td><td rowspan="14">HOLSTEINIAN INTERGLACIAL</td><td rowspan="2">M9</td><td rowspan="2">Pinus</td><td rowspan="2">IV</td><td rowspan="2">NŻ8</td><td rowspan="2">Pinus-Betula-Larix-NAP</td><td rowspan="2">IV</td><td rowspan="14">MAZOVIAN / HOLSTEININ INTERGLACIAL</td></tr>
<tr><td>MM13</td><td>Pinus increased, Quercus decreased. Alnus, Pterocarya, Fagus, and Celtis were regularly present.</td></tr>
<tr><td>MM12</td><td>Pinus declined, Alnus reappeared, Carpinus spread again. Quercus increased. Carpinus and Taxus spread slightly.</td><td>M8</td><td>Carpinus–Quercus-Abies</td><td rowspan="7">III</td><td rowspan="3">NŻ7</td><td rowspan="3">Abies-Carpinus</td><td rowspan="3">III</td></tr>
<tr><td>MM11</td><td>Carpinus and Picea rapidly decrease and Pinus and Betula spread. Abies and Quercus were still present</td><td rowspan="2">M7</td><td rowspan="2">Abies–Carpinus–Quercus-[Corylus]</td></tr>
<tr><td>MM10</td><td>Carpinus was frequent and Abies spread</td></tr>
<tr><td>MM9</td><td>Pinus, Betula, and Alnus dominated, Corylus, Quercus, and Picea were also frequent. Carpinus and Abies spread again.</td><td rowspan="2">M6</td><td rowspan="2">Pinus–Picea-Alnus</td><td rowspan="2">NŻ6</td><td rowspan="2">Pinus-Betula-Picea-(Larix) Intra-interglacial oscillation</td><td rowspan="6">II</td></tr>
<tr><td>MM8</td><td>Pinus increased considerably to a dominant level</td></tr>
<tr><td rowspan="2">MM7</td><td rowspan="2">Quercus, Picea, Taxus, and Corylus are dominant. Betula and Pinus, Carpinus and Abies immigrated</td><td rowspan="2">M5</td><td rowspan="2">Taxus–Picea-Alnus</td><td>NŻ5</td><td>Picea</td></tr>
<tr><td>NŻ4</td><td>Taxus-Picea</td></tr>
<tr><td>MM6</td><td>Alnus and Picea</td><td>M4</td><td>Picea–Alnus–[Taxus]</td><td rowspan="2">II</td><td>NŻ3</td><td>Picea-Alnus</td></tr>
<tr><td>MM5</td><td>Ulmus, Quercus, Fraxinus, Tilia and Picea spread</td><td>M3</td><td>Picea–Alnus–[Pinus]</td><td>NŻ2</td><td>Fraxinus-Ulmus-Tilia</td></tr>
<tr><td>MM4</td><td>Pinus dominated and Quercus, Ulmus, Tilia, Taxus spread</td><td rowspan="2">M2</td><td rowspan="2">Betula–Pinus–[Picea–Alnus]</td><td rowspan="3">I</td><td rowspan="3">NŻ1</td><td rowspan="3">Betula-Larix-(Pinus)</td><td rowspan="3">I</td></tr>
<tr><td>MM3</td><td>Pinus dominated</td></tr>
<tr><td>MM2</td><td>Betula spread</td><td>M1</td><td>Betula-NAP</td></tr>
<tr><td>MM1</td><td>The pioneer vegetation with Poaceae, Artemisia and Hippophaë</td><td>E. G.</td><td>E. G.</td><td colspan="2">NAP</td><td colspan="2">Betula nana-Juniperus-(Larix)-NAP</td><td colspan="2">Elsterian Glaciation</td></tr>
</table>

Within the sediment, moss peat was initially formed, followed by peat comprising mainly *Scheuchzeria palustris* (produced during the intra-interglacial climatic oscillation) and wood peat, which evidences the gradual overgrowing of the peat bog by a forest.

NŻ05 MAZ-4 *Aracites interglacialis* – *Dulichium arundinaceum*

The structure of forests was modified — they were dominated alternately by *Abies* and *Carpinus*, with a small admixture of *Corylus* and *Quercus*. The most intensive development of *Abies alba* is recorded in the temperature range between –4°C in January and 17.5–20°C in July (a mean of 15°C, Zagwijn 1996, Jaworski & Zarzycki 1983). Fir is a thermophylous tree, requiring a high humidity of both air and soil, preferring an atlantic climate, poorly tolerating frosts and not tolerating high fluctuations of temperature between summer and winter. *Corylus* is sensitive to severe and prolonged frost (Tallantire 2002, Thomas & Polwart 2003). Initially, the basin and humid habitats disappeared, nearly or completely (no macroremains of aquatic and swamp plants were found). The disappearance of boggy habitats may have resulted from overdrying, caused by the drop in water level and deterioration of climatic conditions. In the younger part of the zone, refilling of the lake basin began. This most likely resulted in the formation of a very shallow overflow land, which, being devoid of habitats conducive to the development of submerged vegetation thus promptly became dominated by swamp vegetation. It was composed mainly of the extinct species of *Aracites interglacialis* (*Aracites interglacialis* Wieliczk., Mamakowa & Velichkevich 1993 a, b, Velichkevich & Mamakowa 2003, Vielichkevich & Zastawniak 2008), associated with the littoral zone (Łańcucka-Środoniowa 1966). This species was abundant and characteristic in the Mazovian/Holsteinian Interglacial in central and eastern Europe (e.g. Sobolewska 1977, Mai &Walther 1978, Velichkevich 1982, Mamakowa & Velichkevich 1993b). *Dulichium arundinaceum*, a thermophilous species usually forming monospecies, transition communities, and not found in the present-day flora of Europe, was an important species in this zone. Within or around the assemblages of swamps, patches of peat bog re-emerged, with *Eriophorum vaginatum*, which is highly resistant to periodic fluctuations in the water level (Wein 1973, Gore & Urquhart 1966), as the dominant component.

Most likely, the main reason for the disappearance of macroremains of swamp and aquatic plants was the intensive growth of a peat bog, subsequently overgrown by a forest, which is evidenced by the formation of wood peat, followed by sapric peat bearing the remains of trees.

NŻ05 MAZ-5 *Aracites interglacialis – Eriophorum vaginatum – Brasenia borysthenica – Aldrovanda dokturovskyi*

Forest communities were still predominated by *Abies* and *Carpinus*. The climate warmed. Humid and periodically flooded habitats surrounding the basin were covered by *Pterocarya fraxinifolia* and *Alnus glutinsa*. *Pterocarya fraxinifolia*, being a component of riparian forests, indicates a warm and humid climate. Dry habitats, located on elevations or slopes, were inhabited by i.a. *Buxus sempervirens*. *Buxus* has present-day thermal limits of 0°C in January and 17°C in July, and, similarly to *Abies*, requires high precipitation rates to grow (Zagwijn, 1996) or of 1°C in January and of 18°C in July (Aalbersberg & Litt 1998).

The water level of the lake, formerly overgrown by swamps, increased. Among assemblages of swamps, already composed mostly of *Aracites interglacialis* and peat bogs, and still dominated by *Eriophorum vaginatum*, a basin with an open water surface was formed. Most likely it was also surrounded by a mosaic of tree-covered areas with *Alnus glutinosa* and *Carpinus betulus*. The trees directly surrounded the basin and are likely to have limited the growth of swamps.

The basin, as indicated by the plants found within it, was acidic, humotrophic and very shallow. It was marked only by the occurrence of *Brasenia borysthenica* (known to prefer shallow, acidic lakes; Środoń 1987), *Aldrovanda dokturovskyi* and *Potamogeton natans*. The swamp species of *Aracites interglacialis* may have formed a quagmire entering the lake surface.

The sediment was formed by sapric peat with remains of wood.

Palynological data indicate that climate of the Nowiny Żukowskie area in the climatic optimum of the Mazovian/Holsteinian interglacial (Tab. 2) was most likely humid, warm and milder than the present-day. Mean temperatures could have been higher than the present-day by 2–4°C. According to Krupiński (1995a), during mild winters the snow layer was not very thick or long-lasting.

NŻ05 MAZ-6 *Carex rostrata – Menyanthes trifoliata – Eriophorum vaginatum*

NŻ05 MAZ-6a *Aracites interglacialis – Andromeda polifonia*

The surroundings of the basin were again overgrown mostly by boreal pine-birch forests with *Larix*, and, initially, with *Picea*. The appearance of *Betula humilis* was also recorded. The climatic changes also resulted in the raising of the water table in the basin. The belt of swamp surrounding the lake, still comprising mainly *Aracites interglacialis*, became enriched with other species, such as *Sparganium hyperboreum* and *Carex rostrata*, which became its main component. Peat bogs with *Eriophorum vaginatum*, *Menyanthes trifoliata* and *Andromeda polifolia* continued their increase in area and were marked by the appearance of numerous sedges. The basin, already deeper, also saw the appearance of *Potamogeton rutilus*, *P. dorofeevi* and *P. filiformis*, as well as infrequent *Isoëtes lacustris*. Such a floral composition, in which taxa known to prefer mesotrophic conditions (*P.rutilus* and *P. filiformis*) were accompanied by a species attaining its optimum in oligotrophic conditions (*Isoëtes lacustris*), shows that the trophy of the lake was still poor (Tab. 2). The occurrence of *P. filiformis* serves as an indicator of the increasing pH and presence of carbonates (Bennike et al., 1994, Lang 1994). However, the presence of coexisting *Isoëtes lacustris* and *P. filiformis* in only minor amounts suggests that the changes in the water pH were only slight and that the conditions were close to the limits of ecological tolerance of both species.

The sediment bears mainly wood peat, comprising mostly wood fragments not qualifying for determination, and leafy mosses.

NŻ05 MAZ-6b
Myriophyllum spinulosum – Andromeda polifonia – Isoëtes lacustris – Sphagnum sp.

The species composition of forest communities in this zone did not undergo noticeable changes. Swamps continued to become increasingly enriched and diversified. The proportion of *Aracites interglacialis* decreased, while *Carex rostrata*, *Phragmites australis* and *Sparganium hyperboreum* were still abundant. Species such as *Carex gracilis*, *Sparganium emersum*, and *S. minimum* appeared, accompanied by *Typha* species, represented by *T. latifolia* and *T. angustifolia*, the occurrence of which is limited by a mean minimum July temperature of either 13°C (Isarin & Bohncke1999) or 14°C

(Kolstrup 1979). In peat bogs, which were continuing to develop around the basin, *Eriophorum vaginatum* was still numerous and *Andromeda polifolia* was becoming more abundant. The peripheries of the peat bog were inhabited more frequently by *Menyanthes trifoliata*, which is likely to locally form quagmires. The basin was invaded by new species such as *Batrachium* sp. and *Nymphaea candida*, although water conditions did not noticeably change. High pollen values for *Batrachium* sp. evidence mean July temperatures attaining at least ca. 13°C (Granoszewski 2003). The extinct *Myriophyllum spinulosum* was an important component of phytocenoses. On the basis of its great similarity to the North American *Myriophyllum pinnatum* (Velichkevich & Zastawniak 2008), it may be assumed that *M. spinulosum* preferred moderately deep waters and inhabited them in large numbers, particularly when the water level was fluctuating. The abundance of submerged vegetation in the basin is confirmed by the constant occurrence of *Cristatella mucedo* (Økland & Økland 2000), which serves as an indicator of a mean July temperature exceeding 10°C (Birks 2000, Eide et al. 2006). The trophy was very low, as *Isoëtes lacustris* was recorded. The presence of *Sphagnum* sp. also indicates oligotrophic conditions (Tab. 2.).

The peat-like gyttja sediment comprises moss-herbaceous deposits, composed of numerous remains of strongly decomposed leafy mosses, infrequent fragments of wood and remains of *Sphagnum* s. *Palustria*.

NŻ05 MAZ-6c *Aracites interglacialis*

This zone conforms with the "birch oscillation" and is marked by an increase in the proportion of *Betula* and *Larix.* Due to an only very slow increase and strongly compressing of peaty sediment, this "phase" is represented by only one palynological sample (Hrynowiecka-Czmielewska 2010). However, changes during this time in the coincidences in the macroremains of plants suggest that it was quite a long-term episode (Fig. 3). The basin repeatedly reverted to a shallow overflow land, surrounded by swamp, and again dominated by *Aracites interglacialis*. *Carex rostrata* was still an important component of swamp phytocenoses. Regression was observed in peat bogs accompanying the basin. The aquatic vegetation was also strongly diminished. *Isoëtes lacustris* withdrew from the site, most likely due to the increasing trophy and accumulation of sediments, while *Brasenia borysthenica* reappeared (Tab. 2). The regression of peat bogs in the zone suggests that the shallowing of the basin was a consequence of the declining water level.

The detritus gyttja sediment (peat-like) was formed mainly by leafy mosses and abundant remains of *Scheuchzeria palustris* (tissue), which should indicate the frequent occurrence of this taxon. However, this observation was confirmed neither in the palynological record nor in macroremains.

The “birch oscillations” have not been identified in other localities of the Mazovian/Holsteinian interglacial in Poland, nor in central or western Europe. This situation may be the result of low-resolution palinological study, or it may be that it was a local, rather than regional, phenomenon.

NŻ05 MAZ-6d *Potamogeton natans*

Pinus sylvestris was again the most important part of the landscape. The water level of the basin increased again, resulting in a noticeable improvement in its conditions, including the increase in water pH and, most likely, trophy, as evidenced by the occurrence of *Potamogeton obtusifolius*, which is known to prefer eutrophic waters with a thick layer of organic sediments (Kłosowski & Kłosowski 2006). This improvement enabled the regrowth of diversified phytocenoses with *Batrachium* sp., *Potamogeton natans*, *P. rutilus*, *P. filiformis*, *P. pusillus*, and *P. obtusifolius*. Such a species composition suggests mesotrophic waters. In the relatively well developed swamp communities, enriched with i.a. *Cicuta virosa* and *Hippuris vulgaris* (limited by a minimum July temperature of +10°C; Wasylikowa 1964), the occurence of *Aracites interglacialis* noticeably decreased. At the end of the zone, due to the gradual diminishing of peat bogs, taxa forming these communities are represented only by *Eriophorum vaginatum*.

The peat-like gyttja sediment includes mainly leafy mosses.

According to Krupiński (1995 a), the period had a boreal climate (Tab. 2), with a mean July temperature initially reaching 15–17°C, and in the later phase 14–15°C. January temperatures fluctuated between –3 and –1°C, and at the end of the period between –5 and –4°C.

Conclusions

The examined material appeared to be abundant in both pollen and macrofossils. It enabled the identification of numerous extinct taxa (i.a. *Aracites interglacialis* and *Myriphyllum spinulosum*) as well as of taxa not found in the present-day flora of Europe (i.a. *Dulichium arundinaceum* and *Brasenia borysthenica*). Infrequent finds of macroremains of species such as *Pterocarya fraxinifolia* or *Taxus baccata* confirm their great importance as taxa characteristic of the Mazovian/Holsteinian interglacial.

Preliminary results of palaeobotanical studies of sediments from Nowiny Żukowskie indicate that during the Mazovian/Holsteinian interglacial it was the site of development of a rather shallow, acidic lake of low trophy and relatively variable water level. The basin was affected by numerous climatic and hydrological changes. The preserved remains of vegetation of the basin provide a record of noticeable periods of climatic oscillations. The intra-interglacial Holsteinian oscillation was a regressive phase in vegetation development and it is clearly defined by an abrupt decline in temperate taxa and a pronounced increase in pioneer trees. At this time, the water basin turned shallow and swampy. The "birch oscillations" in the thelocratic period of the Holsteinian interglacial was also a regressive phase in vegetation development, but not so large. Throughout the greater duration of its existence, its shores were the site of development of a peat bog of various origins. To define this phase as local or regional will require further detailed study of other sites of the Mazovian/Holsteinian interglacial in Poland.

Studies of macroremains, peat-forming tissues, fungi spores, woods, needles of coniferous trees and non-pollen palynomorphs are to be continued. Analysis of woods and needles should explain the surprising trend observed in trees in zones NŻ05 MAZ-4 and NŻ05 MAZ-5, and provide further details on the macroflora of this site. At the same time, the examination of fungi spores should enable the identification and interpretation of zones with overdried peat and zones devoid of plant macroremains.

This is the first time that a profile recording the Mazovian/Holsteinian interglacial in Poland has been subjected to such detailed study.

Acknowledgements

We thank anonymous reviewers for greatly improving the manuscript. The financial support of the Ministry of Science and Higher Education (grant No. 3646/B/P01/2007/33 and N N307 155538) is kindly acknowledged. Suggestions from Renata Stachowicz-Rybka and Andrzej Obidowicz from the W. Szafer Institute of Botany, Polish Academy of Sciences in Kraków, Mirosława Kupryjanowicz from Białystok Uniwersity and Grzegorz Kowalewski from Adam Mickiewicz University in Poznań were very helpful. We would also like to express our kindest thanks to Mr. Krzysztof Stachowicz and Ms. Barbara Kurdziel, who participated in the laboratory work during the collection and preparation of samples.

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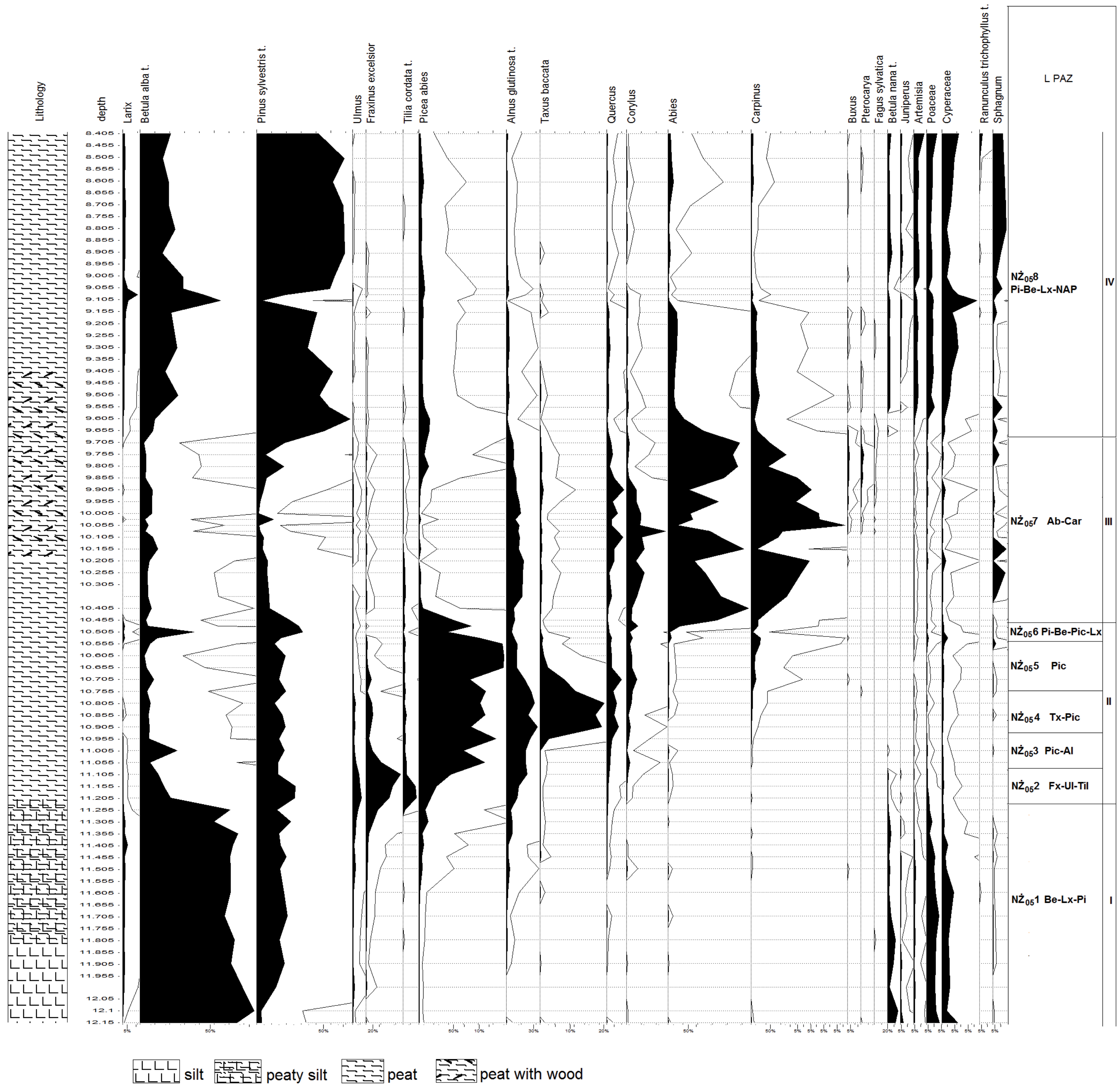

Fig. 2. Abridged percentage pollen diagram of the Nowiny Żukowskie $NŻ_{05}$ profile

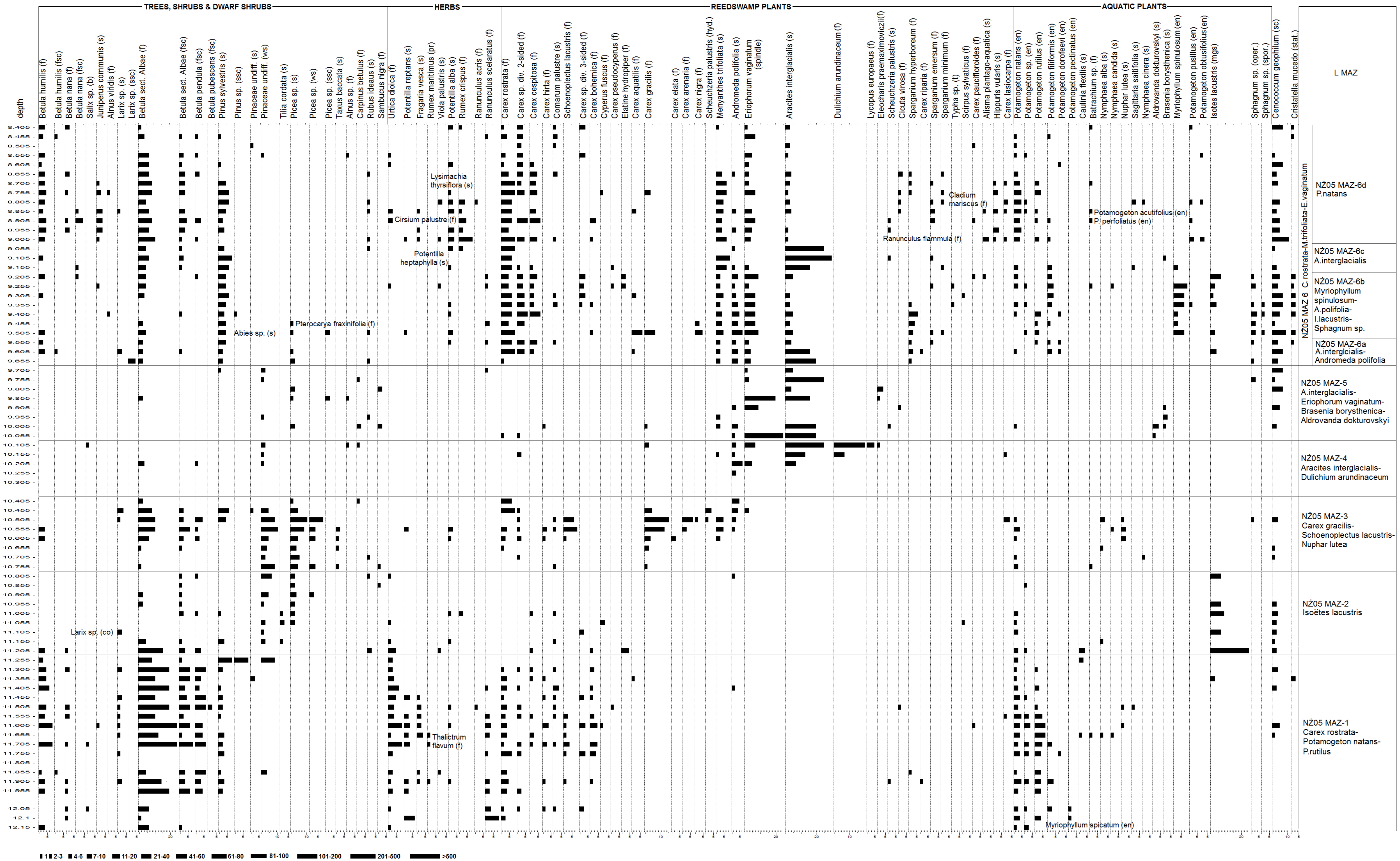

Fig. 3. Valorised macroremains diagram the Nowiny Żukowskie NŻ$_{05}$ profile