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IN THE DEVELOPMENT OF RAISED MIRES
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PALAEOBOTANICAL STUDIES OF RAISED MIRES

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ABSTRACT

Marek KLOSS. *Palaeobotanical studies of raised mires*. Monogr. Bot., Vol. 94, 5-18, 2005.

In 2003-2005, peat analyses were carried out in seven raised bogs to reconstruct their history. They are located in different geographical regions of Poland representing four relief types: young-glacial lowland, old-glacial lowland, upland and mountain. This paper defines the objectives of the research project and provides the applied methods. Palaeobotanical and stratigraphical studies of peatbogs are indispensable to learn about their ecological history. The analyses of plant macrofossils accumulated in biogenic deposits are of particular significance.

Key words: raised mires; peat stratigraphy; macrofossil analyses; subfossil plant communities; phytoindication; pollen analyses; radiocarbon dating; Poland.

1. INTRODUCTION

Research issues connected with subfossil vegetation. Mires are ecosystems capable of accumulating biogenic deposits specifically plant dead remains. The type and succession of accumulated deposits are a record of their developmental stages. Geological structure of a deposit is the starting point to learning about the history of the examined mire ecosystem (TOBOLSKI 2000, 2003). The development of a bog reconstructed by means of palaeophytosociological research enables a cause-effect analysis of plant succession undergoing in a given mire. Such an analysis may relate to the changes lasting for several to several dozen thousand years.

Raised mires feature a specific type of water management. They develop on stagnant waters originating directly from the atmospheric precipitation which usually have no underground influx. The water balance of these ecosystems is first of all the result of precipitation, temperature and evapotranspiration. These values mostly depend on the climate prevailing in a given period of time. Wetter years, stimulating deposit growth are characterised by different vegetation type than drier years. In comparison with different wetland types the changes resulting from the growth or decline in climate humidity are most distinctive in the stratigraphy of raised bogs.

The issues associated with the interaction between raised bog development in the post-glacial period and bog hydrological conditions depending on climate, local factors and human activity have been only partially explained, so far. In the early eighties of the 20th century BARBER (1981) put forward a theory concerning a mechanism of raised bog growth while INGRAM (1983), on the basis of the studies by IVANOV (1975), proposed a theory explaining the hydrology of this type of mires. Under the conditions of southern Sweden the role of peat-forming fossil communities in the development of raised bogs was described in detail by SVENSSON (1988) in his study on the regeneration of hummock and hollow vegetation. Peat deposits are more and more often used as an important source of information about changes undergoing in natural environment. (cf. BARBER 1981, 1993; MOORE 1986, 1991; KORHOLA 1995; LOWE, WALKER 1997; WELLS, WHEELER 1999; TOBOLSKI 2000, 2003; CHARMAN 2002). Hydrological changes in the post-glacial period recorded in lacustrine and river deposits, as well as within diverse type of wetlands: peatlands, muddy ecosystems, alluvia, waterlogged sites and gytjtjas in Poland's lowlands have been depicted by RALSKA-JASIEWICZOWA and STARKEL (1988, 1999), ŻUREK (1993) and ŻUREK, MICHczyńska and PAZDUR (2002). In general they are synchronised with climate fluctuations or phases of human activity. Analyses of plant macrofossils accumulated in biogenic deposits are of a particular significance to assess site moisture conditions and their dynamics (OŚWIT 1973;

GROSSE-BRAUCKMAN 1986; MOORE 1986; TOBOLSKI 1987, 2000, 2003; KLOSS 1993, 1999, 2001, 2004a, b). It has to be emphasised that paleophytosociological issues in raised bog stratigraphical studies are insufficiently recognised. The best paleobotanically recognised are Pomeranian raised bogs (JASNOWSKI 1962; PACOWSKI 1967; MAREK 1994; HERBICHOWA 1998). The development and characterisation of peat-bog subfossil phytocoenoses in hollows without run-off in the Mazury Lakeland has been presented by KLOSS (1993). Biostratigraphical research results illustrating vegetation changes in raised mires of the Knyszyńska Forest are contained in the studies by ŻUREK (1992) and DRZYMULSKA (2004). A detailed characterisation of the greatest raised bog of Poland's uplands, i.e. Białe Ługi Mire deserve special attention (ŻUREK. 2001; ŻUREK *et al.* 2001). The studies of OBIDOWICZ (1975, 1978, 1990), WÓJCIKIEWICZ (1979), MAREK (1998), KLOSS (2004a) and TOMASZEWSKA (2004) and others focused on the issues associated with raised mire subfossil vegetation in the mountain region.

The rational management of water resources requires considering, in the country's water balance, peatlands as natural water bodies increasing water retention in the environment. These habitats belong to the most threatened components of Poland's landscape (JASNOWSKI 1972, 1977). In particular, raised bogs are the ecosystems most vulnerable to destruction. Currently, they are classified as the most threatened habitats needing urgent protective actions. The major threats to a peatland are: the disturbance of its natural water balance as a result of the lowering of the groundwater level, reduction of the quantity of supply waters, enhancement of the surface runoff and peat exploitation (HEATHWAITE 1995). The EU Habitats Directive classifies raised bogs as particularly precious biotopes and recommends their conservation. The knowledge of deposit biostratigraphy is necessary for efficient conservation and monitoring of natural bogs, as well as renaturalisation of destroyed peatlands. The knowledge about the sequence of the communities in the long-term plant succession in raised bogs helps explain the initiation and development process of those ecosystems. The knowledge about phytocoenotic changes is also needed to monitor regeneration of peatbog vegetation in the transformed bogs and to assess whether this process proceeds in the desirable direction. This is essential for the peatlands lying in the Polish Lowlands under the conditions disadvantageous for their existence (KLOSS *et al.* 2004). Acquiring knowledge about bog's past and present hydrology is of particular relevance for the determination of the physiocoenotic role and future of any peatland. Transport of elements is closely connected with water flow routs. Besides, the knowledge about the conditions of development of bog plant populations threatened by extinction is of great important in subfossil vegetation studies. This is of great practical significance for biological diversity conservation of these specific biotopes – raised bogs.

Study objectives. The main objective of this paper is to:

1. Acquire knowledge about the ecological history of peatlands as a basis for their rational conservation.

Fig. 1. Location of the examined mires

1 – Suche Bagno; 2 – Kołowin; 3 – Linje; 4 – Długie Bagno; 5 – Rąbień; 6 – Białe Ługi; 7 – Zieleńiec

2. Determine palaeohydrological changes in peatland development on the basis of relationships between plant subfossil communities and site moisture degree.
3. Acquire knowledge about the history of the selected relic bog plant populations.

The mires under review, i.e. Suche Bagno, Kołowin, Linje, Długie Bagno, Rąbień, Białe Ługi and Zieleńiec are located in different geographical regions of Poland representing four relief types: young-glacial lowland, old-glacial lowland, upland and mountain (Fig. 1).

The main objectives necessitated realisation of partial tasks in each of the mires:

- characterisation of the diversity of contemporary vegetation cover,
- study of the biogenic deposit structure,
- reconstruction of plant subfossil communities,
- reconstruction of mire plant successional stages,
- assessment of habitat moisture conditions at different stages of mire development.

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2. METHODS

The studies were conducted between 2003 and 2005 employing diverse field and laboratory methods used in peat science and geobotany (TOBOLSKI 2000; WYSOCKI, SIKORSKI 2002). Stratigraphical analyses were carried out along the transects intersecting a selected mire in a representative place, usually in its central part. In each mire, one section was made illustrating peat deposit stratigraphy (KLOSS, ŻUREK 2005). The situation-height measurements of the set out lines were made by means of a Pentax level and supplemented with data from detail topographic maps providing information about mire relief. While characterising the contemporary vegetation attention was focused on the vegetation neighbouring the transect. The names of vascular plants were adopted according to MIREK *et al.* (2002), while the names of mosses – according to OCHYRA, ŻARNOWIEC and BEDNAREK-OCHYRA (2003).

Phytosociological studies. The studies on contemporary vegetation of peatlands were carried out using the BRAUN-BLANQUET method (1964). Phytosociological relevés were collected near peat boreholes and probings, as well as on the patches of plant communities that were not recorded along transects (KUCHARSKI, KLOSS 2005). The paper does not contain data pertaining to anthropogenic vegetation that was recorded in the mires under study, e.g. Rąbień Mire. The relevés were presented in synthetic Tables. The syntaxonomic classification was generally adopted after MATUSZKIEWICZ (2001). The map of real vegetation was prepared for each of the mires. The data on the vegetation of the Białe Ługi Mire investigated prior to project commencement were used (PRZEMYSKI, POLINOWSKA 2001).

Studies of the biogenic deposit structure. The recognition of the geological structure of peatlands were possible thanks to probings and borings distributed along the transect in each of the mires (KLOSS, ŻUREK 2005). Boreholes were made using an Instorf-type (Russian) borer with a core tube of a length of 50 cm (TOBOLSKI 2000). In one case, in the Linje Mire, a Więckowski-type core probe was used. The equipment enabled to collect peat profile samples of undisturbed structure. Complete biogenic deposit cores from the surface down to the bottom of the deposit were collected at the boreholes for laboratory analyses. The description made under field conditions included: type of peats, their humification degree, peat deposit thickness, colour and moisture content, character of subpeat deposits, as well as the measurement of groundwater depth. In the case of probings only description documentation was used.

Palaeophytosociological studies. The results of identifications of macroscopic plant remains in peat are the basis for identification of subfossil plant communities contribution to the development of peat deposits (KLOSS 2005). Core samples were taken from different peat deposits and their botanical composition was analysed (371 samples). In the analysis, the selected plant remains were identified,

where possible, to species and the percentage share of the taxon was determined. The results of the botanical analyses were treated as “macrofossil relevés” processed by the methods used in phytosociology (KLOSS 1993). The reconstructed subfossil phytocoenoses were compiled in synthetic Tables. They include the constancy degree or numbers of occurrences of a plant species (section, genus) when the number of analyses representing a given syntaxon was lower than 5, as well as its macrofossil share coefficient. The coefficient illustrates the quantitative share of species in a subfossil community. It was calculated according to the following formula:

$$U = (T/N) \times 100$$

where: U – coefficient of plant macrofossil share; T – percentage sum of the share of a given species (section, genus) in all relevés (analyses) in table; N – total number of relevés (analyses) in table.

The identification of subfossil communities was based not only on dominant species but, first of all, on species combination ascertained according to identification of their remains. Peat species composition corresponds, to a large degree, to the floristic composition of peat-forming phytocoenoses of the past (TOLPA *et al.* 1967; PAŁCZYŃSKI 1975, 1992; GROSSE-BRAUCKMANN 1986; KLOSS 1993, 2001; LOWE, WALKER 1997; WELLS, WHEELER 1999).

Assessment of changes in moisture conditions. When identifying the types of plant communities which occurred in the past and reconstructing their species composition, we obtain, in the indirect way, information about how water relations of the mires were shaped in the past periods (KLOSS 2005). Changes in water conditions in mire development were assessed by the phytoindication method (KLOSS 2004b). For each identified species the moisture value was established using a 10-degree scale indicating species requirement with regard to a habitat's water content (ELLENBERG *et al.* 1992; HILL *et al.* 1999; KLOSS 2004b). The moisture values describe habitat conditions which are the most typical attribute of a species, i.e. such in which it occurs most frequently. For the reconstructed subfossil phytocoenoses the averaged moisture values – phytocoenotic moisture index (FWW) were established (KLOSS 2005). In the examined deposit layers the following formula was used:

$$FWW = \Sigma (U' \times W) / \Sigma U'$$

where: FWW – phytocoenotic moisture index; U' – % share of macrofossils of a given species in a peat sample; W – moisture value for a given species (taxon).

The communities with indicators falling within the range 6.0-6.9 correspond to moist habitats, those within the range 7.0-7.9 – to wet habitats and those within the range 8.0-10.0 – to swampy habitats. The analysis of the distribution of subfossil communities differing in phytocoenotic moisture indicators allowed reconstructing the hydrological changes and assess, using a 10-degree scale, hydrological conditions on a bog's surface at different stages of its development.

Studies of peat age. Peat age was determined on the basis of C^{14} dating. 11 dates were made using a traditional method in the Radiocarbon Laboratory, Institute of Physics, Silesian University in Gliwice (Gd.). The age of 35 samples was determined at the Poznań Radiocarbon Laboratory (Poz.) using the AMS technique. The material for age determination was collected in each mire from one boring considered as a model one near the core subjected to the botanical composition analysis (KLOSS 2005; KLOSS, ŻUREK 2005). The boundaries of climatic periods were adopted after MANGERUD *et al.* (1974).

Studies of peat chemical properties. These analyses served to determine the ash content and acidity of peat samples. The ash content using the muffle furnace burning method and acidity using the potentiometric method were determined at the Laboratory of the Institute of Geography, Świętokrzyska Academy in Kielce and in the Laboratory of the Centre for Ecological Research PAS. In the lake deposits reacting with muriatic acid, calcium carbonate was identified by the Scheibler method.

Palynological studies. Pollen analysis method (FAEGRI, IVERSEN 1989) was applied to the biogenic profiles of the mires: Linje (NORYŚKIEWICZ 2005), Rąbień (BALWIERZ 2005) and Zieleniec (MADEYSKA 2005). Palynological studies in these mires were conducted independent of the realised research project. These are valuable contribution to the research results obtained during the performance of research project no. 3 P04F 007 23.

3. STUDY SITE

The studies were conducted in seven mires representing a raised mire development stage. In general, these mires are located in a belt featuring different climatic conditions that runs across our country from North-East to South-West. The Suche Bagno, Kołowin and Linje mires lie in the part of the lowland covered by the Last Glaciation – Vistulian Glaciation (Fig. 1). The climatic conditions of the area are comparable to those dominating in the northern part of Europe encompassing the range of the raised mire complex. The belt of the northern lake-lands is characterised by relatively high atmospheric precipitation (700 mm/year) and low mean annual air temperatures (6.0-7.0°C) (KLOSS *et al.* 2004). The Długie Bagno and Rąbień mires are associated with the old-glacial lowland region. The region of central Poland is most unfavourable for the existence and development of raised bogs. This area features low annual precipitation sums (500-550 mm) and high mean annual temperatures (7.5-8.5°C). The mires situated in the central part of the Middle Poland Lowlands are under a strong negative impact of human activity. The Białe Ługi Mire located in the upland zone was investigated prior

to project commencement (ŻUREK. 2001; ŻUREK *et al.* 2001). The mean annual precipitation sum is higher there than in the lowland and amounts to about 780 mm. The Zieleniec Mire lies in the mountains. The annual amount of precipitation exceeds there 1300 mm, and the mean annual temperatures range from 3.5 to 6.0°C. The climatic conditions in this area are highly advantageous for the raised bog development.

The Suche Bagno Mire (30 ha; 134 m above sea level) is located in the Wigry National Park in the Augustowska Plateau mesoregion (KONDRACKI 2000; ŻUREK 2005). It fills a narrow, drainless depression surrounded by sandy outwash plains. The transect set out across the mire measures about 280 m.

The Kołowin Mire (20 ha; 132 m a.s.l.) lies in the Mazury Landscape Park in the Mrągowskie Lakeland. It occupies a fragmented melt-out basin located among sand-gravel hills. The examined transect measures about 155 m.

The Linje Mire (6 ha; 90 m a.s.l.) lies in the territory of the Chełmińskie Lakeland. The mire fills a small melt-out depression on the sands of the poorly diversified outwash plain. The transect intersecting the mire measures about 157 m.

The Długie Bagno Mire (6 ha; 82 m a.s.l.) is situated in the Kampinos National Park in the Warsaw Basin. The mire fills the drainless depression among sandy dunes on inundated upper terrace of the Vistula. The transect set across the mire measures about 150 m.

The Rąbień Mire (42 ha; 189 m a.s.l.) is situated in the Łaska Upland mesoregion. It lies among sandy dune hills. The examined transect measures about 400 m.

The Białe Ługi Mire (520 ha; 252-257 m a.s.l.) is located in the southern part of the Świętokrzyskie Mountains. The wetland divided by a sandy watershed into two basins occupies the valley of tectonic origin. The examined transect set in the mire measures about 2500 m and runs through the southern basin.

The Zieleniec Mire (160 ha; 756-763 m a.s.l.) lies in the Bystrzyckie Mountains. It extends over the river watershed in the depression situated on the slope. The transect intersecting the mire measures about 950 m.

The contemporary vegetation cover of the Suche Bagno, Kołowin, Linje, Białe Ługi and Zieleniec mires is relatively well preserved, and their peat deposits are not substantially deformed. However in some of the mires there are traces of past drainage and peat workings. Numerous pits after peat extraction occur in the Rąbień Mire. Similarly, disadvantageous changes are noted in the shallow peat deposit of the Długie Bagno Mire due to the past drainage works and a general decrease in the water level of the Kampinos Forest.

4. REFERENCES

- BALWIERZ, Z. 2005. The history of vegetation of the Rąbień Mire region. *Monogr. Bot.* 94: 135-144.
- BARBER, K.E. 1981. Peat stratigraphy and climatic change: a palaeoecological test of the theory of cycle peat bog regeneration. Rotterdam, Balkema, 219 pp.
- BARBER, K.E. 1993. Peatlands as scientific archives of past biodiversity. *Biodiversity and Conservation* 2: 474-489.
- BRAUN-BLANQUET, J. 1964. *Pflanzensoziologie*. Springer Verl. Wien-New York, 865 pp.
- CHARMAN, D. 2002. *Peatlands and environmental changes*. Wiley and Sons Ltd., Chichester, 301 pp.
- DRZYMULSKA, D. 2004. Późnoglacialna and holocenska historia roślinności wybranych torfowisk Puszczy Knyszyńskiej [Late Glacial and Holocene vegetation history of chosen mires in the Knyszyńska Forest]. Doctoral thesis, Białystok, typescript, 142 pp. (in Polish).
- ELLENBERG, H., WEBER, H., DÜLL, R., WIRTH, V., WERNER, W., PAULISSEN, D. 1992. *Zeigerwerte von Pflanzen in Mitteleuropa*. *Scripta Geobotanica* 18, 158 pp.
- FAEGRI, K., IVERSEN, J. 1989. *Textbook of pollen analysis*. John Wiley and Sons Ltd., Chichester 250 pp.
- GROSSE-BRAUCKMANN, G. 1986. Analysis of vegetative plant macrofossils. In: E.B. BERGLUND (ed.), *Handbook of Holocene Palaeoecology and Palaeohydrology*. John Wiley and Sons Ltd., Chichester: 591-618.
- HEATHWAITE, L. 1995. Problems in the Hydrological Management of Cut-over Raised Mires, with Special Reference to Thorne Moors, South Yorkshire. In: B.D. WHEELER, S.C. SHAW, W.J. FOJT, R.A. ROBERTSON (eds.), *Restoration of Temperate Wetlands*. John Wiley & Sons Ltd.: 315- 329.
- HERBICHOWA, M. 1998. Ekologiczne studium rozwoju torfowisk wysokich właściwych na przykładzie wybranych obiektów ze środkowej części Pobrzeża Bałtyckiego [Ecological study of development of the Baltic-type raised bogs exemplified by selected objects in the middle part of Baltic Sea-Coast]. Wyd. Univ. Gdańskiego, Gdańsk, 119 pp. (in Polish).
- HILL, O.M., MOUNTFORD, O.J., ROY, B.D., BUNCE, H.G.R. 1999. Ellenberg's indicator value for British plants, *Ecofact 2*, Technical Annex, Centre for Ecology and Hydrology Natural Environment Research Council, 46 pp.
- INGRAM, H.A.P. 1983. Hydrology, In: A.J.P. GORE (ed.), *Ecosystems of the world 4A. Mires: swamp, bog, fen and moor*. General studies, Elsevier Sci. Publ. Co. Amsterdam, Oxford, New York, p. 67-158.
- IVANOV, K.E. 1975. *Vodoobmen w bolotnykh landshaftach*. Gidrometeoizdat, Leningrad, 280 pp. (in Russian).
- JASNOWSKI, M. 1962. Budowa and roślinność torfowisk Pomorza Szczecińskiego [Structure and vegetation of mires of the Szczecin Pomerania]. *Soc. Sci. Stet., Wyd. Nauk Przr.-Roln.* 10, 340 pp. (in Polish).
- JASNOWSKI, M. 1972. Rozmiary i kierunki przekształceń szaty roślinnej torfowisk [Extents and directions of changes of plant cover of the bogs]. *Phytocoenosis* 1, 3: 193-209 (in Polish).
- JASNOWSKI, M. 1977. Aktualny stan i program ochrony torfowisk w Polsce [The actual state and plan for the protection of peatlands in Poland]. *Chrońmy Przr. Ojcz.* 33, 3: 18-29 (in Polish).
- KLOSS, M. 1993. Differentiation and development of peatlands in hollows without run-off on young glacial terrains. *Pol. Ecol. Stud.* 19, 3-4: 115-219.
- KLOSS, M. 1999. Rekonstrukcja subfosalnych zbiorowisk roślinnych w rezerwacie torfowiskowym "Białe Ługi" i ich znaczenie bioindykacyjne [Identification and bioindicator of subfossil plant communities in the Białe Ługi mire reserve]. In: S. RADWAN, R. KORNÍJÓW (eds.), *Problemy aktywnej ochrony ekosystemów wodnych i torfowiskowych w polskich parkach narodowych*. Wyd. UMCS, Lublin: 125-130 (in Polish).
- KLOSS, M. 2001. Subfosalna roślinność torfowiska Białe Ługi i jej kierunki sukcesyjne [Subfossil plant communities of Białe Ługi mire and their succession changes]. In: S. ŻUREK, (ed.), *Rezerwat*

- torfowiskowy „Białe Ługi” [The Białe Ługi mire reserve]. Wyd. Homini, Bydgoszcz, p. 59-73 (in Polish with English summary).
- KLOSS, M. 2004a. Palaeohydrological changes in the development of some raised mires in Poland. In: J. PÄIVÄNEN (ed.), *Wise use of peatlands. Proceedings of the 12th International Peat Congress*, Tampere, Finland, Publication of the International Peat Society 2: 869-874.
- KLOSS, M. 2004b. Zastosowanie ekologicznych liczb wskaźnikowych roślin do oceny paleohydrologicznych zmian w rozwoju ekosystemu torfowiskowego [Application of plants indicator values for the assessment of palaeohydrological changes in the mire ecosystem development]. *Ochrona Środowiska i Zasobów Naturalnych* 27: 29-39 (in Polish).
- KLOSS, M. 2005. Identification of subfossil plant communities and palaeohydrological changes in raised mire development. *Monogr. Bot.* 94: 81-116.
- KLOSS, M., ŻUREK, S. 2005. Geology of raised mire deposits. *Monogr. Bot.* 94: 65-80.
- KLOSS, M., KUCHARSKI, L., ŻUREK, S. 2004. Palaeobotanical study as a basis for the protection of raised bogs in Poland. In: J. PÄIVÄNEN (ed.), *Wise use of peatlands. Proceedings of the 12th International Peat Congress*, Tampere, Finland, Publication of the International Peat Society 2: 875-880.
- KORHOLA, A. 1995. Holocene climatic variations in southern Finland reconstructed from peat-initiation data. *The Holocene* 5: 43-58.
- KONDRACKI, J. 2000. *Geografia regionalna Polski* [Regional geography of Poland]. PWN, Warszawa, 441 pp. (in Polish).
- KUCHARSKI, L., KLOSS, M. 2005. Contemporary vegetation of selected raised mires and its preservation. *Monogr. Bot.* 94: 37-64.
- LOWE, J.J., WALKER, M.J.C. 1997. *Reconstructing Quaternary Environments*. Longman, 446 pp.
- MANGERUD, J., ANDERSON, S. T., BERGLUND, B. E., DONNER, J.J. 1974. Quaternary stratigraphy of Norden a proposal for terminology and classification. *Boreas* 3, 3: 109-128.
- MADEYSKA, E. 2005. The History of the Zieleniec Mire and the surrounding areas based on the palynological research. *Monogr. Bot.* 94: 145-157.
- MAREK, S. 1994. Badania nad stratygrafią torfowisk w Polsce [Investigation above stratigraphy of mires in Poland]. *Acta Univ. Wratisl. 1619, Prace Botaniczne LXI*: 7- 24 (in Polish).
- MAREK, S. 1998. Rozwój Wielkiego Torfowiska Batorowskiego w świetle badań biostratygraficznych. [Development of the „Great Batorowskie Peatbog” in the light of biostratigraphy research]. *Szczeciniec*: 49-88 (in Polish).
- MIREK, Z., PIĘKOŚ-MIRKOWA, H., ZAJĄC, A., ZAJĄC, M. 2002. Flowering plants and pteridiophytes of Poland a checklist. *Biodiversity of Poland* 1, 442 pp.
- MOORE, P.D. 1986. Hydrological changes in mires. In: E.B. BERGLUND (ed.), *Handbook of Holocene Palaeoecology and Palaeohydrology*. John Wiley and Sons Ltd., Chichester: 91-117.
- MOORE, P.D. 1991. Holocene paludification and hydrological changes as climate proxy data in Europe. In: B. FRENZEL (ed.), *Evaluation of climate proxy data in relation to the European Holocene*. Gustav Fischer Verlag, Stuttgart, 255-269.
- NORYŚKIEWICZ, A. 2005. Preliminary results of study on vegetation history in the Linje mire region using pollen analysis. *Monogr. Bot.* 94: 117-134.
- OBIDOWICZ, A. 1975. Entstehung und Alter einiger Moore im nördlichen Teil der Hohen Tatra. *Fragm. Flor. Geobot.* 21, 3: 289 - 316.
- OBIDOWICZ, A. 1978. Genese und Stratigraphie des Moores „Bór na Czerwonym” in Orawa-Nowy Targ Mulde. *Fragm. Flor. Geobot.* 24, 3: 447-466.
- OBIDOWICZ, A. 1990. Eine pollenanalytische und moorkundliche studie zur vegetationsgeschichte des Podhale-Gebietes (West-Karpaten). *Acta Paleobot.* 30, 1-2: 147-219.
- OCHYRA, R., ŻARNOWIEC, J., BEDNAREK-OCHYRA, H. 2003. Censur catalogue of Polish mosses. *Biodiversity of Poland* 3, 372 pp.
- OŚWIT, J. 1973. Warunki rozwoju torfowisk w dolinie dolnej Biebrzy na tle stosunków wodnych. [The conditions of peatlands development in the Biebrza valley on background of hydrological relationships]. *Rocz. Nauk Roln.* D 143, 79 pp. (in Polish).

- PACOWSKI, R. 1967. Biologia i stratygrafia torfowiska wysokiego Wieliszewo na Pomorzu Zachodnim [Biologie und stratigraphie des Hochmoores Wieliszewo]. Zesz. Probl. Post. Nauk Roln. 76: 101-196 (in Polish).
- PAŁCZYŃSKI, A. 1975. Bagna Jaćwieskie. Pradolina Biebrzy. Zagadnienia geobotaniczne, paleofitosocjologiczne i gospodarcze [Jaćwieskie Sümpfe. Das Urtal der Biebrza. Die geobotanische, paläophytosoziologische, und wirtschaftliche Probleme]. Roczn. Nauk Roln. D 145, 232 pp. (in Polish).
- PAŁCZYŃSKI, A. 1992. Attempt to accurate the paleophytosociological method in peat deposit investigations. Acta Soc. Bot. Pol. 61, 1: 115-123.
- PRZEMYSKI, A., POLINOWSKA, K. 2001. Szata roślinna rezerwatu torfowiskowego Białe Ługi [Vegetation of the Białe Ługi reserve]. In: S. ŻUREK (ed.), Rezerwat torfowiskowy „Białe Ługi” [The Białe Ługi mire reserve]. Wyd. Homini, Bydgoszcz, 133-178 (in Polish).
- RALSKA-JASIEWICZOWA, M., STARKEL, L. 1988. Record of the hydrological changes during the Holocene in the lake, mire and fluvial deposits of Poland. Folia Quaternaria 57: 91-127.
- RALSKA-JASIEWICZOWA, M., STARKEL, L. 1999. Zmiany klimatu i stosunków wodnych w holocenie [Climate and water condition changes in the Holocene]. In: L. STARKEL (ed.), Geografia Polski. Środowisko przyrodnicze [Geography of Poland. Natural environment]. PWN, Warszawa, 105-127 (in Polish).
- SVENSSON, G. 1988. Fossil plant communities and regeneration patterns on raised bog in south Sweden. J. Ecology 76: 41-59.
- TOBOLSKI, K. 1987. Holocene vegetational development based on the Kluki reference site in the Gardno-Łeba Plain. Acta Palaeobot. 27, 1: 179 - 222.
- TOBOLSKI, K. 2000. Przewodnik do oznaczania torfów i osadów jeziornych [A guide for identifying peats and lacustrine deposits]. Vademecum Geobot. 2. PWN, Warszawa, 508 pp. (in Polish).
- TOBOLSKI, K. 2003. Torfowiska na przykładzie Ziemi Świeckiej [Mires on example of the Świecie Region]. Towarzystwo Przyjaciół Dolnej Wisły, Świecie, 255 pp. (in Polish).
- TOŁPA, S., JASNOWSKI, M., PAŁCZYŃSKI, A. 1967. System der genetischen Klassifizierung der Torfe Mitteleuropas. Zesz. Probl. Post. Nauk Roln. 76: 9-99.
- TOMASZEWSKA, K. 2004. Historia rozwoju wybranych torfowisk Gór Izerskich z uwzględnieniem antropogenicznych przemian roślinności [Development of some raised bogs in the Izerskie Mountains – connected with anthropogenic vegetation changes]. Zesz. Nauk. AR Wrocław 472, Rozprawy 204, 110 pp. (in Polish).
- WELLS, C.E., WHEELER, B.D. 1999. Evidence for possible forcing of late-Holocene vegetation changes in Norfolk Broadland floodplain mires, UK. The Holocene 9, 5: 595-608.
- WÓJCIKIEWICZ, M. 1979. Stratygrafia torfowiska Bór na Czerwonym z uwzględnieniem zespołów subfosalnych oraz rozmieszczenia i zróżnicowania współczesnych zbiorowisk roślinnych [The stratigraphy of the „Bór na Czerwonym” peatbog with the consideration of subfossil associations and distribution and differentiation of contemporary plant communities]. Zesz. Nauk. AR Kraków 153, 10: 133-193 (in Polish).
- WYSOCKI, Cz., SIKORSKI, P. 2002. Fitosocjologia stosowana [Applied phytosociology]. Wyd. SGGW, 449 pp. (in Polish).
- ŻUREK, S. 1992. Stratygrafia, rozwój i kierunki sukcesyjne torfowisk strefy wododziałowej w Puszczy Knyszyńskiej [Stratigraphy, evolution and successional tendency of watershed mires in the Knyszyn Primeval Forest]. Zesz. Nauk. Politechniki Białostockiej, Nauki Techniczne 85, Inżynieria Środowiska 5: 253-317 (in Polish).
- ŻUREK, S. 1993. Zmiany paleohydrologiczne w mokradłach [Palaeohydrological changes in the wetlands]. Przegl. Geogr. 64, 1-2: 75-95 (in Polish).
- ŻUREK, S. 2001. Położenie i historia badań torfowiska Białe Ługi [Site description and history of investigation of the Białe Ługi reserve]. In: S. ŻUREK (ed.), Rezerwat torfowiskowy „Białe Ługi” [The Białe Ługi mire reserve]. Wyd. Homini, Bydgoszcz, 59-73 (in Polish).
- ŻUREK, S. 2005. Abiotic natural environment in the area of selected raised mires. Monogr. Bot. 94: 19-36.

- ŻUREK, S., KLOSS, M., SOŁTYSIK, R. 2001. Stratygrafia torfowiska Białe Ługi [Stratigraphy of Białe Ługi mire]. In: S. ŻUREK (ed.), Rezerwat torfowiskowy „Białe Ługi” [The Białe Ługi mire reserve]. Wyd. Homini, Bydgoszcz, 49-58 (in Polish with English summary).
- ŻUREK, S., MICHczyńska, D., PAZDUR, A. 2002. Time record of paleohydrologic changes in the development of mires during the Late Glacial and Holocene, North Podlasie Lowland and Holy Cross Mts. *Geochronometria* 21: 109-118.

5. BADANIA PALEOBOTANICZNE TORFOWISK WYSOKICH (streszczenie)

Budowa geologiczna torfowiska stanowi punkt wyjścia do poznania historii badanego ekosystemu bagiennego. Rodzaj i kolejność akumulowanych utworów są zapisem etapów jego rozwoju. Złóża torfowe są coraz częściej wykorzystywane jako ważne źródło informacji o zmianach w środowisku przyrodniczym. Szczególnie duże znaczenie dla oceny warunków wilgotnościowych siedliska i ich dynamiki mają badania makroszczątków roślinnych zgromadzonych w osadach biogenicznych. Odtworzony za pomocą badań paleobotanicznych przebieg rozwoju torfowiska umożliwia przyczynowo-skutkową analizę sukcesji roślinnej zachodzącej w danym obiekcie. Na tle różnych typów mokradeł, w stratygrafii torfowisk wysokich obraz zmian hydrologicznych wywołanych wzrostem lub spadkiem wilgotności klimatu jest najbardziej czytelny. Znajomość biostratygrafii złóż jest niezbędna dla skutecznej ochrony i monitoringu naturalnych bagien, a także renaturalizacji zniszczonych obiektów. Poznanie sekwencji zbiorowisk w sekularnej sukcesji roślinności przebiegającej na torfowisku jest konieczne do wyjaśnienia procesu powstania i rozwoju tych ekosystemów. Wiedza o przemianach fitocenoz jest potrzebna również dla kontroli regeneracji roślinności torfowiskowej na przekształconych torfowiskach i oceny, czy przebiega ona w pożądanym przez nas kierunku. Ważną przesłanką badań roślinności subfossylnej jest również wyjaśnienie warunków rozwoju ginących populacji roślin torfowiskowych. Ma to duże znaczenie praktyczne dla ochrony różnorodności biologicznej tych specyficznych biotopów, torfowisk wysokich.

Podstawowym celem pracy jest:

- Poznanie przeszłości ekologicznej torfowisk jako podstawy do ich racjonalnej ochrony.
- Określenie zmian paleohydrologicznych w rozwoju torfowisk na podstawie związków między subfossylnymi zbiorowiskami roślinnymi a stopniem uwilgotnienia siedliska.
- Poznanie historii wybranych populacji reliktowych roślin torfowiskowych.

Cele zasadnicze wymagały realizacji zadań cząstkowych, jakimi dla każdego obiektu torfowiskowego są: charakterystyka zróżnicowania współczesnej szaty roślinnej na torfowisku, rozpoznanie budowy złoża osadów biogenicznych, rekonstrukcja subfossylnych zbiorowisk roślinnych, odtworzenie etapów sukcesji roślinności tor-

fowiskowej, ocena warunków wilgotnościowych siedliska w różnych okresach rozwoju torfowiska.

Prace badawcze wykonano na siedmiu torfowiskach reprezentujących w swym rozwoju etap torfowiska wysokiego. Torfowiska Suche Bagno, Kołowin, Linje, Długie Bagno, Rąbień, Białe Ługi i Zieleniec, są położone w różnych regionach geograficznych Polski, reprezentujących cztery typy rzeźby: niziną młodoglacjalną, niziną staroglacjalną, wyżynną i górką (Fig. 1). Badania prowadzono w latach 2003-2005. Wykorzystano następujące metody stosowane w torfoznawstwie i geobotanice:

- fitosocjologiczną BRAUN-BLANQUETA (1964) celem charakterystyki współczesnej roślinności na torfowiskach,
- transektów stratygraficznych (wiercenia torfowe) dla rozpoznania budowy geologicznej złóż,
- paleofitosocjologiczną (analizy makroszczątków roślinnych w torfie) w związku z rekonstrukcją subfosalnych zbiorowisk roślinnych i ich sukcesji,
- fitoindykacyjną (ekologiczne liczby wilgotnościowe) dla określenia zmian hydrologicznych w rozwoju mokradeł,
- radiowęglową (datowania C14) dla oceny wieku torfów,
- palinologiczną (analizy pyłkowe) celem charakterystyki historii roślinności w rejonach wybranych torfowisk.

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**ABIOTIC NATURAL ENVIRONMENT IN THE AREA
OF SELECTED RAISED MIRES**

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ABSTRACT

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The study was carried out in seven raised mires situated along the transect intersecting Poland from northeast to southwest. Three of these have developed in young glacial landscapes: an outwash plain-lake landscape (at Suche Bagno and Kołowin) and a moraine landscape (at Linje). Two occur in old-glacial landscapes: supra-flood terrace (at Długie Bagno) and upland plain (at Rąbień), with two more in the tectonic depression of the Świętokrzyskie Mountains (at Białe Ługi) and the watershed depression of the Bystrzyckie Mountains (at Zieleniec). Mires lie in drainless depressions formed by snow melting (at Suche Bagno, Kołowin and Linje), in a drainless thermokarst depression (at Rąbień), in a drainless deflation depression (at Długie Bagno) or in upland and alpine outflow depressions (at Białe Ługi and Zieleniec). Only the mountain Zieleniec Mire receives decidedly higher precipitation (over 1000 mm) than lowland and upland mires, where precipitation fluctuates between 538 mm (Warsaw) and 674 mm (Kielce). Lower mean annual temperatures occur only in the mountains and north-eastern Poland (5.9-6.0°C), but in the lowlands they may exceed 7.0°C.

Key words: raised mires; relief and geological structure; climate; Poland.

1. INTRODUCTION

Reconstructing the conditions for the sedimentation of biogenic deposits, their origin and age in raised bogs enables us to detect the climatic conditions, in which they were formed. The development of these mires was basically the effect of climatic factors, as detailed research conducted in the Biebrza Valley (cf. OŚWIT, ŻUREK 1981) has shown. It turned out that particular periods of the Late Glacial and Holocene favoured the development of specific subfossil mire communities. The relief of subpeat depressions, the lithology of their surroundings and the level of underground water influenced whether a mire was preceded by a lake phase, or whether the formation of the bog was due to paludification, i.e. the peat began accumulating directly on a mineral bedding.

The relief and lithology of a mire region has a direct influence on the circulation of water, defining the conditions for its inflow and outflow. Thus they shape the conditions in which the process of bog formation develops in concave forms of terrain. These factors, though important (cf. ŻUREK 1982, 1990a) have not been the subject of separate research within the framework of studies on selected raised bogs. Apart from cursory inspection of the terrain, use was made of 1: 50 000 scale topographical and geological maps as well as of the existing literature on this subject.

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2. GEOMORPHOLOGICAL AND GEOLOGICAL CONDITIONS

The Suche Bagno Mire. The raised bog of Suche Bagno is located in the physical geographical mesoregion of Augustowska Plain (KONDRACKI 2000), in an outwash plain-lake landscape, 500 metres south of Krzyżacka Bay on lake Wigry. Its geographical position is marked by the co-ordinates: 54°00'45''-54°00'00''N and 23°08'45''-23°09'15''E. The mire fills the bottom of an elongated, drainless depression 1.3 kilometres in length and 250-300 metres in width. This depression is the longest fragment of a channel stretching south (for a length of 2.4 kilometres), along an extension of the Krzyżacka Bay of lake Wigry, near the village of Czerwony Krzyż. In the channel's southern extension are two smaller drainless,

paludified depressions. The mire covers an area of 30 hectares and its catchment covers 56 hectares. The ratio of the catchment area without the mire to the surface of the mire itself is 1.9, which is less than the 2.7 boundary ratio for raised mires (cf. ŻUREK 1990b). The percentage share of mire surface in the area of the whole catchment amounts to 54, as with other raised mires. This mire (134 m above sea level) lies 13-17 metres lower than the rather flat area (143-145 m a.s.l.) indicated on the 1:50 000 geological map as outwash plain (BER 1998). South of lake Wigry (BER 2000), in his assistant professor thesis (Fig. 13), indicates hills of Pomeranian phase frontal moraine and 2 kilometres further south - the hills of the Wigry sub-phase frontal moraine. The author grants them the rank of recession-oscillatory phases of the Main Stadial of Vistula Glaciation.

Shallow geological boreholes (down to 1 metre in depth) made by the author and Dr. K. Wójcicki of the Silesian University in the region of the mire's stratigraphical section, showed that glacial deposits form the surface of the "outwash plain". About 35 metres to the west of the mire, on a flat top (about 140.5 m a.s.l.) and under a layer of humus, was a 50 cm covering of sand with gravel and pebbles. Between 50 and 85 centimetres, sandy boulder clay with pebbles occurred underlain to 100 centimetres down by brown loamy sand with gravel and pebbles of up to 3 centimetres in diameter. The age of the sample sandy boulder clay taken from a depth of 50-65 centimetres was defined by Dr. I. Olszak in the laboratory of University of Gdańsk at 17.3 ± 2.6 ka BP, using a thermoluminescence method. The boring also carried out in the western part of the section, 4 metres from the mire (about 135 m a.s.l.) showed that the surface deposits of the rising slope were loose medium sands with pebbles up to 3 centimetres in diameter, with a thin layer of iron pan at a depth of 70-80 centimetres. These are outwash deposits.

On the eastern side of the mire, about 10 metres east of the road joining Czerwony Krzyż with Tobołów (about 144 m a.s.l.), boring showed a 5-centimetre thin layer of humus in the top layer, 20 centimetres of loamy sand with gravel and pebbles and a 40-centimetre layer of rusty brown sandy boulder clay. The age of the sample boulder clay taken at a depth of 50-60 centimetres was defined in the laboratory of University of Gdańsk using the thermoluminescence method at 18.2 ± 2.7 ka BP. In both cases, the author of the analyses, Dr. I. Olszak draws attention to the fact that the samples represent redeposited material, for example discharge clay. The boring carried out in the eastern part, at the foot of the uphill slope above the mire (about 135 m a.s.l.) showed loose, various-grained sands with gravel and pebbles down to 100 centimetres.

Geological bores from both sides of the channel showed that superficial glacial deposits are linked to the presence of a Pomeranian phase glacier that flowed into this outwash plain (ŻUREK, ZIĘTEK 2004). WOŁŁOSOWICZ (1926) has already written about the "Wigry transgression" and this was not later denied by BER (1974, 1982). The glacier formed an 18 to 20-metre deep channel filled with ice, which as it melted at the end of the Glacial Period left the channel uncovered. The channel filled with water and the clayey water deposits at its bottom, at a depth of 677-680

centimetres, were dated by the AMS method at 14480 ± 79 BP (Poz-4768), i.e. still at the end of the Last Glacial Period, just when the glacier was leaving the borders of Poland in the region of the Gardno moraines (KLOSS *et al.* 2004).

The Kołowin Mire. The Kołowin Mire is found in the eastern part of the physical geographical mesoregion of Mrągowskie Lakeland, bordered by the mesoregion Great Mazurian Lakeland (KONDRACKI 2000). This mire lies in an young-glacial lacustrine outwash landscape, 2.5 kilometres north-east of the Mokre lake and 2 kilometres east of the Kołowin lake. Its geographical position is marked by the co-ordinates: $53^{\circ}43'38''$ - $53^{\circ}43'12''$ N and $21^{\circ}26'12''$ - $21^{\circ}26'35''$ E. This drainless depression, with its very varied shoreline, is filled with peat and gyttja. The area of this mire amounts to 21 hectares and the surrounding catchment area measures 18 hectares. The height above sea level reaches 132.1 metres. There are several mineral islands on the mire. Numerous sandy gravel hills rise to 5-10 metres in height around the mire (LISICKI 1992). Only in the northern and north-eastern part is the mire bordered by a zone of clayey or gravel hills, lying on boulder clay.

K. Świerczyński conducted detailed studies of the relief in this region and published his results in several works (ŚWIERCZYŃSKI 1959, 1961, 1967, 1972). He initially concentrated on the sheet with lake Wągiel near Piecek and then in the region of Lake Mokre and Kołowin. Lying about 10 kilometres north of the Kołowin Mire, the loamy moraine hills of Krzywe Góry near Brejdyn and the neighbourhood of Jakubów, linked by KONDRACKI (1952) with the Pomeranian phase frontal moraine of the Last Glaciation, are according to ŚWIERCZYŃSKI (l.c.) only the deglaciation stage of the Poznań phase of the glacier. South of these hills, there once stretched blocks of dead ice which, even before melting, were covered up by outwash sands and gravel. Mainly outwash plain areas create the so-called Mrągowska Channel (ŚWIERCZYŃSKI 1967) and the adjoining terrain is speckled with glacial melt-out depressions, kames and kame terraces. The various stages of melting of blocks of dead ice are described in detail by ŚWIERCZYŃSKI (1971), using the examples of lakes Mokre, Kołowin, Łabędek and Piersławek, lying directly west of the Kołowin mire. ŚWIERCZYŃSKI writes about outwash shrinkage terraces and the lowering of the level of the bottom of troughs as the dead ice melted. The beginning of the Kołowin mire's gyttja accumulation at a depth of 523-528 centimetres occurred around 11920 ± 60 BP (Poz-4740), which is to say the melting of dead ice must have happened at the very beginning of the Allerød or in the Bölling (cf. KLOSS *et al.* 2004). The Kołowin Mire is rimmed by a so-called "pitted" outwash plain. The area between the village of Kołowin in the east and Lake Kołowin in the west is a "sea" of small hills and dry bottomed, shallow, drainless depressions. The sandy bottom of these depressions formed by melting does not reach level I of underground water, but is dry and absorbent. These drainless areas absorb rainwater and have an abundant underground outflow. These are underground waters in an infiltrative equilibrium (WIĘCKOWSKA 1959, 1963). Only two mires, Kołowin and the small swamps lying to the west are paludified and their peat content is underlain by gyttjas. Because their bottom is found considerably below the curve of

the underground water level, these depressions have filled with water and gyttja deposits. These lakes underwent terrestrialisation in the Holocene.

The Linje Mire. The Linje Mire is found in the Chełmińskie Lakeland mesoregion (KONDRACKI 2004), in a young-glacial moraine landscape, 1.5 kilometres north-east of Dąbrowa Chełmińska. Its geographical position is marked by the co-ordinates: 53°11'30"-53°11'15"N and 18°18'37"-18°18'48"E. This mire, 6 hectares in area, is ellipsoid in shape, with a length of 300 metres and a width of 150-200 metres. The moraine plateau of the region around Dąbrowa Chełmińska are built of boulder clay 20-30 metres in thickness (KOZŁOWSKA, KOZŁOWSKI 1986, 1990) and their surface is broken by dune and kame hills. This mire, whose surface lies about 90 m a.s.l., is rimmed by a sandy outwash plain. Sword dune stretch east of the mire (to a height of 102 m a.s.l.). To the north of the mire lies a clay moraine hills (95.5 m a.s.l.) and to the west a moraine hill of dead ice rises to 105 m a.s.l. On the 1:50 000 geological map, the Linje Mire is marked as an area of depressions left after dead ice, filled with peaty alluvium. For this reason, it was not described in the course of the preliminary documentation of mires (ŻUREK 1983, 1996).

The moraine plateau of the southern part of the Chełmińska Plateau is a zone of basal moraine located between the Kujawy phase frontal moraines to the south and the Krajeńsko-Wąbrzeska phase of the Vistulian Glaciation to the north (NIEWIAROWSKI, TOMCZAK 1969). This is a zone of forms that arose in dead ice (NIEWIAROWSKI 1959). The melting and decay of large blocks of stagnating ice took place during the disappearance of the glacier of the Kujawska phase and the forming of the Wąbrzeskie frontal moraines. PASIERBSKI (1966) wrote about the stagnating ice of the Dąbrowa Chełmińska region. Patches of flat moraine plateau occur in the region of the Linje Mire, its original features being its flatness and level surface. This did not later undergo any denudation-erosion transformations. Only dune and kame forms occur on its surface. Following the retreat of the continental glacier (about 16-15 thousand years ago), periglacial conditions existed here in the Late Glacial Period and dunes and windswept sand fields formed in its cooler periods (the Oldest, Older and Younger Dryas). The "rejuvenation" of the landscape is the result of the melting of buried blocks of dead ice. In the case of the Linje Mire, a depression formed about 12 metres deeper than the surface of the mire and 24 metres below the dunes towering over the mire. The ice melted in the Alleröd, as evidenced by the age of the bottom level brown moss peats, dated at 10740±270 BP (Gd-30069) and by pollen analysis of the Younger Dryas. The palynological materials from this mire were reported by Dr. A. Noryśkiewicz at a convention of the Polish Botanical Society in Toruń. (TOBOLSKI *et al.* 2004).

The Długie Bagno Mire. This mire lies in the physico-geographical mesoregion of the Warsaw Basin (KONDRACKI 2000). Its geographical position is marked by the co-ordinates: 52°20'00"-52°19'50"N and 20°45'15"-20°46'45"E. The surface area of the Długie Bagno Mire amounts to 6 hectares. The bottom of the Warsaw Basin is filled with Vistula river flood and supra-flood terraces – covered by dunes.

Above these terraces, tower surfaces of erosion planations, partially covered by varve clays (the Błońska and Wołomińska Plains). Fragments of denuded upland gradually rise to such high-lying plateaus as Rawska and Siedlecka. The dissection of Middle Poland's glaciation plateau took place at various times – between the melting of the Warta glacier and the accumulation of the loams in the Warsaw ice-dammed lake (BARANIECKA 1982). The age of these loams was recently estimated at 51-53 thousand years (BARANIECKA, KONECKA-BETLEY 1987). The deep dissection of the surface of this ice-dammed lake occurred before the Last Glaciation attained its maximum range and the Vistula valley became deep filled with sand at the time of its blockage beneath the Płock Baltic glacier. The highest Otwock terrace, south of Warsaw, was formed at that time (RÓŻYCKI 1972), as well as the dune terrace north of Warsaw (10-15 metres above river level). The lower Falenica and Praga flooded lower terraces lie 4-8 metres above the level of the channel and are scattered with alluvial soils and mires. These developed as a result of the dissection of the Otwock terrace at the time of the retreat of the Baltic glacier. Further dissection to the floor of the innudated terrace probably took place at the time the Glacial Period turned into the Late Glacial Period. Dune accumulation took place on the Kampinos and Otwock supra-flood terraces in the Late Glacial Period. Parabolic and arched dunes, sword dunes and blowout developed in the Oldest, Older and Younger Dryas (KOBENDZINA 1961; BARANIECKA 1982; KONECKA-BETLEY 1982). Holocene dunes are small and have anthropogenic origins similarly as in the Wielkopolski area (TOBOLSKI 1969).

From the Late Glacial Period, accumulation of gyttja and peat commenced in depression supra-flood terrace forms and in the Holocene, on a flood terrace. The largest mire complexes developed in the two swamp belts of Puszcza Kampinoska (KACZOROWSKA 1926). Two raised bogs, Długie Bagno filling the blowout inside the southern dune belt, northeast of the Pociecha forester's lodge, and the Cichowąż mire, lying nearby to the southeast, in the southern swamp belt, began their peat accumulation from the Alleröd (BORÓWKO-DŁUŻAKOWA 1961). These are shallow deposits up to 145 centimetres in depth. The peat deposit of the Cichowąż Mire was described by researchers from the Agricultural University (DZIAK, LIWSKI 1958; LIWSKI *et al.* 1967). A detailed geological description of the surroundings of Długie Bagno was carried out within the framework of geological mapping for 1:50000 scale maps. The area surrounding the mire is to be found on the following 1:50000 scale maps: Warsaw – West (MORAWSKI 1978), Legionowo (NOWAK 1974) and Modlin-Twierdza (NOWAK, SKOMPSKI 1992). The Długie Bagno Mire itself is featured on the northwest edge of the Warsaw West map section.

The Rąbień Mire. This mire, located about 5 kilometres west of the city of Łódź, is in the Łaska Plateau physical geographical mesoregion (KONDRACKI 2000). This is a plain morainic plateau called the Lutomierski Hills by DYLIK (1948). The mire's geographical position is marked by the co-ordinates 51°48'28"-51°48'07"N and 19°17'45"-19°18'37"E. The Rąbień mire has a surface area of 42 hectares and its catchment area amounts to 68 hectares. In the nearby town of Rąbień, Quaternary

deposits to a depth of 84.4 metres are underlain by Tertiary clays (RÓŻYCKI 1956). In Aleksandrów Łódzki located to the north, a floor of grey boulder clay occurs at 93 metres. Tertiary deposits 25 metres thick lie there on Cretaceous marls and limestone.

This mire is surrounded by slightly uplifted plateau elevations lying in the overthrust contact zone of the western glacier lobe of the Warta Stadial (KŁATKOWA 1972). To the east of the mire, the convex denudation forms, up to 203.5 m a.s.l., are circular by nature and fall to 190 m a.s.l. According to DYLIK (1948), these are low hills. They border on the lower areas with river valleys such as Lubczyna in the south or Bełdówka from the northwest. The mire itself, about 189 m a.s.l., is edged on the west by sword dune rising to between 197 and 198 m a.s.l.

Thus the relief surrounding the mire is polygenetic by nature and one can see traces in it of the activity of at least three cycles: glacial – connected with the glaciation of the stadial Warta (low upland hills), periglacial – connected with the last glaciation (denudation retouching, lowering of hills and long hill slopes with congelifluction cover at their foot), as well as a dune and river cycle, connected with the Late Glacial Period and Holocene. The periglacial cycle shows features of great age, as evidenced by the residual deposits on the plateau and valley slopes. Dune processes took place in the Late Glacial Period (DYLIKOWA 1967, 1970) and the result are the sandy parabolic dunes and sword lying adjacent to and west of the Rąbień Mire. The mire's drainless depression is itself probably a thermokarst depression from the time of the areal shirking of the Warta glacier, as a result of unequal glacial accumulation or the melting of blocks of dead ice and the renewed melting of ground ice in the Late Glacial Period. WIECZORKOWSKA (1975, 1976) describes very numerous depressions of this type in the Romanowskie Hills, southeast of Łódź. In this last case, the origin of the depression may be connected with the development of the thermokarst basin described by DYLIK (1970) and JAHN (1970). KŁATKOWA (1997) discussed drainless depressions in central Poland, and among other things mentioned a group of scattered depressions forming on the leeward side at the foot of dunes such as those at the Rąbień Mire.

The Białe Ługi Mire. The Białe Ługi Mire is located in the Świętokrzyskie Mountains mesoregion (KONDRACKI 2000) and the Daleszyckie Hills microregion (KONDRACKI, RICHLING 1994). Its geographical position is marked by the co-ordinates: 50°46'20"-50°44'05"N and 20°48'30"-20°52'42"E. The mire occupies a longitudinal great depression about 500-700 metres wide and about 10 kilometres in length. It is situated between two ranges of hills: the Cisowskie Range, surrounding the mire from the north and east and culminating in the Stołowa mount (423.6 m a.s.l.), and the Szczecniańskie Range, with its Kamień mount (302.2 m a.s.l.), lying southwest of the mire. The axis of the depression is pointed from the northwest to the southeast. This depression broadens considerably towards the north, at its outlet to the perpendicularly running Belnianka valley. In its southeastern section, a flat alluvial fan has formed, which is dissected by the river Czarna Staszowska. Between the slopes of the mountain ranges and the mire stretch gradually rising,

quite flat, sandy zones of deluvial-proluvian origin. The zone at the foot of the slopes, made up of deluvia sands, with here and there aeolian transformations, reaches as high as 255 to 275 m a.s.l. and turns into mountain slopes. It is 1-2 kilometres wide at the foot of the Cisowskie Range and narrows to just a few dozen metres on its western side. The sandy zone turns into a mire surface without any distinct degree. The Białe Ługi Mire surface falls away distinctly in two directions. Its central section is a transverse mineral ridge of some 257.2 m a.s.l. in height, along which a road runs today, intersecting the mire. In the south-eastern and north-western direction, the surface of the mire is lower, ending up at 250 m a.s.l. in the south, in the region of Szklana Huta and 247 m a.s.l. in the north, near the mouth of the river Trupień, where it joins the river Belnianka.

Geological research carried out by KOWALSKI (2001) has shown that the Białe Ługi valley depression is not the erosion denudation of a river valley, but rather a fault trough formed in the Miocene, as a result of tectonic tensions in the young Carpathian mountain complex. The deepening of the bottom of the fossil trough (subsidence) is as much as 120 metres. This trough was covered with sediment during the whole time of the quaternary. In the Holocene and simultaneously with this peat accumulation, deluvial-proluvian deposits collected in the area surrounding the mire. Under the sands of this mire and the adjacent sandy zone, lie shallow, impenetrable silts hampering deep infiltration of water. The surface area of the mire amounts to 520 hectares and its small catchment area allows a slight inflow of ground water, sufficient to slowly raise the underground water level along with the growing peat deposit (ŻUREK, KLOSS 2001).

The Zieleniec Mire. The Zieleniec Mire is in the physical geographical mesoregion of Bystrzyckie Mountains, in the Sudety Mountains (KONDRACKI 2000). It lies on the watershed of two rivers: Czerwona Woda, flowing north into the Bystrzyca Dusznicka, which then flows north and east to the Nysa Kłodzka and Oder rivers, as well as the Orlica river, flowing south-east and west, into the Łaba and leading to the North Sea. The mire's geographical position is marked by the co-ordinates: 50°21'25''-50°20'52''N and 16°24'30''-16°25'05''E.

This mire consists of two basin peats: Topielisko and Czarne Bagno, with a total surface area of 160 hectares. It is divided by a mineral dam (752.8-755 m a.s.l.). The Topielisko Mire, with a surface area of 60 hectares is ellipsoid in shape and its longer axis, which runs north to south, is about 1000 metres long, the shorter axis being about 700 metres in length. In the north-eastern section of the Topielisko mire there occurs a flattened dome at a height of about 762.5 m a.s.l., declining in a southwesterly direction to 756 m a.s.l. A pond about 30 metres in diameter lies on the banks of this cupola (762 m a.s.l.) and is probably a relict from cracking of the dome in the erosion phase of the mire. Two smaller ponds occur in the southern section of the mire, also at a height of 758.7 m a.s.l. and 757.4 m a.s.l. The adjacent southerly Czarne Bagno Mire, has an ellipsoid shape with a longer axis of 1200 metres (from NE to SW) and a shorter axis about 350-400 metres in length. The surface of Czarne Bagno is more even, with a height of 755 m a.s.l.

From the east, gentle slopes fall towards the mire and turn into surface of planations 767-780 m a.s.l. (CYMERMAN 1992a). From the west, quite gentle slopes with fragments of planations (760-780 m a.s.l.) fall steeply into the deeply cut Bystrzyca Dusznicka valley.

The underground waters of the area surrounding the mires are first level waters in deluvial clays with debris rock, gravels and sands of alluvial cones with a depth of from 0 to 4 metres. The deep waters are crevice waters in Cretaceous Upper deposits (CYMERMAN 1992b). As the detailed 1:25 000 scale geological map shows, the whole mire in the shoreline zone features seepages and bog-swamp springs which, alongside precipitation, play a part in its water supply. A small watercourse also flows from the central section of the mire into Bystrzyca Dusznicka. Its lower section falls down several steps and a considerable part of it flows down an artificial ditch excavated in the years 1754-1755 (KLEMENTOWSKI 2001).

The bottom of the mire is underlain by compact clays with lime detritus as a result of weathering (cf. KLEMENTOWSKI 2001). The largest bored thickness of this detritus amounted to 32 centimetres. Clayey detritus constitutes the impenetrable bed on which the paludification processes developed. Initially, several-centimetre thick peat formation accumulated, with here and there pieces of wood and on top of these, raised bog peats.

3. WEATHER CONDITIONS

Because climate is a characteristic arrangement of weather conditions for a defined area over a period of many years (KACZOROWSKA 1977), we will discuss the present weather conditions for the regions in which raised mires are found. The most essential elements for the development of mires are precipitation and temperature. From printed PIHM materials, precipitation was reported for the fifteen-year period 1954-1968 and the mean annual temperatures for the weather stations closest to the mires were recorded for the years 1954-1965 (Table1). These were: Suwałki (the Suche Bagno Mire), Mikołajki (the Kołowin Mire), Warsaw-Bielany (the Długie Bagno Mire), Bydgoszcz (the Linje Mire), Łódź-Lublinek (the Rąbień Mire), Kielce (the Białe Ługi Mire) and Duszniki Zdrój (the Zieleniec Mire). The distances of these meteorological stations from the mires under study amounts to the following: Suwałki – 18 kilometres, Mikołajki – 12 kilometres, Warsaw-Bielany – 14 kilometres, Bydgoszcz – 20 kilometres, Łódź-Lublinek – 12 kilometres, Kielce – 10 kilometres, Duszniki Zdrój – 7 kilometres.

The mean annual temperature in the years 1954-1965 (Table1) was lowest in the Sudety Mountains (5.9°C) and the closest to this in the rest of Poland was in the Northeast (6.0°C). This rose to 6.6°C in the Mazury Lakeland and 7.0°C on

Table 1

Mean annual temperatures and precipitation on meteorological stations in area of the investigated bogs

Sources: Roczniki Hydrograficzne (1954-1968), Roczniki Meteorologiczne (1954-1968), Roczniki Meteorologiczne. Opady Atmosferyczne (1954-1968)

Altitude m a.s.l.	164.7		130.0		101.0		69.7		184.0		268.1		540.0	
Stations	Suwałki		Mikołajki		Warszawa-Bielany		Bydgoszcz		Łódź-Lublinek		Kielce		Duszniki-Zdrój	
Years	T*	O**	T	O	T	O	T	O	T	O	T	O	T	O
1954	5.7	572.7	6.2	550.5	7.4	511.7	7.0	690.8	7.0	494.8	6.8	578.0	5.4	1079.7
1955	6.0	467.1	6.8	448.7	8.0	517.8	7.3	523.4	7.3	415.2	7.0	647.0	5.4	990.3
1956	4.7	571.7	5.4	653.1	6.4	533.8	6.3	443.8	5.9	516.0	5.8	545.5	4.6	1056.4
1957	6.9	753.4	7.4	765.8	8.6	475.4	8.1	578.9	8.3	635.3	8.0	592.0	6.8	1131.6
1958	6.0	737.4	6.6	557.1	8.0	505.7	7.6	542.4	7.6	537.3	7.6	604.0	6.4	1080.2
1959	7.0	432.1	7.6	459.7	8.7	436.5	8.6	404.4	8.4	366.9	7.9	546.8	6.8	631.2
1960	6.2	829.8	6.8	727.5	8.3	551.2	7.7	708.4	7.7	672.1	7.5	820.7	6.4	1041.3
1961	7.1	584.1	7.9	547.4	8.8	469.0	8.2	589.6	8.1	593.7	7.8	573.3	6.9	959.0
1962	5.6	606.0	6.0	513.0	7.4	677.0	6.9	590.0	6.8	664.0	6.4	770.0	5.4	820.0
1963	5.8	566.0	6.3	476.0	7.3	541.0	6.9	492.0	6.8	468.0	6.6	569.0	5.4	825.0
1964	5.9	506.0	6.5	465.0	7.8	451.0	7.5	475.0	7.3	515.0	6.7	533.0	5.6	1072.0
1965	5.3	591.0	6.0	533.0	7.0	713.0	6.2	507.0	6.6	529.0	6.0	686.0	5.5	1183.0
1966		671.0		652.0		672.0		583.0		777.0		1001.0		1246.0
1967		600.0		749.0		544.0		771.0		710.0		817.0		1233.0
1968		395.0		569.0		475.0		483.0		559.0		830.0		932.0
Mean	6.0	592.2	6.6	544.8	7.8	538.3	7.4	558.8	7.3	563.5	7.0	674.2	5.9	1018.7
Numbers of observations	12	15	12	15	12	15	12	15	12	15	12	15	12	15

T* - Mean annual temperature in °C; O** - Precipitation in mm

the Kielce Uplands. It was highest in the lowland plains zone, fluctuating between 7.0°C (Łódź) to 7.4°C (Bydgoszcz) and 7.8°C (Warsaw).

The highest annual precipitation in the years 1954-1968 was recorded in the Sudety Mountains, exceeding 1000 mm. However, in the region of the remaining raised mires, this fluctuated between 538 mm (Warsaw) and 674 mm (Kielce). In the course of the year, the highest precipitation was in July (Table 2), partly in June and August and the lowest recorded was in January and February. The extreme values for both temperatures and precipitation are given in both these tables.

More important than temperature and precipitation, which show considerable variation in particular regions, is the location of the mires studied within the climatic regions. For Poland, the most important syntheses were carried out by ROMER (1912), who on the basis of the rich literature available issued the first approximation for a schedule of temperatures and precipitation for the regions of Poland. He then developed his opinion concerning Poland's climate (ROMER

Table 2

Annual and month precipitations on the meteorological stations in 1931-1960 years in area of the investigated bogs

Sources: Atlas klimatyczny Polski (1979) – Część tabelaryczna; Stacja Zieleniec – WALCZAK (1961); Meteorologiczna Stacja Kielce – materiały PIHM (mscr.)

Months Stations	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Rok	XI- IV	V-X
Suwałki	24	28	29	37	43	76	93	81	56	47	39	36	594	198	396
Mikołajki	24	26	24	34	48	74	90	72	44	42	33	30	541	171	370
Warszawa Astronomical Observatory	32	36	29	39	47	67	86	67	42	38	41	37	561	206	359
Łódź-Lublinek	31	33	30	38	45	68	94	68	46	38	38	36	565	206	359
Kielce 1931-1960	38	39	33	40	51	82	94	81	49	45	46	43	641	239	402
Kielce 1975- 1988	36	26	35	41	53	66	81	76	57	40	40	44	594		
Zieleniec 1931-1960	94	103	95	90	110	118	160	144	102	93	96	90	1295	568	727
Zieleniec 1891-1930	105	98	93	95	106	120	143	130	104	113	98	116	1321	–	–

1938) and after the war laid down Poland's climatic regions (ROMER 1949) on the basis of an original method using isogradients, i.e. lines with an equal intensity of climate elements or indicators. He distinguished 8 types and 59 climatic districts. The mires under study come within the following areas: Sejneńska (Suche Bagno), Olsztyńska (Kołowin), Warszawska (Linje, Długie Bagno, Rąbień), the Świętokrzyska Upland (Białe Ługi) and Kłodzka (Zieleniec). This division correlates exceptionally well with variability of the mean annual temperatures shown in Table 1. The variation in precipitation in the lowland regions is not so distinct.

The division of Poland into climatic regions, developed on the basis of the main meteorological elements by WISZNIEWSKI and CHEŁCHOWSKI (1975) has made it possible to distinguish 14 separate regions, but this is a very simplified picture.

Considerably more information on the climate in the region of the raised bogs under study can be obtained from special natural history monographs. One of these concerns the Wigierski National Park and the weather profile and the WNP topoclimatic conditions were outlined by KICIŃSKA *et al.* (2001). The climate of the Kampinos Forest was outlined by ANDRZEJEWSKA (2003) in the monograph on Kampinos National Park. The climate of the region in which the Zieleniec Mire lies was discussed by WALCZAK (1961) in the monograph *Kłodzko Land*. This quotes data from the Zieleniec weather station for the years 1891-1930 concerning atmospheric precipitation, temperature and cloudiness. Zieleniec constitutes a separate climatic unit alongside Kłodzko, Duszniki Zdrój and Śnieżnik. Detailed topoclimatic research was conducted on the Białe Ługi Mire and was published in a monograph edited by ŻUREK (2001).

4. REFERENCES

- ANDRZEJEWSKA, A. 2003. Klimat [Climate]. In: R. ANDRZEJEWSKI (ed.), *Kampinoski Park Narodowy*, T.1. Wyd. Kampinoski Park Narodowy, Izabelin: p. 41-68.
- ATLAS KLIMATYCZNY POLSKI 1979. Część tabelaryczna [Climatic Atlas of Poland. The tabular part]. Wyd. Komunikacji i Łączności, Warszawa, 67 pp.
- BARANIECKA, M.D. 1982. Sytuacja geologiczna i rozmieszczenie wydmy okolic Warszawy [Geological situation and arrangement of dunes in the Warsaw environs] *Roczniki Gleboznawcze* 33, 3-4: 33-57.
- BARANIECKA, M.D., KONECKA-BETLEY, K. 1987. Fluvial sediments of the Vistulian and Holocene in the Warsaw Basin. *Geographical Studies, Special Issue* 4: 151-170.
- BER, A. 1974. Czwartorzęd Pojezierza Suwalskiego [The Quaternary of the Suwałki Lake District]. *Z Badań Czwartorzędu w Polsce* 15: 23-106.
- BER, A. 1982. Marginal zones and deglaciation during the North-Polish Glaciation in the Suwałki-Augustów Lakeland. *Biuletyn Instytutu Geologicznego* 343: 71-89.
- BER, A. 1998. Szczegółowa Mapa Geologiczna Polski 1:50000. Arkusz Krasnopol [Detailed Geological Map of Poland 1:50000 sheet Krasnopol]. PIG, Warszawa.
- BER, A. 2000. Plejstocen Polski północno-wschodniej w nawiązaniu do głębszego podłoża i obszarów sąsiednich [Pleistocene of north-eastern Poland and neighbouring areas against crystalline and sedimentary basement]. *Prace PIG* 170, 89 pp.
- BORÓWKO-DŁUŻAKOWA, Z. 1961. Historia flory Puszczy Kampinoskiej w późnym glacie i holocenie [The History of the Flora of the Kampinos Forest During The Late Glacial and Holocene Period]. *Przegl. Geogr.* 33, 3: 365-382.
- CYMERMAN, Z. 1992a. Szczegółowa mapa geologiczna Sudetów 1:25000. Arkusz Duszniki Zdrój [Detailed Geological Map of Poland 1:25000 sheet Duszniki Zdrój]. PIG, Warszawa.
- CYMERMAN, Z. 1992b. Objaśnienia do szczegółowej mapy geologicznej Sudetów 1:25000. Arkusz Duszniki Zdrój [Explanations for Detailed Geological Map of Poland 1:25000 sheet Duszniki Zdrój]. PIG, Warszawa, 72 pp.
- DYLIK, J. 1948. Ukształtowanie powierzchni i podział na krainy podłódzkiego obszaru [Unités morphographiques des environs de Łódź]. *Acta Geographica Univ. Lodz.* 1: 1-46.
- DYLIK, J. 1953. O peryglacjalnym charakterze rzeźby środkowej Polski [Du caractère périglaciaire de Pologne Centrale]. *Acta Geographica Univ. Lodz.* 4: 1-109.
- DYLIK, J. 1970. Kras termiczny, jego istota i kierunki rozwoju [Thermocarst. Its essence and directions of development]. *Łódzkie Tow. Nauk., Sprawozdania z Czynności i Posiedzeń Naukowych* 25, 7: 1-14.
- DYLIKOWA, A. 1967. Wydmy środkowopolskie i ich znaczenie dla stratygrafii schyłkowego plejstoenu [Middle Poland dunes and their significance for stratigraphy of late pleistocene]. In: R. GALON, J. DYLIK (eds.), *Czwartorzęd Polski*. PWN, Warszawa: 353-371.
- DYLIKOWA, A. 1970. Cechy podłoża wydmy w Katarzynowie koło Łodzi [Traits du substratum des dunes a Katarzynów aux environs de Łódź]. *Acta Geographica Lodziensia* 24: 135-154.
- DZIAK, W., LIWSKI, S. 1958. Dokumentacja geologiczna złóż torfu Puszczy Kampinoskiej [Geological documentation of peat deposits of Kampinoska Forest]. *Katedra Torfoznawstwa SGGW, Warszawa (mscr.)*.
- JAHN, A. 1970. Zagadnienia strefy peryglacjalnej [Problems of periglacial zone]. PWN, Warszawa: 1-202.
- KACZOROWSKA, J. 1926. Studium geograficzne Puszczy Kampinoskiej [Etude géographique sur la „lande” de Kampinos]. *Przegl. Geogr.* 6: 45-61.
- KACZOROWSKA, Z. 1977. Pogoda i klimat [Weather and climate]. Wyd. Szkolne i Pedagogiczne, Warszawa: 1-310.

- KICIŃSKA, B., OLSZEWSKI, K., ŻMUDZKA, E. 2001. Warunki klimatyczne i topoklimatyczne Wigierskiego Parku Narodowego [Climatic and topoclimatic conditions of Wigierski National Park]. In: A. RICHLING, J. SOLON (eds.), *Z badań nad strukturą i funkcjonowaniem Wigierskiego Parku Narodowego*. Wydział Geografii i Studiów Regionalnych UW, Warszawa: 47-54.
- KŁATKOWA, H. 1972. Paleogeografia Wyżyny Łódzkiej i obszarów sąsiednich podczas zlodowacenia warciańskiego [Paleogeographie du plateau de Łódź et de terrain avoisinant pendant la glaciation de Warta]. *Acta Geographica Lodziensia* 28: 1-220.
- KŁATKOWA, H. 1997. Zagłębienia bezodpływowe w Polsce środkowej i przydatność analizy ich wypełnień do interpretacji paleogeograficznych [Closed depressions in central Poland and a significance of their fillings to the palaeogeographical interpretation]. *Acta Univ. Lodz., Folia Geographica Physica* 1: 23-45.
- KLEMENTOWSKI, J. 2001. Przekształcenie stosunków wodnych torfowiska wysokiego Topieliska w Sudetach w następstwie prób polepszenia spławności Bystrzycy Dusznickiej [Conversion of water conditions the Topielisko bog in Sudety Mountains in the aftermath of attempt improvement floating of the Bystrzyca Dusznicka river]. In: *Wpływ użytkowania terenu i antropogenicznych przekształceń środowiska przyrodniczego na elementy obiegu wody w zlewni rzecznej*. Kielce-Wółka Milanowska 25-27 września 2001, Instytut Geografii, Kielce: 50-62.
- KLOSS, M., KUCHARSKI, L., ŻUREK, S. 2004. Palaeobotanical study as a basis for the protection of raised bogs in Poland. In: J. PÄIVÄNEN (ed.), *Wise use of peatlands. Proceedings of the 12th International Peat Congress*, Tampere, Finland, Publication of the International Peat Society 2: 875-880.
- KOBENDZINA, J. 1961. Próba datowania wydmy Puszczy Kampinoskiej [Attempt to Date Dunes in the Kampinos Primeval Forest]. *Przegl. Geogr.* 33, 3: 383-399.
- KONDRACKI, J. 1952. Uwagi o ewolucji morfologicznej Pojezierza Mazurskiego [Remarks about morphological evolution of the Mazurian Lake District]. *Z badań Czwartorzędu w Polsce* 1, Biul. PIG 65: 513-597.
- KONDRACKI, J. 2000. *Geografia regionalna Polski* [Regional Geography of Poland], PWN, Warszawa, 441 pp.
- KONDRACKI, J., RICHLING, A. 1994. Regiony fizycznogeograficzne [Physico-geographical regions]. In: *Atlas Rzeczypospolitej Polskiej. Cz. 2. Instytut Geografii i Przestrzennego Zagospodarowania PAN, Warszawa*.
- KONECKA-BETLEY, K. 1982. Gleby kopalne i reliktowe wydmy okolic Warszawy [Fossil and relic soils in dunes of the environs Warsaw]. *Rocznik Gleboznawczy* 33, 3-4: 81-112.
- KOWALSKI, B. 2001. Geneza doliny rezerwatu przyrodniczego Białe Ługi [Genesis of valley of Białe Ługi reserve]. In: S. ŻUREK (ed.), *Rezerwat torfowiskowy „Białe Ługi”*. Wyd. Homini, Bydgoszcz: 27-40.
- KOZŁOWSKA, M., KOZŁOWSKI, I. 1986. Szczegółowa Mapa Geologiczna Polski 1:50000. Arkusz Unisław [Detailed Geological Map of Poland 1:50000 sheet Unisław]. PIG, Warszawa.
- KOZŁOWSKA, M., KOZŁOWSKI, I. 1990. Objasnienia do Szczegółowej Mapy Geologicznej Polski 1:50000. Arkusz Unisław [Explanations for Detailed Geological Map of Poland 1:50000 sheet Unisław]. Wydawnictwa Geologiczne, Warszawa, 69 pp.
- LISICKI, S. 1995. Objasnienia do Szczegółowej Mapy Geologicznej Polski 1:50000. Arkusz Piecki [Explanations for Detailed Geological Map of Poland 1:50000 sheet Piecki]. PIG, Warszawa, 42 pp.
- LISICKI, S. 1998. Szczegółowa Mapa Geologiczna Polski 1:50000. Arkusz Piecki [Detailed Geological Map of Poland 1:50000 sheet arkusz Piecki]. PIG, Warszawa.
- LIWSKI, S., MACIAK, F., KARPIŃSKA, J. 1967. Torfowiska Puszczy Kampinoskiej [Peatlands of the Kampinos Forest]. *Roczniki Gleboznawcze* 18, 1: 159-185.
- MORAWSKI, W. 1978. Szczegółowa Mapa Geologiczna Polski 1:50000. Arkusz Warszawa-Zachód [Detailed Geological Map of Poland 1:50000 sheet Warszawa-Zachód]. Wydawnictwa Geologiczne, Warszawa.

- NIEWIAROWSKI, W. 1959. Formy polodowcowe i typy deglacjacji na Wysoczyźnie Chełmińskiej [Glacial form and types of deglaciations on the moraine plateau of Chełmno]. *Studia Societatis Scientiarum Torunensis* 4, 1, Sec. C, *Geographia et Geologia*: 1-171.
- NIEWIAROWSKI, W., TOMCZYK, A. 1969. Morfologia i rozwój rzeźby miasta Torunia i jego okolic [Morphology and relief development of town area and vicinity of Toruń]. *Zesz. Nauk. UMK, Geografia* 6: 39-89.
- NOWAK, J. 1974. Szczegółowa Mapa Geologiczna Polski 1:50000. Arkusz Legionowo [Detailed Geologic Map of Poland 1:50000 sheet Legionowo]. Wydawnictwa Geologiczne, Warszawa.
- NOWAK, J., SKOMPSKI, S. 1992. Szczegółowa Mapa Geologiczna Polski 1:50000. Arkusz Modlin-Twierdza [Detailed Geologic Map of Poland 1:50000 sheet Modlin-Twierdza]. Wydawnictwa Geologiczne, Warszawa.
- OŚWIT, J., ŻUREK, S. 1981. Rekonstrukcja rozwoju zabagnień w Pradolinie Biebrzy [Reconstruction of swamp development in the proglacial stream valley of the Biebrza]. *Zesz. Nauk. Akademii Rolniczej Wrocław, Rolnictwo* 38: 59-69.
- PASIERBSKI, M. 1966. Formy powstałe w lodzie stagnującym w południowo-zachodniej części Wysoczyzny Chełmińskiej [The forms in stagnant ice in the south west part of the Chełmińska Morainic Plateau]. *Zesz. Nauk. UMK, Geografia* 5: 61-74.
- ROCZNIKI HYDROGRAFICZNE ODRY I RZEK PRZYMORZA MIĘDZY ODRĄ I WISŁĄ. 1954-1968 [Hydrographic Annals of Oder and Coastal Rivers between Oder and Vistula River]. Wyd. PIHM, Warszawa.
- ROCZNIKI HYDROGRAFICZNE WISŁY I RZEK PRZYMORZA NA WSCHÓD OD WISŁY. 1954-1968 [Hydrographic Annals of Vistula and Coastal Rivers on the east from Vistula River]. Wyd. PIHM, Warszawa.
- ROCZNIKI METEOROLOGICZNE ODRY I RZEK PRZYMORZA. 1954-1968 [Meteorological Annals of Oder and Coastal Rivers]. Wyd. PIHM, Warszawa.
- ROCZNIKI METEOROLOGICZNE WISŁY I RZEK PRZYMORZA 1954-1968. [Meteorological Annals of Vistula, and Coastal Rivers]. Wyd. PIHM, Warszawa.
- ROCZNIKI HYDROGRAFICZNE. OPADY ATMOSFERYCZNE. 1954-1968 [Hydrographic Annals. Precipitation]. Wyd. PIHM, Warszawa.
- ROCZNIKI METEOROLOGICZNE. 1954-1965 [Meteorological Annals]. Wyd. PIHM, Warszawa.
- ROCZNIKI METEOROLOGICZNE. OPADY ATMOSFERYCZNE. 1954-1968 [Meteorological Annals. Precipitation]. Wyd. PIHM, Warszawa.
- ROMER, E. 1912. Klimat Ziem Polskich. [Climate of Poland]. *Encyklopedia Polska*. T. 1, Geografia fizyczna ziem polskich i charakterystyka fizyczna ludności. Nakładem Akademii Umiejętności, p. 171-248.
- ROMER, E. 1938. Pogląd na klimat Polski [Quelques remarques methodiques au sujet des cartes climatiques de la Pologne]. *Czasopismo Geograficzne* 16: 193-224.
- ROMER, E. 1949. Regiony klimatyczne Polski. [Les régions climatiques de la Pologne], *Prace Wrocławskiego Tow. Nauk., Ser. B* 16. Wrocław, 26 pp.
- RÓŻYCKI, F. 1956. Trzeciorząd Łodzi i okolic [Tertiary deposits in Łódź and environs]. *Acta Geographica Universitatis Lodzensis* 6: 1-47.
- RÓŻYCKI, S.Z. 1972. Plejstocen Polski Środkowej [The Pleistocene of Middle Poland]. PWN, Warszawa, 316 pp.
- ŚWIERCZYŃSKI, K. 1959. Stosunki geomorfologiczne [The geomorphological relations]. *Prace Geograficzne IG PAN* 19: 11-35.
- ŚWIERCZYŃSKI, K. 1961. Wojnowo, Brejdyny, Mrągowo, Kiersztanowo, Beżławki. In: J. KONDRACKI, S. PIETKIEWICZ (eds.), *Guide-Book of Excursion D, North-East Poland*, VI Congress INQUA, Poland 1961: 48-54.
- ŚWIERCZYŃSKI, K. 1967. Geomorfologia rynny mrągowskiej i obszarów przyległych [Geomorphology of the Mrągowo channel and adjacent area]. *Prace i Studia Instytutu Geograficznego UW, Katedra Geografii Fizycznej* 1: 125-142.

- ŚWIERCZYŃSKI, K. 1972. Formy wytopiskowe w południowej części Pojezierza Mrągowskiego [Die Schmelzwasserformer des Gebietes des Suedlichen Teils des Seengebietes von Mragowo]. *Prace i Studia Instytutu Geograficznego UW, Katedra Geografii Fizycznej* 4: 85-114.
- TOBOLSKI, K. 1969. Fazy wydmowe w świetle badań palynologicznych – zagadnienie ich liczby i charakterystyka przebiegu [Dune forming stages in the light of palynological examinations – problems dealing with the number of stages and the characteristic of their history]. *Prace Geograficzne IG PAN* 75: 101-116.
- TOBOLSKI, K., NORYSKIEWICZ, B., FILBRANDT-CZAJA, A., KLOSS, M., LAMENTOWICZ, M., MILECKA, K., NORYSKIEWICZ, A.M., OBREMSKA, M., PAJĄKOWSKI, J., ŻUREK S. 2004. Postglacialna historia lasów, jezior i torfowisk na wybranych przykładach Ziemi Chełmińskiej i Borów Tucholskich [Postglacial history of the forest lakes and mires on the selected examples of Chełmno District and Tuchola Forests]. In: E. KRASICKA-KORCZYŃSKA, M. KORCZYŃSKI (eds.), *Wycieczki geobotaniczne. Region Kujawsko-Pomorski. Oddział PTB Bydgoszcz i Toruń, Toruń-Bydgoszcz*: 58-69.
- WALCZAK, W. 1961. Ziemia Kłódzka [Kłodzko Land]. *Sport i Turystyka*, Warszawa, 195 pp.
- WIECZORKOWSKA, J. 1975. Rozwój stoków Pagórków Romanowskich na tle paleogeografii obszaru [Evolution of the slopes Pagórki Romanowskie versus palaeogeography of the area]. *Acta Geographica Lodziensia* 35: 1-118.
- WIECZORKOWSKA, J. 1976. Rola zagłębień bezodpływowych w rozwoju rzeźby okolic Łodzi [The Role of the closed depressions in the development of the relief environs Łódź]. *Acta Geographica Lodziensia* 37: 183-190.
- WIĘCKOWSKA, H. 1959. Wody [Waters]. *Prace Geograficzne IG PAN* 19: 37-49.
- WIĘCKOWSKA, H. 1963. Typy występowania górnych horyzontów wody podziemnej w Polsce [Types of occurrence of higher levels of subsurface waters in Poland]. *Czasopismo Geograficzne* 34, 4: 339-359.
- WISZNIEWSKI, W., CHEŁCHOWSKI, W. 1975. Charakterystyka klimatu i regionizacja klimatologiczna Polski [Characteristic of climate and climatologic regionalization of Poland]. *IMGW, Warszawa*, 40 pp.
- WOŁOSOWICZ, S. 1926. Morena denną tzw. „transgresji wigierskiej” i jej znaczenie w budowie dyluwium Pojezierza Suwalskiego [Bassal till of the „wigry transgressions” and its significance in the structure dyluwium Suwałki Lakeland]. *Sprawozdania PIG, III* 3/4: 434-465.
- ŻUREK, S. 1982. Różnicowanie się torfowisk na tle rzeźby [Peatland differentiation versus relief]. *Torf* 3/74: 26 -47.
- ŻUREK, S. 1983. Stan inwentaryzacji torfowisk w Polsce [State of inventory of peatlands in Poland]. *Wiadomości Melioracyjne i Łąkarskie* 7: 210-215.
- ŻUREK, S. 1990a. Związek procesu zatorfienia z elementami środowiska przyrodniczego wschodniej Polski [Interrelation between the peat-forming process and the elements of natural environment of Eastern Poland]. *Roczniki Nauk Rolniczych, Ser. D, Monografie* 220: 1-174.
- ŻUREK, S. 1990b. Identyfikacja torfowisk topogenicznych [Identification of the topogenic peatlands]. *Wiadomości Melioracyjne i Łąkarskie* 1-3: 21-24.
- ŻUREK, S. 1996. Wetlands and grasslands in the Warsaw Region. *Materiały Seminaryjne IMUZ* 35, Wyd. IMUZ, Falenty: 58-69.
- ŻUREK, S. (ed.). 2001. Rezerwat torfowiskowy „Białe Ługi” [Białe Ługi mire reserve]. Wyd. Homini, Bydgoszcz: 1-268.
- ŻUREK, S., KLOSS, M. 2001. Geneza i wiek torfowiska Białe Ługi [Genesis and age of Białe Ługi mire]. In: S. ŻUREK (ed.), *Rezerwat torfowiskowy „ Białe Ługi „, „. Wyd. Homini, Bydgoszcz*: 85-88.
- ŻUREK, S., ZIĘTEK, J. 2004. Torfowisko Suche Bagno w Wigierskim Parku Narodowym w świetle badań geologicznych i georadarowych [Suche Bagno mire in the Wigierski National Park in the light of geological and georadar research]. *Prace Komisji Paleogeografii Czwartorzędu PAU* 2: 61-66.

5. ABIOTYCZNE ŚRODOWISKO PRZYRODNICZE W REJONIE WYBRANYCH TORFOWISK WYSOKICH (streszczenie)

Badano siedem torfowisk wysokich występujących w różnych typach krajobrazu, na transekcie przecinającym Polskę z północnego wschodu na południowy zachód. Trzy z nich rozwijają się w krajobrazie młodoglacjalnym. Torfowisko Suche Bagno wypełnia głębokie na 13-17 m bezodpływowe zagłębienie rynnowe, leżące na południowy wschód od jeziora Wigry. Rynna wycięta jest w sandrze przykrytym cienką warstwą utworów glacialnych: glin morenowych i piasków gliniastych. Ich wiek datowano metodą TL na 18.2 ± 2.7 i 17.3 ± 2.6 ka BP. „Transgresja wigierska” opisana już w 1926 r. przez WOŁOSOWICZA miała charakter recesyjno-oscylacyjny. Wytopienie lodu w rynn timer nastąpiło około 15-14.5 tys. lat temu (datowanie C14 spagowej gytii na 14480 ± 79 BP). Torfowisko Kołowin leżące na zachód od Mikołajek wypełnia zagłębienie bezodpływowe w pojeziernym krajobrazie sandrowym. Wytopienie lodu nastąpiło tu w Böllingu lub wcześniej, gdyż spagowa gytia zaczęła się akumulować 11920 ± 69 lat BP. Torfowisko Linje, leżące na północ od Dąbrowy Chełmińskiej, otoczone jest sandrem i wałami wydmowymi, leżącymi na glinie morenowej fazy kujawskiej zlodowacenia wisły. Łód w bezodpływowym zagłębieniu wytopił się prawdopodobnie w Allerödie, gdyż spagowe torfy mszyste datowane są na 10740 ± 270 lat BP.

Dwa torfowiska wysokie występują w krajobrazie staroglacjalnym. Torfowisko Długie Bagno wypełnia nieckę deflacyjną wewnątrz południowego pasa wydmowego Puszczy Kampinoskiej. Ponieważ to płytkie złoż timer torfowe zaczęło się rozwijać od Allerödu, wydmy otaczające bagno usypane zostały w najstarszym lub starszym dryasie. Torfowisko Rąbień leżące na zachód od Łodzi otoczone jest wydmami i peryglacjanie przekształconymi pagórkami wysoczyznowymi. Bezodpływowe zagłębienie jest prawdopodobnie wytopiskiem z czasu zamierania lodowca stadiału warty, odnowionym w późnym glacialu ostatniego zlodowacenia (kras termiczny).

Torfowisko wyżynne Białe Ługi zajmuje wielkopromienne zagłębienie między dwoma pasmami Gór Świętokrzyskich. Nie jest ono fluwialną kopalną doliną, lecz rowem tektonicznym obniżanym i zasypywanym w czasie całego czwartorzędu. Od początków późnego glacialu (od 12900 ± 310 lat temu) zaczęło rozwijać się torfowisko a równolegle do niego gromadziły się w otoczeniu torfowiska mineralne osady deluwialno-proluwialne. Dziś dwa torfowiska wysokie oddzielone mineralnym wododziałem przechodzą w torfowiska niskie z których odpływają w różnych kierunkach dwie rzeczki: Trupień i Czarna Staszowska. Torfowisko Gór Bystrzyckich - Zieleniec leży na wododziale dwóch rzek odpływających w różnych kierunkach. Dno zagłębienia wyściela ilasta zwietrzelina, na której rozwinęły się w okresie atlantyckim stosunkowo młode lecz miększe do 8 m torfy wysokie (od 6255 ± 35 lat BP).

Współczesne warunki klimatyczne torfowisk wysokich są dosyć zbliżone. Jedynie na torfowisku górkim Zieleniec występują wyższe wyraźnie opady przekraczające

1000 mm rocznie. W rejonie innych torfowisk wysokich wahają się one od 538 mm (Długie Bagno) do 674 mm (Białe Ługi). Średnie temperatury roczne są niższe jedynie w górach i Polsce północno wschodniej (5.9-6.0°C), na niżu przekraczają 7.0°C.

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**CONTEMPORARY VEGETATION OF SELECTED
RAISED MIRES
AND ITS PRESERVATION**

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ABSTRACT

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In 7 raised mires of Suche Bagno, Kołowin, Linje, Długie Bagno, Rąbień, Białe Ługi and Zieleniec, phytocoenoses of over 20 plant communities and associations have been detected. In the study, phytosociological documentation for 13 plant communities and associations of low, transitional, raised and forest mire is included. The most precious include patches of *Caricetum limosae*, *Sphagnetum magellanicum*, *Pino mugo-Sphagnetum*, *Ledo-Sphagnetum magellanicum* and *Sphagno-Caricetum pauciflorae*. In the wetlands, presence of the precious species of Polish flora has been recorded. They include, among others: *Betula nana* (in the mires of Linje and Zieleniec), *Chamaedaphne calyculata* (in the Kołowin Mire), *Oxycoccus microcarpus* (in the Suche Bagno Mire) and *Pinus x rhaetica* (in the Zieleniec Mire). The mires under review can be divided into three groups. The first group includes wetlands whose vegetation has undergone minor synatropization (Zieleniec and Suche Bagno). Wetlands with apparent effects of human activity include Linje, Długie Bagno, Kołowin and Białe Ługi. The vegetation of these mires is subject to regeneration. The Rąbień Mire has the most transformed vegetation.

Key words: raised mires; plant communities; Poland.

1. INTRODUCTION

Raised mires belong to Poland's rare ecosystems. They develop mainly in the Boreal Zone of the Holarctic Region, extending to the northern edges of the moderate climate zone. It is assumed that this type of mire occurs in Europe in a belt between 44° (54°) and 62° N altitude (HERBICHOWA 1998). In Poland, the most typical peatlands are located in areas where precipitation exceeds evaporation in a yearly cycle, that is, in the northern part of the country and in the mountains.

The data concerning the occurrence and differentiation of plant communities within the *Oxycocco-Sphagnetum* class in our country are still incomplete. About 20 plant associations and over 15 sub-associations belonging to the *Oxycocco-Sphagnetum* class are known in Poland's raised mires. Many of the described syntaxons have very sparse phytosociological documentation. Most of the data concerning the raised mire vegetation come from the northern and eastern part of the country (KUCHARSKI, KOPEĆ 2005).

Identification of plant communities. The study includes a characteristic of the contemporary vegetation of 7 mires where palaeobotanic analyses of peat were carried out between 2003 and 2005 (KLOSS 2005). The vegetation research was carried out by the BRAUN-BLANQUET (1964) method. 10-15 phytosociological relevés were collected in each of the mires near the stratigraphical transects where peat boreholes were distributed. Most of the relevés arranged in synthetic phytosociological tables are attached to the work (Tables 1-3). The syntaxonomic division was generally adopted following MATUSZKIEWICZ (2001). The vegetation of the Rąbień and Białe Ługi mires had been investigated prior to project commencement. The vegetation characteristic of the mires was based on the works published earlier (PRZEMYSKI, POLINOWSKA 2001; KUCHARSKI *et al.* 2004). Owing to the limited content of the works, only brief characteristics of the vegetation of the study sites and descriptions of the identified syntaxons are attached. A detailed vegetation characteristic of the surveyed peatlands will be the subject of separate publications. A real vegetation map is drawn up for each site (Fig. 1-7).

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2. MIRE VEGETATION

The Suche Bagno Mire. The vegetation of this peatland has not been subject to research so far. Fragmentary data on this vegetation are included in the work by SOKOŁOWSKI (1988) on the vegetation of the Wigry National Park. Currently, the wetland is covered by the phytocoenoses of *Sphagnetum magellanici*, *Ledo-Sphagnetum magellanici* and the communities of *Eriophorum vaginatum*-*Sphagnum fallax* [= *Eriophoro vaginati-Sphagnetum recurvi*] (Fig. 1). The narrow mire edge develops a floristically-poor community of *Eriophorum vaginatum*-*Sphagnum fallax*, with *Eriophorum vaginatum* as the main plant component. In the central part of

Fig. 1. Contemporary vegetation of the Suche Bagno mire
 1 – *Eriophorum vaginatum*-*Sphagnum fallax* community; 2 – mosaic of communities of *Sphagnetum magellanici* and *Ledo-Sphagnetum magellanici*; 3 – location of stratigraphical section

the site, a mosaic of patches of *Sphagnetum magellanicum* and *Ledo-Sphagnetum magellanicum* is found. The community features a loose layer of low trees (mainly *Pinus sylvestris*) and domination of characteristic species of the *Oxycocco-Sphagnetum* class in the forest floor vegetation. Also other conifer species can be found there, however they are less frequent than the raised mire species. Among the interesting plants found in the Suche Bagno Mire, the relic site of cranberry *Oxycoccus microcarpus* deserves special attention.

The Kołowin Mire. The vegetation of the central part of the Kołowin Mire features a belt-type arrangement (Fig. 2). The western edge of the mire is covered by the rump phytocoenosis of *Carici-Agrostietum caninae*. The community is built of *Carex nigra*, with the accompanying *Eriophorum vaginatum*, *Molinia caerulea* and *Carex lasiocarpa*. Tree seedlings occur in the patch, and the moss layer is poorly developed. Another vegetation belt is represented by the phytocoenosis of the *Eriophorum vaginatum-Sphagnum fallax* community. The herb layer is made up of *Eriophorum vaginatum*, while in the moss layer, *Sphagnum fallax* predominates. On the boundary between *Carex nigra* and *Eriophorum vaginatum-Sphagnum fallax*, the share of *Carex lasiocarpa* increases. The third belt is composed of a mosaic of *Eriophorum vaginatum-Sphagnum fallax* and *Sphagnetum magellanicum*. A larger proportion of trees are observed there, including the dominant *Betula pendula*. The moss layer with a number of *Sphagnum* species is well developed. In the central part of the peatland, there is a compact patch of *Chamaedaphne calyculata*, accompanied by the clusters of *Ledum palustre*, as well as the seedlings and the young individuals of *Betula pendula*, *Pinus sylvestris* and *Picea abies*. In the herbaceous layer, *Eriophorum vaginatum* dominates. In the east of the above described vegetation belt, there occur a phytocoenosis of the *Eriophorum vaginatum-Sphagnum fallax* community with single individuals of *Chamaedaphne calyculata* and few tree seedlings. In the east, it neighbors the phytocoenosis of *Calamagrostietum strictae*. The share of trees and shrubs in the herb layer of this community is minor. The eastern edge of the mire is covered by a patch of *Caricetum vesicariae* with a large presence of *Carex elata*. It is the floristically-richest community in the mire. The northwestern fragment of the site is covered by the vegetation of the *Scheuchzerio-Caricetea nigrae* class, with abundance of *Betula pendula* and *B. pubescens*. In the northeastern part of the Kołowin Mire, the phytocoenoses of *Calamagrostietum strictae* predominate. In the south of the above characterized mire fragments, there is a mosaic of communities of the *Scheuchzerio-Caricetea nigrae* class and the alliance of *Magnocaricion*.

The Linje Mire (The Linje Mire reserve). The described site has been placed under legal protection in the form of a nature reserve since 1957. There, one can find Polish lowlands' only habitat of *Betula nana* (BOIŃSKI *et al.* 2001; CEYNOWA-GIELDON 1971). The eastern edge of the peatland is covered by a community with dominant *Eriophorum vaginatum* and *Sphagnum fallax* representing different phases of development (Fig. 3). The closer to the center of the mire, the larger is

Fig. 2. Contemporary vegetation of the Kołowin mire

1 – communities of *Scheuchzeria-Caricetea nigrae*; 2 – mosaic of communities of *Eriophorum vaginatum-Sphagnum fallax* and *Sphagnetum magellanicum*; 3 – mosaic of communities of *Scheuchzeria-Caricetea nigrae* with *Betula pendula* and *B. pubescens*; 4 – mosaic of communities of *Scheuchzeria-Caricetea nigrae* and *Magnocaricion*; 5 – *Sphagno squarrosi-Alnetum*; 6 – mosaic of communities of *Caricion lasiocarpae*; 7 – location of stratigraphical section

Fig. 3. Contemporary vegetation of the Linje mire

1 – *Ledo-Sphagnetum magellanici*; 2 – *Sphagno squarrosi-Alnetum*; 3 – *Eriophorum vaginatum-Sphagnum fallax* community; 4 – mosaic of communities of *Phragmitetea* and *Scheuchzerio-Caricetea nigrae*; 5 – location of stratigraphical section

the proportion of trees and shrubs in vegetation patches. The central part of the peatland is covered by a community whose floral composition resembles *Ledo-Sphagnetum magellanici*. A large part of the old pines have withered; only young individuals growing up to 1.5-2 m have survived. *Betula nana* can be found in the forest floor vegetation in great abundance. This part of the mire was drained in the past through building a network of ditches whose traces still can be found. The rising of the ground water level in the peat deposit caused a drop-out of older trees in the habitat. In the west, patches of the above mentioned communities neighbor the phytocoenoses of *Eriophorum vaginatum-Sphagnum fallax*. The western edge

of the surveyed part of the mire is overgrown by a forest community resembling *Sphagno squarrosi-Alnetum*. In the northern part of the reserve, where peat has been excavated, there is a mosaic of reed communities of the *Phragmitetea* class and communities of the *Scheuchzerio-Caricetea nigrae* class, with patches of *Carici canescentis-Agrostietum caninae* and *Junco effusi-Sphagnetum recurvi* covering the largest area.

The Długie Bagno Mire. Długie Bagno is covered by the phytocoenoses of the *Eriophorum vaginatum-Sphagnum fallax* community and *Vaccinio uliginosi-Pinetum* (Fig. 4). On the western edge of the bog, a forest community with dominant *Betula pubescens* has developed. A large share of the species typical for the bog coniferous forest points to the development alliances with the *Vaccinio uliginosi-Pinetum* association. Phytocoenoses of the bog coniferous forest have developed in the eastern and northeastern part of the mire. The central and southern edges of the wetland are covered with patches of the *Eriophorum vaginatum-Sphagnum fallax* community at different stages of succession. The phytocoenosis of this community, in its optimum phase of development, can be found on the southern edge of the mire in the most wet area. There also occur the *Chamaedaphne calyculata* habitat. North-west of it, there is a patch of bog vegetation, including *Eriophorum vaginatum* and *Sphagnum fallax*, with a large share of *Betula pubescens*. It is in its terminal stage of development. The eastern part of the mire with traces of peat extraction is covered by a mosaic of communities of the *Oxycocco-Sphagneteta* and *Phragmitetea* classes.

Fig. 4. Contemporary vegetation of the Długie Bagno mire

1 – *Vaccinio uliginosi-Pinetum*; 2 – *Vaccinio uliginosi-Pinetum* with *Betula pubescens*; 3 – *Eriophorum vaginatum-Sphagnum fallax* community; 4 – mosaic of communities of *Oxycocco-Sphagneteta* and *Phragmitetea*; 5 – *Eriophorum vaginatum-Sphagnum fallax* community with *Betula pubescens*; 6 – location of stratigraphical section

The Rąbień Mire (The Torfowisko Rąbień reserve). The Rąbień Mire is the most destroyed peatland among the surveyed sites. Peat deposits have been exploited in over 60 per cent. The southwestern (exploited) part of the mire is covered with the phytocoenoses of anthropogenic communities. The vegetation typical for raised bogs has been preserved only in the central part of the site (Fig. 5). This part of the bog is covered by a mosaic of patches of the *Eriophorum angustifolium*-*Sphagnum fallax* and *Eriophorum vaginatum*-*Sphagnum fallax* communities. Forest vegetation encroaches on part of the patches of the latter community. First comes the forest community of *Betula pubescens* and *Pinus sylvestris* (initial phase of bog coniferous forest), and next – *Vaccinio uliginosi*-*Pinetum*. The northern and north-eastern edge of the mire is covered by a mosaic of birch stands made up of *Betula pubescens* and *Betula pendula*, as well as the strongly deformed *Sphagno squarrosi*-*Alnetum*. The shallowed peat extraction pits in the eastern part of the mire house *Salicetum pentandro-cinereae*. The youngest peat extraction pits located in the western part of the bog are the site for the phytocoenoses of *Typhetum angustifoliae* and *Phragmitetum australis*. The southern and eastern (drained) edges of the mire are covered with the phytocoenoses of the mixed coniferous forest *Quercus*

Fig. 5. Contemporary vegetation of the Rąbień mire

1 – young Pine tree forest; 2 – *Vaccinio uliginosi*-*Pinetum*; 3 – mosaic of communities of *Oxycocco-Sphagneteta* and *Scheuchzerio-Cariceteta nigrae*; 4 – cut-over bog; 5 – communities of *Artemisieteta*; 6 – *Salicetum pentandro-cinereae*; 7 – communities of *Phragmiteteta*; 8 – *Betula pubescens* and *Pinus sylvestris* community; 9 – communities of *Molinio-Arrhenathereteta*; 10 – *Sphagno squarrosi*-*Alnetum*; 11 – *Quercus roboris*-*Pinetum*; 12 – drainage ditch ; 13 – location of stratigraphical section

roboris-Pinetum. A total number of 13 phytosociological units have been found there in the form of associations and communities (KUCHARSKI *et al.* 2004).

The Białe Ługi Mire (The Białe Ługi Mire reserve). The vegetation of the Białe Ługi reserve was the subject of a separate study (PRZEMYSKI, POLIŃSKA 2001). The palaeobotanical investigations covered the peat deposits of the southern basin of the Białe Ługi Mire. The central part of the peatland is occupied by a mosaic of the *Sphagnetum magellanici* and *Caricetum lasiocarpae* phytocoenoses (Fig. 6). The phytocoenoses of the latter association include the glacial relic of *Salix myrtilloides*. In the patches of *Caricetum lasiocarpae*, one can note a large presence of the species characteristic for the *Oxycocco-Sphagnetea* class. On the northwestern edge of the studied mire, *Caricetum lasiocarpae* phytocoenoses in different phases

Fig. 6. Contemporary vegetation of the Białe Ługi mire

1 – mosaic of communities of *Scheuchzerio-Caricetea nigrae* and *Oxycocco-Sphagnetea*; 2 – *Vaccinio uliginosi-Pinetum*; 3 – *Sphagnetum magellanici*; 4 – *Caricetum lasiocarpae*; 5 – communities of *Dicrano-Pinion*; 6 – *Fraxino-Alnetum*; 7 – location of stratigraphical section

of development are observed, and in its periphery – a mosaic of raised bog communities with dominant *Sphagnetum magellanici*, accompanied by small patches of *Ledo-Sphagnetum magellanici*. A small patch of the raised-bog community mosaic was found also on the southern edge of the mire under study. On the opposite, southern-eastern edge of the wetland, *Vaccinio uliginosi-Pinetum* dominates. The bog coniferous forest has also developed in the northeastern and southwestern part of the mire.

The Zieleniec Mire (The Torfowisko pod Zieleńcem reserve). The interest in this peatbog dates back to the beginnings of the 20th century. The description of this site, including a characteristic of its vegetation cover, can be found, among others, in the works by HERRMANN (1920). In the second half of the past century, the flora

Fig. 7. Contemporary vegetation of the Zieleniec mire

1 – *Sphagnetum magellanici*; 2 – *Pino mugo-Sphagnetum*; 3 – *Sphagno-Piceetum*; 4 – bog pool; 5 – location of stratigraphical section

of this mire was also mentioned by FABISZEWSKI (1985), WALCZAK (1986) (after POTOCKA 2004) and POTOCKA (2004). For the needs of this study, the northern part of the Zieleniec Mire, called Topielisko, was included in the research. The vegetation of this fragment of the wetland features a belt-type arrangement of plant communities (Fig. 7). The most external vegetation belt includes *Sphagno-Piceetum*. The spruce stand represents the final stage of succession in the mountain raised bog. The next vegetation belt is built up of *Pino mugo-Sphagnetum magellanici*. The phytocoenoses of this community cover about half of the area of the mire under study. In the patches of *Pino mugo-Sphagnetum magellanici*, small areas (5-15 m²) of *Rhynchosporium albae* and *Sphagno-Caricetum pauciflorae* have been recorded. *Sphagnetum magellanici* occupies the central part of the Zieleniec Mire. In the patches of this community, in the southern part of the mire, there is *Betula nana* – a glacial relic. It is one of two habitats of this species in the Sudety Mountains. In the northern part of the mire, on the edges of a small dystrophic pool, small patches of *Caricetum limosae* have been recorded.

3. PLANT DIFFERENTIATION

3.1. A list of identified communities

The syntaxonomic division was generally adopted following MATUSZKIEWICZ (2001).

Class: *Phragmitetia* Tx. et Prsg. 1942

Order: *Phragmitetia* Koch 1926

Aliance: *Phragmitetia australis* Koch 1926

Association: *Phragmitetia australis* (Gams 1927) Schmale 1939

Typhetum angustifoliae (Allörge 1922) Soó 1927

Equisetetum fluviatilis Steffen 1931

Aliance: *Magnocaricion* Koch 1926

Association: *Caricetum vesicariae* Br.-Bl. et Denis 1926

Caricetum rostratae Rübel 1912

Class: *Scheuchzeria-Caricetia fuscae* (Nordh. 1937) R.Tx. 1937

Order: *Scheuchzerietalia palustris* Nordh. 1937

Aliance: *Rhynchosporion albae* Koch 1926

Association: *Caricetum limosae* Br.-Bl. 1921

Rhynchosporium albae Koch 1926

Aliance *Caricion lasiocarpae* Vanden Bergh. ex Lebrun et al. 1949

Association: *Caricetum lasiocarpae* Koch 1926

Calamagrostietum strictae (Steffn. 1931) Tolpa 1956

- Community *Sphagnum recurvum*-*Eriophorum angustifolium* Jasn. 1968
pro. ass.
- Order: *Caricetalia nigrae* Koch 1926 em. Nordh. 1937
- Aliance: *Caricion nigrae* Koch 1926 em. Klika 1934
- Association: *Carici canescentis-Agrostietum caninae* R.Tx. 1937
Junco effusi-Sphagnetum recurvi Palcz. 1964, Pass. 1964
- Class: *Oxycocco-Sphagnetea* Br.-Bl. et R.Tx. 1943
- Order: *Sphagnetalia magellanici* (Pawł. 1928) Moore (1964) 1968
- Aliance: *Sphagnion magellanici* Kästner et Flössner 1933 em. Dierss. 1975
- Association: *Sphagnetum magellanici* (Malc. 1929) Kästner et Flössner 1933
Pino mugo-Sphagnetum Kästner et Flössner 1933 em.
Neuhäusl 1969 corr. Dierss. 1975
Ledo-Sphagnetum magellanici Sukopp 1959 em. Neuhäusl 1969
Sphagno-Caricetum pauciflorae Klika et Šmarda 1946
- Community: *Eriophorum vaginatum-Sphagnum fallax* Hueck 1928 pro ass.
- Class: *Alnetea glutinosae* Br.-Bl. et R.Tx. 1943
- Order: *Alnetalia glutinosae* R.Tx. 1937
- Aliance: *Alnion glutinosae* (Malc. 1929) Meijer Drees 1936
- Association: *Salicetum pentandro-cinereae* (Almq. 1929) Pass. 1961
Sphagno squarrosi-Alnetum Sol.-Górń. (1975) 1987
- Class: *Vaccinio-Piceetea* Br.-Bl. 1939
- Order: *Cladonio-Vaccinietalia* Kiell.-Lund 1967
- Aliance: *Dicrano-Pinion* Libb. 1933
- Association: *Vaccinio uliginosi-Pinetum* Kleist 1929
- Order: *Vaccinio-Piceetalia* Br.-Bl. 1939
- Aliance: *Piceion abietis* Pawł. et al. 1928
- Association: *Sphagno-Piceetum* Hartmann 1942

3.2. Community characteristics

Communities of the *Phragmitetea* class

Reed communities are of marginal significance in the vegetation of natural raised bogs. Their proportion increases in the vegetation cover of the wetlands where traces of man's interference are visible. In the study sites, *Phragmitetum australis* is the most common reed community. Patches of this reed community have been recorded in the vegetation of wetlands where once peat was extracted. The patches of *Phragmitetum* are accompanied by the phytocoenoses of *Typhetum angustifoliae* and *Equisetetum fluviatilis*. This type of vegetation has been recorded in the Linje and Torfowisko Rąbień reserves. In the shallowed peat extraction pits, rump phytocoenoses of *Caricetum rostratae* and *Caricetum vesicariae* are found. Patches

of the latter communities are also components of the vegetation growing on the edges of the mires.

Communities of the *Scheuchzeria-Caricetea nigrae* class (Table 1)

The community composed of *Carex limosa* and *Scheuchzeria palustris* are associated with hollows in the Atlantic-type and Baltic-type raised mire complexes (MATUSZKIEWICZ 2001). In Poland, *Caricetum limosae* is most widely spread in the Pomerania, Mazurian Lakeland and Suwalszczyzna, as well as in the eastern part of the country. It is also recorded in the mires of the upper montane belt or the sub-Alpine belt (KUCHARSKI, GRZYL 1993). Among the study sites, it was found only in the Zieleniec Mire. It forms a narrow (1-1.5 m wide) strip, along a small lake situated in the northern part of the mire, and in the shallowed water body in the southern part of the mire. This community is floristically poor. *Carex limosae* is the main vegetation component, while *Scheuchzeria palustris* is of small significance in the phytocoenoses.

The association of white beak-sedge *Rhynchosporium albae* is one of the most widespread transitional bog communities in our country (KUCHARSKI *et al.* 2001). Usually it develops in shallowed depressions, in a complex of transitional bogs, frequently in exposed peats or wet sands. Among the studied mires, the community has been recorded only in the Zieleniec Mire. The community's phytocoenoses have developed in the bottoms of small depressions which are periodically filled with water.

The community formed by *Carex lasiocarpa* is one of the most frequent communities of the *Scheuchzeria-Caricetea nigrae* class in our country (KUCHARSKI *et al.* 2001). Among the investigated sites, it has been recorded in the Kołowin and Białe Ługi mires. In the Białe Ługi reserve, it occurs in two trophic forms – typical, in more fertile habitats, and in the acidophilous form – in oligotrophic habitats. In the phytocoenoses of *Caricetum lasiocarpae* which occur in more fertile soils, presence of *Salix myrtilloides* has been noted. In the phytocoenoses of poor habitats, increased share of raised bog species has been confirmed (PRZEMYSKI, POLIŃSKA 2001). In the Kołowin Mire, the community of *Carex lasiocarpa*, together with *Carici-Agrostietum caninae* and the *Molinia caerulea* community, make up the mire-edge vegetation.

Calamagrostietum strictae is a frequent component of low moor vegetation in the northern regions of our country. It is less common in the south of the country (KUCHARSKI *et al.* 2001). The phytocoenoses of this community have been found only in the Kołowin Mire. *Calamagrostis stricta* forms a floristically-poor, rump community with a quite well developed moss layer in which peatmosses dominate. It forms a transitional belt between the raised bog community (*Eriophorum vaginatum-Sphagnum fallax*) and the reed community (*Caricetum vesicariae*).

Table 1
Differentiation of associations of *Scheuchzerio-Caricetea nigrae* class

A – *Carici-Agrostietum caninae* R. Tx. 1937

B – *Caricetum lasiocarpae* Koch 1926

C – *Caricetum limosae* Br.-Bl. 1921

D – *Rhynchosporietum albae* Koch 1926

E – *Calamagrostietum strictae* (Steffn. 1931) Tołpa 1956

Succesive No.	1	2	3	4	5
Name of mire	Koł.	B.Ł.	Ziel.	Ziel.	Koł.
Numbers of relevés	1	25	5	3	2
Numbers of species in relevé	12	15-28	5-11	6-7	7-10
Numbers of species in plant community	12	51	17	10	12
Syntaxonomic unit	A	B	C	D	E
Ch. <i>Scheuchzerio-Caricetea nigrae</i> :					
<i>Eriophorum angustifolium</i>	.	V ⁺⁻⁵	I ⁺	.	2 ⁺
<i>Carex nigra</i>	4	IV ⁺⁻²	.	.	.
<i>Agrostis canina</i>	1	I ⁺	.	.	.
<i>Carex lasiocarpa</i>	1	V ⁺⁻⁵	.	.	.
<i>Carex limosa</i>	.	.	V ⁺⁻⁴	.	.
<i>Scheuchzeria palustris</i>	.	.	V ⁺⁻³	.	.
<i>Rhynchospora alba</i>	.	.	.	3 ³⁻⁴	.
<i>Calamagrostis stricta</i>	.	.	.	.	2 ⁴⁻⁵
Sporadic species: <i>Carex canescens</i> 2 (II ⁺⁻²); <i>Comarum palustre</i> 2 (II ⁺⁻²); <i>Epipactis palustris</i> 2 (I ⁺); <i>Menyanthes trifoliata</i> 2 (I ⁺⁻³); <i>Viola palustris</i> 2 (I ⁺⁻¹).					
Ch. <i>Oxycocco-Sphagnetea</i> :					
<i>Eriophorum vaginatum</i>	+	I ⁺⁻²	III ¹⁻²	.	2 ⁺⁻¹
<i>Sphagnum fallax</i> d	2	V ¹⁻⁵	IV ²⁻⁴	2 ¹⁻²	.
<i>Drosera rotundifolia</i>	.	IV ⁺⁻¹	V ⁺⁻¹	3 ⁺⁻¹	.
<i>Oxycoccus palustris</i>	.	V ²⁻³	IV ¹⁻³	3 ¹⁻²	.
<i>Sphagnum magellanicum</i> d	.	III ⁺⁻³	II ¹⁻²	1 ²	.
<i>Sphagnum capillifolium</i> d	.	I ⁺	I ¹	.	2 ³
<i>Andromeda polifolia</i>	.	V ⁺⁻²	.	2 ¹	.
<i>Polytrichum strictum</i> d	.	V ⁺⁻²	I ¹	.	.
<i>Sphagnum rubellum</i> d	.	I ⁺	I ¹	.	.
Sporadic species: <i>Aulacomnium palustre</i> d 2 (III ⁺⁻²); <i>Pohlia sphagnicola</i> d 2 (II ⁺); <i>Sphagnum cuspidatum</i> d 2 (V ²⁻⁵); <i>Betula nana</i> 3 (III ¹⁻³).					

Ch. <i>Phragmitetea</i> :					
<i>Carex rostrata</i>	+	II ^{+·2}	II ^{+·1}	.	2 ¹
<i>Lysimachia thyrsoiflora</i>	.	I ⁺	.	.	1 ¹
Sporadic species: <i>Carex vesicariae</i> 2 (I ^{1·2}); <i>Equisetum fluviatile</i> 2 (I ⁺); <i>Peucedanum palustre</i> 2 (III ^{+·2}); <i>Phragmites australis</i> 2 (II ^{+·5}); <i>Carex elata</i> 5 (1 ¹); <i>Galium palustre</i> 5 (1 ⁺).					
Others:					
<i>Betula pendula</i> c	1	IV ^{+·2}	.	.	1 ⁺
<i>Juncus effusus</i>	1	I ⁺	.	.	1 ¹
<i>Picea abies</i> c	.	I ⁺	I ¹	1 ¹	.
<i>Pinus sylvestris</i> c	1	V ^{+·2}	.	.	2 ^{+·1}
<i>Polytrichum commune</i> d	.	III ^{+·1}	.	1 ¹	1 ⁺
<i>Sphagnum palustre</i> d	.	IV ^{+·3}	I ⁺	2 ^{2·3}	.
<i>Calluna vulgaris</i>	.	IV ^{+·2}	I ¹	.	.
<i>Pinus mugo</i> c	.	.	II ^{+·1}	1 ¹	.
<i>Vaccinium uliginosum</i>	.	V ^{+·1}	I ⁺	.	.
Sporadic species: <i>Cladonia</i> sp. 1 (1); <i>Molinia caerulea</i> 1 (1); <i>Quercus robur</i> c 1 (1); <i>Alnus glutinosa</i> c 2 (I ⁺); <i>Betula pubescens</i> c 2 (V ^{+·3}); <i>Calamagrostis canescens</i> 2 (I ⁺); <i>Drepanocladus revolvens</i> d 2 (I ⁺); <i>Dryopteris cristata</i> 2 (II ⁺); <i>Epilobium palustre</i> 2 (I ⁺); <i>Frangula alnus</i> c 2 (I ⁺); <i>Ledum palustre</i> 2 (II ^{+·2}); <i>Lysimachia vulgaris</i> 2 (III ^{+·2}); <i>Lythrum salicaria</i> 2 (I ⁺); <i>Pleurozium schreberi</i> d 2 (I ⁺); <i>Populus tremula</i> c 2 (III ⁺); <i>Potentilla erecta</i> 2 (I ^{+·1}); <i>Salix cinerea</i> c 2 (V ^{+·1}); <i>Salix myrtilloides</i> 2 (II ^{+·2}); <i>Vaccinium vitis-idaea</i> 2 (I ⁺).					

Explanations: B.Ł. – Białe Ługi mire; Koł. – Kołowin mire; Ziel. – Zieleniec mire; I-V – constancy; ^{+·5} – quantitation

The phytocoenoses of *Carici-Agrostietum caninae* – one of the most common associations of the *Scheuchzerio-Caricetea fuscae* class - have been seldom encountered in the study sites. Small patches of the association with dominant *Carex nigra* were found only on the edges of the Kołowin Mire. They feature a well developed moss layer and a relatively species-rich and diversified herb layer.

In the northern part of the Linje Mire, the vegetation that colonises peat workings is composed of a mosaic of plants including *Junco effusi-Sphagnetum recurvi* phytocoenoses. This community, described so far mainly in Lubelszczyzna (FIJAŁKOWSKI 1991), is one of the regeneration stages of the destroyed raised mires.

Sphagnetum magellanicum is one of the most frequently described associations of the raised bogs in our country. Most of the information about this association comes from the studies on the vegetation cover of the West-Pomeranian Lakeland, Mazurian Lakeland and Suwalskie Lakeland, as well as of Lubelszczyzna. This syn-taxon features high internal diversity. 6 sub-associations have been described so far within *Sphagnetum magellanicum* (KUCHARSKI, KOPEĆ 2005). Among the study sites, it has been recorded in the vegetation of Suche Bagno, Zieleniec and Białe Ługi. The phytocoenoses of *Sphagnetum magellanicum pinetosum* dominate in the wetlands of Suche Bagno and Białe Ługi. *Sphagnetum magellanicum typicum* can be found in the Zieleniec Mire.

Eriophorum vaginatum-Sphagnum fallax [= *Eriophoro vaginati-Sphagnetum recurvi*] is the most frequently recorded raised bog community in our country. It is made up of *Eriophorum vaginatum* and *Sphagnum fallax*. In extreme cases, it is nearly a single-species facies of *Eriophorum vaginatum*, with a small share of *Sphagnum* mosses (Suche Bagno). The community develops in the regenerating raised bogs. It is also one of the stages of the primary succession developing into *Sphagnetum magellanicum*. Moreover, in the raised bogs utilised commercially, it can be of anthropogenic nature. It is the main raised-bog community among the vegetation of the studied lowland mires (Rąbień, Długie Bagno, Kołowin). No presence of the *Sphagnum magellanicum* in patches of the associations has been found at these sites.

The phytocoenoses of *Pino mugo-Sphagnetum* feature a loose layer of low trees or shrubs of the *Pinus* genus. This association has been described so far only in the Sudety Mountains (POTOCKA 1997, 2001; MATUSZKIEWICZ 2001). Among the mires under study, phytocoenoses of *Pino mugo-Sphagnetum* have been recorded only in the Zieleniec Mire. They have a well developed shrub layer composed mainly of *Pinus mugo* and some rare specimens of *Pinus x rhaetica*. The herb layer is poor in species. The community comprises species characteristic for forests and raised mires.

Ledo-Sphagnetum magellanicum is another raised-bog community with a well developed layer of low trees and shrubs. In the phytocoenoses of *Ledo-Sphagnetum magellanicum*, in the tree-shrub layer, *Pinus sylvestris* and *Betula pubescens* dominate. Under their canopy, *Ledum palustre* occurs on a mass scale. The patches of the association do not form hummocks. The association's phytocoenoses resemble patches of the *Vaccinio uliginosi-Pinetum* bog coniferous forest, however, with regard to floristic composition, species characteristic for the *Oxycocco-Sphagnetea* class distinctly dominate over conifers. In Poland, it has been described so far in the northeastern and eastern part of the country (LORENS 1987; FIJAŁKOWSKI 1991; KLOSS 1996; SUGER, POPIOŁEK 1998; MICHALIK 1998; PISAREK, POLAKOWSKI 2001). Among the surveyed mires, patches of the described association have been found in the following mires: Suche Bagno, Linje and Białe Ługi. The best developed

Table 2

Differentiation of associations and plant communities of *Oxycocco-Sphagnetea* classA – *Sphagno-Caricetum pauciflorae* Klika et Šmarda 1946B – *Sphagnetum magellanici* (Malc. 1929) Kästner et Flössner 1933C – Community *Eriophorum vaginatum-Sphagnum fallax* Hueck 1928 pro ass.D – *Ledo-Sphagnetum magellanici* Sukopp 1959 em. Neuhäusl 1969E – *Pino mugo-Sphagnetum* Kästner et Flössner 1933 em. Neuhäusl 1969 corr. Dierss. 1975

Successive No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Name of mire	Ziel.	S.B.	Ziel.	Koř.	Lin.	D.B.	Rař.	S.B.	Koř.	Lin.	B.L.	S.B.	Ziel.
Numbers of relevés	2	3	4	5	3	3	7	2	2	7	13	7	9
Numbers of species in relevé	8-10	10-11	6-9	8-15	5-7	8-11	7-19	6-7	8-7	6-11	12-22	7-14	8-14
Numbers of species in plant community	12	14	15	27	10	14	33	8	15	14	36	15	34
Syntaxonomic unit	A	B	B	B	C	C	C	C	C	D	D	D	E
Ch. <i>Oxycocco-Sphagnetea</i> :													
<i>Pinus x rhaetica</i> a	.	.	.	.	.	.	.	.	.	.	.	.	I ¹
<i>Pinus mugo</i> b	.	.	.	.	.	.	.	.	.	.	.	.	V ¹⁻³
<i>Pinus mugo</i> c	1 ¹	.	2 ¹	.	.	.	.	.	.	.	.	.	
<i>Eriophorum vaginatum</i>	2 ¹	3 ²	4 ³⁻⁴	V ³⁻⁴	3 ¹⁻⁴	3 ⁵	V ²⁻³	2 ⁵	2 ⁴⁻⁵	V ¹⁻³	V ¹⁻⁴	V ¹⁻²	IV ¹⁻⁴
<i>Sphagnum fallax</i> d	.	3 ¹⁻²	2 ²⁻³	III ²⁻³	3 ³⁻⁴	3 ³	III ²⁻³	2 ¹⁻²	2 ²	V ³⁻⁴	V ³⁻⁵	III ¹⁻²	II ²⁻³
<i>Oxycoccus palustris</i>	.	2 ¹⁻²	4 ¹⁻²	III ²	3 ²⁻³	.	V ⁺⁻³	1 ⁺	2 ²	V ¹⁻³	V ²⁻³	V ¹⁻²	V ²⁻³
<i>Polytrichum strictum</i> d	.	1 ¹	2 ¹	II ¹	.	1 ⁺	.	2 ¹⁻²	1 ¹	.	V ¹⁻²	V ¹⁻²	III ²
<i>Andromeda polifolia</i>	1 ¹	3 ²	4 ¹⁻²	I ⁺	.	.	.	.	.	IV ⁺⁻¹	V ⁺⁻²	V ⁺⁻²	III ⁺⁻²
<i>Drosera rotundifolia</i>	1 ⁺	3 ⁺	3 ⁺⁻²	.	.	.	I ²	.	.	I ⁺	I ⁺	.	I ⁺⁻²
<i>Ledum palustre</i>	.	3 ¹	.	III ¹	.	1 ⁺	I ⁺	.	.	V ¹⁻³	V ⁺⁻⁴	V ²⁻⁴	.
<i>Sphagnum magellanicum</i> d	.	3 ³	4 ²⁻³	II ⁺⁻¹	.	.	.	.	.	.	V ¹⁻⁴	III ²⁻⁴	I ¹
<i>Aulacomnium palustre</i> d	.	.	.	III ¹	.	2 ⁺⁻¹	I ¹	.	.	.	IV ⁺⁻¹	.	I ¹
<i>Sphagnum capillifolium</i> d	.	.	1 ³	I ¹	.	.	I ⁺	.	.	.	II ⁺	.	II ¹⁻³
<i>Carex pauciflora</i>	2 ³	.	2 ⁺⁻¹	.	.	.	.	.	.	2 ⁺⁻¹	.	.	I ⁺⁻¹
<i>Betula nana</i>	1 ⁺	.	1 ⁺	.	.	.	.	.	.	V ¹⁻³	.	.	.
Sporadic species: <i>Sphagnum fuscum</i> d 2 (I ²); <i>Chamaedaphne calyculata</i> 4 (III ¹⁻³); 9 (I ¹); <i>Pohlia sphagnicola</i> d 11 (I ⁺); <i>Cephalozia connivens</i> d 13 (I ¹); <i>Sphagnum rubellum</i> d 13 (I ¹)													

Ch. <i>Scheuchzeria- Caricetea nigrae</i> :													
<i>Eriophorum angustifolium</i>	.	.	.	.	2 ¹⁻²	3 ⁺	V ²⁻³	.	.	IV ⁺¹	III ⁺²	.	III ⁺³
<i>Carex nigra</i>	.	.	.	.	.	1 ⁺	.	1 ¹	.	.	V ¹⁻⁴	.	I ¹
<i>Drepanocladus aduncus</i> d	.	.	.	III ⁺¹	.	.	I ¹	.	1 ¹	.	.	.	.
Sporadic species: <i>Carex limosa</i> 1 (1 ¹); <i>Calamagrostis stricta</i> 4 (I ¹), 9 (1 ⁺); <i>Straminergon stramineum</i> d 4 (I ¹); <i>Carex lasiocarpa</i> 5 (1 ⁺), 10 (II ⁺¹); <i>Carex canescens</i> 7 (III ⁺¹), 13 (I ⁺³); <i>Comarum palustre</i> 7 (I ⁺); <i>Warnstorfia fluitans</i> d 7 (I ¹); <i>Carex echinata</i> 13 (I ¹)													
Ch. <i>Phragmitetea</i> :													
<i>Lysimachia thyrsiflora</i>	.	.	.	I ⁺	.	.	I ⁺	.	.	.	.	.	.
<i>Phragmites australis</i>	.	.	.	.	.	.	II ¹⁻²	.	.	.	II ⁺⁴	.	.
<i>Carex rostrata</i>	.	.	.	.	1 ³	.	.	.	1 ¹	.	.	.	.
<i>Peucedanum palustre</i>	.	.	.	.	.	.	I ⁺	.	.	.	.	.	.
Others:													
<i>Pinus sylvestris</i> a	.	3 ⁺¹	.	.	.	.	.	.	.	V ⁺²	V ¹⁻⁴	V ¹⁻³	.
<i>Pinus sylvestris</i> b	.	.	.	.	.	.	III ⁺¹	.	.	.	.	.	.
<i>Pinus sylvestris</i> c	.	.	.	II ⁺	2 ⁺¹	2 ⁺	.	2 ¹	2 ⁺	.	.	.	.
<i>Quercus robur</i> c	.	.	.	I ⁺	1 ¹	1 ⁺	I ¹	.	.	.	I ⁺	.	.
<i>Betula pubescens</i> a	.	.	.	.	1 ¹	3 ⁺²	V ⁺²	.	.	I ⁺¹	.	.	.
<i>Betula pubescens</i> b	.	.	.	.	.	.	.	.	.	.	III ⁺²	.	I ¹
<i>Betula pubescens</i> c	1 ⁺	.	.	.	.	.	.	2 ⁺¹	.	.	.	.	.
<i>Betula pendula</i> a	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Betula pendula</i> b	.	.	.	V ⁺¹	.	.	III ¹	.	1 ¹	.	III ⁺²	.	.
<i>Betula pendula</i> c	.	.	.	.	1 ¹	.	.	.	.	.	.	.	.
<i>Picea abies</i> b	.	.	.	.	.	.	.	.	.	.	.	.	III ⁺²
<i>Picea abies</i> c	.	.	1 ⁺	V ⁺	.	.	.	1 ⁺	.	.	.	.	.
<i>Salix cinerea</i> b	.	.	.	.	.	.	II ⁺¹	.	.	.	I ⁺¹	.	.
<i>Salix cinerea</i> c	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Populus tremula</i> a	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Populus tremula</i> b	.	.	.	.	.	.	.	.	.	.	II ⁺	.	.
<i>Populus tremula</i> c	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Quercus petraea</i> c	.	.	.	.	.	.	.	.	.	.	I ⁺	.	.
<i>Quercus rubra</i> c	.	.	.	.	.	.	I ¹	.	.	.	.	.	.
<i>Vaccinium uliginosum</i>	2 ¹⁻²	2 ⁺¹	2 ⁺²	I ⁺	.	.	.	.	1 ⁺	I ¹	V ⁺²	IV ¹⁻⁴	V ¹⁻²

<i>Calluna vulgaris</i>	2 ¹	3 ²⁻³	3 ¹	.	.	.	IV ⁺²	.	.	.	V ⁺²	V ⁺¹	IV ⁺²
<i>Polytrichum commune</i> d	.	.	2 ¹	I ¹	.	.	II ²	.	2 ¹⁻²	.	III ⁺²	.	I ¹⁻²
<i>Vaccinium myrtillus</i>	.	.	.	I ⁺	.	.	I ¹	.	.	.	I ⁺	V ⁺²	IV ¹⁻³
<i>Pleurozium schreberi</i> d	.	.	.	III ¹⁻²	.	.	.	.	.	.	III ⁺¹	II ²	I ⁺¹
<i>Polytrichastrum formosum</i> d	.	.	.	I ¹	.	.	I ¹	.	1 ¹	.	.	I ¹	I ²⁻³
<i>Juncus effusus</i>	.	.	.	.	.	1 ⁺	.	.	.	.	I ⁺	.	I ⁺²
<i>Sphagnum fimbriatum</i> d	.	.	.	.	.	.	II ¹⁻²	.	.	.	I ⁺	.	I ⁺
<i>Sphagnum palustre</i> d	.	.	.	I ²	.	.	.	.	.	.	IV ⁺²	.	I ¹
<i>Pohlia nutans</i> d	.	.	.	III ⁺¹	.	.	.	.	1 ⁺	.	.	I ¹	.

Sporadic species: *Dicranum polysetum* d 2 (I¹), 12 (II¹⁻²); *Cladonia* sp. 4 (II⁺¹), 9 (I¹); *Polytrichastrum longisetum* d 4 (II⁺¹), 9 (II⁺¹); *Frangula alnus* c 6 (2⁺), 11 (I⁺); *Dryopteris carthusiana* 6 (3⁺); *Calla palustris* 7 (V⁺²); *Epilobium palustre* 7 (I⁺); *Lycopus europaeus* 7 (I⁺); *Molinia caerulea* 10 (I⁺), 13 (I¹); *Cladonia coniocera* d 11 (I⁺); *Cladonia fimbriata* d 11 (I⁺); *Cladonia macilenta* d 11 (I⁺); *Drepanocladus revolvens* d 11 (I⁺); *Sphagnum warnstorffii* d 11 (I⁺); *Vaccinium vitis-idaea* 11 (I⁺); *Cephalozia bicuspidata* d 11 (II⁺); *Dicranum bonjeanii* d 13 (I²); *Deschampsia flexuosa* 13 (I¹); *Tetraphis pellucida* d 13 (I¹)

Explanations: B.Ł. – Białe Ługi mire; D.B. – Długie Bagno mire; Koł. – Kołowin mire;
 Lin. – Linie mire; Rąb. – Rąbień mire; S.B. – Suche Bagno mire; Ziel. – Zieleniec mire;
 I-V – constancy; ⁺-⁵ – quantitation

phytocoenoses occur in the wetlands of Suche Bagno and Białe Ługi. Regression of this community has been observed in the Linje reserve.

Communities of the *Alnetea glutinosae* class (Table 3)

The floristically-poor osiers of *Salix cinerea* occur in the Rąbień Mire. The community resembles *Salicetum pentandro-cinereae*. The phytocoenoses of thicket develop in the exploited part of the mire. They usually colonize the shallowed peat pits. In their succession, they develop into *Sphagno squarrosi-Alnetum*.

Phytocoenoses of *Sphagno squarrosi-Alnetum* have been found in the mires of Kołowin, Rąbień and Białe Ługi. Patches of the transitional community between peatmoss alder carr and bog coniferous forest have been recorded also in the Długie Bagno Mire. The described alder carr features a poorly developed hummock structure of the forest floor vegetation and the presence, in its patches, of the species typical for transitional and raised bogs. The best developed phytocoenoses of the peatmoss alder wood have been observed in Białe Ługi and Kołowin

Table 3

Differentiation of associations of the classes *Vaccinio-Piceetea* and *Alnetea glutinosae*A – *Salicetum pentandro-cinereae* (Almq. 1929) Pass. 1961B – *Vaccinio uliginosi-Pinetum* Kleist 1929C – *Sphagno squarrosi-Alnetum* Sol.-Gór. (1975) 1987

Succesive No.	1	2	3	4	5	6	7
Name of mire	Rąb.	D.B.	Rąb.	B.Ł.	Rąb.	Lin.	B.Ł.
Numbers of relevés	3	4	8	20	4	2	5
Numbers of species in relevé	12-19	10-20	13-25	17-28	18-34	11-15	29-51
Numbers of species in plant community	26	31	45	46	71	18	79
Syntaxonomic unit	A	B	B	B	C	C	C
Trees and shrubs:							
<i>Pinus sylvestris</i> a	1 ¹	4 ⁺³			1 ¹	.	III ⁺²
<i>Pinus sylvestris</i> b	.	.	V ⁺²	V ⁺⁴	.	.	.
<i>Pinus sylvestris</i> c	.	.			.	.	.
<i>Betula pendula</i> a	.	.	V ¹⁻³		4 ¹⁻²	.	.
<i>Betula pendula</i> b	3 ⁺²	3 ⁺¹	V ¹⁻³	II ⁺¹	.	.	.
<i>Betula pendula</i> c	.	.	II ¹		.	.	.
<i>Betula pubescens</i> a	.	4 ⁺⁴	III ¹⁻²		1 ¹	2 ⁺²	IV ⁺²
<i>Betula pubescens</i> b	.	.	II ¹	V ⁺³	1 ¹		
<i>Betula pubescens</i> c	.	.	IV ⁺¹		.	.	
<i>Quercus robur</i> a	.	.	I ¹	II ⁺	1 ¹	.	.
<i>Quercus robur</i> b	.	.	I ¹		2 ⁺¹	.	I ⁺
<i>Alnus glutinosa</i> a	.	.	.	.	2 ¹		V ⁺⁴
<i>Alnus glutinosa</i> b	.	.	.	.	4 ¹⁻²	2 ²⁻³	
<i>Alnus glutinosa</i> c	.	.	.	.	4 ¹⁻²		
<i>Fagus sylvatica</i> c	.	.	.	I ⁺	.	.	I ⁺
<i>Abies alba</i> c	.	.	.	I ⁺	.	.	I ⁺
<i>Populus tremula</i> a	.	.	.		2 ¹	.	.
<i>Populus tremula</i> b	.	.	.	I ⁺	.	.	.
<i>Populus tremula</i> c	.	.	.		1 ²	.	.
<i>Quercus petraea</i> b	.	.	.	II ⁺	.	.	.
<i>Quercus petraea</i> c	.	.	.		.	.	I ⁺
<i>Picea abies</i> a	.	.	.		.	.	IV ⁺²
<i>Picea abies</i> b	.	.	.	II ⁺¹	.	.	
<i>Picea abies</i> c	.	.	.		.	.	
<i>Quercus rubra</i> a	.	.	I ¹	.	.	.	.
<i>Quercus rubra</i> b	.	.	.	.	1 ¹	.	.
<i>Quercus rubra</i> c	.	.	II ⁺	.	3 ⁺¹	.	.
<i>Salix cinerea</i> b	3 ³⁻⁵	.	II ¹	III ⁺³	4 ¹	2 ⁺²	III ⁺³
<i>Salix cinerea</i> c	.	.	II ⁺¹		4 ¹		

<i>Frangula alnus</i> b	3 ¹⁻²	2 ⁺³	II ¹	I ⁺¹	4 ¹⁻³	2 ⁺¹	V ⁺³
<i>Frangula alnus</i> c	.	.	I ¹		2 ¹⁻²		.
<i>Sorbus aucuparia</i> b	.	.	.	I ⁺¹	4 ¹	.	II ⁺
<i>Sorbus aucuparia</i> c	.	1 ¹	I ⁺		2 ⁺¹	.	
<i>Acer pseudoplatanus</i> c	.	.	.	.	1 ⁺	.	.
<i>Crataegus monogyna</i> b	.	.	.	.	1 ⁺	.	.
<i>Juniperus communis</i> b	.	.	.	I ⁺	1 ⁺	.	II ⁺
<i>Ribes spicatum</i> c	.	.	.	.	1 ⁺	.	.
<i>Ribes nigrum</i> b	.	.	.	.	1 ¹	.	.
<i>Ribes nigrum</i> c	.	.	.	.	1 ⁺	.	.
<i>Rubus idaeus</i> c	.	1 ⁺	.	I ¹	.	.	.
<i>Viburnum opulus</i> c	.	.	.	.	1 ⁺	.	.
Ch <i>Vaccinio-Piceetea</i> :							
<i>Vaccinium myrtillus</i>	1 ⁺	3 ⁺³	V ⁺³	IV ⁺⁴	3 ¹	.	V ⁺¹
<i>Vaccinium vitis-idaea</i>	.	2 ⁺²	.	IV ⁺¹	1 ⁺	.	I ¹
<i>Dicranum polysetum</i> d	.	1 ³	.	II ⁺¹	.	.	I ⁺
<i>Dicranum scoparium</i> d	.	.	I ²	.	1 ¹	.	I ⁺
<i>Ledum palustre</i>	.	4 ⁺¹	IV ¹⁻²	V ⁺⁴	.	.	.
<i>Pleurozium schreberi</i> d	.	2 ¹⁻³	.	V ⁺⁴	.	.	I ⁺
<i>Vaccinium uliginosum</i>	1 ¹	.	V ¹⁻³	V ⁺⁴	.	.	.
Sporadic species: <i>Trientalis europaea</i> 2 (1 ¹); <i>Calamagrostis villosa</i> 4 (I ¹⁻⁴), 7 (II ⁺¹); <i>Lycopodium annotinum</i> 4 (I ⁺), 7 (I ⁺); <i>Hylocomnium splendens</i> d 4 (I ⁺²); <i>Melampyrum pratense</i> 4 (II ⁺); <i>Ptilium crista-castrensis</i> d 4 (I ⁺); <i>Sphagnum girgensohnii</i> d 7 (III ⁺³); <i>Thuidium tamariscinum</i> d 7 (II ⁺).							
Ch. <i>Alnetea glutinosae</i> :							
<i>Sphagnum squarrosum</i> d	1 ²	.	I ²	I ⁺	3 ²	2 ²	V ¹⁻³
<i>Carex elongata</i>	.	.	I ¹	.	4 ¹⁻³	1 ¹	III ⁺²
<i>Lycopus europaeus</i>	1 ¹	.	I ⁺	.	3 ¹⁻³	2 ⁺¹	.
<i>Solanum dulcamara</i>	1 ¹	.	.	.	4 ¹⁻²	2 ⁺¹	.
Sporadic species: <i>Calamagrostis canescens</i> 5 (1 ¹); <i>Dryopteris cristata</i> 7 (II ⁺¹); <i>Thelypteris palustris</i> 7 (III ¹⁻²).							
Ch. <i>Oxycocco-Sphagnetes</i> :							
<i>Sphagnum fallax</i> d	2 ²⁻³	4 ⁺⁵	V ²⁻⁴	V ³⁻⁵	.	2 ²⁻³	III ²⁻³
<i>Aulacomnium palustre</i> d	.	1 ⁺	I ²	IV ⁺²	1 ⁺	.	I ⁺
<i>Oxycoccus palustris</i>	1 ⁺	1 ⁺	V ¹⁻³	V ⁺³	.	2 ⁺	.
<i>Eriophorum vaginatum</i>	.	4 ²⁻⁴	V ²⁻³	V ⁺²	.	1 ¹	.
<i>Sphagnum capillifolium</i> d	.	1 ⁺	.	I ⁺²	.	.	I ³

Sporadic species: *Polytrichum strictum* d 2 (1⁺), 4 (II⁺¹); *Andromeda polifolia* 3(I⁺), 4 (III⁺¹); *Drosera rotundifolia* 3 (I¹), 4 (I⁺); *Sphagnum magellanicum* d 4 (IV⁺⁴), 7 (I¹); *Sphagnum rubellum* d 4 (I⁺²).

Ch. Scheuchzerio-Caricetea nigrae:

<i>Carex nigra</i>	.	1 ⁺	I ⁺	V ⁺⁴	1 ¹	.	IV ⁺³
<i>Eriophorum angustifolium</i>	2 ¹⁻³	1 ¹	V ¹⁻²	II ⁺¹	.	1 ¹	.
<i>Comarum palustre</i>	2 ¹⁻²	.	I ⁺	.	1 ⁺	.	II ⁺¹
<i>Carex canescens</i>	2 ¹	.	III ¹⁻²	.	.	.	III ⁺¹
<i>Sphagnum cuspidatum</i> d	.	.	I ²	I ⁺	.	.	III ²

Sporadic species: *Drepanocladus aduncus* d 2 (1⁺); *Agrostis canina* 3 (I¹), 5 (2¹⁻²); *Carex echinata* 4 (I¹), 7 (I⁺); *Carex lasiocarpa* 4 (I³), 6 (2¹); *Viola palustris* 5 (3¹⁻²), 7 (IV⁺²); *Menyanthes trifoliata* 7 (II¹⁻²).

Ch. Phragmitetea:

<i>Phragmites australis</i>	2 ¹	.	IV ⁺¹	II ⁺⁴	4 ⁺¹	.	III ⁺²
<i>Carex rostrata</i>	2 ¹⁻²	.	I ²	.	.	2 ¹⁻²	I ⁺
<i>Peucedanum palustre</i>	3 ⁺¹	.	II ⁺¹	.	4 ¹⁻²	.	V ⁺¹
<i>Equisetum fluviatile</i>	1 ¹	.	.	.	.	1 ²	IV ⁺¹
<i>Galium palustre</i>	2 ⁺¹	.	.	.	4 ¹⁻²	.	II ⁺

Sporadic species: *Typha latifoliae* 1 (1¹); *Carex gracilis* 3 (I¹); *Carex pseudocyperus* 5 (4⁺¹), 7 (II⁺); *Glyceria fluitans* 5 (2¹), 7 (IV⁺); *Scutellaria galericulata* 5 (3⁺¹), 7 (II⁺); *Carex acutiformis* 7 (II¹⁻³); *Carex elata* 7 (I⁺); *Cicuta virosa* 7 (I⁺).

Others:

<i>Juncus effusus</i>	3 ¹⁻²	.	I ¹	II ⁺	1 ¹	2 ¹	.
<i>Lysimachia vulgaris</i>	3 ¹⁻²	.	I ¹	I ²	2 ¹⁻²	.	IV ¹⁻²
<i>Polytrichum commune</i> d	.	3 ⁺²	I ¹	V ⁺³	.	1 ¹	I ⁺
<i>Calla palustris</i>	2 ¹⁻²	.	II ¹⁻²	.	1 ¹	.	III ²⁻⁴
<i>Dryopteris carthusiana</i>	.	2 ⁺	.	I ⁺	4 ⁺	.	IV ⁺¹
<i>Equisetum palustre</i>	.	.	.	I ⁺¹	2 ⁺	2 ¹	II ⁺¹
<i>Pohlia nutans</i> d	.	3 ⁺¹	II ¹	.	1 ⁺	.	III ⁺
<i>Calliergonella cuspidata</i> d	2 ⁺²	.	.	.	1 ¹	.	II ⁺¹
<i>Calluna vulgaris</i>	2 ⁺	.	V ⁺²	V ⁺¹	.	.	.
<i>Lythrum salicaria</i>	3 ⁺¹	.	I ¹	.	3 ⁺²	.	.
<i>Plagiothecium denticulatum</i> d	.	.	I ¹	.	1 ⁺	.	II ⁺
<i>Polytrichastrum formosum</i> d	.	.	II ¹	.	1 ¹	.	II ⁺¹
<i>Sphagnum fimbriatum</i> d	.	1 ⁺	III ¹	.	4 ⁺¹	.	.

Sporadic species: *Epilobium palustre* 1 (3⁺¹), 3 (II⁺²); *Brachythecium curtum* d 2 (1¹); *Cladonia chlorophaea* d 2 (1⁺); *Cladonia cornuta* d 2 (1⁺); *Holcus lanatus* 2 (2⁺), 3 (1⁺); *Molinia caerulea* 2 (1⁺), 4 (III⁺²); *Lophocolea heterophylla* d 3 (1⁺); *Potentilla erecta* 4 (1⁺), 5 (1⁺); *Sphagnum palustre* d 4 (IV⁺²), 7 (IV⁺³); *Dactylorhiza maculata* 4 (1⁺); *Luzula pilosa* 4 (1⁺); *Poa pratensis* 4 (1⁺); *Sphagnum warnstorffii* d 4 (1⁺); *Aulacomnium androgynum* d 5 (1⁺), 7 (1⁺); *Climacium dendroides* d 5 (1⁺), 7 (1⁺); *Plagiomnium affine* d 5 (1⁺), 7 (III⁺); *Bidens cernua* 5 (1⁺); *Bidens tripartita* 5 (2¹); *Brachythecium rutabulum* d 5 (3⁺¹); *Brachythecium salebrosum* d 5 (2⁺); *Calliergon cordifolium* d 5 (2⁺); *Cardamine pratense* 5 (1¹); *Cirsium palustre* 5 (2¹); *Deschampsia caespitosa* 5 (3¹⁻³); *Geum urbanum* 5 (1¹); *Impatiens parviflora* 5 (1⁺); *Majanthemum bifolium* 5 (1⁺); *Ranunculus repens* 5 (2⁺); *Rhizomnium punctatum* d 5 2⁺¹); *Rubus idaeus* 5 (2¹⁻²); *Urtica dioica* 5 (1¹); *Viola sylvestris* 5 (1⁺); *Athyrium filix-femina* 7 (1⁺); *Atrichum undulatum* d 7 (1⁺); *Calypogeia trichomanis* d 7 (II⁺); *Cephalozia fluitans* d 7 (1⁺); *Dicranella heteromalla* d 7 (II⁺); *Drepanocladus revolvens* d 7 (1⁺); *Dryopteris filix-mas* 7 (1⁺); *Haplozia lanceolata* d 7 (1⁺); *Hypnum cupressiforme* d 7 (III⁺); *Lepidozia reptans* d 7 (II⁺); *Lophocolea bidentata* d 7 (III⁺); *Mnium hornum* d 7 (II⁺¹); *Pellia epiphylla* d 7 (1⁺); *Plagiochila asplenoides* d 7 (II⁺); *Plagiomnium cuspidatum* d 7 (II⁺); *Plagiomnium undulatum* d 7 (1⁺); *Plagiothecium laetum* d 7 (1⁺); *Plagiothecium nemorale* d 7 (II⁺¹); *Scirpus sylvaticus* 7 (1⁺); *Tetraphis pellucida* d 7 (V⁺).

Explanations: Rąb – Rąbień mire; D.B. – Długie Bagno mire; B.Ł. – Białe Ługi mire; Lin. – Linje mire; I-V – constancy; ⁺, ⁻, ⁺⁻ – quantitation

mires. The alder wood habitat in the Torfowisko Rąbień reserve has undergone eutrophication. Therefore, part of the patches resembles *Ribeso nigri-Alnetum*.

Community of the *Vaccinio-Piceetea* class (Table 3)

Sphagno-Piceetum is a widespread community in the Izerskie Mountains (POTOCKA 1997). Phytocoenoses of this community have been ascertained also on the edges of the Zieleniec Mire. They represent the final stage of plant succession at this site, replacing the phytocoenoses of *Pino mugo-Sphagnetum*.

Vaccinio uliginosi-Pinetum is the most important forest community occurring at the study sites. Patches of bog coniferous forest have been found in all lowland raised mires where palaeobotanical studies have been carried out. The largest areas of well developed phytocoenoses of *Vaccinio uliginosi-Pinetum* have been recorded in the mires of Białe Ługi and Rąbień. At the remaining mires, forest community patches with abundant *Betula pubescens* have been reported. It is one of the successional phases developing into a bog coniferous forest.

4. STATUS OF RAISED MIRE VEGETATION

The ecosystems of raised mires are very sensitive to synantropization. Among the study sites, natural bogs, as well as those which have been transformed as a result

of man's commercial activity can be distinguished. The least transformed mires include Zieleniec and Suche Bagno. Their common feature is poor flora diversity. The belt-type vegetation arrangement is a characteristic feature of the undisturbed raised bogs (KULCZYŃSKI 1939/1940). At such sites, a bog edge is formed with the communities of the *Scheuchzerio-Caricetea fuscae* class and the *Magnocaricion* alliance. The center of the mire is occupied by the phytocoenoses of the *Oxycocco-Sphagnetum* class.

The Torfowisko Rąbień reserve has the most transformed vegetation cover. Increased flora and vegetation richness is the result of synatropization of the oligotrophic raised mires. Plants typical for eutrophic habitats and anthropophytes have appeared. The old pits left after peat extraction are colonized by reed vegetation – *Phragmitetum australis*, *Typhetum angustifoliae* and more seldom – by *Equisetum fluviatilis*. In the shallowed peat extraction pits, patches of *Caricetum rostratae*, *Caricetum vesicariae* and *Junco effusi-Sphagnetum* develop. In drained wetlands, *Phragmites australis* appears in the raised mire communities. This expansive species pushes the communities typical for raised mires out of the habitats which they colonize. At the drained sites, acceleration of plant succession developing into *Vaccinio uliginosi-Pinetum* (Długie Bagno) is being observed.

The raised mires under study can be divided into three groups. The first one includes wetlands whose vegetation has undergone minor transformations as a result of human interference. These are the mires of Zieleniec and Suche Bagno. Wetlands with apparent traces of man's commercial activity include Linje, Długie Bagno, Kołowin and Białe Ługi. The vegetation of these peatbogs is undergoing regeneration. The Rąbień Mire belongs to a group of sites with strongly transformed vegetation. The raised-mire vegetation patches have survived only in the central, least damaged part of the present reserve.

5. RECAPITULATION

Raised mires are among the rare components of Poland's vegetation cover. The most typical ecosystems of this type occur in the areas with excess of precipitation over evaporation in a yearly cycle, that is, in the northern part of the country and in the mountains.

Precious plant species of Polish flora have been found at the sites under review. They include *Betula nana* (Linje, Zieleniec), *Chamaedaphne calyculata* (Kołowin), *Oxycoccus microcarpos* (Suche Bagno), *Salix myrtilloides* (Białe Ługi) and *Pinus x rhaetica* (Zieleniec). The vegetation of these mires is composed of the phytocoenoses of 21 plant associations and communities belonging to 5 phytosociological classes. The most precious include patches of *Caricetum limosae*, *Sphagnetum magellanicum*, *Pino mugo-Sphagnetum*, *Ledo-Sphagnetum magellanicum* and *Sphagno-Caricetum pauciflorae*.

The raised mire ecosystems are very sensitive to synanthropization. Among the study sites, natural peatbogs and those transformed as a result of man's commercial activity can be distinguished. The least transformed mires include Zieleniec and Suche Bagno. They feature minor flora diversity and undisturbed, belt-type vegetation arrangement. The wetlands with visible effects of man's commercial activity include Linje, Długie Bagno, Kołowin and Białe Ługi. The vegetation of these mires is subject to regeneration. The Torfowisko Rąbień reserve has the least transformed vegetation cover. The patches of natural, raised-mire vegetation have survived there only in the central, least destroyed part of the present reserve.

6. REFERENCES

- BOIŃSKI, M., CYZMAN, W., ZAŁUSKI, T. 2001. Szata roślinna. In: A. PRZYSTALSKI (ed.), Przyroda województwa kujawsko-pomorskiego. Bydgoszcz, p. 54-73 (in Polish).
- BRAUN-BLANQUET, J. 1964. Pflanzensoziologie. Grundzüge der Vegetationskunde. Springer Verl., Wien-New York, 865 pp.
- CEYNOWA-GIELDON, M. 1971. Osobliwości florystyczne i rezerваты ziemi chełmińskiej. Przewodnik florystyczny. TNT, Toruń (in Polish).
- FABISZEWSKI, J. 1985. Szata roślinna. In: A. JAHN (ed.), Karkonosze polskie. Zakł. Narod. im. Ossolińskich. Wyd. PAN, Wrocław, Warszawa, Kraków, Gdańsk, Łódź, p. 191-246 (in Polish).
- FIJAŁKOWSKI, D. 1991. Zespoły roślinne Lubelszczyzny. Wyd. UMCS, Lublin (in Polish).
- HERBICHOVA, M. 1998. Ekologiczne studium rozwoju torfowisk wysokich właściwych na przykładzie wybranych obiektów ze środkowej części Pobrzeża Bałtyckiego [Ecological study of development of the Baltic-type raised bogs exemplified by selected objects in the middle part of Baltic Sea-Coast]. Wyd. Uniw. Gdańskiego, Gdańsk, 119 pp. (in Polish with English summary).
- HERRMANN, E. 1920. Zur Geschichte der Seefelder bei Reinerz. In: H. CONWENTZ (ed.), Beiträge zur Naturdenkmalpflege. Gebrüder Borntraeger, Berlin: 130-247.
- KLOSS, M. 1996. Plant succession on *Chamaedaphne calyculata* (L.) Moench mire in the Kampinos Forest. Pol. Ecol. Stud. 22, 3-4: 129-139.
- KLOSS, M. 2005. Palaeobotanical studies of raised mires. Monogr. Bot. 94: 5-18.
- KUCHARSKI, L., GRZYL, A. 1993. Rozmieszczenie *Carex limosa* L. i *Scheuchzeria palustris* L. w Polsce [Distribution of *Carex limosa* L. and *Scheuchzeria palustris* L. in Poland]. Acta Univ. Lodz., Folia bot. 10: 93-107 (in Polish with English summary).
- KUCHARSKI, L., KOPEĆ, D. 2005. Przegląd zespołów torfowiskowych z klasy *Oxycocco-Sphagnetea* stwierdzonych w Polsce [Review of raised bogs communities from *Oxycocco-Sphagnetea* distinguished in Poland]. Wiad. Bot. (in press).
- KUCHARSKI, L., KURZAC, M., RAKOWSKA, B., SITKOWSKA, M. 2004. Changes in the flora and vegetation of the Torfowisko Rąbień reserve near Łódź (Poland), and their proposed conservation methods. Nature Conservation 60: 49-62.
- KUCHARSKI, L., MICHALSKA-HEJDUK, D., KOŁODZIEJEK, J. 2001. Przegląd zespołów torfowiskowych z klasy *Scheuchzerio-Caricetea fuscae* stwierdzonych w Polsce [Review of raised bogs communities from *Scheuchzerio-Caricetea fuscae* distinguished in Poland]. Wiad. Bot. 45, 1/2: 33-44 (in Polish with English summary).

- KULCZYŃSKI, S. 1939/1940. Torfowiska Polesia. T. 1, 2. Księgarnia Gebethnera i Wolfa, Nakładem autora, Kraków (in Polish).
- LORENS, B. 1987. Analiza ekologiczno-statystyczna runa w strefie kontaktowej zespołów *Ledo-Sphagnetum magellanici* Sukopp 1959 em. Neuhäusl 1969 i *Vaccinio uliginosi-Pinetum* Kleist 1929. Ann. UMCS, Sec. C 42, 7: 77-93 (in Polish with English summary).
- MATUSZKIEWICZ, W. 2001. Przewodnik do oznaczania zbiorowisk roślinnych Polski. PWN, Warszawa, 537 pp. (in Polish).
- MICHALIK, S. 1998. Stan poznania zbiorowisk roślinnych w polskiej części międzynarodowego rezerwatu biosfery „Karpaty Wschodnie” [State of knowledge of plant communities in the Polish part of the International Biosphere Reserve „Eastern Carpathians”]. Roczniki Bieszczadzkie 7: 97-106 (in Polish with English summary).
- PISAREK, W., POLAKOWSKI, B. 2001. Szata roślinna rezerwatu „Zielony Mechacz” i problemy związane z jego ochroną [Plant cover of a nature reserve „Zielony Mechacz” and problems connected with its protection]. Acta Bot. Warmiae, Masuriae 1: 71-101 (in Polish with English summary).
- POTOCKA, J. 1997. Flora i zbiorowiska roślinne wybranych torfowisk Gór Izerskich. II Charakterystyka fitosocjologiczna [The flora and plant communities of selected peat-bogs in the Izera Mountains (Sudetes) II. Plant communities]. Acta Univ. Wratisl., Prace Botaniczne 73: 115-144 (in Polish with English summary).
- POTOCKA, J. 2001. Współczesna szata roślinna Wielkiego Torfowiska Batorowskiego. Szczeliniec 3: 49-99 (in Polish with English summary).
- POTOCKA, J. 2004. Sudeckie torfowiska wysokie. In: J. HERBICH (ed.), Poradnik ochrony siedlisk i gatunków Natura 2000 – podręcznik metodyczny. T. 2. Wody słodkie i torfowiska. Ministerstwo Środowiska, Warszawa: 125-132 (in Polish).
- PRZEMYSKI, A., POLINOWSKA, K. 2001. Szata roślinna rezerwatu torfowiskowego Białe Ługi [Plant cover of the Białe Ługi mire reserve]. In: S. ŻUREK (ed.) Rezerwat torfowiskowy „Białe Ługi” [Białe Ługi mire reserve]. Wyd. Homini, Bydgoszcz: 133-178 (in Polish with English summary).
- SOKOŁOWSKI, A.W. 1988. Fitosocjologiczna charakterystyka zbiorowisk roślinnych Wigierskiego Parku Narodowego [Phytosociological characteristic of plant communities of Wigry National Park]. Prace IBL 673: 1-80 (in Polish with English summary).
- SUGER, P., POPIOLEK, Z. 1998. Roślinność wodna i przybrzeżna jeziora Moszne w Poleskim Parku Narodowym [Aquatic and bank vegetation of Moszne Lake in the Polesie National Park]. Ann. UMCS, Sec. C 53: 185-200 (in Polish with English summary).

7. WSPÓŁCZESNA ROŚLINNOŚĆ WYBRANYCH TORFOWISK WYSOKICH I STAN JEJ ZACHOWANIA (streszczenie)

Torfowiska wysokie należą do rzadkich ekosystemów w naszym kraju. Rozwijają się one głównie w strefie borealnej państwa holarktycznego dochodząc do północnych skrajów strefy klimatu umiarkowanego. W Polsce najbardziej typowe torfowiska wysokie występują na obszarach z przewagą opadów nad parowaniem w cyklu rocznym, a więc w północnej części kraju oraz w górach.

W opracowaniu przeprowadzono charakterystykę roślinności 7 obiektów, na których dokonano analizy paleobotanicznej torfów. Roślinność torfowisk Rąbień i Białe Ługi była badana przed rozpoczęciem projektu. Charakterystykę roślinności tych obiektów oparto na wcześniej opublikowanych pracach. Roślinność pozosta-

łych obiektów była badana w trakcie wykonywania wierceń. Na każdym z torfowisk wykonano 10-15 zdjęć fitosocjologicznych, zwykle w pobliżu transektów stratygraficznych.

Na badanych torfowiskach wysokich stwierdzono ponad 20 zespołów i zbiorowisk roślinnych. W pracy zamieszczono dokumentację fitosocjologiczną dla 13 zespołów i zbiorowisk torfowisk niskich, przejściowych, wysokich i leśnych. Na badanych obiektach stwierdzono cenne dla fory polskiej gatunki roślin. Są wśród nich: *Betula nana* (Linje, Zieleniec), *Chamaedaphne calyculata* (Kołowin), *Oxycoccus microcarpus* (Suche Bagno), *Salix myrtilloides* (Białe Ługi) i *Pinus x rhaetica* (Zieleniec).

Ekosystemy torfowisk wysokich są bardzo wrażliwe na synantropizację. Wśród badanych obiektów można wyróżnić torfowiska o charakterze naturalnym i takie, które uległy znacznym przekształceniom w wyniku gospodarczej działalności człowieka. Do najmniej przekształconych należą Zieleniec i Suche Bagno. Cechuje je niewielkie zróżnicowanie flory. Charakterystyczną cechą niezakłóconych torfowisk wysokich jest pasowy układ roślinności. Obiektem o najbardziej przekształconej szacie roślinnej jest rezerwat „Torfowisko Rąbień”.

Objęte badaniami torfowiska wysokie można podzielić na trzy grupy. Pierwszą stanowią mokradła, których szata roślinna ma charakter naturalny. Należą do nich torfowiska Zieleniec i Suche Bagno. Mokradłami, na których widoczne są skutki działalności gospodarczej człowieka są Linie, Długie Bagno, Kołowin i Białe Ługi. Roślinność tych obiektów podlega regeneracji. Rezerwat „Torfowisko Rąbień” należy do obiektów o najbardziej przekształconej szacie roślinnej. Płaty roślinności wysokotorfowiskowej przetrwały tylko w środkowej, najmniej zniszczonej części obecnego rezerwatu.

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GEOLOGY OF RAISED MIRE DEPOSITS

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ABSTRACT

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Stratigraphical studies were carried out in seven raised mires located in different geographic regions of Poland between 2003 and 2005. One stratigraphical section was made in each of the mires, representing its geological structure. At borehole locations, peat and subpeat deposits were characterized in a continuous manner from the surface down to the mineral bedding. In the cores taken from biogenic deposits, plant macrofossil analyses were made and radiocarbon dating was carried out. Moreover, humification degree, ash content and acidity were determined, as well as the peat type.

Key words: raised mires; peat stratigraphy; radiocarbon dating; Poland.

1. INTRODUCTION

In the raised mires of Suche Bagno (Augustowska Plain Mesoregion), Kołowin (Mrągowskie Lakeland mesoregion), Linje (Chełmińskie Lakeland mesoregion), Długie Bagno (Warsaw Basin mesoregion), Rąbień (Łaska Plateau mesoregion), Białe Ługi (Świętokrzyskie Mountains mesoregion) and Zieleniec (Bystrzyckie Mountains mesoregion), a stratigraphical section was made in the central part of each mire, reflecting its specifics. In 2003-2005, peat boring and probing was performed along transects by the methods applied in peat investigations. The aims of the research project and the research methods have been more broadly presented by KLOSS (2005). The geomorphological characteristic in the area of the mires under study has been prepared by ŻUREK (2005). During boring and probing, peat and subpeat deposits were described in a continuous manner from the site surface down to the underlying mineral bedding. At borehole locations, complete biogenic sediment cores were collected for further laboratory tests (to determine ash content, acidity, macrofossil analysis, C^{14} dating, etc.). Height measurements in the mires were performed using a Pentax level. Distribution of the genetically diverse layers in the deposits of the peatbogs under study is depicted in Figures 1-7. In the case of the Białe Ługi Mire, the earlier studies by the same authors have been supplemented (ŻUREK, KLOSS 2001; ŻUREK *et al.* 2001).

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2. PEAT DEPOSIT STRATIGRAPHY

The Suche Bagno Mire. Levelling measurements of a 279 m-long transect have shown that the surface area of the Suche Bagno Mire is flat (Fig. 1). The difference between the extreme values of height measurements does not exceed 20 cm. The transect cross-cuts the mire in its central part from North-West to South-East. Numerous low hummock-type sphagnum elevations bring some variety to the flat surface of the mire. The mire was formed as a result of terrestrialization of the lake. In the past, the lake occupied a fragment of the postglacial channel extending along meridians to the Wigry Lake. Stratified sands and gravels dominate the area around the mire. Peat thickness and subpeat deposit thickness reach 7.5 m. The bottom of the basin is undulated. The peat deposit comprises: low peats (reed peat with ferns,

Fig. 1. Stratigraphical section of the Suche Bagno mire

1 – raised sphagnum peat; 2 – raised sphagnum peat (higher degree of humification); 3 – transitional sphagnum peat; 4 – transitional sphagnum peat (higher degree of humification); 5 – transitional peat with wood; 6 – reed peat; 7 – tall-sedge peat; 8 – sedge-brown moss peat; 9 – brown moss peat; 10 – alder peat; 11 – muck, mineralized peat; 12 – organic deposits in the cut-over bog; 13 – gyttja; 14 – water; 15 – strongly decomposed peat layer; 16 – clayey formation; 17 – fine-grained sand; 18 – middle-grained sand; 19 – sand with gravel; 20 – bed-rock; 21 – peat boring; 22 – peat sounding; 23 – C^{14} age

sedge-brown moss peat), transitional bog peats (sphagnum-sedge peat), raised bog peats (sphagnum-hollow peat, sphagnum-hummock peat, cotton grass-sphagnum peat). Profile 2 collected from the centre of the mire is fully representative. The arrangement of deposit layers is as follows:

0-8 cm, sphagnum-hummock peat, living and decaying sphagnum mosses (average peat humification degree in the layer – $R < 5\%$; average ash content – $P 2.4\%$).

8-15 cm, sphagnum-hummock peat ($R 30\%$; $P 2.4\%$).

15-32 cm, sphagnum-hollow peat ($R 20\%$; $P 1.5\%$).

32-125 cm, sphagnum-hummock peat ($R 35\%$; $P 2.6\%$).

125-132 cm, cotton grass-sphagnum peat ($R 55\%$; $P 2.8\%$).

132-230 cm, sphagnum-hummock peat ($R 25\%$; $P 1.4\%$).

230-295 cm, sphagnum-sedge peat ($R 26\%$; $P 2.2\%$).

295-460 cm, sedge-brown moss peat ($R 30\%$; $P 2.4\%$).

460-480 cm, reed peat with ferns ($R 35\%$; $P 5.7\%$).

480-553 cm, detritus gyttja ($P 9.3\%$).

553-618 cm, calcareous gyttja ($P 75.7\%$).

618-680 cm, clayey gyttja ($P 81.7\%$).

The age of the oldest lacustrine sediments is 14480 ± 70 BP (Poz-4768). They are underlain by sands with gravel. The mire initiation in the shallowed lake basin dates back to 6670 ± 40 BP (Poz-4666). The development of transitional bog peats occurred about 4125 ± 35 BP (Poz-9798), while that of raised bog peats - about 3095 ± 35 BP (Poz-9748). The peatbog water level occurs at a depth of about several centimetres. The peats show no signs of mucking.

The Kołowin Mire. The examined transect measures 155 m and intersects east-west the central part of the mire. Generally, the surface area of the bog is flat (Fig. 2). The maximum difference in heights between the bottom of the shallow edge on the eastern bank and the small elevation of the central fragments of the mire is about 60 cm. The mire surface features a mosaic hummock-hollow structure. The mire is surrounded by sand-gravel hills. It was formed as a result of terrestialization of a water body. Peat thickness, including gyttja, reaches about 6 m. The peat deposit comprises: low peats (brown moss peat, sedge-brown moss peat), transitional bog peats (sphagnum-sedge peat), raised bog peats (sphagnum-hummock peat). Profile 2 from the centre of the transect, representative of the mire's geological structure, has the following layer arrangement:

0-5 cm, sphagnum-hollow peat, living and decaying sphagna ($R < 5\%$; $P 3.5\%$).

5-35 cm, sphagnum-hummock peat ($R 30\%$; $P 2.9\%$).

35-75 cm, sphagnum-sedge peat ($R 23\%$; $P 2.3\%$).

75-312 cm, sedge-brown moss peat ($R 25\%$; $P 2.7\%$).

312-380 cm, brown moss peat ($R 15\%$; $P 3.3\%$).

380-455 cm, detritus gyttja ($P 5.4\%$).

455-528 cm, detritus-clayey gyttja ($P 60.6\%$).

Fig. 2. Stratigraphical section of the Kołowin mire
Explanations see Fig.1

Underneath lie various-grained sands with gravel. The detritus-clayey gyttja started to accumulate about 11920 ± 60 s BP (Poz-4740). The complete filling up of the lake with sediments occurred about 8000 BP. The age determination at 2860 ± 300 BP (Gd-16226) for the brown moss peat phase, which started the peat-forming process, has turned to be incorrect. The development of sedge-brown moss peats started at about 6790 ± 40 BP (Poz-9725) and lasted till the encroachment of transitional bog peats at 1160 ± 30 BP (Poz-9723). The building up of raised bog peats started in modern times, around 200-300 years ago. A slight lowering of the water level resulted in a spontaneous succession of common birch and downy birch. The ground water table in the central part of the mire occurs at a depth of about 20 cm. The top peat layers do not show signs of mucking.

The Linje Mire. The characterised section is situated in the southern part of the Linje Mire, along the East-West line. The transect intersecting the wetland measures 157 m. The surface area of the mire is flat (Fig. 3). The hypsometric difference between the lowest measurement point in the bottom of the eastern edge and the highest point in the sphagnum moss bog is 37 cm. The irregularly distributed *Sphagnum* hummocks, lawns and hollows form a mosaic of microhabitats and add some variety to the mire. The mire is surrounded by the moraine hills of sandy outwash plain. The maximum recorded biogenic deposits thickness is 11.9 m. The process of peat sedimentation occurred through paludification of the mineral bottom of the depression. The initial suggestions concerning the lacustrine origin

Fig. 3. Stratigraphical section of the Linje mire
 Explanations see Fig.1

of the mire have proved incorrect in the process of investigations (compare TOBOLSKI *et al.* 2004). The deposits are made up of the following peats: raised bog peats (sphagnum-hummock peat, sphagnum-hollow peat, cotton grass-sphagnum peat), transitional bog peats (sphagnum-sedge peat, sphagnum-*Scheuchzeria* peat) and low peats (sedge-brown moss peat, brown moss peat, osier peat). After the completion of boreholes and probing in the indicated profiles and its surrounding, it was decided that one more profile would be made using a Więckowski probe. It was made about 40 m north of borehole 2. Owing to its better-preserved core structure and higher depth, profile 4 was selected as a benchmark for further examinations (palynological analyses, radiocarbon dating, etc.). Borehole 4 is fully representative of the Linje Mire. In the palynological study, the examined core is denominated as profile LX. The stratigraphy of the collected sediments in this borehole is as follows:

0-10 cm, sphagnum-hollow peat, living and decaying sphagna (R < 5%; P 4.0%).

10-52 cm, sphagnum-hollow peat (R 17%; P 4.6%).

52-310 cm, sphagnum-hummock peat (R 27%; P 2.3%).

310-500 cm, sphagnum-hummock peat (R 45%; P 2.1%).
 500-520 cm, sphagnum-hollow peat (R 40%; P 1.7%).
 520-580 cm, sphagnum-hummock peat (R 45%; P 1.7%).
 580-640 cm, sphagnum-hollow peat (R 40%; P 1.6%).
 640-660 cm, sphagnum-*Scheuchzeria* peat (R 50%; P 1.7%).
 660-700 cm, sphagnum-hummock peat (R 50%; P 1.7%).
 700-990 cm, sphagnum-hummock peat with abundant *Ericaceae* (R 60%; P 2.8%).
 990-1030 cm, sphagnum-sedge peat (R 50%; P 5.5%).
 1030-1050 cm, brown moss peat (R 35%; P 15.2%).

Underneath are various-grained sands with gravel. The start of biogenic sediment accumulation dates back to the decline of Late Glacial. The age of sedge-brown moss peats was determined at 10740 ± 270 BP (Gd-30069). The late-glacial nature of the deposits is confirmed by the pollen spectrum record in the examined profile (NORYŚKIEWICZ 2005). At the turn of the Younger Dryas and the Preboreal Period (about 10000 BP), the accumulation of transitional bog peats started. The age of the raised bog peat layer (955-960 cm) was dated to 9010 ± 350 BP (Gd-18266). The ombrotrophic nature of the sediments was maintained throughout the entire Holocene. In the deposit structure, a top layer of raised bog peats can be distinguished. Its thickness in the central part of the site reaches up to about 3 m. It features a slight degree of peat humification amounting to 30%. Underlying it is a larger (in terms of volume) part of the mire with raised bog peats and transitional bog peats featuring stronger transformation of plant remains and higher degree of peat humification estimated at above 40-45%. Because of a higher content of colloidal particles, the morphology of this deposit resembles coarse detritus gyttja. The deepest layer is made up of brown moss peats with a low humification degree. In some places, in the bottom of boreholes 1 and 2, thin peat insertions with a large percentage of *Salix* sp. wood were recorded. The peat deposit is well hydrated and the ground water table is close to the surface of the mire. In the northern part of the Linje Mire, traces of limited peat extraction can be found.

The Długie Bagno Mire. The transect made in the Długie Bagno Mire runs through its centre along the shorter North-South axis. The section measures 150 m. No elevation is recorded in the mire (Fig. 4). Numerous tussocks of *Eriophorum vaginatum* add some variety to its flat surface. Fine-grained dune sands dominate in the surroundings of the mire. Biogenic sediment thickness is up to 1.4 m. The bottom of the paludified basin is even. The waters supplying the mire have contributed to peat deposition directly on the underlying mineral bedding. The deposit structure comprises: low peats (tall-sedge peat, brown moss peat), transitional bog peats with wood, and raised bog peats (sphagnum-hollow peat, cotton grass-sphagnum peat). The distribution of layers in borehole 2 representative of the mire is as follows:

0-10 cm, sphagnum-hollow peat, living and decaying sphagna (R 5%; P 6.1%).
 10-18 cm, sphagnum-hollow peat (R 10%; P 8.5%).

Fig. 4. Stratigraphical section of the Długie Bagno mire
 Explanations see Fig.1

18-30 cm, cotton grass-sphagnum peat with wood, mucking, with numerous carbonaceous remains (R 70%; P 9.5%).

30-50 cm, cotton grass-sphagnum peat with wood (R 65%; P 8.1%).

50-55 cm, transitional bog peat with wood (R 65%; P 10.3%).

55-85 cm, tall-sedge peat (R 45%; P 4.4%).

85-110 cm, brown moss peat (R 27%; P 13.1%).

Underneath are silty, various-grained humus sands. Accumulation of brown moss peat on the underlying sand bed started at the beginning of the Holocene – 9760 ± 50 BP (Poz-9760). Palynological investigations date the start of paludification in the area of Długie Bagno to the Alleröd (BORÓWKO-DŁUŻAKOWA 1961; KOBENDZI-NA 1961). The initiation of accumulation of tall-sedge peats took place around 9120 ago (Poz-9793). The age of transitional peats was determined at 6960 ± 50 BP (Poz-9746). The development of raised bog peats occurred some time later. A cotton grass-sphagnum peat sample dates back to 6740 ± 50 BP (Poz-9792). In the strongly decomposed raised peat (18-30 cm), hard, small carbonaceous debris can be found, which are indicative of the past fire. The general lowering of the ground water table in the territory of the Kampinos Forest (in the second half of the 20th century), the high amplitude of water level oscillations and the long peat drying periods are the factors initiating the mucking and mineralization processes in the relatively shallow deposit.

The Rąbień Mire. In the Rąbień Mire, the examined transect measures 400 m. It runs from South to North in the eastern part of the site. The area of the mire is flat, without any natural elevation (Fig. 5). In the vicinity of the section, as well as throughout the whole mire area, numerous peat workings can be found. They are remnants of the past peat extraction. Dune sands shaped in the form of a bank (sword dunes) predominate in the mire catchment. Peat thickness including gyt-tja reaches 3 m. The bottom of the depression is even. The mire was formed as a result of lake shallowing. The peat deposit is made up of the following peats: low peats (sedge-brown moss peat), transitional bog peats (sphagnum-sedge peat, sphagnum-*Scheuchzeria* peat), and raised bog peats (sphagnum-hummock peat, sphagnum-hollow peat, cotton grass-sphagnum peat, raised bog peat with wood). In profile 1, in the central part of the transect, sediment distribution is as follows:

- 0-15 cm, mineralised muck peat with fragments of *Ericaceae* and *Betula* sp. (P 8.9%).
- 15-20 cm, sphagnum-hollow peat (R 30%; P 6.8%).
- 20-40 cm, mucking raised bog peat with wood (R 67%; P 6.0%).
- 40-50 cm, raised bog peat with wood (R 60%; P 4.4%).
- 50-55 cm, cotton grass-sphagnum peat (R 50%; P 3.1%).
- 55-125 cm, sphagnum-hummock peat (R 31%; P 1.5%).
- 125-144 cm, sphagnum-*Scheuchzeria* peat (R 35%; P 1.7%).
- 144-156 cm, sedge-brown moss peat (R 40%; P 3.4%).
- 156-180 cm, coarse detritus gyt-tja (P 13.4%).
- 180-284 cm, fine detritus gyt-tja (P 18.6%).

Fig. 5. Stratigraphical section of the Rąbień mire
Explanations see Fig.1

Underneath lies the medium-grained sand with humus. The start of gyttja deposition in the bottom of the lake is dated to 11880 ± 60 BP (Poz-9730). The infill of the reservoir with sediments and the development of sedge-brown moss peats dates back to 7150 ± 50 BP (Poz-9729). Palynological studies correlate the end of lake terrestrialization to the younger part of the Atlantic Period (BALWIERZ 2005). The time of sedge-brown moss formation was very shortly. Accumulation of transitional bog peats took place about 7100 ± 40 BP (Poz-9728). The oldest layer of raised bog peats (sphagnum-hummock peats) was dated to 6780 ± 40 BP (Poz-9727). Raised bog peats with a large share of pinewood appeared about 3660 ± 35 BP (Poz-9726). Peat extraction works, carried out relatively not long ago, have had some effect on the mire. Numerous peat workings overgrown with secondary plant communities have remained. Draining has caused an increase in deposit thickness subject to aeration. This has halted the peat accumulation process and initiated mucking, followed by a peat mass loss.

The Białe Ługi Mire. The surveyed North-West – South-East transect runs along the longer axis in the southern basin of the mire. The longitudinal section is 2500 m long. The stratigraphy of the Białe Ługi Mire was the subject of studies already between 1997 and 1998 (ŻUREK, KLOSS, SOŁTYSIK 2001). These studies have now been supplemented. The mire and its underlying mineral bedding show a distinct reduction of their surface area (Fig. 6). The hypsometric difference between the highest point of the bog in the vicinity of a watershed and the end of the transect is about 450 cm. Because of its location on a slope, the site under studies resembles the Podhale mires (WÓJCIKIEWICZ 1979; OBIDOWICZ 1990). The bog surface features a mosaic hummock-hollow structure. The sandy deposits occurring in the area surrounding the mire comprise mainly various-grained, loose and weak-loam sands. Białe Ługi can be classified into paludification bogs. Peat deposition occurred directly on the underlying mineral bedding. The maximum thickness of the deposit reaches ca. 4 m. Its structure is made up of raised bog peats (sphagnum-hummock peat, sphagnum-hollow peat, cotton grass-sphagnum peat), transitional bog peats (sphagnum-sedge peat, transitional peat with wood) and low peats (sedge-brown moss peat, brown moss peat, alder peat) (ŻUREK *et al.* 2001). In the central part of the transect, in profile 3 representative of the mire, the arrangement of layers is as follows:

0-10 cm, sphagnum-hollow peat, living and decaying sphagnum mosses (R < 5%; P 7.7%).

10-33 cm, sphagnum-hollow peat (R 15%; P 6.7%).

33-65 cm, cotton grass-sphagnum peat (R 30%; P 12.7%).

65-101 cm, cotton grass-sphagnum peat (R 57%; P 7.9%).

101-125 cm, transitional bog moss peat with wood (R 45%; P 3.5%).

125-255 cm, sphagnum-sedge peat (R 33%; P 2.3%).

255-325 cm, sedge-brown moss peat (R 30%; P 9.4%).

325-333 cm, sphagnum-hummock peat (R 20%; P 6.4%).

333-355 cm, brown moss peat (R 40%; P 12.2%).

355-380 cm, sedge-brown moss peat (R 40%; P 14.4%).

380-390 cm, brown moss peat (R 35%, P 21.0%).

Fig. 6. Stratigraphical section of the Białe Ługi mire
Explanations see Fig.1

The underlying bed is built up of various-grained sands. The brown moss peat recorded in the bottom of the mire is dated to 12900 ± 360 BP (Gd-14018). The age of the raised peat layer (325-333 cm) separating the low peats was established at 11200 ± 50 BP (Poz-9721). The start of accumulation of transitional bog peats was determined at $9810 \pm$ BP (Poz-9719), and its end at 1950 ± 30 BP (Poz-10220). The moment of accumulation of less humified peats fell on modern times - 240 ± 30 BP (Poz-9716). The Białe Ługi Mire was not exploited in the past or strongly drained. The ground water level is close to the surface and the peat deposit is in the phase of accumulation.

The Zieleniec Mire. The surveyed transect is located within the area of Topielisko – the northern basin of the Zieleniec Mire. The section measures 950 m and runs through the centre of the mire along the South-East – North-West line. The mire is formed in the shape of an elevated spur (Fig. 7). It developed in a trough situated in a watershed on the western slope of the Bystrzyckie Mountains massif. The difference in height between the beginning and the end of the transect is about 750 cm. A mosaic of bog moss hummocks, marshy hollows and small, crevice water pools add some variety to the sloping mire surface. The deposit thickness reaches 820 cm. Accumulation of biogenic deposits started directly in the bedrock.

Fig. 7. Stratigraphical section of the Zieleniec mire
 Explanations see Fig.1

The bedrock is made up of the following peats: raised bog peats (sphagnum-hummock peat, sphagnum-hollow peat, cotton grass-sphagnum peat) and transitional bog peats (sphagnum-sedge peat). Profile 3 extracted from the centre of the mire is representative of its structure. The arrangement of peat layers is as follows:

- 0-5cm, sphagnum-hollow peat (R < 10%; P 8.5%).
- 5-15 cm, sphagnum-hollow peat (R 20%; P 7.6%).
- 15-50 cm, cotton grass-sphagnum peat (R 46%; P 6.7%).
- 50-520 cm, sphagnum-hummock peat (R 33%; P 1.3%).
- 520-528 cm, cotton grass-sphagnum peat (R 70%; P 1.8%).
- 528-750 cm, sphagnum-hummock peat (R 37%; P 1.3%).
- 750-790 cm, sphagnum-sedge peat (R 50%; P 2.0%).
- 790-820 cm, transitional bog peat (R 62%, P 2.5%).

Sphagnum peats predominate in the structure of the deposit. This fact was confirmed by the results of the studies carried out in the 1950s by KUŹNIEWSKI (1958). However, no presence of a gyttja layer was found in the accumulated sediment floor. Strongly humified hydrated transitional peats with remains of *Eriophorum vaginatum*, *Carex rostrata*, *Scheuchzeria palustris* can be found in the lowest parts of the bottom of the mire, while in the upper parts – there are transitional peats with abundant spruce and birch wood. The underlying bed of the mire is composed of

water impermeable clayey-silty soils with a thickness of several scores of centimetres, like clays and silts, created in the top part of the Upper Cretaceous, quartzite marl sandstones (KUŹNIEWSKI 1958; STAFFA 1992; KLEMENTOWSKI 2001; WÓJCICKI 2004). On the clayey detritus there is a thin, up to several-centimetre layer of mineralised peaty formations. The beginning of the paludification processes in the examined profile dates back to 6980 ± 50 BP (Poz-9809). For the sample collected from the mire bottom, in its central part, KLEMENTOWSKI (2001) established its age at about 6660 ± 140 BP (Gd-15172), while for a sample from the borehole located closer to the edge – at 7830 ± 150 BP (Gd-15173). The initial pollen analysis of the peat from the bottom of the profile (Probe 3 – 658 cm), situated near the western edge, indicates an age older than 8000 BP (NITA unpublished). The Atlantic Period saw the beginning of the raised mire on the alpine meadow of the Hala Izerska in the Izerskie Mountains. The age of the peat sample collected from the bottom is established at 7080 ± 220 BP (Gd-10943) (KLOSS 2004). On the basis of a palynological analysis of the core from the southern basin of the Zieleniec Mire (Czarne Bagno), MADEYSKA (2005) correlates the start of the paludification processes to the turn of the Pre-Boreal and Boreal Periods, around 9000 BP. The start of raised peat accumulation in the northern basin of the Zieleniec Mire (Topielisko) is dated to 5840 ± 40 BP (Poz-9802). The age of the strongly humified cotton grass-sphagnum layer (520-528 cm) was determined at 3790 ± 40 BP (Poz-9800). It is indicative of site desiccation. Currently, the ground water table is close to the surface of the deposit and the mire has entered a stagnation phase. This is evidenced by the proceeding overgrowing of the site by dwarf pine.

3. RECAPITULATION

1. The mires of Suche Bagno, Kołowin and Rąbień were formed as a result of lake terrestrialization, while the mires of Linje, Długie Bagno, Białe Ługi and Zieleniec – through direct paludification of the underlying mineral bedding.
2. Except the mountain Zieleniec Mire, the investigated peatlands followed the classical development path, from fen, through transitional to raised bog.
3. The mountain Zieleniec Mire and the upland Białe Ługi Mire have an elevated surface and are located on a slope. The surfaces of the other mires are even, without sloping.
4. The lowland bogs and the upland bog of Białe Ługi have accumulated their biogenic sediments (peaty and lacustrine) since Late Glacial, while the younger mountain mires – since the Boreal and Atlantic Periods.

4. REFERENCES

- BALWIERZ, Z. 2005. The history of vegetation of the Rąbień Mire region. *Monogr. Bot.* 94: 135-144.
- BORÓWKO-DŁUŻAKOWA, Z. 1961. Historia flory Puszczy Kampinoskiej w późnym glacie i holocenie [The history of the flora of the Kampinos Forest during the Late Glacial and Holocene periods]. *Przegl. Geogr.* 33, 3: 365-382 (in Polish).
- KLEMENTOWSKI, J. 2001. Przekształcenie stosunków wodnych torfowiska wysokiego Topieliska w Sudetach w następstwie polepszenia spławności Bystrzycy Dusznickiej [Conversion of water conditions of the Topielisko bog in Sudety Mountains in the aftermath of attempt improvement floating of the Bystrzyca Dusznicka river]. In: *Materiały Konferencji, Wpływ użytkowania terenu i antropogenicznych przekształceń środowiska przyrodniczego na elementy obiegu wody w zlewni rzecznej*. PTG, Akademia Świętokrzyska, Kielce, p. 59-62 (in Polish).
- KLOSS, M. 2004. Palaeohydrological changes in the development of some raised mires in Poland. In: J. PÄIVÄNEN (ed.), *Wise use of peatlands. Proceedings of the 12th International Peat Congress*, Tampere, Finland, Publication of the International Peat Society 2: 869-874.
- KLOSS, M. 2005. Palaeobotanical studies of raised mires. *Monogr. Bot.* 94: 5-18.
- KOBENDZINA, J. 1961. Próba datowania wydmy Puszczy Kampinoskiej [Attempt of dating of dunes of the Kampinoska Forest]. *Przegl. Geogr.* 33, 3: 383-399 (in Polish).
- KUŹNIEWSKI, E. 1958. Torfowisko Zieleniec koło Dusznik [The Zieleniec mire near Duszniki city]. *Rocznik Ziemi Kłodzkiej*. T. 3, p. 169-211 (in Polish).
- MADEYSKA, E. 2005. The history of the Zieleniec Mire and the surrounding areas based on the palynological research. *Monogr. Bot.* 94: 145-157.
- NORYŚKIEWICZ, A. M. 2005. Preliminary results of study on vegetation history in the Linje mire region using pollen analysis. *Monogr. Bot.* 94: 117-134.
- OBIDOWICZ, A. 1990. Eine pollenanalytische und moorkundliche studie zur vegetationsgeschichte des Podhale-Gebietes (West-Karpaten). *Acta Paleobot.* 30, 1-2: 147-219.
- WÓJCICKI, K. 2004. Torfowisko Zieleniec. Analiza próbek podtorfowych [The Zieleniec mire. Analysis of samples of under-peat layer]. Uniwersytet Śląski, Sosnowiec, typescript, 3 pp. (in Polish).
- WÓJCIKIEWICZ, M. 1979. Stratygrafia torfowiska Bór na Czerwonym z uwzględnieniem zespołów subfosylnych oraz rozmieszczenia i zróżnicowania współczesnych zbiorowisk roślinnych [The stratigraphy of the „Bór na Czerwonym” peatbog with the consideration of subfossil associations and distribution and differentiation of contemporary plant communities]. *Zesz. Nauk. AR, Kraków* 153, 10: 133-193 (in Polish).
- STAFFA, M. (ed.) 1992. Góry Bystrzyckie, Góry Orlickie. Słownik geografii turystycznej Sudetów [The Bystrzyckie Mts., The Orlickie Mts. Dictionary of touristic geography of Sudeten Mountains]. Wyd. PTTK Kraj, Warszawa-Kraków. T. 14, 320 pp. (in Polish).
- TOBOLSKI, K., NORYŚKIEWICZ, B., FILBRANDT-CZAJA, A., KLOSS, M., LAMENTOWICZ, M., MILECKA, K., NORYŚKIEWICZ, A., OBREMSKA, M., PAJĄKOWSKI, J., ŻUREK, S. 2004. Postglacialna historia lasów, jezior i torfowisk na wybranych przykładach Ziemi Chełmińskiej i Borów Tucholskich [Postglacial history of the forests, lakes and peatbogs on the selected examples of Chełmno district and Tuchola forest]. In: E. KRASICKA-KORCZYŃSKA, M. KORCZYŃSKI (eds.), *Wycieczki geobotaniczne – Region Kujawsko-Pomorski* [Geobotanical trips – The Kujawsko-Pomorski Region]. Polskie Towarzystwo Botaniczne, Bydgoszcz-Toruń, p. 33-54 (in Polish).
- ŻUREK, S. 2005. Abiotic natural environment in the area of selected raised mires. *Monogr. Bot.* 94: 19-36.
- ŻUREK, S., KLOSS, M. 2001. Geneza i wiek torfowiska Białe Ługi. [Genesis and age of Białe Ługi mire]. In: S. ŻUREK (ed.), *Rezerwat torfowiskowy „Białe Ługi”* [The Białe Ługi mire reserve]. Wyd. Homini, Bydgoszcz, p. 85-87 (in Polish with English summary).

ŻUREK, S., KLOSS, M., SOŁTYSIK, R. 2001. Stratygrafia torfowiska Białe Ługi. [Stratigraphy of Białe Ługi mire]. In: S. ŻUREK (ed.), Rezerwat torfowiskowy „Białe Ługi” [The Białe Ługi mire reserve]. Wyd. Homini, Bydgoszcz, p. 49-58 (in Polish with English summary).

5. BUDOWA GEOLOGICZNA ZŁÓŻ TORFOWISK WYSOKICH (streszczenie)

Na siedmiu torfowiskach wysokich, leżących w różnych regionach geograficznych Polski, przeprowadzono w latach 2003-2005 badania torfoznawcze. Na torfowiskach wysokich Suche Bagno (mezoregion Równina Augustowska), Kołowin (mezoregion Pojezierze Mrągowskie), Linje (mezoregion Pojezierze Chełmińskie), Długie Bagno (mezoregion Kotlina Warszawska), Rąbień (mezoregion Wysoczyzna Łaska), Białe Ługi (mezoregion Góry Świętokrzyskie), Zieleniec (mezoregion Góry Bystrzyckie) wytyczono po jednym przekroju stratygraficznym przedstawiającym jego budowę geologiczną. Rozmieszczone wzdłuż wytyczonej linii sondowania i wiercenia, wykonane za pomocą świda typu Instorf umożliwiły rozpoznanie i scharakteryzowanie osadów torfowych i podtorfowych w sposób ciągły od powierzchni terenu do podłoża mineralnego. W miejscach wierceń pobrano do analiz laboratoryjnych pełne profile torfowe. Dzielono je na warstwy, w zależności od makroskopowego zróżnicowania torfów stwierdzonych w terenie. W pobranych rdzeniach osadów wykonano analizy makroszczątków roślinnych, datowania radiowęglowe, oznaczono stopień rozkładu, popielność, kwasowość oraz ustalono gatunek i rodzaj torfu. Ułożenie warstw w złożach badanych torfowisk przedstawiają ryciny 1-7. Transekty zlokalizowano w typowym miejscu torfowiska odzwierciedlającym jego specyfikę, na ogół w jego środkowej części. W złożach torfowych występują torfy: niskie (szuwarowy z paprociami, turzycowy, turzycowo-mszysty, mszysty, łozowy), mszarne przejściowe (torfowcowo-turzycowy, torfowcowo-bagnicowy, przejściowy z drewnem), mszarne wysokie (torfowcowy dolinkowy, torfowcowy kępowy, wełniankowo-torfowcowy i mszarny wysoki z drewnem).

Torfowiska Suche Bagno, Kołowin i Rąbień powstały w rezultacie zglądowania jezior, a torfowiska Linje, Długie Bagno, Białe Ługi i Zieleniec – przez bezpośrednie zatorfienie podłoża mineralnego. Badane bagna, oprócz torfowiska górskiego Zieleniec, przeszły klasyczną drogę rozwoju, od torfowiska niskiego przez przejściowe do wysokiego. Torfowisko górskie Zieleniec i torfowisko wyżynne Białe Ługi mają wypiętrzoną powierzchnię terenu i leżą na stoku, w przypadku pozostałych mokradeł ich powierzchnia jest wyrównana i brak jest nachylenia. Torfowiska niżowe i torfowisko wyżynne Białe Ługi gromadzą swoje osady biogeniczne (torfowe lub jeziorne) od późnego glacjału, młodsze torfowiska górskie od okresów borealnego i atlantyckiego.

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**IDENTIFICATION OF SUBFOSSIL PLANT
COMMUNITIES AND PALAEOHYDROLOGICAL
CHANGES IN RAISED MIRE DEVELOPMENT**

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ABSTRACT

Marek KŁOSS. *Identification of subfossil plant communities and palaeohydrological changes in raised mire development*. Monogr. Bot., Vol. 94, 81-116, 2005.

In seven raised mires of Suche Bagno, Kołowin, Linje, Długie Bagno, Rąbień, Białe Ługi and Zieleńiec located in different geographical regions of Poland, palaeobotanical studies were carried out between 2003 and 2005. On the basis of the analysis of plant macrofossils selected from the extracted peat cores, subfossil peat-forming communities were reconstructed. 23 subfossil phytocoenoses of different syntaxonomic rank were identified and described.

Vegetation successional phases were reconstructed from the time of mire formation. Palaeohydrological changes in mire development were determined using indicative properties of plants and communities. The analysis of botanical composition of biogenic deposits enabled detecting the presence of selected relic plants from the end of the Late Glacial.

Key words: raised mires; macrofossil analyses; plant succession; relic species; palaeohydrological changes; Poland.

1. INTRODUCTION

Plant communities and individual plant species are good indicators allowing for reliable evaluation of the natural environment. They may serve, among others, as good indicators of site moisture content relatively easy to identify. Each individual phytocoenosis in the mire develops under specific ecological conditions, particularly hydrological ones. Any changes in hydrological conditions cause changes in species composition of a community. Wetter periods are characterised by different vegetation type than drier periods. The palaeobotanical analyses carried out between 2003 and 2005 in seven raised mires provided the material allowing reconstruction of peat-forming phytocoenoses from the end of Late Glacial until present. The mires of Suche Bagno (Augustowska Plain mesoregion), Kołowin (Mrągowskie Lakeland mesoregion), Linje (Chełmińskie Lakeland mesoregion) lie in the lowland covered by the Last Glaciation. The mires of Długie Bagno (Warsaw Basin mesoregion) and Rąbień (Łaska Plateau mesoregion) are located in the old-glacial lowland. The mire Białe Ługi is situated in the upland belt (Świętokrzyskie Mountains mesoregion) while Zieleniec in the mountains (Bieszczady Mountains mesoregion). The aim and methods of the study have been broadly presented by KLOSS (2005), and the geomorphologic characterisation of the region – by ŻUREK (2005).

Reconstruction of subfossil plant communities. The reconstruction of phytocoenoses was based on detailed analyses of the botanical composition of peat samples representing different genetic layers of organic deposits. The results of plant macrofossil analyses were processed using phytosociological methods (KLOSS 1993, 2005). The reconstructed phytocoenoses were synthesised in tables (Tables 1-4). The identification of subfossil plant communities within a peat profile from the bottom upwards to the deposit surface provided information about local plant succession from the moment of mire inception. Plant remains originate almost exclusively from *in situ* growing species. Among the mires under study only Białe Ługi Mire was provided with a subfossil plants characterisation (KLOSS 2001). In the examined 21 peat profiles about 80 plant taxa of different taxonomic rank (species, section, genus, family) were identified. A total of 371 analyses of botanical composition of peats were performed. The reconstruction of a list of species and their combination helped restore 23 subfossil phytocoenoses of different syntaxonomic rank. The specification of species against the background of higher syntaxons of the contemporary phytosociological system is presented below.

Evaluation of hydrological conditions in the successive phases of peat development. The identification of geological structure of a mire associated with the re-

construction of subfossil plant communities and their succession, as well as recognition of the hydrological requirements of peat-forming plant species (moisture indicator value) is a basis for evaluation of the dynamics of moisture conditions in a peat deposit. By identifying the phytocoenotic types that developed in the mire in the past and by reconstructing their species composition we obtain in indirect way the information about hydrological relations of the mire. It has been assumed that ecological requirements of the subfossil communities and the corresponding contemporary phytocoenoses are similar and the range of edaphic requirements of peatbog species did not undergo substantial changes during the postglacial period. Ecological indicator values are currently widely used in geobotanical studies (ELLENBERG *et al.* 1992; HILL *et al.* 1999; ZARZYCKI *et al.* 2002). The method for identification of water conditions in meadow sites, including mires, using plant indicators has been developed by OŚWIT (1992). However there is a paucity of research works using the phytoindication method in paleobotanical studies. The ecological plant indicator value method used to evaluate changes in hydrological conditions throughout the history of mire development has been presented by KLOSS (2004a). In their studies KLOSS (1999, 2001, 2004b) and DRZYMULSKA (2004) used phytoindication abilities of the earlier reconstructed subfossil vegetation to determine paleohydrological changes in the raised bogs in Poland. Moisture indicator values in biostratigraphical studies of peatbogs of northern Russia have been also used by ELINA and YURKOVSKAYA (1992). A general picture of paleohydrological changes in mire development and recorded in other biogenic deposits in Poland has been presented by RALSKA-JASIEWICZOWA and STARKEL (1988, 1999), as well as by ŻUREK (1993), ŻUREK and PAZDUR (1999) and by ŻUREK *et al.* (2002).

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2. DIFFERENTIATION OF THE SUBFOSSIL VEGETATION

2.1. Subfossil communities contributing to the mire development

The below syntaxonomic classification is generally adopted according to MATUSZKIEWICZ (2001):

Class: *Phragmitetea* R.Tx. et Preisg. 1942

Order: *Phragmitetalia* Koch 1926

Alliance: *Magnocaricion* Koch 1926

Subfossil community: *Caricetum elatae caricetosum lasiocarpae*

- Subfossil community: *Caricetum elatae caricetosum lasiocarpae* var.
Pseudocalliergon trifarium
- Subfossil community: *Thelypteridi-Phragmitetum*
- Class: *Scheuchzerio-Caricetea nigrae* (Nordh. 1937) R.Tx. 1937
- Order: *Scheuchzerietalia palustris* Nordh. 1937
- Alliance: *Rhynchosporion albae* Koch 1926
- Subfossil community: *Eriophorum vaginatum-Carex rostrata*
- Subfossil community: *Sphagnum fallax-Sphagnum cuspidatum*
- Subfossil community: *Scheuchzerio-Caricetum limosae*
- Subfossil community: *Eriophoro angustifolii-Sphagnetum fallacis*
- Alliance: *Caricion lasiocarpae* Vanden Bergh. ap. Leburn et al. 1949
- Subfossil community: *Caricetum lasiocarpae sphagnetosum*
- Subfossil community: *Caricetum lasiocarpae typicum*
- Subfossil community: *Caricetum lasiocarpae typicum* var. *Carex elata*
- Subfossil community: *Caricetum lasiocarpae bryopsidaetosum*
- Subfossil community: *Scorpidium scorpioides*
- Subfossil community: *Menyantho-Sphagnetum teretis*
- Class: *Oxycocco-Sphagnetea* Br.-Bl. et R.Tx. 1943
- Order: *Sphagnetalia magellanici* (Pawł. 1928) Moore (1964) 1968
- Alliance: *Sphagnion magellanici* Kästn. et Flösnn. 1933 em. Dierss. 1975
- Subfossil community: *Eriophorum vaginatum-Sphagnum fallax*
- Subfossil community: *Sphagnetum magellanici eriophoretosum*
- Subfossil community: *Sphagnetum magellanici sphagnetosum fallacis*
- Subfossil community: *Sphagnetum magellanici sphagnetosum fusci*
- Subfossil community: *Sphagnetum magellanici typicum*
- Subfossil community: *Sphagnetum magellanici typicum* var. *Oxycoccus palustris*
- Subfossil community: *Sphagnetum magellanici pinetosum*
- Class: *Alnetea glutinosae* Br.-Bl. et R.Tx. 1943
- Order: *Alnetalia glutinosae* R.Tx. 1937
- Alliance: *Alnion glutinosae* (Malc. 1929) Meijer Drees 1936
- Subfossil community: *Sphagnum-Betula pubescens*
- Class: *Vaccinio-Piceetea* Br.-Bl. 1939
- Order: *Vaccinio-Piceetalia* Br.-Bl. 1939
- Alliance: *Dicrano-Pinion* Libb. 1933
- Subfossil community: *Vaccinio uliginosi-Pinetum*
- Alliance: *Piceion abietis* Pawł. et al. 1928
- Subfossil community: *Sphagnum-Picea abies*

2.2. Characterisation of subfossil communities

2.2.1. Communities of the *Phragmitetea* class

Caricetum elatae caricetosum lasiocarpae is a subfossil community characterised by a high share of tufted sedge accompanied by *Carex rostrata* and *Phragmites australis*. Its floristic composition is associated with the *Caricetum lasiocarpae* phytocoenoses. The presence of *Carex lasiocarpa* and other species of class *Scheuchzerio-Caricetea nigrae* is distinct. The typical variant (Table 1A) of the subassociation is characterised by the occurrence of *Equisetum fluviatile* and *Menyanthes trifoliata*, with scarcity of brown mosses. In the botanical composition, the grasses of the *Calamagrostis* genus are prominent. Low sedge peats of that type have been identified only in the Długie Bagno Mire. They feature strong humification, on average 55%. The *Pseudocalliergon trifarium* variant is a community with distinct abundance of brown mosses (Table 1B). Brown moss peats associated with the discussed community can be found in the bottom of the Długie Bagno Mire. Their humification is on average 27%. The *Caricetum elatae* community a variant with *Carex lasiocarpa* in the Mazury Lakeland has been described by the author (KLOSS 1993). Detailed characteristics of the *Caricetum elate* subfossil community have been presented by OŚWIT (1976) and OŚWIT *et al.* (1981).

The *Thelypteridi-Phragmitetum* subfossil phytocoenosis features a high participation of *Thelypteris palustris* fern residues (Table 1C). This species is accompanied by *Phragmites australis* and *Cladium mariscus*. The botanical composition is represented by species of class *Scheuchzerio-Caricetea nigrae*. *Menyanthes trifoliata* and *Carex lasiocarpa* are common species. This community is also distinctive for the presence of *Carex diandra* and *Meesia triquetra*. The *Thelypteridi-Phragmitetum*

Table 1

Subfossil plant communities of the class *Phragmitetea* R.Tx. et Preisg. 1942

A - *Caricetum elatae caricetosum lasiocarpae*

B - *Caricetum elatae caricetosum lasiocarpae* var. *Pseudocalliergon trifarium*

C - *Thelypteridi-Phragmitetum*

Subfossil community	A	B	C
Number of botanical analyses	7	3	5
Mean share of plant macrofossils %			
Trees	2.0	< 1	0.0
Dwarf shrubs	0.0	< 1	0.0
Herbaceous plants	76.6	32.7	83.4
Brown mosses	7.2	61.7	13.6
Peatmosses	4.3	< 1	< 1
Mean peat decomposition degree %	55	27	35
Locality	DB	DB	SB

	S	U	L	U	S	U
Ch. <i>Phragmitetea</i> :						
<i>Carex elata</i>	V	3643	3	2167	I	20
<i>Phragmites australis</i>	V	829	2	7	V	1180
<i>Carex rostrata</i>	V	1287	2	367	II	140
<i>Equisetum fluviatile</i>	V	9	-	-	II	80
<i>Cladium mariscus</i>	-	-	-	-	V	900
<i>Carex vesicaria</i>	-	-	-	-	I	100
Ch. et D. <i>Scheuchzerio-Caricetea fuscae</i> :						
<i>Carex lasiocarpa</i>	V	430	3	270	V	820
<i>Carex nigra</i>	IV	7	3	10	II	120
<i>Sphagnum s. Cuspidata</i>	IV	7	1	3	II	4
<i>Sphagnum fallax</i>	III	330	2	37	II	4
<i>Pseudocalliergon trifarium</i>	III	73	3	4833	II	120
<i>Drepanocladus sendtneri</i>	II	529	3	337	I	200
<i>Menyanthes trifoliata</i>	IV	47	-	-	V	1400
<i>Scorpidium scorpioides</i>	-	-	1	500	II	240
<i>Comarum palustre</i>	II	3	1	3	-	-
<i>Carex diandra</i>	-	-	-	-	IV	84
<i>Meesia triquetra</i>	-	-	-	-	III	6
<i>Calliergon giganteum</i>	-	-	-	-	II	500
<i>Drepanocladoideae</i>	-	-	-	-	II	42
<i>Sphagnum cuspidatum</i>	II	43	-	-	-	-
<i>Eriophorum angustifolium</i>	I	1	-	-	-	-
<i>Calliergon sp.</i>	-	-	-	-	I	100
<i>Carex limosa</i>	-	-	-	-	I	2
Others:						
<i>Carex sp.</i>	V	429	3	333	IV	104
<i>Thelypteris palustris</i>	V	557	3	137	V	3200
<i>Bryopsida</i>	IV	117	3	500	III	162
<i>Salix sp.</i>	III	4	1	3	-	-
<i>Calamagrostis sp.</i>	V	216	-	-	-	-
<i>Betula pubescens</i>	IV	203	-	-	-	-
<i>Eriophorum vaginatum</i>	III	243	-	-	-	-
<i>Pinus sylvestris</i>	-	-	1	3	-	-
<i>Betula nana</i>	-	-	1	3	-	-
<i>Scirpus lacustris</i>	-	-	-	-	I	200
<i>Sphagnum s. Sphagnum</i>	-	-	-	-	II	4

S - Constancy; L - Number of occurrence; U - Plant macrofossil share coefficient;
Localities: SB - Suche Bagno; DB - Długie Bagno

phytocoenosis initiated the process of peat formation in the Suche Bagno Mire basin filled with lake sediments. Low reed peats with a marked share of ferns are characterised by an intermediate humification degree – 35%. In the Suche Bagno Mire deposit, peats have the form of a thin layer overlying the gyttja. The *Thelypteridi-Phragmitetum* subfossil community has been earlier described in the peatlands of the Mazury Lakeland by KLOSS (1993).

2.2.2. Communities of the *Scheuchzerio-Caricetea nigrae* class

The dominant species of the *Eriophorum vaginatum-Carex rostrata* subfossil community is sheathed cotton grass *Eriophorum vaginatum*. Less abundant is beaked sedge *Carex rostrata* (Table 2A). Plants typical for the *Scheuchzerio-Caricetea nigrae* class occur with high constancy. These are: *Eriophorum angustifolium*, *Carex lasiocarpa*, *Scheuchzeria palustris*, *Juncus filiformis* and also *Sphagnum fallax*, *S. cuspidatum* and *Warnstorfia fluitans*. Among raised bog vegetation attention deserve species such as *Sphagnum magellanicum*, *S. sec. Acutifolia*, *Aulacomnium palustre* and *Oxycoccus palustris*. The contribution of sphagnum mosses is insignificant. The *Eriophorum vaginatum-Carex rostrata* community in the floor of the mountain bog – Zieleniec Mire has been identified. The phytocoenoses of this mire started the development of peat deposits. The transitional bog peats are strongly humified. They feature an intermediate degree of humification amounting to 58%. Similar phytocoenoses of *Eriophorum vaginatum-Carex rostrata* have been identified in a raised bog deposit at Hala Izerska where they started the plaudification process (KLOSS 2004b). Also TOMASZEWSKA (2004) has identified those peat deposit-forming phytocoenoses in the Izerskie Mountains.

The share of sphagnum mosses in the botanical composition of the *Sphagnum fallax-Sphagnum cuspidatum* subfossil community are highly abundant (78.3%) (Table 2B). The prevailing species are *Sphagnum fallax* and *S. cuspidatum*. They are accompanied by *Warnstorfia fluitans*. Among the raised bog species of the community the presence of *Eriophorum vaginatum* and *Oxycoccus palustris* is noticeable. The share of sedges is negligible. The phytocoenosis under review has been identified in the mires: Długie Bagno, Rąbień, Białe Ługi and Zieleniec. Transitional sphagnum peats accumulated by the *Sphagnum fallax-Sphagnum cuspidatum* community occur in surface layers of the deposit. They feature a slight degree of peat humification averaging to 18%.

The *Eriophoro angustifolii-Sphagnetum fallacis* community contains subfossil phytocoenoses where plants of the *Scheuchzerio-Caricetea nigrae* class occur with high constancy, represented by *Eriophorum angustifolium*, *Menyanthes trifoliata*, *Carex lasiocarpa*, *Sphagnum fallax* and plants of the *Oxycocco-Sphagnetum* class represented by *Oxycoccus palustris*, *Eriophorum vaginatum* and *Sphagnum magellanicum* (Table 2C). The *Phragmitetea* class is represented by *Carex rostrata* and to a lesser degree by *Phragmites australis*. In the botanical composition *Betula pu-*

Table 2

Subfossil plant communities of the class *Scheuchzerio-Caricetea nigrae* (Nordh. 1937) R.Tx. 1937

- A - Community *Eriophorum vaginatum*-*Carex rostrata*
 B - Community *Sphagnum fallax*-*Sphagnum cuspidatum*
 C - *Eriophoro angustifolii*-*Sphagnetum fallacis*
 D - *Scheuchzerio*-*Caricetum limosae*
 E - *Caricetum lasiocarpae sphagnetosum*
 F - *Caricetum lasiocarpae typicum*
 G - *Caricetum lasiocarpae typicum* var. *Carex elata*
 H - *Caricetum lasiocarpae bryopsidaetosum*
 I - Community *Scorpidium scorpioides*
 J - *Menyantho*-*Sphagnetum teretis*

Subfossil community	A	B	C	D	E	F	G	H	I	J
Number of botanical analyses	5	9	9	35	19	19	8	16	6	6
Mean share of plant macrofossils %										
Trees	2.4	1.0	2.4	< 1	1.3	< 1	< 1	< 1	< 1	< 1
Dwarf shrubs	4.6	6.2	4.9	4.7	< 1	< 1	0.0	< 1	< 1	0.0
Herbaceous plants	72.8	6.6	56.3	52.7	57.6	76.0	84.0	31.5	23.0	20.5
Brown mosses	1.8	3.6	5.1	2.7	6.0	12.0	10.9	60.9	71.8	9.2
Peatmosses	12.6	78.3	24.0	34.6	29.4	4.2	0.3	1.2	1.1	68.3
Mean peat decomposition degree %	58	18	51	35	31	35	21	30	35	29
Locality	Z	R; DB; Z; BL	L; BL; Z	SB; K; R; Z; L	SB; BL; Z; L	SB; R; BL; L; K	K	K; L; BL	BL; L	BL
Ch. et D. <i>Oxycocco-Sphagneteta</i> :	S	U	S	S	S	U	S	U	S	U
<i>Aulacomnium palustre</i>	III	6	I	I	I	I	11	II	58	I 17
<i>Sphagnum s. Acutifolia</i>	V	46	I	I	II	43	II	I	13	II 250
<i>Sphagnum magellanicum</i>	V	560	I	111	IV	53	I	I	2	II 3
<i>Eriophorum vaginatum</i>	V	4100	V	402	V	317	II	I	1	I 2
<i>Ericaceae</i>	V	340	V	381	V	38	I	I	19	
<i>Oxycoccus palustris</i>	III	162	IV	213	V	I	1			
<i>Polytrichum strictum</i>		I	I	I	I			I	I	II 150
<i>Vaccinium uliginosum</i>	II	4	III	14	I	I	0.3			

[illegible]

bescens and *Pinus sylvestris* has been recorded. The *Eriophoro angustifolii-Sphagnetum fallaxis* community has been found in peat deposits of the Linje, Białe Ługi and Zieleniec mires. Transitional bog peats associated with this community are strongly humified. The average humification degree amounts to 51%.

The *Scheuchzerio-Caricetum limosae* subfossil community is relatively abundant in species such as *Scheuchzeria palustris*, *Carex limosa*, as well as *Sphagnum fallax* and *S. cuspidatum* (Table 2D). Among the raised bog species these are accompanied by, among others: *Eriophorum vaginatum*, *Oxycoccus palustris* and *Sphagnum magellanicum*. The reedbed plants are represented by *Carex rostrata*. The *Scheuchzerio-Caricetum limosae* community has been reconstructed in the peat deposits of Suche Bagno, Kołowin, Linje, Rąbień and Zieleniec mires. The average humification of the transitional bog peats, sphagnum-sedge peats and sphagnum-*Scheuchzeria* peats deposited by this community is 35%. The *Caricetum limosae* subfossil phytocoenoses in the Wieliszewo Mire were characterised by PACOWSKI (1967), in the Bór na Czerwonym Mire – by WÓJCIKIEWICZ (1979) and in the mires of the Mazury Lakeland – by KLOSS (1993).

In the botanical composition of the *Caricetum lasiocarpae* subfossil community there is a prevalence of plants of the *Scheuchzerio-Caricetea nigrae* class. Among the identified subfossil plants *Carex lasiocarpa* occur with high constancy and abundance. This species is accompanied by *Eriophorum angustifolium*, *Menyanthes trifoliata* and *Carex nigra*. *Carex rostrata* and *Thelypteris palustris* are an important element of the phytocoenoses. The *Caricetum lasiocarpae* subfossil phytocoenosis are frequent. Within the discussed community three sub-associations can be distinguished depending on species combination.

Caricetum lasiocarpae sphagnetosum subfossil phytocoenoses feature the high share of sphagnum mosses: *Sphagnum fallax*, *S. teres*, *S. subsecundum*, *S. sec. Cuspidata* (Table 2E). Among plant remains *Eriophorum vaginatum* can be found. The *Caricetum lasiocarpae sphagnetosum* has been reconstructed in the mires: Linje, Suche Bagno, Białe Ługi and Zieleniec. The average humification of transitional bog peats, sphagnum-sedge peats associated with the community under study amounts to 31%.

For the *Caricetum lasiocarpae typicum* subfossil phytocoenoses sphagnum mosses are of minor importance (Table 2F, G). In the botanical composition *Carex elata* are in high abundance. Species of the oligotrophic sites occur only occasionally (Table 2F). Phytocoenoses of the *Carex elata* variant are characterised by mosses: *Pseudocalliergon trifarium*, *Drepanocladus aduncus* and *Meesia longiseta* (Table 2G). The low peats, sedge-brown moss peats representing the *Caricetum lasiocarpae typicum* community form deposits in the mires of Suche Bagno, Kołowin, Linje, Rąbień and Białe Ługi. The phytocoenoses of the *Carex elata* variant have been identified only in the Kołowin Mire. The average degree of peat humification in the typical variant amounts to 39% and that of *Carex elata* – 21%.

The *Caricetum lasiocarpae bryopsidaetosum* subfossil phytocoenoses feature a mass occurrence of brown moss species (*Bryopsida*) (Table 2H). Their share in

macrofossils does not exceed 60% on average. *Drepanocladus sendtneri* and *Pseudocalliergon trifarium* are among the most common species. The *Caricetum lasiocarpae bryopsidaetosum* phytocoenoses have been recorded in peat deposits of the Kołowin, Linje and Białe Ługi mires. The fen peats, brown moss peats accumulated by this community can be most frequently found in the bottom of the deposits. On average the peats are humified in 30%. The *Caricetum lasiocarpae* subfossil phytocoenoses under study are comparable with those previously described by the author in the Mazury Lakeland (KLOSS 1993).

The subfossil community with *Scorpidium scorpioides* is distinguished by the mass presence of this moss species (Table 2I). It is accompanied by a more abundant *Warnstorfia exannulata*. The average share of brown moss remains is 71.8%. *Carex rostrata* and *Menyanthes trifoliata* in the community occur with high constancy. The species of the *Oxycocco-Sphagnetum* class are very rare. The brown moss peats deposited by this community occur sporadically in the bottom of peat deposits of the Linje and Białe Ługi mires (KLOSS 2001). The degree of peat humification amounts to 35% on average.

The *Menyantho-Sphagnetum teretis* subfossil community features a high share of *Sphagnum teres* (Table 2J). This species is accompanied by a group of plants of the *Scheuchzerio-Caricetea nigrae* class: *Menyanthes trifoliata*, *Sphagnum fallax*, *Warnstorfia exannulata* and *Meesia triquetra*. The occurrence of *Carex rostrata* in the plant remains is high. The raised bog species occur sporadically. The *Menyantho-Sphagnetum teretis* subfossil community has been identified in the peat deposit of the Białe Ługi Mire (KLOSS 2001). The transitional bog peats, sphagnum-sedge peats, representing phytocoenoses with the dominance of *Sphagnum teres* feature a slight degree of humification averaging to 29%.

2.2.3. Communities of the *Oxycocco-Sphagnetum* class

The *Eriophorum vaginatum-Sphagnum fallax* subfossil community is characterised by a high share of sheathed cotton grass residues in peat deposits accompanied by sphagnum mosses *Sphagnum fallax* and *S. cuspidatum* (Table 3A). *Oxycoccus palustris* in the phytocoenoses occur with high constancy. Also the share of *Warnstorfia fluitans* is noteworthy. The *Eriophorum vaginatum-Sphagnum fallax* community has been identified in peat profiles in the upper part of the deposit in the Linje, Długie Bagno and Białe Ługi mires. The raised bog peats, cotton grass-sphagnum peats, deposited by this community feature an intermediate degree of peat humification on average amounting to 30%. Similar floristic composition of subfossil phytocoenoses has been described by HERBICHOWA (1998) in the Baltic-type raised bogs deposits.

In the botanical composition of the *Sphagnetum magellanici* subfossil community the greatest group are species of the *Oxycocco-Sphagnetum* class (Table 3B-G). The sphagnum mosses occur with high constancy and on a mass scale. Differences

Table 3

Subfossil plant communities of the alliances *Sphagnion magellanici* Kästn. et Flösmn. 1933 em. Dierss. 1975 and *Dicrano-Pinion* Libb. 1933*

A - Community *Eriophorum vaginatum*-*Sphagnum fallax*

B - *Sphagnetum magellanici eriophoretosum*

C - *Sphagnetum magellanici sphagnetosum fallacis*

D - *Sphagnetum magellanici sphagnetosum fuscis*

E - *Sphagnetum magellanici typicum*

F - *Sphagnetum magellanici typicum* var. *Oxycoccus palustris*

G - *Sphagnetum magellanici pinetosum*

H - *Vaccinio uliginosi-Pinetum**

Subfossil community	A	B	C	D	E	F	G	H
Number of botanical analyses	5	10	41	12	96	14	17	11
Mean share of plant macrofossils %								
Trees	1.2	1.9	< 1	< 1	< 1	< 1	11.4	25.2
Dwarf shrubs	2.0	6.3	6.4	5.1	7.1	27.6	6.5	10.6
Herbaceous plants	55.0	64.5	11.6	11.5	14.8	26.2	46.6	29.6
Brown mosses	4.8	< 1	< 1	2.9	< 1	< 1	< 1	< 1
Peatmosses	32.4	19.4	76.0	76.1	73.6	36.4	19.4	9.8
Mean peat decomposition degree %	30	53	22	29	33	57	58	65
Locality	DB; L; BŁ	Z; R; BŁ	SB; K; Z; L; DB; BŁ	R; Z; L; BŁ	SB; K; R; Z; BŁ; L	L	SB; BŁ; DB	BŁ; DB; R
Ch. et D. Oxycocco-Sphagneteta:	S	S	S	S	S	S	S	S
<i>Sphagnum magellanicum</i>	III	V	IV	V	V	V	III	IV
<i>Eriophorum vaginatum</i>	V	5200	600	877	V	908	596	130
<i>Ericaceae</i>	V	124	V	1018	V	2571	4376	2155
<i>Oxycoccus palustris</i>	IV	84	V	159	V	514	266	693
<i>Sphagnum s. Acutifolia</i>	I	2	V	317	V	V	171	48
<i>Ledum palustre</i>	I	2	-	V	IV	V	149	56
<i>Sphagnum capillifolium</i>	I	2	-	II	III	I	171	120
<i>Aulacomnium palustre</i>	I	2	I	V	II	I	I	I
<i>Polytichum strictum</i>	-	-	I	-	I	37	3	1
<i>Vaccinium uliginosum</i>	-	-	II	85	I	I	I	18
<i>Andromeda polifolia</i>	-	-	III	2	II	-	19	139
<i>Sphagnum fuscum</i>	-	-	I	I	II	-	-	-
<i>Chamaedaphne calyculata</i>	-	-	-	V	I	-	-	-
	-	-	-	5625	89	-	-	-
	-	-	-	-	I	-	-	-
	-	-	-	-	0.1	-	-	-

Ch et D. Scheuchzerio-Caricetea nigrae:

<i>Sphagnum fallax</i>	V	2840	V	690	V	6320	V	138	V	1244	V	2064	V	1231	V	792
<i>Sphagnum cuspidatum</i>	V	262	II	150	III	163	II	3	II	98	I	2	II	43	III	22
<i>Sphagnum s. cuspidata</i>	II	42	II	42	IV	255	IV	63	IV	188	III	286	II	8	II	83
<i>Carex lasiocarpa</i>	I	20	II	31	I	6	I	8	I	1	I	2	I	29	II	56
<i>Eriophorum angustifolium</i>	I	100	I	1	II	70	I	43	I	4	I	1	I	1	II	29
<i>Wernstorffia fluitans</i>	III	480	II	11	I	3	-	-	-	9	I	1	I	1	I	2
<i>Scheuchzeria palustris</i>	-	-	-	-	III	214	I	2	II	104	III	31	II	42	I	55
<i>Menyanthes trifoliata</i>	-	-	-	-	-	7	I	67	-	-	I	1	I	18	II	28
<i>Carex nigra</i>	II	102	-	-	II	35	-	-	-	1	-	-	II	59	I	10
<i>Carex limosa</i>	I	60	I	1	I	0.2	-	-	-	0.3	-	-	-	-	-	-
<i>Straminergon stramineum</i>	-	-	-	-	I	40	I	33	I	0.4	I	1	-	-	-	-
<i>Sphagnum majus</i>	-	-	-	-	I	0.2	-	-	-	-	-	-	-	-	-	-
Others:																
<i>Bryopsisida</i>	II	6	III	5	II	7	II	52	I	4	II	45	II	31	I	36
<i>Pinus sylvestris</i>	III	102	IV	112	II	17	I	2	II	9	II	3	V	824	V	1218
<i>Betula pubescens</i>	II	24	II	80	II	10	-	-	-	1	III	5	V	307	V	1118
<i>Carex rostrata</i>	I	20	-	-	I	0.5	I	8	I	4	II	17	II	89	IV	137
<i>Carex sp.</i>	-	-	I	20	II	9	I	1	I	1	II	9	II	31	III	65
<i>Calluna vulgaris</i>	-	-	II	2	-	5	-	-	-	1	-	-	I	1	II	38
<i>Polytrichum commune</i>	-	-	-	-	-	0.2	-	-	-	2	-	-	II	31	I	45
<i>Betula nana</i>	-	-	-	-	-	1	I	2	I	2	III	6	-	-	-	-
<i>Phragmites australis</i>	-	-	-	-	-	2	-	-	-	-	-	-	II	3	II	318
<i>Sphagnum flexuosum</i>	-	-	-	-	-	0.5	-	-	-	0.1	-	-	-	-	-	45
<i>Beula sp.</i>	-	-	-	-	-	-	-	-	-	2	I	1	-	-	-	18
<i>Polypodiales</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	12	II	38
<i>Sphagnum rubellum</i>	-	-	-	-	-	0.2	-	-	-	114	-	-	-	-	-	-
<i>Pleurozium schreberi</i>	-	-	-	-	-	0.2	-	-	-	6	-	-	-	-	-	-
<i>Sphagnum s. Sphagnum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	II	11
<i>Poaceae</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	III	85
<i>Sphagnum angustifolium</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Sphagnum balticum</i>	-	-	-	-	-	-	-	-	-	0.4	-	-	-	-	-	-
<i>Picea abies</i>	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-

S - Constancy; U - Plant macrofossil share coefficient;
Localities: SB - Suche Bagno; K - Kotowin; L - Linie; DB - Długie Bagno; R - Rąbień; BŁ - Białe Ługi; Z - Zieloniec

in floristic combination enabled distinguishing five sub-associations within this community.

In the botanical composition of peat remains in the *Sphagnetum magellanici eriophoretosum* subfossil community *Eriophorum vaginatum* is the dominant species (Table 3B). Other permanent components of raised bogs include: *Sphagnum magellanicum*, *S. sec. Acutifolia* and dwarf shrubs: mainly *Oxycoccus palustris*, less frequently *Vaccinium uliginosum*. Also the share of *Pinus sylvestris* is noteworthy. The raised bog peats, cotton grass-sphagnum peats that developed as a result of an accumulative activity of the community can be found in peat deposits of the Rąbień, Białe Ługi and Zieleniec mires. They are strongly humified. The average degree of peat humification amounts to 53%. The *Sphagnetum magellanici eriophoretosum* subfossil phytocoenoses were described by PACOWSKI (1967), OŚWIT *et al.* (1981), KLOSS (1993) and DRZYMULSKA (2004).

The *Sphagnetum magellanici sphagnetosum fallacies* phytocoenoses are characterised by significant admixture of plants typical for the *Scheuchzerio-Caricetea nigrae* class (Table 3C). *Sphagnum fallax* are abundant, *S. magellanicum* and *S. cuspidatum* are less frequent there. *Eriophorum vaginatum* and *Oxycoccus palustris* in the community occur with high constancy. The phytocoenoses of the sub-association under study have been detected in the peat profiles of the Suche Bagno, Kołowin, Linje, Długie Bagno, Białe Ługi and Zieleniec mires. The raised bog peats, sphagnum-hollow peats representing this community are poorly humified and can be found mainly in the surface deposit layers. The average degree of peat humification amounts to 22%. In the subfossil state the *Sphagnetum magellanici sphagnetosum fallaxis* phytocoenoses were earlier described by KLOSS (1993) and DRZYMULSKA (2004). Their floristic composition can be related to the *Eriophoro-Sphagnetum apiculati* subfossil community described by PACOWSKI (1967) in the profiles of the Wieliszewo Mire and by WÓJCIKIEWICZ (1979) in the peat deposit of the Bór na Czerwonym Mire.

The dominance of *Sphagnum fuscum* and a permanent presence of *Sphagnum capillifolium* is a characteristic feature of the *Sphagnetum magellanici sphagnetosum fusci* subfossil community (Table 3D). The *Oxycocco-Sphagnetetea* class is also abundantly represented by *Sphagnum magellanicum*, *Eriophorum vaginatum* and *Oxycoccus palustris*. This phytocoenosis has been recorded in the peat profiles of the Linje, Rąbień, Białe Ługi and Zieleniec mires. The intermediate humification of raised bog peat, sphagnum-hummock peat deposited by this community is 29%. The *Sphagnetum magellanici sphagnetosum fusci* community distinguished in the mires under study can be referred to the *Sphagnum fuscum*-dominated subfossil phytocoenoses described by PACOWSKI (1967), OŚWIT *et al.* (1981), KLOSS (1993) and HERBICHOVA (1998).

The phytocoenoses of *Sphagnetum magellanici typicum* are dominated by *Sphagnum magellanicum* with a significant share of other sphagnum species (Table 3E). Among vascular plants *Eriophorum vaginatum* and *Oxycoccus palustris* and *Ledum palustre* have been recorded. In the variant with *Oxycoccus palustris* the presence

of *Aulacomnium palustre* is its distinctive feature (Table 3F). The raised bog peats, sphagnum-hummock peats whose parental community is *Sphagnetum magellanicum typicum* occur in the deposits of the Suche Bagno, Kołowin, Linje, Rąbień and Białe Ługi mires. The average humification degree of these peats amounts to – 33%. The subfossil phytocoenoses of the *Oxycoccus palustris* variant have been detected only in the lower part of the deposit of the Linje Mire. The peats associated with this community are strongly humified, on average amounting to 57%. The sub-association under study can be identified with *Sphagnetum magellanicum (medii)* subfossil communities described by PACOWSKI (1967), PAŁCZYŃSKI (1975), WÓJCIKIEWICZ (1979), OBIDOWICZ (1990), KLOSS (1993) and DRZYMULSKA (2004).

The *Sphagnetum magellanicum pinetosum* phytocoenoses in the fossil state are characterised by a high share of *Pinus sylvestris* and *Betula pubescens* remains (Table 3G). Among raised bog plants *Eriophorum vaginatum* is markedly more abundant. Sheathed cotton grass is accompanied by *Sphagnum fallax*, *S. magellanicum* and *Ericaceae* dwarf shrubs, including *Oxycoccus palustris* and *Ledum palustre*. The *Sphagnetum magellanicum pinetosum* community has been identified in peat deposits of the Suche Bagno, Długie Bagno and Białe Ługi mires. It forms a raised bog peat with a high degree of humification, on average 58%. The community under study shows high similarities to those described by PACOWSKI (1967), WÓJCIKIEWICZ (1979), KLOSS (1993) and DRZYMULSKA (2004).

2.2.4. Community of the *Alnetea glutinosae* class

Sphagnum-Betula pubescens subfossil community features a high share of wood remains in peat composition (19.1%) (Table 4A). The wood of *Betula pubescens* prevails. *Carex lasiocarpa*, *Sphagnum fallax*, *Menyanthes trifoliata* of the *Scheuchzeria-Caricetea nigrae* class have a major share in the botanical composition. These species are accompanied by *Eriophorum vaginatum*, *Phragmites australis* and *Carex rostrata* and are a stable component of the phytocoenoses. *Sphagnum-Betula pube-*

Table 4

Subfossil plant communities of the alliances *Alnion glutinosae* Malc. 1929) Meijer Drees 1936* and *Piceion abietis* Pawł. et al. 1928**

A - Community *Sphagnum-Betula pubescens**

B - Community *Sphagnum-Picea abies***

Subfossil community	A	B
Number of botanical analyses	7	11
Mean share of plant macrofossils %		
Trees	19.1	52.2
Dwarf shrubs	2.2	1.7
Herbaceous plants	51.6	26.7
Brown mosses	1.2	0.7
Peatmosses	9.7	10.5
Mean peat decomposition degree %	61	59

Locality	DB; Z; BŁ		Z	
	S	U	S	U
Ch. et D. <i>Alnetea glutinosae</i> :				
<i>Betula pubescens</i>	V	1629	II	409
<i>Thelypteris palustris</i>	III	100	III	21
<i>Alnus glutinosa</i>	II	3	-	-
Ch. et D. <i>Vaccinio-Piceetea</i> :				
<i>Pinus sylvestris</i>	IV	89	IV	265
<i>Picea abies</i>	I	14	V	3773
<i>Polytrichum commune</i>	I	1	III	13
<i>Vaccinium uliginosum</i>	I	1	-	-
Ch. <i>Phragmitetea</i> :				
<i>Phragmites australis</i>	V	1816	IV	900
<i>Carex rostrata</i>	V	444	V	401
<i>Equisetum fluviatile</i>	-	-	III	65
<i>Carex elata</i>	I	1	-	-
Ch. et D. <i>Scheuchzerio-Caricetea nigrae</i> :				
<i>Sphagnum fallax</i>	V	703	V	773
<i>Menyanthes trifoliata</i>	V	860	V	500
<i>Carex lasiocarpa</i>	V	287	II	38
<i>Sphagnum s. Cuspidata</i>	III	60	V	53
<i>Scheuchzeria palustris</i>	III	4	IV	182
<i>Eriophorum angustifolium</i>	II	3	II	4
<i>Carex nigra</i>	I	143	I	1
<i>Comarum palustre</i>	I	1	I	2
<i>Sphagnum cuspidatum</i>	II	143	-	-
<i>Pseudocalliergon trifarium</i>	II	73	-	-
<i>Straminergon stramineum</i>	-	-	II	21
<i>Sphagnum teres</i>	-	-	II	3
<i>Warnstorfia fluitans</i>	-	-	I	2
Others:				
<i>Eriophorum vaginatum</i>	V	1330	V	246
<i>Ericaceae</i>	III	116	IV	165
<i>Carex sp.</i>	V	160	III	75
<i>Sphagnum s. Sphagnum</i>	IV	20	V	211
<i>Betula sp.</i>	V	189	IV	773
<i>Bryopsida</i>	III	46	III	39
<i>Poaceae (Calamagrostis sp.)</i>	II	16	III	101
<i>Sphagnum s. Acutifolia</i>	I	57	III	30
<i>Salix sp.</i>	II	3	II	4
<i>Oxycoccus palustris</i>	I	1	I	1
<i>Aulacomnium palustre</i>	I	1	-	-

S - Constancy; U - Plant macrofossil share coefficient

Localities: DB - Długie Bagno; BŁ - Białe Ługi; Z - Zieleniec

scens phytocoenoses have been identified in the peat deposits of the Długie Bagno, Białe Ługi and Zieleniec mires. Transitional peats as a result of the accumulative activity of this community are usually strongly humified, 61% on average.

2.2.5. Communities of the *Vaccinio-Piceetea* class

In its botanical composition the *Vaccinio uliginosi-Pinetum* subfossil community corresponds to the *Sphagnetum magellanicum pinetosum* phytocoenosis. It has a larger share of wood fragments (25.2%) among which the remains of *Betula pubescens* and *Pinus sylvestris* occur with high constancy (Table 3H). They are accompanied by, among others, *Eriophorum vaginatum* and *Sphagnum magellanicum* from a group of the raised bog species. The dwarf shrubs of the *Ericaceae* family are a regular component of this phytocoenosis. *Sphagnum fallax* and *Carex rostrata* should also be mentioned. The presence of *Poaceae* species is noted. A community of the *Vaccinio uliginosi-Pinetum* type has been identified in the peat profiles of the Długie Bagno, Rąbień, and Białe Ługi mires. Raised bog peats developed in this community are very strongly humified, up to 65% on average.

The *Sphagnum-Picea abies* subfossil community is dominated by *Picea abies* with an insignificant participation of *Pinus sylvestris* and *Betula* sp. remains (Table 4B). The average share of wood in the botanical composition of peat is 52.2%. Reedbed species include *Phragmites australis* and *Carex rostrata* and *Equisetum fluviatile* occurs with lower constancy. Species frequently found are: *Eriophorum vaginatum*, *Menyanthes trifoliata*, *Scheuchzeria palustris*, *Sphagnum fallax*, *S. sec. Sphagnum*, *S. sec. Acutifolia*. The presence of *Polytrichum commune* is a distinctive element of these phytocoenoses. The *Sphagnum-Picea abies* community has been reconstructed in the bottom layer of the Zieleniec Mire. Transitional peats that originated as a result of the peat-forming activity of the community under study are strongly humified. The average degree of peat humification amounts to 59%. The spruce forest subfossil phytocoenoses identified in the bottom part of the peat deposits have been recognised by TOMASZEWSKA (2004) in the peatbogs of the Izerskie Mountains.

2.3. Subfossil plant succession

The palaeophytosociological analyses enabled reconstruction of plant communities and determination of plant succession in the places where peat profiles were taken. A series of changes in plant communities, starting from the initial stage of bog development differs amongst the investigated mires (Figures 1-7). Each bog is represented by one peat core taken from its central part. The local changes in vegetation are illustrated below by the developmental series in which the last stage is the contemporary community.

Changes in the vegetation of the Suche Bagno Mire. The succession of plant communities in the central part of the transect, in the Suche Bagno Mire (borehole 2, Fig. 1) is as follows:

Potametea → *Thelypteridi-Phragmitetum* → *Caricetum lasiocarpae typicum* → *Caricetum lasiocarpae sphagnetosum* → *Sphagnetum magellanici typicum* → *Sphagnetum magellanici pinetosum* → *Sphagnetum magellanici typicum* → *Sphagnetum magellanici sphagnetosum fallacis* → *Sphagnetum magellanici typicum* → ***Ledo-Sphagnetum magellanici***.

Changes in the vegetation of the Kołowin Mire. The succession of plant communities in the central part of the transect in the Kołowin Mire (borehole 2, Fig. 2) is as follows:

Potametea → *Caricetum lasiocarpae bryopsidaetosum* → *Caricetum lasiocarpae typicum var. Carex elata* → *Caricetum lasiocarpae typicum* → *Scheuchzerio-Caricetum limosae* → *Sphagnetum magellanici typicum* → *Sphagnetum magellanici sphagnetosum fallacis* → ***Sphagnetum magellanici***.

Changes in the vegetation of the Linje Mire. The succession of plant communities in the central part of the Linje Mire (borehole 4, Fig. 3) is as follows:

community *Scorpidium scorpioides* → *Scheuchzerio-Caricetum limosae* → *Sphagnetum magellanici typicum var. Oxycoccus palustris* → *Sphagnetum magellanici typicum* → *Scheuchzerio-Caricetum limosae* → *Sphagnetum magellanici sphagnetosum fallacis* → *Sphagnetum magellanici typicum* → *Sphagnetum magellanici sphagnetosum fallacis* → *Sphagnetum magellanici typicum* → *Sphagnetum magellanici sphagnetosum fuscum* → *Sphagnetum magellanici typicum* → *Sphagnetum magellanici sphagnetosum fallacis* → ***Ledo-Sphagnetum magellanici***.

Changes in the vegetation of the Długie Bagno Mire. The succession of plant communities in the central part of the transect in the Długie Bagno Mire (borehole 2, Fig. 4) is as follows:

Caricetum elatae caricetosum lasiocarpae var. Pseudocalliergon trifarium → *Caricetum elatae caricetosum lasiocarpae* → community *Sphagnum-Betula pubescens* → *Sphagnetum magellanici pinetosum* → *Sphagnetum magellanici sphagnetosum fallacis* → community ***Eriophorum vaginatum-Sphagnum fallax***.

Changes in the vegetation of the Rąbień Mire. The succession of plant communities in the central part of the transect in the Rąbień Mire (borehole 1, Fig. 5) is as follows:

Potametea → *Caricetum lasiocarpae typicum* → *Scheuchzerio-Caricetum limosae* → *Sphagnetum magellanici typicum* → *Sphagnetum magellanici sphagnetosum fuscum* → *Sphagnetum magellanici eriophoretosum* → *Vaccinio uliginosi-Pinetum* → community *Sphagnum fallax-Sphagnum cuspidatum* → community *Betula pubescens-Ericaceae* → ***Vaccinio uliginosi-Pinetum***.

Changes in the vegetation of the Białe Ługi Mire. The succession of plant communities in the central part of the transect in the Białe Ługi Mire (borehole 3, Fig. 6) is as follows:

community *Scorpidium scorpioides* → *Caricetum lasiocarpae typicum* → *Caricetum lasiocarpae bryopsidaetosum* → *Sphagnetum magellanici sphagnetosum fusci* → *Caricetum lasiocarpae typicum* → *Caricetum lasiocarpae sphagnetosum* → *Sphagnetum magellanici eriophoretosum* → community *Eriophorum vaginatum-Sphagnum fallax* → *Sphagnetum magellanici sphagnetosum fallacis* → ***Sphagnetum magellanici***.

Changes in the vegetation of the Zieleniec Mire. The succession of plant communities in the central part of the transect in the Zieleniec Mire (borehole 3, Fig. 7) is as follows:

community *Eriophorum vaginatum-Carex rostrata* → *Scheuchzerio-Caricetum limosae* → *Sphagnetum magellanici typicum* → *Sphagnetum magellanici sphagnetosum fuscae* → *Sphagnetum magellanici typicum* → *Sphagnetum magellanici eriophoretosum* → *Sphagnetum magellanici typicum* → *Sphagnetum magellanici eriophoretosum* → *Sphagnetum magellanici sphagnetosum fallacis* → ***Sphagnetum magellanici***.

2.4. Stages of mire development

The mires under study can be divided into three groups differing in the main stages of vegetation development. The first group includes the Suche Bagno, Kołowin and Rąbień mires. The process of peat initiation in these bogs began during the Atlantic Period of the Holocene in the shallowed water bodies where organic sediments accumulated. The main stages and directions of plant succession are as follows:

- Lake phase → low mire phase → transitional mire phase → raised mire phase.

The second group encompasses the Linje, Długie Bagno and Białe Ługi mires. The peat accumulation process in these bogs began already during the Late Glacial or at the turn of the Late Glacial/Holocene directly on the mineral bedding.

The main stages and directions of plant succession are as follows:

- Low mire phase → transitional mire phase → raised mire phase.

The third, separate group encompasses a mountain bog – Zieleniec Mire. The process of peat initiation began during the Boreal Period of the Holocene as a result of paludification of the mineral bedding. The main stages and directions of plant succession are as follows:

- Transitional mire phase → raised mire phase.

2.5. Glacial relics

Betula nana L. and *Chamaedaphne calyculata* (L.) Moench have in Poland the status of glacial relics and are species threatened by extinction (KLOSS, SIENKIEWICZ 1999; KRUSZELNICKI 2001; KRUSZELNICKI, FABISZEWSKI 2001). Amongst bogs under review, dwarf birch can be found in the mires of Linje and Zieleniec while in the Kołowin Mire – leather leaf. The botanical composition analysis of biogenic deposits enables detecting the presence of relic species from the end of the Late Glacial, i.e. from the cold climate period until present.

Peat deposits coming from the profile of the Linje Mire date back to the Younger Dryas Period (10740 ± 270 BP). The macroscopic remains of *Betula nana* in the form of fragments of leaves, wood or nuts can be found in many zones within the entire peat core. According to the palynographic diagrams, pollen identified as a *Betula nana* type is present in the entire profile (NORYŚKIEWICZ 2005). This is confirmed by the relic character of the dwarf birch stand in the Linje Mire. In the Zieleniec Mire the presence of *Betula nana* has been documented since bog initiation (Boreal Period) until contemporary times both in the form of pollen grains and in the form of leaves (MADEYSKA 2005).

Different situation has been found in the Kołowin Mire containing *Chamaedaphne calyculata*. The remains of this dwarf shrub have been identified only in the top layers of the bog profile. The age in the highest, ceiling layer of lake sediments in the bottom of the peat deposit is about 8000 BP, which precludes the continuous presence of the *Chamaedaphne calyculata* population since the glacial times. Also *Chamaedaphne calyculata* in the Sicienko Mire, in the Drawieński National Park is a young component of the bog's flora (LATAŁOWA 2001).

3. PALAEOHYDROLOGICAL CHANGES IN MIRE DEVELOPMENT

In the mires under review the phytocoenotic moisture index (FWW) for the reconstructed subfossil phytocoenoses have been determined on the basis of moisture indicator values developed for individual plant species (KLOSS 2004a, 2005). This allowed assessment of the conditions in the acrotelm of the bog in different phases of its development using a 10-degree scale. The communities with the indicators falling within the range 6.0-6.9 correspond to moist habitats, those within the range 7.0-7.9 – to wet habitats and those within the range 8.0-10.0 – to swampy habitats. A schematic of moisture degrees and conditions of wetland sites in connection to moisture numbers is given in Table 5. Analysing the distribution of subfossil phytocoenoses with different indicator values in the peat profiles under review a picture of hydrological changes in the successive stages of bog development has been obtained (Tables 6-12). Changes in the stratigraphy

Fig. 8. Changes in stratigraphy of seven peat profiles, against the time scale of Late Glacial and Holocene
 1 – raised sphagnum peat; 2 – transitional sphagnum peat; 3 – transitional sphagnum peat with wood; 4 – sedge-brown moss peat; 5 – brown moss peat; 6 – tall-sedge peat; 7 – reed peat; 8 – gytja; 9 – sand; 10 – clayey formation; 11 – bed-rock; 12 – data C¹⁴. SA – Subatlantic; SB – Subboreal; AT – Atlantic; BO – Boreal; PB – Preboreal; YD – Younger Dryas; ALL – Alleröd; OD – Older Dryas; BÖLL – Bölling

Table 5
Division of wetland sites

Type of site moisture		Phytocoeonotic moisture index [FWW]
Moist	moderate moist	6.0-6.4
	heavily moist	6.5-6.9
Wet	moderate wet	7.0-7.4
	heavily wet	7.5-7.9
Swampy	waterlogged	8.0-8.4
	heavily waterlogged	8.5-8.9
	floating mat	≥ 9.0

of seven peat profiles representing the bogs under study against the time scale is presented in Figure 8.

The Suche Bagno Mire. This peatbog developed in a shallowed lake basin in the middle of the Atlantic Period. Strongly diluted organic deposits of the gyttja, relatively rich in calcium, were overlain by reed peats containing *Thelypteris palustris* and *Cladium mariscus*. Pararel to the accumulation of peat deposits the peat-forming phytocoenoses developed gradually becoming independent of the peat-bog groundwaters accompanied by a steady decline in the trophy. Reed peats gave way to sedge-brown moss peats. Hydrological conditions on the surface of the bog developed under the growing influence of capillary ascension, which enhanced the oligotrophisation of habitats and development of the transitional bog brown moss peats. At the final stage of bog development in the second half of the Sub-boreal Period the water management of the wetland changed from the capillary

Table 6
Hydrological conditions change in the Suche Bagno mire development (profile 2)

Depth [cm]	Type of site moisture	FWW	H	Age C ¹⁴ BP
000-005	moderate wet	7.2	2	~100-200
010-015	moderate wet	7.2 ↓	30	
015-020	heavily wet	7.6	25	
025-030	heavily wet	7.9 ↑	15	
045-050	moderate wet	7.1	30	
060-070	moderate wet	7.2	35	
085-095	moderate wet	7.1	35	
102-107	moderate wet	7.1	40	
125-132	heavily moist	6.9 ↓	55	
142-150	moderate wet	7.0	35	
150-155	moderate wet	7.1	10	1735±30
165-170	moderate wet	7.1	25	
190-195	moderate wet	7.1	30	
205-210	moderate wet	7.1	25	
220-225	moderate wet	7.1 ↓	25	

235-240	waterlogged	8.0	20	3320±35
245-250	waterlogged	8.2 ↓	20	
250-255	heavily waterlogged	8.6	30	
265-270	heavily waterlogged	8.6	30	
285-290	heavily waterlogged	8.6 ↓	30	4125±35
300-305	floating mat	9.0	30	
405-410	floating mat	9.1	30	
435-440	floating mat	9.0	30	
460-470	floating mat	9.0	40	6670±40
475-480	floating mat	9.0 ↓	45	
480-680	lake			

FWW – Phytocoenotic moisture index; H – Peat decomposition degree;

↓ – Decrease in moisture degree; ↑ – Increase in moisture degree

ascension type into the ombrogenic one. The bog has been under the prevalent effect of precipitation waters and dominated by raised bog moss communities. In the hydrogenetic classification differentiating wetlands with regard to the origin of the feeding waters, the Suche Bagno Mire can be described as mixed topogenous-ombrogenous type (cf. v. POST, GRANLUND 1926; OKRUSZKO 1983).

The stratigraphical studies in profile 2 document the eightfold changes in the water level (Table 6). Six of them are associated with the dry phase and one with the moisture growth phase.

The Kołowin Mire. The peat formation process in the water body filled in with sediments took place at the turn of the Boreal and Atlantic Periods. This process was initiated by moss phytocoenoses, which colonised the surface of the lake in the form of a brown moss or sedge-moss blanket. The sedge-brown moss peats developed during most of the time of deposit growth, which is indicative of great stability of water relations and strong waterlogging of habitats with waters supplemented by the underground water inflow from the catchment. It was not earlier than the middle of the Subatlantic Period when substantial changes in water supply to the bog occurred. The changes in hydrological relations consisted in the growing dependence of the peatland on precipitation waters. The water management in the peatland changed into ombrogenous one which resulted in the development of sphagnum peats, first transitional bog and then, in modern times, raised bog peats.

Table 7
Hydrological conditions change in the Kołowin mire development (profile 2)

Depth [cm]	Type of site moisture	FWW	H	Age C ¹⁴ BP
000-005	heavily wet	7.7	< 5	~200-300
005-015	moderate wet	7.0	20	
015-035	moderate wet	7.1 ↓	40	

Tab. cont.

035-045	waterlogged	8.3	30	1160±30
050-060	waterlogged	8.0	20	
070-075	waterlogged	8.3 ↓	20	
075-085	heavily waterlogged	8.8	30	
090-100	heavily waterlogged	8.7	30	
135-145	heavily waterlogged	8.9	25	
180-190	heavily waterlogged	8.9	25	
210-220	heavily waterlogged	8.8	20	
230-240	heavily waterlogged	8.8	20	
250-260	heavily waterlogged	8.9	20	
270-280	heavily waterlogged	8.9	20	6790±40
290-300	heavily waterlogged	8.9	20	
300-312	heavily waterlogged	8.9	20	
312-320	heavily waterlogged	8.9	20	
335-345	heavily waterlogged	8.8	20	
352-357	heavily waterlogged	8.9	10	
357-362	heavily waterlogged	8.9 ↓	10	
362-372	floating mat	9.0	10	
372-380	floating mat	9.0 ↓	20	
380-528	lake			~8000 11920±60

Explanations see Table 6

A hydrogenetic type of the Kołowin Mire can be defined as mixed topogenous-ombrogenous type of peatbog.

In the deposit of profile 2, four phases featuring a decline in water level (Table 7) have been recorded.

The Linje Mire. The initiation of the peat formation process in the Linje Mire dates back to the Younger Dryas. It developed as a result of paludification of the mineral bedding. The development of heavily waterlogged, bottom sedge-brown

Table 8
Hydrological conditions change in the Linje mire development (profile 4)

Depth [cm]	Type of site moisture	FWW	H	Age C ¹⁴ BP
010 - 020	heavily wet	7.8	5	670±110
030 - 040	heavily wet	7.8	15	
040 - 052	heavily wet	7.6 ↑	30	
052 - 062	moderate wet	7.3 ↓	20	
062 - 070	heavily wet	7.5	20	
070 - 080	heavily wet	7.5	20	
090 - 100	heavily wet	7.7	30	
100 - 110	heavily wet	7.6	30	
110 - 120	heavily wet	7.8	25	
120 - 130	heavily wet	7.7 ↑	30	

140 - 150	moderate wet	7.4	30	2020±130
160 - 170	moderate wet	7.4	30	
180 - 190	moderate wet	7.3	30	
190 - 195	moderate wet	7.3	30	
195 - 210	moderate wet	7.1	30	
230 - 240	moderate wet	7.1	30	3230±160
270 - 280	moderate wet	7.4	30	
290 - 300	moderate wet	7.4	30	
300 - 310	moderate wet	7.4	30	
320 - 330	moderate wet	7.2	45	
350 - 360	moderate wet	7.3	45	3540±180
380 - 390	moderate wet	7.3	45	
390 - 400	moderate wet	7.4	40	
400 - 410	moderate wet	7.3	45	
425 - 440	moderate wet	7.2	45	
460 - 470	moderate wet	7.3	45	4070±200
490 - 500	moderate wet	7.4 ↓	45	
500 - 510	heavily wet	7.7	40	
510 - 520	heavily wet	7.7 ↑	40	
530 - 540	moderate wet	7.4	45	
550 - 560	moderate wet	7.3	45	4190±40
570 - 580	moderate wet	7.3 ↓	45	
580 - 610	heavily wet	7.9	40	
620 - 630	heavily wet	7.8 ↓	40	
650 - 660	waterlogged	8.0 ↑	50	
670 - 680	heavily wet	7.5	50	6010±345
690 - 700	heavily wet	7.5	50	
700 - 710	heavily wet	7.6	60	
730 - 740	heavily wet	7.7	60	
760 - 770	heavily wet	7.5	60	
780 - 790	heavily wet	7.5	60	8230±200
800 - 810	heavily wet	7.5	60	
830 - 840	heavily wet	7.5	60	
860 - 870	heavily wet	7.5	60	
890 - 900	heavily wet	7.6	55	
910 - 920	heavily wet	7.7	60	9010±350
940 - 950	heavily wet	7.5	60	
960 - 970	heavily wet	7.6	45	
970 - 990	heavily wet	7.5 ↓	60	
995 - 1005	waterlogged	8.4	50	
1005 - 1015	waterlogged	8.3	45	10740±270
1020 - 1030	waterlogged	8.3 ↓	50	
1030 - 1035	heavily waterlogged	8.9	40	
1040 - 1045	heavily waterlogged	8.9	30	

Explanations see Table 6

moss peats and brown moss peats took place under the impact of waters having contact with catchment's groundwaters accumulated at the bottom of the depression. Soon the deposit grew above the peatbog groundwater level and became independent of the groundwaters. Accordingly, water relations on the surface of the mire became dependent on the main source of water supply, i.e. atmospheric precipitation. Already at the beginning of the Holocene, the peatland's water management changed into ombrogenous one. A thick deposit of raised bog peats developed on rather thin layer of transitional bog peats. The Linje Mire represents an ombrogenous hydrogenetic type of wetland.

In profile 2, six phases featuring a decline in water level and four phases of moisture growth have been recorded (Table 8).

The Długie Bagno Mire. The peatbog developed as a result of the paludification process of the mineral bedding at the beginning of the Preboreal Period. Initially, the mire development was influenced by the gravitation steered movement of nutrient-rich catchment groundwater, which formed a uniform layer together with the peatbog water. The low sedge peats, locally overlying brown moss peats, accumulated in the bottom part of the deposit. With the proceeding accretion of peat layers the role of water ascending from the bottom of deposits become more prominent in creating hydrological conditions on the bog's surface to be later dominated by precipitation waters. This resulted in oligotrophisation of the habitats and accumulation of raised bog peats. Since the middle of the Atlantic Period the bog is ombrotrophic in character. According to the hydrogenetic classification the Długie Bagno Mire can be categorised as mixed topogenous-ombrogenous type.

In the stratigraphy of the shallow deposit (profile 2), two changes associated with a decrease in bog's water content have been recorded (Table 9).

Table 9
Hydrological conditions change in the Długie Bagno mire development (profile 2)

Depth [cm]	Type of site moisture	FWW	H	Age C ¹⁴ BP
000-010	heavily wet	7.9	5	6740±50
010-018	heavily wet	7.9 ↑	10	
018-030	moderate wet	7.4	70	
030-040	moderate wet	7.1	70	
040-050	moderate wet	7.0 ↓	65	
050-055	heavily wet	7.6 ↓	65	6960±50
055-065	heavily waterlogged	8.7	50	9120±50
065-075	heavily waterlogged	8.8	45	
075-085	heavily waterlogged	8.7	45	
085-096	heavily waterlogged	8.9	40	
096-107	heavily waterlogged	8.9	10	
107-110	heavily waterlogged)	8.7	30	9760±50

Explanations see Table 6

The Rąbień Mire. In the case of the Rąbień Mire, the peat formation process in the shallowed lake was initiated in the middle of the Atlantic Period. Sedge-brown moss peats quickly gave way to transitional bog peats followed by raised bog peats. Changes in water relations reflected in the transition from the waterlogged floating mat through the ascension type to ombrogenous water management of the bog occurred over the period of less than 500 years. Throughout most of its history from the mid Atlantic Period until contemporary times, the development of the Rąbień Mire was based on accumulated, stagnating rainfall waters. It represents the ombrogenous hydrogenetic type of wetland.

In peat profile 1, five changes in bog's water content associated with the bog drying have been recorded. Two changes are associated with moisture growth (Table 10).

Table 10
Hydrological conditions change in the Rąbień mire development (profile 1)

Depth [cm]	Type of site moisture	FWW	H	Age C ¹⁴ BP
000-015	heavily moist	6.8 ↓		3660±35
015-020	waterlogged	8.2 ↑	30	
020-030	heavily moist	6.9 ↑	70	
035-040	moderate moist	6.4	65	
045-050	moderate moist	6.2 ↓	60	
050-055	moderate wet	7.2	50	
058-065	moderate wet	7.0	30	
070-075	moderate wet	7.0	25	
075-080	moderate wet	7.0	25	
085-090	moderate wet	7.0	30	
090-100	moderate wet	7.1	25	6780±40
110-120	moderate wet	7.1	40	
120-125	moderate wet	7.2 ↓	40	
125-130	heavily waterlogged	8.5	40	
130-135	heavily waterlogged	8.6	35	
135-140	heavily waterlogged	8.5	35	
140-144	heavily waterlogged	8.5 ↓	35	
144-150	floating mat	9.0	40	
150-156	floating mat	9.1 ↓	40	
156-284	lake			11880±60

Explanations see Table 6

The Białe Ługi Mire. The paludification process in the Białe Ługi Mire was started directly on the mineral bed as early as Older Dryas Period (ŻUREK, KLOSS 2001). Deposit accumulation was influenced by waters running down the slopes surrounding the depression. Sedge-brown moss and brown moss peats prevailed. At the turn of the Alleröd/Younger Dryas Periods a short episode associated with a decline in water content and development of ombrotrophic sphagnum moss communities were noted. In the Younger Dryas sedge-moss communities and associa-

Table 11
Hydrological conditions change in the Białe Ługi mire development (profile 3)

Depth [cm]	Type of site moisture	FWW	H	Age C ¹⁴ BP
000-010	heavily wet	7.9	5	~50
010-025	waterlogged	8.0	15	
025-033	waterlogged	8.0 ↑	15	
033-045	heavily wet	7.6	30	
055-065	heavily wet	7.5 ↑	30	240±30
065-075	moderate wet	7.1	55	1950±30
090-101	moderate wet	7.2 ↓	60	
101-115	heavily wet	7.7 ↓	50	
115-125	heavily waterlogged	8.6	40	
135-145	heavily waterlogged	8.5 ↑	30	9610±50
160-170	waterlogged	8.2 ↓	25	
185-195	heavily waterlogged	8.6	30	
205-215	heavily waterlogged	8.7	30	
220-230	heavily waterlogged	8.6 ↑	40	9810±50
245-255	waterlogged	8.4 ↓	40	
260-270	heavily waterlogged	8.7	30	
280-290	heavily waterlogged	8.7	30	
310-325	heavily waterlogged	8.8 ↑	30	11200±50
325-333	moderate wet	7.1 ↓	20	
345-355	heavily waterlogged	8.9	40	
365-375	heavily waterlogged	8.9	40	
380-390	heavily waterlogged	8.9	35	12900±350

Explanations see Table 6

ted sedge-brown moss peats returned to the wetland. With the increase in deposit thickness, hydrological relations on the surface of the peatbog were shaped by ascending waters and those filtrated by the deposit. The site underwent gradual oligotrophisation. From the beginning of the Holocene, the accumulation of transitional bog peats, first of all sphagnum-sedge peats was initiated. At the beginning of the Subatlantic Period, the water management in the wetland changed from ascending to ombrogenous. The dominant role in supplying water to the wetland was taken over by precipitation waters. The development of raised sphagnum peats began under the influence of stagnant, nutrient-poor waters. Due to the way of supplying water into the bog the Białe Ługi Mire can be described as mixed topogenous-ombrogenous type.

The stratigraphical studies of profile 3 document fivefold changes in the water conditions of the mire associated with lowering of the water level and five resulting from moisture growth (Table 11).

The Zieleniec Mire. The peatbog developed as a result of paludification of the mineral bedding. The peat formation process took place in the older half of the

Table 12
Hydrological conditions change in the Zieleniec mire development (profile 3)

Depth [cm]	Type of site moisture	FWW	H	Age C ¹⁴ BP
000-005	heavily wet	7.8	< 10	~150-250
005-015	heavily wet	7.8 ↑	20	
015-025	moderate wet	7.2	45	
025-035	moderate wet	7.0	45	
035-050	heavily moist	6.8 ↓	50	
050-075	moderate wet	7.1	35	
075-100	moderate wet	7.1	35	
100-125	moderate wet	7.2	35	
125-150	moderate wet	7.3	30	
150-175	moderate wet	7.2	35	
175-200	moderate wet	7.2	40	
200-225	moderate wet	7.2	35	
225-250	moderate wet	7.2	35	
250-275	moderate wet	7.3	30	
275-300	moderate wet	7.4	30	
300-325	moderate wet	7.4	35	
325-350	moderate wet	7.2	30	
350-375	moderate wet	7.2	30	
375-400	moderate wet	7.2	25	
400-425	moderate wet	7.2	35	
425-450	moderate wet	7.2	45	3790±40
450-475	moderate wet	7.2	25	
475-500	moderate wet	7.1	35	
500-520	moderate wet	7.1	35	
520-528	heavily moist	6.9 ↓	70	
528-550	moderate wet	7.1	40	
550-575	moderate wet	7.1	40	
575-600	moderate wet	7.1	40	
600-630	moderate wet	7.1	40	
630-650	moderate wet	7.1	30	
650-675	moderate wet	7.1	30	5840±40
675-700	moderate wet	7.2	45	
700-725	moderate wet	7.2	50	
725-750	moderate wet	7.1 ↓	40	6970±50
750-775	waterlogged	8.4	50	
775-790	waterlogged	8.3 ↑	50	6980±50
790-800	heavily wet	7.5	65	
800-820	heavily wet	7.6	60	

Explanations see Table 6

Boreal Period. Initial plaudification developed under the influence of downslope waters poor in calcium and mineral nutrients and low pH. Such conditions favoured the development of phytocoenoses typical for transitional bogs. Then the

accumulation of strongly humified and water-rich transitional bog peats followed. Their species composition contains *Eriophorum vaginatum*, *Carex rostrata* and *Scheuchzeria palustris*. This stage of mire development lasted for relatively short time. With the increase of deposit thickness, the decrease in trophy of ascending waters led to impoverishment of the habitat. Wetland vegetation became largely depended on atmospheric precipitation and bog's retentive capacity. Immobile precipitation and melt waters had a decisive effect on shaping water relations on the mire surface. As early as in the second half of the Atlantic Period, water management in the mire changed into ombrogenous, which led to the accumulation of a thick deposit of raised bog peats. The Zieleniec Mire is a hydrogenetic type of the ombrogenous mountain wetland.

In the stratigraphical structure of profile 3, three phases associated with a decrease in bog's water content and two accounting for a rise in water level have been recorded (Table 12).

4. RECAPITULATION

1. The plant macrofossil analysis in peat cores enabled reconstruction of subfossil communities and succession of peat-forming phytocoenoses. In the raised bogs under study, 23 subfossil phytocoenoses of different syntaxonomic ranks have been identified.
2. There are no fixed and unchangeable patterns of succession of subfossil phytocoenoses taking part in bog development; each mire under study has its own specifics.
3. The established dates documenting phases of bog's water content decrease can be set up in the following time intervals:
 - in the Subatlantic Period around 700 and 1200, and 1700-2000 years BP,
 - in the Subboreal Period 3000-3100, 3300-3800 and 4000-4200 years BP,
 - in the Atlantic Period 5500-5800 and 6700-7150 years BP,
 - in the Preboreal Period around 9700 years BP,
 - in the Late Glacial around 10300 and 11200 years BP.
4. The results correspond to the dry phase periods distinguished in Poland on the basis of dating of strongly humified peats (ŻUREK and PAZDUR 1999; ŻUREK *et al.* 2002).
5. A substantial change in hydrological relations took place in the period 6700-7000 years BP. High similarity between the data from the Suche Bagno, Długie Bagno, Rąbień, Zieleniec mires indicates that it was associated with pan-regional climate changes.
6. Changes associated with the increase of site water content were weaker and usually concern modern times.

7. The comparison of phytocoenotic moisture index (FWW) in a long-term period of wetland existence provides an objective view of the hydrological dynamics at different stages of its development. These changes are reflected in the succession of subfossil vegetation.
8. Each mire under study forms a separate specific stage of vegetation changes. The deposits depict, first of all, changes on the local, but also on pan-regional scale.
9. The character and succession of accumulated peat deposits, among others, their botanical composition provide information about biocoenotic and habitat changes throughout the history of bog development. Thanks to peat deposits that develop through centuries, bog ecosystems are the most precious natural archives.
10. The examined mires were classified to the three hydrogenetic types:
 - mixed topogenous-ombrogenous type is represented by Suche Bagno, Kołowin, Długie Bagno and Białe Ługi mires,
 - ombrogenous lowland type is represented by Linje and Rąbień mires,
 - ombrogenous mountain type is represented by Zieleniec Mire.

5. REFERENCES

- DRZYMULSKA, D. 2004. Późnoglacialna i holocenińska historia roślinności wybranych torfowisk Puszczy Knyszyńskiej [Late Glacial and Holocene vegetation history of chosen mires in the Knyszyńska Forest]. Doctoral thesis, Białystok, typescript, 142 pp. (in Polish).
- ELLENBERG, H., WEBER, H., DÜLL, R., WIRTH, V., WERNER, W., PAULISSEN, D. 1992. Zeigerwerte von Pflanzen in Mitteleuropa. Scripta Geobotanica 18, 158 pp.
- ELINA, G.A., YURKOVSKAYA, T.K. 1992. Methods of palaeohydrological regime determination as the basis for the objectivisation of the causes of mire vegetation successions. Botanicheski zhurnal 77: 120-124 (in Russian).
- HERBICHOWA, M. 1998. Ekologiczne studium rozwoju torfowisk wysokich właściwych na przykładzie wybranych obiektów ze środkowej części Pobrzeża Bałtyckiego [Ecological study of development of the Baltic-type raised bogs exemplified by selected objects in the middle part of Baltic Sea-Coast]. Wyd. Uniw. Gdańskiego, Gdańsk, 119 pp. (in Polish).
- HILL, O.M., MOUNTFORD, O.J., ROY, B.D., BUNCE, H.G.R. 1999. Ellenberg's indicator value for British plants, Ecofact 2, Technical Annex, Centre for Ecology and Hydrology Natural Environment Research Council, 46 pp.
- KLOSS, M. 1993. Differentiation and development of peatlands in hollows without run-off on young glacial terrains. Pol. Ecol. Stud. 19, 3-4: 115-219.
- KLOSS, M. 1999. Rekonstrukcja subfosalnych zbiorowisk roślinnych w rezerwacie torfowiskowym "Białe Ługi" i ich znaczenie bioindykacyjne [Identification and bioindicator of subfossil plant communities in the Białe Ługi mire reserve]. In: S. RADWAN, R. KORNIJÓW (eds.), Problemy aktywnej ochrony ekosystemów wodnych i torfowiskowych w polskich parkach narodowych. Wyd. UMCS, Lublin, p. 125-130 (in Polish).
- KLOSS, M. 2001. Subfosalna roślinność torfowiska Białe Ługi i jej kierunki sukcesyjne [Subfossil plant communities of Białe Ługi mire and their succession changes]. In: S. ŻUREK (ed.), Rezerwat torfo-

- wiskowy „Białe Ługi” [The Białe Ługi mire reserve]. Wyd. Homini, Bydgoszcz, p. 59-73 (in Polish with English summary).
- KLOSS, M. 2004a. Zastosowanie ekologicznych liczb wskaźnikowych roślin do oceny paleohydrologicznych zmian w rozwoju ekosystemu torfowiskowego [Application of plants indicator values for the assessment of palaeohydrological changes in the mire ecosystem development]. *Ochrona Środowiska i Zasobów Naturalnych* 27: 29-39 (in Polish).
- KLOSS, M. 2004b. Palaeohydrological changes in the development of some raised mires in Poland. In: J. PÄIVÄNEN (ed.), *Wise use of peatlands. Proceedings of the 12th International Peat Congress*, Tampere, Finland, Publication of the International Peat Society 2: 869-874.
- KLOSS, M. 2005. Palaeobotanical studies of raised mires. *Monogr. Bot.* 94: 5-18.
- KLOSS, M., SIENKIEWICZ, J. 1999. Zagrożenia rzadkich gatunków flory Polski występujących na siedliskach torfowiskowych: brzozy karłowatej, modrzewnicy północnej i maliny moroszeki [Threats to rare species growing on raised bogs: *Betula nana*, *Chamaedaphne calyculata* and *Rubus chamaemorus*]. *Ochrona Środowiska i Zasobów Naturalnych* 17: 89-103 (in Polish).
- KRUSZELNICKI, J. 2001. *Chamaedaphne calyculata* (L.) Moench – chamedafne północna. In: K. ZARZYCKI, R. KAZIMIERCZAKOWA (eds.), *Polska Czerwona Księga Roślin [Polish Red Data Book of Plants]*. Instytut Botaniki im. W. Szafera, PAN, Kraków, p. 283-285 (in Polish).
- KRUSZELNICKI, J., FABISZEWSKI J. 2001. *Betula nana* L. – brzoza karłowata. In: K. ZARZYCKI, R. KAZIMIERCZAKOWA (eds.), *Polska Czerwona Księga Roślin [Polish Red Data Book of Plants]*. Instytut Botaniki im. W. Szafera, PAN, Kraków, p. 82-83 (in Polish).
- LATAŁOWA, M. 2001. Sicienko – History of vegetation. 25th Bog Excursion, North-west Poland, Part I: Wolin Island and Drawa National Park, Excursion Guide, p. 127-130.
- MADEYSKA, E. 2005. The history of the Zieleniec Mire and the surrounding areas based on the palynological research. *Monogr. Bot.* 94: 145-157.
- MATUSZKIEWICZ, W. 2001. Przewodnik do oznaczania zbiorowisk roślinnych Polski [A guide for identifying plant communities of Poland]. PWN, Warszawa, 537 pp. (in Polish).
- NORYSKIEWICZ, A.M. 2005. Preliminary results of study on vegetation history in the Linje mire region using pollen analysis. *Monogr. Bot.* 94: 117-134.
- OBIDOWICZ, A. 1990. Eine pollenanalytische und moorkundliche studie zur vegetationsgeschichte des Podhale-Gebietes (West-Karpaten). *Acta Palaeobot.* 30, 1-2: 147-219.
- OKRUSZKO, H. 1983. Zróżnicowanie warunków hydrologicznych mokradł w aspekcie ich melioracji [Differentiation of hydrologic conditions of wetlands under their reclamation of view]. *Wiad. IMUZ* 15, 1: 13-31.
- OŚWIT, J. 1976. Subfossile and contemporary plant communities of the *Caricetum elatae* association. *Proceedings of the 5th International Peat Congress*, Poznań, Poland 2: 37-46.
- OŚWIT, J. 1992. Identyfikacja warunków wilgotnościowych w siedliskach łąkowych za pomocą wskaźników roślinnych [Identification of humidity conditions in meadow sites using vegetation indices]. *Biblioteczka Wiadomości IMUZ* 79: 39-67.
- OŚWIT, J., PACOWSKI, R., ŻUREK, S. 1981. Charakterystyka ważniejszych gatunków torfu w Polsce [The characterization of main peat species in Poland]. *Biul. Inf. Torf.* 3: 1-10 (in Polish).
- PACOWSKI, R. 1967. Biologia i stratygrafia torfowiska wysokiego Wieliszewo na Pomorzu Zachodnim [Biologie und stratigraphic des Hochmoores Wieliszewo]. *Zesz. Probl. Post. Nauk Roln.* 76: 101-196 (in Polish).
- PĄCZYŃSKI, A. 1975. Bagna Jaćwieskie. Pradolina Biebrzy. Zagadnienia geobotaniczne, paleofitologiczne i gospodarcze [Jaćwieskie Sümpfe. Das Urtal der Biebrza. Die geobotanische, paläophytosociologische, und wirtschaftliche Probleme]. *Rocz. Nauk Roln.* D 145, 232 pp. (in Polish).
- POST VON, L., GRANLUND, E. 1926. Södra Sveriges torvtillng ngar, 1. Sver. Geol. Unders. C 335, 19, 2, 127 pp.
- RAJSKA-JASIEWICZOWA, M., STARKEL, L. 1988. Record of the hydrological changes during the Holocen in the lake, mire and fluvial deposits of Poland. *Folia Quaternaria* 57: 91-127.

- RAJSKA-JASIEWICZOWA, M., STARKEL, L. 1999. Zmiany klimatu i stosunków wodnych w holocenie [Climate and water condition changes in the Holocene]. In: L. STARKEL (ed.), *Geografia Polski. Środowisko przyrodnicze* [Geography of Poland. Natural environment]. PWN, Warszawa, p. 105-127 (in Polish).
- TOMASZEWSKA K. 2004. Historia rozwoju wybranych torfowisk Gór Izerskich z uwzględnieniem antropogenicznych przemian roślinności [Development of some raised bogs in the Izerskie Mountains – connected with anthropogenic vegetation changes]. *Zesz. Nauk. AR Wrocław* 472, *Rozprawy* 204, 110 pp. (in Polish).
- WÓCIKIEWICZ, M. 1979. Stratygrafia torfowiska Bór na Czerwonym z uwzględnieniem zespołów subfosalnych oraz rozmieszczenia i zróżnicowania współczesnych zbiorowisk roślinnych [The stratigraphy of the „Bór na Czerwonym” peatbog with the consideration of subfossil associations and distribution and differentiation of contemporary plant communities]. *Zesz. Nauk. AR Kraków* 153, 10: 133-193.
- ZARZYCKI, K., TRZCIŃSKA-TACIK, H., RÓŻAŃSKI, W., SZELĄG, Z., WOLEK, J., KORZENIAK, U. 2002. Ecological indicator values of vascular plants of Poland. *Biodiversity of Poland* 2, 183 pp.
- ŻUREK, S. 1993. Zmiany paleohydrologiczne w mokradłach [Palaeohydrological changes in the wetlands]. *Przegl. Geogr.* 64, 1-2: 75-95 (in Polish).
- ŻUREK, S. 2005. Abiotic natural environment in the area of selected raised mires. *Monogr. Bot.* 94: xx-xx.
- ŻUREK, S., KLOSS, M. 2001. Geneza i wiek torfowiska Białe Ługi [Genesis and age of Białe Ługi mire]. In: S. ŻUREK (ed.), *Rezerwat torfowiskowy „Białe Ługi”* [The Białe Ługi mire reserve]. Wyd. Homini, Bydgoszcz, p. 85-87 (in Polish with English summary).
- ŻUREK, S., PAZDUR, A. 1999. Zapis zmian paleohydrologicznych w rozwoju torfowisk Polski [Palaeohydrological changes recorded in mires development of Poland]. In: A. PAZDUR (ed.), *Geochronologia górnego czwartorzędu Polski*. Instytut Fizyki Politechniki Śląskiej, Gliwice, p. 215-228 (in Polish).
- ŻUREK, S., MICHczyńska, D., PAZDUR, A. 2002. Time record of paleohydrologic changes in the development of mires during the Late Glacial and Holocene, North Podlasie Lowland and Holy Cross Mts. *Geochronometria* 21: 109-118.

6. REKONSTRUKCJA SUBFOSYLNÝCH ZBIOROWISK ROŚLINNYCH I ZMIANY PALEOHYDROLOGICZNE W ROZWOJU TORFOWISK WYSOKICH (streszczenie)

W latach 2003-2005, na siedmiu torfowiskach wysokich: Suche Bagno, Kołowin, Linje, Długie Bagno, Białe Ługi i Zieleniec wykonano prace paleofitosocjologiczne. Obiekty te leżą w różnych regionach geograficznych Polski i reprezentują cztery typy rzeźby: nizinną młodoglacjalną, nizinną staroglacjalną, wyżynną i górską. Wykonane wiercenia torfowe umożliwiły rozpoznanie budowy geologicznej złóż i dostarczyły materiału umożliwiającego odtworzenie torfotwórczych fitocenoz od początku powstania torfowisk. Rekonstrukcję fitocenoz oparto na szczegółowych analizach składu botanicznego prób torfowych. W opracowanych 21 profilach torfowych, oznaczono szczątki około 80 taksonów roślin. Łącznie wykonano 371 analiz składu botanicznego torfu. Zrekonstruowanie składu gatunków i ich kombinacji umożliwiło odtworzenie 23 subfosalnych fitocenoz. Subfosalne zbiorowiska

zestawiono w czterech tabelach syntetycznych. Tabela 1 charakteryzuje fitocenozy z klasy *Phragmitetea*, 2 – fitocenozy z klasy *Scheuchzerio-Caricetea nigrae*, 3 - fitocenozy z klasy *Oxycocco-Sphagnetetea*, 4 - fitocenozy z klas *Vaccinio-Piceetea* i *Alnetea glutinosae*. Identyfikacja subfosalnych zbiorowisk roślinnych w obrębie profilu torfowego, od dna do powierzchni złoża, dała obraz lokalnej sukcesji roślinności (Figury 1-7). Warunki wilgotnościowe siedlisk torfowych oceniono metodą fitoindykacji. Wykorzystując wskaźnikowe liczby wilgotnościowe opracowane dla poszczególnych gatunków roślin, określono fitocenotyczne wskaźniki wilgotności (FWW) dla zrekonstruowanych zbiorowisk subfosalnych. Umożliwiło to ocenę, w 10-stopniowej skali, warunków wodnych panujących w akrotelmie torfowiska, w różnych okresach jego rozwoju. Zbiorowiska o wskaźnikach 6.0-6.9 wyróżniają siedliska wilgotne, w zakresie 7.0-7.9 – siedliska mokre, zaś o liczbach 8.0-10.0 siedliska bagienne (Tabela 5). Analizując rozmieszczenie subfosalnych fitocenoz, różniących się liczbami wskaźnikowymi, uzyskano obraz zmian hydrologicznych w kolejnych etapach rozwoju badanych torfowisk (Tabele 6-12). Zmiany w stratygrafii siedmiu profili torfowych reprezentujących obiekty badań na tle skali czasowej przedstawia Figura 8. Torfowiska Suche Bagno, Kołowin, Długie Bagno i Białe Ługi reprezentują topogeniczno-ombrogeniczny typ hydrogenetyczny torfowiska. Torfowiska Linje i Rąbień reprezentują typ ombrogeniczny niżowy, a torfowisko Zieleniec reprezentuje typ ombrogeniczny górski. Zgromadzone daty radiowęglowe dokumentujące fazy spadku uwodnienia torfowisk, można zestawić w następujących przedziałach czasowych:

- w okresie subatlantyckim około 700 i 1200 oraz 1700-2000 lat BP,
- w okresie subborealnym 3000-3100, 3300-3800 oraz 4000-4200 lat BP,
- w okresie atlantyckim 5500-5800 i 6700-7150 lat BP,
- w okresie preborealnym około 9700 lat BP,
- w późnym glacie około 10300 i 11200 lat BP.

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**PRELIMINARY RESULTS OF STUDY
ON VEGETATION HISTORY IN THE LINJE MIRE
REGION USING POLLEN ANALYSIS**

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ABSTRACT

Agnieszka M. NORYŚKIEWICZ. *Preliminary results of study on vegetation history in the Linje Mire region using pollen analysis*. Monogr. Bot., Vol. 94, 117-134, 2005.

This paper describes the results of palynological investigations carried out on the Linje Mire, with its relic stand of *Betula nana*. This site is located in the southwestern part of the Chełmno Lakeland in a fresh-glacial moraine landscape, 2.5 kilometres north-east of Dąbrowa Chełmińska. Eight local pollen assemblage zones have been distinguished in the pollen diagram from this site. The sediment registers the history of vegetation from the end of the Vistula Late Glacial Period (Younger Dryas) through the Holocene to the present day. Five stages in the development of Linje Mire are recognised and compared with the results of analysis of peat humification degree, average ash content and the percentage share of macroscopic remains, which allow us to explain the transformations that took place on the mire.

Key words: raised mire; pollen analyses; vegetation history; relic species; Chełmno Lakeland; Poland.

1. INTRODUCTION

The mire in Linje is located in the southwestern part of the Chełmińskie Lakeland (Fig. 1) in a young-glacial moraine landscape (KONDRACKI 1980), 2.5 kilometres north-east of Dąbrowa Chełmińska (18°18'55"E and 53°15'20"N). In 1956, the Linje Mire reserve was established on this terrain in order to protect this forest mire with its characteristic raised mire vegetation and the only lowland stand of dwarf birch (*Betula nana*) in Poland (CEYNOWA-GIELDON 1971; BOIŃSKI *et al.* 2001).

Fig. 1. Location map of the studied site
1 – villages; 2 - location of the examined site; 3 – roads; 4 - surface waters

This reserve currently occupies an area of 12.3 hectares, of which the 5.8 hectares of mire are embraced by the strict protection. In its central part, the mire is raised in character, however its peripheral fragments show a transitory character. The dwarf birch growing in the reserve occupies an area of one hectare and mainly grows in the central part of the mire, here and there creating compact thickets. In the northeastern part of the mire there are to be found pits in the peat, reminders of past peat extraction. Today these peat workings are partly overgrown by a *Sphagno-Juncetum effusi* complex. However, on the land surrounding the mire there occurs a poor form of mixed coniferous forest *Quercu roboris-Pinetum*.

In order to learn the history of the forests in the Pomeranian Region, a pollen analysis of the Linje Mire was carried out at the very beginning of the palynological method being applied. Following publication of these results (PASZEWSKI 1928), it turned out that the profile had been taken in a place disturbed by peat digging. The results of renewed research appeared six years later (PASZEWSKI 1934). The author examined another two profiles and according to the pollen analysis method of the time, counted only the pollen grain of trees and hazel, thanks to which these results have only limited diagnostic value in modern times. The palynological picture presented by the author in the course of taking the cores (samples were analysed every 25 centimetres) seems to be distorted with pollen on the secondary deposit. Thus the paleobotanical research conducted in the reserve since 2003 (TOBOLSKI *et al.* 2004) is a new attempt at explaining the history of regional and of course local vegetation, with particular regard for the history of the dwarf birch in Linje. The study presented concentrated on the history of the mire and vegetation cover of the southwestern part of the Chełmno Lakeland. A separate work is in progress explaining the history of the dwarf birch on the mire under study, including detailed research into fossil and present-day *Betula nana* pollen.

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2. MATERIALS AND REMARKS ON METHODS APPLIED

The material for palynological research was taken in September 2003 using a Livingston probe modified by WIECKOWSKI (1970) with a 5-centimetre cross-section and 110-centimetre long core tube. Monoliths were placed in PCV troughs and after being tightly wrapped in foil, were transported to the Institute of Archaeology, UMK where the profile was then tested and deposits were separated for individual analysis. For pollen research, samples with a volume of 1 cm³ were taken, every 5 centimetres (altogether 213 samples). So far 106 samples have been examined. These were subjected to standard laboratory processing (BERGLUND,

RAJSKA-JASIEWICZOWA 1986); 10% HCl, 10% KOH and Erdtman acetolysis. In order to calculate the concentration of sporomorphs (STOCKMARR 1971), 2 tablets containing a known number of *Lycopodium* spores were added to every sample at the beginning of laboratory processing. Sporomorphs were counted under a Carl Zeiss Jena "Axioskop 2" microscope, applying 200, 400 and 630 times magnification and critical forms were indicated using a 1000 times magnification and with the aid of immersion oil. In every spectrum, at least 1000 grains of tree and shrub pollen (AP – Arboreal Pollen) were counted, as well as all the accompanying sporomorphs (pollen grains of dwarf shrubs, pollen of herbaceous plants, aquatic and marshy plants as well as the spores of *Filicales monoete*, *Equisetum* and *Sphagnum* mosses and also non-pollen deposits such as among other things *Pediastrum*, *Habrotricha* and *Gaeummannomyces*). It was in those samples with a comparatively low frequency of pollen grains, from the bottom of the profile, that less than 500 AP grains were counted, however in a further stage of the research these samples would also be included. The sum of tree and shrub pollen (AP) as well as the pollen of dwarf shrubs and herbaceous terrestrial plants (NAP) was adopted as the basis for computing percentage values; $AP + NAP = 100\%$. The percentage share of aquatic and marshy plants pollen and spores was calculated in relation to the basic sum increased by the sum of sporomorphs of an appropriate group. The results of the analysis were recorded and presented using the POLPAL program (WALANUS, NALEPKA 1999). A percentage pollen diagram (Fig. 2) was drawn up according to a depth scale, beginning with the mire level.

Eleven radiocarbon dating tests were carried out for the LX profile from the Linje Mire (Table 1). Ten of these were carried out in the Radiocarbon Laboratory in Gliwice (symbol Gd) within the framework of KBN grant No. 3 P04F 007 23 and one in Poznań (symbol Poz) within the framework of UMK internal grant No. 357/2004-NH.

Table 1
Linje; ^{14}C dates obtained for LX profile

Depth [cm]	Age BP	Sample symbol
55-60	670 ± 110	Gd-16255
115-120	1015 ± 50	Gd-15645
119-195	2020 ± 130	Gd-30065
295-300	3230 ± 160	Gd-17263
395-400	3540 ± 180	Gd-18268
490-495	4070 ± 200	Gd-17275
554-556	4190 ± 40	Poz-9484
700-705	6010 ± 345	Gd-17272
830-835	8230 ± 200	Gd-16219
955-960	9010 ± 350	Gd-18266
1045-1050	10740 ± 270	Gd-30069

3. DESCRIPTION OF THE POLLEN ASSEMBLAGE ZONES

Eight separate biostratigraphical units, meaning local pollen assemblage zones (Fig. 2), were distinguished in the LX profile of the pollen diagram from the Linje Mire (LPAZ - local pollen assemblage zones) (BIRKS, BERGLUND 1979; JANCZYK-KOPIKOWA 1987). The boundaries of assemblage zones were marked by the traditional method of visual analysis and this was compared with the boundaries obtained by the CONSLINK numerical method (WALANUS, NALEPKA 1999). Zones were marked with the symbol LX (L – Linje; X – profile No. X) with numbering beginning at the bottom of the profile. In the macrofossil study, the core studied is marked as borehole 4 (KLOSS 2005).

L X-1 L PAZ; *Betula-Artemisia-Juniperus* (1050-1020 cm). The characteristic feature of this zone was its highest proportion of herbaceous plants for the whole profile, including mainly *Poaceae*, *Artemisia* and *Cyperaceae* as well as shrubs such as dwarf birch *Betula nana* and to a lesser degree *Juniperus*. Among the trees presently occurring, there were only *Pinus* and *Betula*. In the whole zone under discussion, the only aquatic and marshy plants were *Sphagnum* moss spores. In the top layer sample, from a depth of 1030 centimetres, the first *Equisetum* spores also appeared. The upper limit of the zone was set at the point of increased share of *Pinus* (from less than 40 to 70%) and the decline in NAP (from 28 to 5%) including mainly *Artemisia*, *Cyperaceae* and *Poaceae*.

L X-2 L PAZ; *Pinus-Betula* (1020-975 cm). The characteristic feature of the LX-2 zone was the high proportion of birch and pine (with an absolute *Pinus* maximum of 77.7% for the profile). The proportion of *Cyperaceae* and *Poaceae* and *Artemisia* fell considerably in this zone. There appeared however a continuous curve for *Filipendula*. Next, *Betula nana*, *Juniperus* and *Salix* pollen occurred in almost entire zone. From among the aquatic and marshy plants, for the first time *Menyanthes trifoliata* appeared, forming an almost continuous curve, and individual *Nymphaea* and *Potentilla palustris*. *Sphagnum* spores were also very evident in the whole zone, increasing their proportion in the top layer of the zone, also *Equisetum*, which at the bottom part of this zone achieved its absolute maximum for this profile (10%). The upper limit of the zone saw an increase in *Corylus*, *Ulmus* and *Quercus*.

L X-3 L PAZ; *Pinus-Ulmus-Corylus* (975-940 cm). Pine pollen predominated at this assemblage zone (57-60%), while elm and oak formed a small but continuous percentage curve. The proportion of shrubs and dwarf shrubs (mainly *Corylus*, but also *Calluna vulgaris* and *Ericaceae* undiff.) increased. *Picea* and *Alnus* also formed a small culmination on the floor of this assemblage zone. There was a slight reduction in the proportion of *Artemisia* (0.6-0.3%), *Poaceae* (1.9-1.2%) and *Cyperaceae* (1.6-0.5%). Among the aquatic and marshy plants, the already earlier-appearing taxa such as *Menyanthes trifoliata*, *Nymphaea* and *Potentilla palustris* occurred in the bottom part of this zone. Among spore-producing plants present in the bottom,

there was plenty of evidence of *Sphagnum*, which like *Equisetum*, had a distinctly reduced proportion towards the top layer. The opposite occurred in the case of *Filicales monolete* spores, which towards the top layer increased their proportion. The upper limit of the assemblage zone saw a sharp increase in *Corylus* and *Alnus* and the beginning of *Ulmus*, *Quercus* and *Tilia*, accompanied by a decrease in *Pinus* and *Betula*.

L X-4 L PAZ; *Corylus-Ulmus-Quercus* (940-830 cm). At this assemblage zone, the pollen of trees and shrubs predominated, mainly that of *Pinus* (35-52%), *Betula* (14-40%), *Alnus* (4-12%) and *Corylus* (10-25%), but also *Ulmus* (1.1-2.7), *Tilia* (0.1-1.7) and *Quercus* (0.7-2.4). Despite the considerable taxonomic variety of the whole profile, the total curve of herbaceous plants achieved its lowest percentage here and only grasses were represented in all spectra of this assemblage zone. Among aquatic and marshy plants, individual *Potentilla palustris* and *Typha latifolia* pollen were recorded. There was also a distinct reduction in the frequency of spore-producing plants. The proportion of *Sphagnum* was drastically reduced towards the final part of the zone, while *Equisetum* and *Pteridium* appeared sporadically in two analysed samples and only ferns were represented throughout the whole assemblage zone. The upper limit of the assemblage zone saw an increase in the percentage share of *Ulmus*, *Tilia* and *Quercus* and a decrease in *Pinus* and *Corylus*.

L X-5 L PAZ; *Ulmus-Tilia-Fraxinus-Quercus* (830-630 cm). Among trees, alongside pine, birch and alder, there was an increase in the proportion of taxa creating *Quercetum mixtum* (*Ulmus*, *Tilia*, *Fraxinus* and *Quercus*). At the same time the first three of these additionally achieve their absolute maximum for the profile in this zone: 4.8%, 7% and 1.9% respectively. The proportion of shrubs (*Corylus*) and again herbaceous plants was reduced, only dwarf shrubs were represented by a fixed, small percentage curve (*Betula nana*, *Calluna vulgaris*, *Ericaceae* undiff.). Among aquatic and marshy plants, there were sporadic occurrences of *Nymphaea*, *Potamogeton s. Eupogamogeton*, *Potentilla palustris*, *Sparganium* and *Typha latifolia*. Among spore-producing plants, *Sphagnum* and *Filicales monolete* again form a continuous curve and *Pteridium* creates two local maximums (1.5% and 2.4% - the absolute maximum for the profile). The upper limit of this zone saw a distinct increase in the percentage share of *Ulmus* (below 2%) and an increase of *Pinus* and *Quercus*.

L X-6 L PAZ; *Corylus-Quercus* (630-440 cm). This zone is characterised by a culmination of *Quercus* (max.13.9%) and *Corylus* (max. 22.9%) and a decline in the curve for *Ulmus* (throughout the entire assemblage zone, this taxa does not exceed a value of 3%). An almost continuous, though not very high percentage curve is formed by the remaining trees (*Carpinus*, *Fagus*, *Acer*, *Picea*). Among herbaceous plants, there occurs a small increase in the proportion of *Poaceae* and *Cyperaceae* and new taxa appear, among others *Plantago lanceolata* and *Melampyrum*. Among aquatic and marshy plants, *Drosera*, *Iris*, *Nymphaea*, *Sparganium*, *Typha latifolia*

and *Ranunculus trichophyllus* were recorded. Spore-producing plants were mainly represented by *Sphagnum*, with an ever-smaller proportion of ferns and only sporadic *Equisetum*. The upper limit of this assemblage zone saw an increase in the proportion of *Carpinus* (over 3%) and a decrease in the proportion of pine and later – also *Betula*.

L X-7 L PAZ; *Carpinus-Quercus* (440-110 cm). This assemblage zone is characterized by an increasing proportion of *Carpinus* and *Fagus*. However such taxa as *Corylus*, *Ulmus*, *Tilia* and *Fraxinus* constituted a gradually reduced proportion. *Carpinus* achieved its local maximums here, with its absolute maximum amounting to 22.1%. In this assemblage zone both the quantity and variety of herbaceous plants, mainly anthropogenic indicators also increased. Their variable presence was additionally correlated with fluctuations in the proportion of pine and birch. Among aquatic and marshy plants, there were sporadic occurrences of the already earlier appearing *Iris*, *Menyanthes trifoliata*, *Nymphaea*, *Potamogeton s. Eupotamogeton*, *Potentilla palustris*, *Sparganium* and *Typha latifolia* and the only new species was *Myriophyllum spicatum*. *Sphagnum* was continuously but variably present, however remaining spore-producing plants occurred only sporadically. The upper limit of this assemblage zone saw a decrease in the percentage share of *Carpinus* and *Quercus* and an increase in *Pinus* and NAP.

L X-8 L PAZ; *Pinus-NAP* (110-10 cm). Pine predominated on the whole of this assemblage zone (46-70%). Among the remaining trees only four taxa achieved a value above 1%: *Betula* maximally 32%, *Carpinus* 3.1%, *Quercus* 4.7% and *Alnus* 8.1%, however their proportion also fell drastically in comparison to the LX-7 assemblage zone. The proportion of NAP increased and oscillated between 7 and 22%, these being mainly *Poaceae*, *Rumex* and cereals (*Cerealia* type and *Secale*). Among aquatic and marshy plants, *Drosera*, *Potentilla palustris* and *Typha latifolia* were recorded. Among spore-producing plants, again only *Sphagnum* showed any considerable values, mainly at the upper and at the bottom part of this zone (with an absolute maximum of 75%), while *Filicales monoletae* and *Equisetum* appeared only sporadically.

4. THE HISTORY OF VEGETATION

The palynological records included in pollen diagram from the LX profile of the Linje Mire make it possible to reconstruct the vegetation from the area surrounding the mire from the end of the Vistula Late Glacial Period to the present time.

***Betula-Artemisia-Juniperus* LPAZ; Younger Dryas.** The large proportion of herbaceous vegetation may indicate the presence of not particularly compact forest communities, with abundant juniper that formed brushwood and thermophilous

herbaceous plants in the Linje region. The arrangement of sporomorphs in particular spectra indicates a mosaic of vegetation cover, which was by nature park tundra with patches of herbaceous and shrubby tundra and steppes. Steppe-type communities developed in drier and poorer habitats. Evidence of this may be seen in the high values of *Artemisia*, the permanent presence of *Asteroideae*, *Caryophyllaceae*, *Chenopodiaceae* family and *Juniperus*. Mainly *Poaceae* and *Cyperaceae* developed in the more favourable, more fertile and moister habitats. The presence of *Betula nana* and *Salix* points however to the development of patches of shrubby tundra. Among tree species, birch occurs with an admixture of pine, and its predominant proportion in pollen spectra is in large measure the result of *Pinus* pollen being transported from long distance.

***Pinus-Betula* LPAZ; Preboreal Period.** Following the cooling of the Younger Dryas, along with the improvement in climatic and edaphic conditions, vegetation underwent a rapid transformation. Considerable areas in the Linje region were covered with pine and birch forests. Elm and, in the undergrowth, hazel also began to slowly colonise the stands on more fertile soils. Forests from this period were not yet very dense, as evidenced by both the spread of hazel and in turn the comparatively high proportion of heliophilous plants. The appearance of *Filipendula*, along with the beginning of this zone, also points to an improvement in climatic conditions.

***Pinus-Ulmus-Corylus* LPAZ; younger part of Preboreal and older part of Boreal Period.** The dominant forest community continues to be pine and birch forests, however their nature changes as the habitat and climatic conditions improve. As well as elm, oak spreads into the forests and at the time of the end of this zone, also lime. As a result of the greater density of stands, forming a high, multi-species forest, the role of the birch was reduced in favour of hazel. The increase in the proportion of this shrub, preceding the development of multispecies deciduous forests, is a common phenomenon in Holocene pollen diagrams. Hazel is the first shrub of postglacial shade-tolerant forest communities (IVERSEN 1960; BERGLUND 1966). Depending on soil conditions, it could occur in various communities, (RALSKA-JASIEWICZOWA 1966), which would explain its such early and dynamic spread in the Linje area.

***Corylus-Ulmus-Quercus* LPAZ; Boreal Period.** We see considerable transformation in vegetation (forest) cover in the assemblage zone under discussion. The acreage of pine and birch forests gradually reduces. In the most fertile habitats, these were forced out by multispecies deciduous forests with stands of elm, oak and lime, with an admixture of ash and hazel in the undergrowth. Pine forests with a considerable admixture of oak developed on sandy soils. The tree that spread most strongly at the beginning of this zone was alder. Its dynamic development is no doubt connected with the increasing acreage of waterlogged sites with a high level of ground waters.

***Ulmus-Tilia-Fraxinus-Quercus* LPAZ; the Boreal /Atlantic transition.** This was the period of optimum development of forests – the period of climax forests for the Holocene. The composition of deciduous forests stabilised, building up a *Quercetum mixtum*. Equilibrium occurred between individual species (*Ulmus*, *Tilia*, *Quercus* and *Fraxinus*) and there was a maximum density of tree stands. Pine continued to dominate sandy soils, as testified to by its high percentage share in the whole assemblage zone (about 50%). It created a pine and mixed (with oak and hazel) coniferous type of community. On fertile soils however rich, thermophilous mixed deciduous forests spread, with lime, elm, ash and oak, along with maple, which systematically showed up in the pollen spectra for this zone. The recent SW limit of the distribution area of *Picea* runs closely outside the investigated region. In this zone, *Picea* forms an almost continuous percentage curve and at the top it forms a small maximum exceeding 1%. So its appearance is certainly climate-indicative here and this may testify to the entry of individual spruces in the forest communities in the Linje region.

***Corylus-Quercus* LPAZ; younger part of the Subboreal Period.** This zone is characterised by a further reconstruction of forest communities. The oak became the predominant tree of deciduous forests. In the pollen diagram, the increase in its proportion is linked with a decline in the percentage curve for elm. The increasing acidity of soils may have been a factor supporting the increase in oak expansion. However, the decrease the share of elm in this period is a synchronic phenomenon in Northwestern Europe and in this connection, the cause for the decline in the curve for elm is widely discussed in literature (NILSSON 1964; IVERSEN 1973; RALSKA-JASIEWICZOWA 1982; AABY 1986). In summing up the discussion, BIRKS (1986), RALSKA-JASIEWICZOWA, VAN GEEL (1992) explain this general phenomenon as resulting from a combination of a range of universally occurring factors such as: climatic changes and connected edaphic changes, man's interference and elm disease. In the Linje region however, more fertile soils continued to be colonised by multispecies deciduous forests with oak, lime, ash and elm. New tree species also slowly entered the scene, such as *Carpinus betulus* and *Fagus sylvatica*, which from the middle of the assemblage zone form continuous, though not yet very high curves. Simultaneously with the increase in the proportion of oak, the curve for *Corylus* also rises, which may indicate less compact stands, especially at the beginning of the zone and the related greater production of pollen by hazel and may also be the effect of hazel development in the undergrowth of oak woods. The proportion of spruce is maintained at a similar level to that in the earlier mentioned period, which may indicate the formation of a stable range by this taxon at a certain distance from the region under discussion. Boggy terrain and depressions with high ground water level continued to be occupied by alder carrs and flood-plain forests. The relatively stable proportion of *Alnus* in the pollen diagram may point to the stabilised acreage settled by these communities.

***Carpinus-Quercus* LPAZ; the central and younger part of the Subboreal, the beginning of the Subatlantic.** In this period in the Linje region, similarly as with the whole of the Chełmno Lakeland, considerable changes occurred in the composition of multispecies deciduous forest. These were due to both natural changes in forest site conditions, brought about by a progressive acidification of soils (TOBOLSKI 1976) and, to a large degree, man's interference in the natural environment. There is a decrease in the proportion of ash, lime and elm in the forests in favour of pine and the newly arrived species *Carpinus betulus* and *Fagus sylvatica*. By the end of this zone, hornbeam was the predominant component in the forest, but beech, which also achieves its maximum in the Subatlantic Period, did not play so important a role in the forests of the Chełmno Lakeland. It was doubtless a component of the forests, but mainly on fertile soils. It should also be remembered that the regional expansion of this species is manifested by its 2 to 5% proportion of pollen grains in pollen spectra (LATAŁOWA *et al.* 2004) and in the profile from Linje it only once achieves 1.5 % at a depth of 150 cm. Along with the development of hornbeam forests, there was a definite reduction in the role of hazel, whose proportion fell from about 10% at the beginning of the assemblage zone to about 3-4%. The proportion of *Quercus* in the tree stand was still considerable. On sandy, less fertile site, it may have created along with pine the same type of community as the present-day *Quercus-Pinetum*. On fertile soil however, together with *Carpinus*, it may have formed hornbeam forests whose structure may have been approximate to the pattern proposed by TOBOLSKI (1990, 1991) for the Wielkopolska Region.

***Pinus*-NAP LPAZ; younger part of the Subatlantic Period.** In this zone, there occurred a sharp deforestation, which in consequence led to the present-day shaping of the forest area in the region of the present reserve. The proportion of NAP in pollen spectra grew by about 10%, which when we assume that compared to trees, herbaceous vegetation produces considerably smaller quantities of pollen, suggests deforestation on a scale unparalleled earlier in the Holocene. The proportion of hornbeam, oak and alder fell considerably, by about 20, 10 and 10% respectively. Such taxa as elm, lime and beech almost disappeared entirely in this zone. Only pine shows a sharp increase, however this is surely in no small measure caused by a combination of the further transportation of its pollen. The continuing several percentage share of alder, oak, hornbeam and also hazel and birch is a reflection of pollen rain from the forest surrounding the mire.

5. THE HISTORY OF THE MIRE

The bottom part of the profile is covered by fine-grained sands with gravel. These sands are covered by raised bog type peat layers. The history of the Linje Mire has

Table 2
Description of deposits according to KLOSS, ŻUREK (2005) against the background of the mire development stages

Depth [cm]	Type of peat	Degree of peat humification [%]	Average ash content [%]	Mire development stages
Acc. to KLOSS and ŻUREK (2005)				
0-10	<i>Sphagnum</i> -hollow peat, alive and decaying <i>Sphagnum</i>	< 5	4.0	Stage V
10-52	<i>Sphagnum</i> -hollow peat	17	4.6	
52-310	<i>Sphagnum</i> -hummock peat	27	2.3	
310-500	<i>Sphagnum</i> -hummock peat	45	2.1	Stage IV
500-520	<i>Sphagnum</i> -hollow peat	40	1.7	
520-580	<i>Sphagnum</i> -hummock peat	45	1.7	
580-640	<i>Sphagnum</i> -hollow peat	40	1.6	
640-660	<i>Sphagnum</i> - <i>Scheuchzeria</i> peat	50	1.7	Stage III
660-700	<i>Sphagnum</i> -hummock peat	50	1.7	
700-990	<i>Sphagnum</i> -hummock peat with large proportion of <i>Ericaceae</i>	60	2.8	
990-1030	<i>Sphagnum</i> -sedge peat	50	5.5	Stage II
1030-1050	brown moss peat	35	15.2	Stage I

been traced on the basis of the variable percentage share of *Sphagnum* in individual spectra and the type of deposit. Five stages (Fig. 3) were recognised, which allow us to explain the transformations that took place on the mire. These were then correlated with the results of analysis of peat humification degree, average ash content (Table 2) and the percentage share of macroscopic remains, as carried out by KLOSS from the Centre for Ecological Research, PAS near Łomianki (KLOSS, ŻUREK 2005).

Stage I (1050-1020 cm). In the initial phase of the mire, moss peat was accumulated with a large proportion of *Cyperaceae* and presently featuring comparatively low humification of deposits and a high degree of ash content, as much as 15%. *Cyperaceae* and *Poaceae* made up a considerable proportion of the local vegetation in the pollen diagram. *Betula nana*, which no doubt overgrew the mire at that time, achieves its maximum value for the whole profile in this assemblage zone. Individual algae (*Pediastrum cenobia*) at a depth of 1040 cm may point to the occurrence of small bodies of water in the mire. Among macrofossils, three species of *Sphagnum*, five species of *Cyperaceae*, *Menyanthes trifoliata* and numerous species of brown moss were distinguished (KLOSS 2005).

Stage II (1020-970 cm). An increase in the proportion of sphagnum mosses and the break up of the curve for *Poaceae* and *Cyperaceae* marks the next stage in the history of the mire. This is characterized by a comparatively high, 50 percent peat humification, and a still high ash content (5.5%). In the initial phase of transformations on the mire, we observe an increase in the proportion of *Equisetum*

spores. *Betula nana* is a permanent presence, but in a considerably smaller proportion. Pollen of plants connected with an aquatic and marshy environment, *Nymphaea* and *Menyanthes trifoliata*, also appear in the diagram. Numerous remains of *Sphagnum* mosses (six species), as well as *Cyperaceae* (seven species), *Ericaceae* species, *Menyanthes trifoliata*, *Equisetum fluviatile* and single *Betula nana* trees were discovered among the macroremains (KLOSS 2005). The picture gained from both analyses points to the considerable predominance of *Sphagnum* occurring in the mire in this period. Its proportion in individual pollen spectra fluctuated between 1.5 and 47%, whereas in the deposit mass, it made up as much as 30-65%. Also in the case of both analyses we observe here a maximum proportion for the profile of such marshy plants as *Menyanthes trifoliata* and *Equisetum fluviatile*. This points to the complicated arrangement of vegetation in the mire.

Stage III (970-630 cm). The third stage sees another decrease in the proportion of *Sphagnum*; indeed in places even a complete lack of these spores was noted in the analysed spectra. There appears however a percentage curve for heather species (*Ericaceae* undiff.) which accords with the discovery of their macrofossils in deposits. The degree of peat humification fluctuates here between 60 and 50% and is the highest in the whole profile. Ash content however continues to diminish (from 2.8 to 1.7%). In the whole of the profile, pollen of aquatic and marshy plants appear individually, mainly *Sparganium* and *Typha latifolia*, indicating the development of a reedbed in the mire. Among macroremains apart from the numerous *Ericaceae* and *Sphagnum* species, *Cyperaceae* (mainly cotton grass), *Scheuchzeria palustris*, a few brown mosses and remains of pine and birch were also identified (KLOSS 2005). The presence of trees and dwarf shrubs suggests a fall in the level of ground water at this stage.

Stage IV (630-300 cm). The next stage is a period of a renewed rise in the proportion of *Sphagnum* sp. (over one percent). The degree of peat humification again decreases and fluctuates between 40 and 45% and ash content grows towards the top (from 1.6 to 2.1%). The record of lake vegetation shows the reappearance of the whole group of limnophytes, including *Nymphaea*, *Potamogeton* s. *Eupotamogeton*, *Myriophyllum spicatum* and again individual algae (*Pediastrum*) cenobia appear in great number in the pollen spectra. This surely indicates the presence of water table in the mire. However there is no evidence by which to estimate its distance from the place where the core sample was taken. Among macrofossils, a predominant role is played by *Sphagnum* mosses (seven species recorded), whose proportion in the deposit mass amounts to 77% on average (and fluctuates between 50 and 90%). A smaller role in deposit formation is played however by heather species (mainly *Oxycoccus palustris*) and *Cyperaceae* species (cotton grass). However no brown mosses were recorded in the whole of the assemblage zone (KLOSS 2005).

Stage V (300-10 cm). This is the last and not a homogeneous stage. It is generally characterized by an increase in the proportion of *Sphagnum* sp., a systematic

reduction in the degree of peat humification (from 27 to 17% and in the top layer even less than 5%) and an increased ash content (from 3.3 to 4%). Among local mire vegetation in the pollen diagram, there is an increased proportion of *Ericaceae*, *Poaceae* and *Cyperaceae*. *Betula nana* also continues to be present and in one sample (at a depth of 240 cm), an increased quantity of *Stachys* type pollen appears. Following detailed analysis, this taxon was attributed to *Stachys palustris* and so a marshy plant and probably its local expansion caused such a strong overrepresentation (30%). Among aquatic plants, only individual grains of *Iris* were recorded and in addition, among marshy plants *Menyanthes trifoliata*, *Sparganium* and *Typha latifolia* were noted. A drastic increase in the proportion of *Sphagnum* appears in the top layer of the core, an explanation for which lies in the type of deposit, because this assemblage zone encompasses both the live and dead part of the mire. Among macrofossils, the predominant proportion is still that of *Sphagnum*, averaging to 82% of the deposit mass (and oscillated between 70 and 90%). The proportion of *Ericaceae* and *Cyperaceae* (mainly cotton grass) became even. There appears a distinct layer of *Scheuchzeria palustris* in the central part of this assemblage zone. However its increased proportion is not reflected in the picture obtained from pollen analysis.

6. CONCLUSIONS

The history of the vegetation cover in the neighbourhood of the Linje Mire is based on analysis of the material taken from the central, deepest part of the mire, the LX profile (Fig. 2 and 3). Pollen analysis made it possible to trace the history of the vegetation on this ecosystem from the decline of the Younger Dryas to the Subatlantic Period. Eight pollen assemblage zones (1-8 LPAZ) were distinguished in the diagram. The first zone represents late-glacial vegetation (from the Younger Dryas), whose predominant type is park tundra with individual specimens of *Pinus* and *Betula alba*, as well as *Juniperus* and *Betula nana*. Analysis of deposits, macrofossils and pollen (mainly vegetation local to the mire) made it possible to differentiate five (sedentational) stages in the development of the mire.

The presence of pollen from birch, identified as *Betula nana*, along with fragments and even whole leaves and seeds of this species, confirms earlier hypotheses that *Betula nana* has been growing on the mire since the Younger Dryas and is therefore a late-glacial relic in this area.

7. REFERENCES

- AABY, B. 1986. Trees as anthropogenic indicators in regional pollen diagrams from eastern Denmark. In: K.E. BEHRE (ed.), *Anthropogenic indicators in pollen diagrams*. A.A. Balkema, Rotterdam, Boston, p. 73-94.
- BERGLUND, B.E. 1966. Late-Quaternary Vegetation in eastern Blekinge, south-eastern Sweden. A pollen-analytical study. II. Post-Glacial time. *Opera Bot.* 12, 2.
- BERGLUND, B.E., RALSKA-JASIEWICZOWA, M. 1986. Pollen analysis and pollen diagrams. In: B.E. BERGLUND (ed.), *Handbook of Holocene Palaeoecology and Palaeohydrology*. John Wiley & Sons Ltd., Chichester, p. 455-484.
- BIRKS, H.J.B. 1986. Late-Quaternary biotic changes in terrestrial and lacustrine environments, with particular reference to north-west Europe. In: B.E. BERGLUND (ed.), *Handbook of Holocene Palaeoecology and Palaeohydrology*, John Wiley & Sons Ltd., Chichester, p. 3-65.
- BIRKS, H.J.B., BERGLUND, B.E. 1979. Holocene pollen stratigraphy of southern Sweden: a reappraisal using numerical methods. *Boreas* 8: 257-279.
- BOIŃSKI, M., CYZMAN, W., ZAŁUSKI, T. 2001. Szata roślinna. In: A. PRZYSTALSKI (ed.), *Przyroda województwa kujawsko-pomorskiego*, Bydgoszcz, p. 54-73.
- CEYNOWA-GIELDON, M. 1971. Osobliwości florystyczne i rezerваты ziemi chełmińskiej. *Przewodnik florystyczny*. Toruńskie Towarzystwo Naukowe, Toruń, 108 pp.
- IVERSEN, J. 1960. Problems of the Early Post-Glacial forest development in Denmark. *Dan. Geol. Unders.* 4, 4-3.
- IVERSEN, J. 1973. The Development of Denmark's Nature since the Last Glacial. *Geol. Surv. Denmark*, V, 7-C: 1-126.
- JANCZYK-KOPIKOWA, Z. 1987. Uwagi na temat palynostratygrafii Czwartorzędu. *Kwart. Geol.* 31: 155-163.
- KLOSS, M. 2005. Identification of subfossil plant communities and palaeohydrological changes in raised mire development. *Monogr. Bot.* 94: 81-116.
- KLOSS, M., ŻUREK, S. 2005. Geology of raised mire deposits. *Monogr. Bot.* 94: 65-80.
- KONDRACKI, J. 1980. *Geografia fizyczna Polski*. PWN, Warszawa.
- LATAŁOWA, M., RALSKA-JASIEWICZOWA, M., MIOTK-SZPIGANOWICZ, G., ZACHOWICZ, J., NALEPKA, D. 2004. *Fagus sylvatica* L. – Beech. In: M. RALSKA-JASIEWICZOWA, M. LATAŁOWA, K. WASYLKOWA, K. TOBOLSKI, E. MADEYSKA, H.E. WRIGHT JR., CH. TURNER (eds.), *Late Glacial and Holocene history of vegetation in Poland based on isopollen maps*. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków, p. 95-104.
- NILSSON, T. 1964. *Entwicklungsgeschichtliche Studien im Ageröds Mosse, Schonen, Lunds Univ. Årsskr. N. F. A.* 2. 59, 8.
- PASZEWSKI, A. 1928. Pollenanalytische Untersuchung einiger Moore in Nordwest-Polen. (Vorläufige Mitteilung). *Acta Soc. Bot. Pol.* 5, 4: 353-366.
- PASZEWSKI, A. 1934. Uwagi o historyi lasów na pomorzu w świetle analizy pyłkowej. *Acta Soc. Bot. Pol.* 11. Suppl.: 265-284.
- RALSKA-JASIEWICZOWA, M. 1966. Osady denne Jeziora Mikołajskiego na Pojezierzu Mazurskim w świetle badań paleobotanicznych [Bottom Sediments of the Mikołajki Lake (Masurian Lake District) In the Light of Palaeobotanical Investigations]. *Acta Palaeobot.* 7, 2: 1-118.
- RALSKA-JASIEWICZOWA, M. 1982. Prehistoric man and natural vegetation: the usefulness of pollen evidence in interpretation of man-made changes. *Memorab. Zoologica* 37: 31-45.
- RALSKA-JASIEWICZOWA, M., VAN GEEL, B.M. 1992. Early human disturbances of the natural environment recorded in annually laminated sediments of Lake Gościąg, central Poland. *Vegetation History and Archaeobot.* 1: 33-42.
- STOCKMARR, J. 1971. Tablets with spores in absolute pollen analysis. *Pollen and Spores* 13, 4: 615-621.

- TOBOLSKI, K. 1976. Przemiany klimatyczno-ekologiczne w okresie czwartorzędu a problem zmian we florze [Climatic-ecological transformations in the Quaternary and problem of changes in the flora]. *Phytocoenosis* 5, 3/4: 187-197 (In Polish with English summary).
- TOBOLSKI, K. 1990. Naturalne i antropogeniczne przemiany szaty leśnej. Pierwotna roślinność leśna środkowej Wielkopolski i jej antropogeniczne przekształcenia. In: K. TOBOLSKI (ed.), *Paleoekologia i paleolimnologia postglacjalu niżu polskiego (na przykładzie środkowej Wielkopolski i Borów Tucholskich)*. SGGW-AR, Warszawa: 11-20.
- TOBOLSKI, K. 1991. Dotychczasowy stan badań paleobotanicznych i biostratygraficznych Lednickiego Parku Krajobrazowego [Gegenwärtiger Stand der paläobotanischen und biostratigraphischen Forschungen im Ledmicer Landschaftspark]. In: K. TOBOLSKI (ed.), *Wstęp do paleoekologii Lednickiego Parku krajobrazowego*. Bibl. Stud. Legnickich. UAM, Poznań: 11-34 (In Polish with English summary).
- TOBOLSKI, K., NORYŚKIEWICZ, B., FILBRANDT-CZAJA, A., KLOSS, M., LAMENTOWICZ, M., MILECKA, K., NORYŚKIEWICZ, A., OBREMSKA, M., PAJĄKOWSKI, J., ŻUREK, S. 2004. Postglacjalna historia lasów, jezior i torfowisk na wybranych przykładach Ziemi Chełmińskiej i Borów Tucholskich [Postglacial history of the forests, lakes and peatbogs on the selected examples of Chełmno district and Tuchola forest]. In: E. KRASICKA-KORCZYŃSKA, M. KORCZYŃSKI (eds.), *Wycieczki geobotaniczne – Region Kujawsko-Pomorski* [Geobotanical trips – The Kujawsko-Pomorski Region]. Polskie Towarzystwo Botaniczne, Bydgoszcz-Toruń, p. 33-54 (in Polish).
- WALANUS, A., NALEPKA, D. 1999. POLPAL Program for counting pollen grains, diagrams plotting and numerical analysis. *Acta Palaeobot. Supplementum* 2: 659-661.
- WIECKOWSKI, K. 1970. New type of lightweight piston core sampler. *Bull. Acad. Pol. Sci., Ser. Geol.* 18, 1: 57-62.

8. WSTĘPNE WYNIKI BADAŃ NAD HISTORIĄ ROŚLINNOŚCI OKOLIC TORFOWISKA LINJE NA PODSTAWIE ANALIZY PYŁKOWEJ (streszczenie)

Badania paleoekologiczne, których wyniki przedstawione zostały w niniejszej pracy rozpoczęto w 2003. Prowadzone są one we wschodniej części ziemi chełmińskiej na terenie rezerwatu florystycznego w Linjach (Fig. 1). Jest to jedyne w Polsce niżowej stanowisko *Betula nana*. Analizie poddano osady biogeniczne ze środkowej części torfowiska, w miejscu sąsiadującym ze współczesnym występowaniem tego gatunku.

Celem badań palinologicznych było pogłębienie historii roślinności tego terenu ze szczególnym uwzględnieniem przeszłości *Betula nana* oraz roli człowieka ingerującego w naturalną szatę roślinną tego terenu (druga część zagadnienia będzie tematem osobnego rozważania). Na podstawie analizy diagramów pyłkowych (procentowego, koncentracji sporomorf oraz CONSLINK) wydzielono osiem poziomów pyłkowych (Fig. 2) oraz pięć etapów rozwoju torfowiska (Fig. 3). Zapis palinologiczny obejmuje pełną sukcesję szaty roślinnej tego terenu, od schyłku późnego glacialu przez cały holocen po czasy współczesne. Poziom pierwszy biostratygraficznie należy do młodszego dryasu i odzwierciedla mozaikową pokrywę roślinną, której dominującym typem jest tundra parkowa z płatami tundry zielnej

i krzewiastej oraz stepów. Ocieplenie klimatu na początku holocenu spowodowało rozprzestrzenienie się zbiorowisk leśnych. W początkowym etapie były to lasy sosnowo-brzozowe (poziom L X-2) o niezbyt jeszcze dużym zwarcie drzewostanów. Wraz z poprawą warunków siedliskowych i klimatycznych zmieniał się jednak charakter tych lasów, pojawiają się nowe gatunki drzew i zwiększa się zwarcie drzewostanu (poziom L X-3, L X-4). Poziom L X-5 odzwierciedla już okres optymalnego rozwoju lasów dla holocenu, tzw. okres lasów klimaksowych. Ustabilizował się wtedy ich skład i utrzymała równowaga pomiędzy poszczególnymi gatunkami. Po tym okresie nastąpiła ponowna przebudowa w składzie mieszanych lasów liściastych wywołana naturalnym procesem zakwaszenia gleb oraz w dużym stopniu również ingerencją człowieka. Początkowo dominującym składnikiem stał się dąb (poziom L X-6), który stopniowo wypierany był przez nowo przybyły gatunek, jakim był *Carpinus* (poziom L X-7). Poziom ostatni L X-8 charakteryzuje najbardziej współczesny obraz przemian w szacie roślinnej tego regionu. Nastąpiło wtedy gwałtowne odlesienie, za przyczyną ekspansji człowieka. Obecność pyłku brzozy zakwalifikowanego do gatunku *Betula nana* i fragmenty a nawet całe liście i nasiona tej rośliny potwierdzają wcześniejsze sugestie, że *Betula nana* rośnie na torfowisku od młodszego dryasu jest, zatem późnoglacialnym reliktem na tym terenie.

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**THE HISTORY OF VEGETATION
OF THE RĄBIEŃ MIRE REGION**

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ABSTRACT

Zofia BALWIERZ. *The history of vegetation of the Rąbień Mire region*. Monogr. Bot., Vol. 94, 135-144, 2005.

The paper presents the results of a palynological investigations of a profile collected from the Rąbień Mire (the region of Łódź). This peatbog is located at the foot of a dune on which archaeological researches were carried out in the 1990s. On pollen analysis basis, the development of the water body and then of the mire is depicted, including changes in the vegetation cover in the study area in the Late Glacial and in the Holocene.

Key words: raised mires; palynology; Holocene; region of Łódź; Poland.

1. INTRODUCTION

The area once called the Łódź Upland (PAPIŃSKA 1993) is located beyond the limits of the Last Glaciation. It is devoid of lake deposits which usually provide a good material for palynological studies. It is one of the reasons for the lack of such studies. Particularly, no profiles exist covering the entire Holocene Period. The only sites with a complete Holocene succession that have been studied so far are: Napoleonów (BALWIERZ 1980), Parchliny and Chabielice (BALWIERZ *et al.* in press). However, they do not meet the criteria set for reference sites. In recent years, a mire at Żabieniec has been discovered (BALWIERZ *et al.* 2002). Situated in the locality of Syberia, in the area of the Łódzkie Hills, it has a chance to become such a site.

In the 1990s, archeological investigations were carried out by the Archeological Museum in Łódź on a dune in Aleksandrów Łódzki. In connection therewith, boreholes were made in the Rąbień Mire adjacent to the dune. The purpose of the boring was to take samples for palynological studies (borehole 1/3) and radiocarbon dating (borehole 2/3 and 3/3). The boring was carried out in the eastern part of the mire, at an interval of no more than one meter. Additionally, samples were taken from the mire-dune contact zone. The results of all the analyses and their correlation to the results of archeological and geomorphological research, as well as of radiocarbon dating will be subject to a separate study. This paper depicts a brief history of vegetation on the basis of the results of a palynological analysis of one of the boreholes.

Acknowledgements. The author is thankful to the anonymous reviewer for his thorough review of the work and critical remarks.

2. MATERIAL AND REMARKS ON METHODS APPLIED

Boreholes were made using an Instorf-type borer. 70 samples were taken from one of the extracted 350 cm-long cores at equal 5-cm intervals. The sediment, after boiling with KOH, was subjected to acetolysis (ERDTMAN 1943). Some of the samples including an admixture of mineral sediment were treated with hydrofluoric acid (FAEGRI, IVERSEN 1989). Such prepared material was immersed in glycerin, and then, microscopic slides were made of it. The percentage share of taxa was calculated following the generally accepted criteria (BERGLUND, RALSKA-

JASIEWICZOWA 1986), that is, in relation to the sum of pollen grains of trees and shrubs (AP) and herbs and dwarf shrubs (NAP). The sum did not include the taxa of aquatic and reed plants, spores of mosses, ferns and algae. The analysis results were presented in the form of a pollen diagram in Figure 1 (WALANUS, NALEPKA 2000), in a simplified form. Local pollen assemblage zones were distinguished in the diagram (LPAZ) (JANCZYK-KOPIKOWA 1987).

3. DESCRIPTION OF LOCAL POLLEN ASSEMBLAGE ZONES (LPAZ)

Poaceae-Cyperaceae LPAZ (samples 67-70) features a large share of NAP (87.5%). First, the proportion of *Poaceae* pollen dominates (71.7%), then, its value drop, while the *Cyperaceae* curve rises (65.2%). The pollen of taxa characteristic for cool and open habitats was recorded (*Juniperus*, *Betula* cf. *nana*, *Helianthemum*, *Artemisia*, *Chenopodiaceae*, *Chamaenerion*, *Empetrum*, *Armeria*). The rise of the AP curve marks the upper limit of the zone.

Salix-Hippophaë-Juniperus LPAZ (samples 65-66). The AP curve, comprising mainly *Betula* and *Pinus*, rises to 71.9%. Also the curve of *Salix* pollen grains (11.05% in sample 65) is high. Maximum quantities of *Hippophaë* and *Juniperus* pollen are present here. The share of *Artemisia* increases, and the curves for the pollen grains of some other herbs recorded in the above mentioned pollen assemblage zone, are maintained on the same level. The proportion of the *Pediastrum* is very high.

Pinus-Betula LPAZ (samples 61-64). A further rise to about 85% of the AP curve is observed first for *Betula* and *Pinus*, and then – only for *Pinus* to 68.5%. The values for *Juniperus* and *Salix* are slightly lower than in the previous zone. A drop of the *Pinus* curve and a recurring rise in the share of *Betula* mark the limit of the next pollen assemblage zones.

In **Betula-Pinus LPAZ** (samples 59), the pollen curves for these trees reach similar values (41.8 and 46.5%). The recurring rise of the pollen curve value of *Pinus* and its fall for *Betula* mark the upper limit of the zone.

Table 1
Rąbień. Lithology of borehole 1/3

Depth in cm	Deposit description
0-20	mucking and crumbling peat, strongly humified
20-30	raised bog peat, intermediately humified
30-50	raised bog peat, strongly humified
50-90	raised bog peat, strongly humified
90-110	sedge-brown moss peat
110-325	gyttja
325-350	grey sand with humus

***Pinus* LPAZ** (samples 52-58). The AP curve rises to the value of over 80% and is composed mainly of the *Pinus* curve (60-70%) and the much lower (20-26%) *Betula* curve. The pollen of *Salix* and *Juniperus* is present. Its curve rises slightly in the upper part of the zone, while *Poaceae*, *Cyperaceae* and *Artemisia* continue to dominate amongst the herbs. The upper limit of the zone is marked by the beginning of the continuous curves of *Ulmus* and *Corylus*.

***Pinus-Corylus-Ulmus* LPAZ** (samples 44-51). The share of AP is very high. In addition to *Pinus* and *Betula*, also *Ulmus* and *Corylus* pollens are present. Also the pollen curves of *Alnus* and *Quercus* have their beginning there. Owing to the oscillations of the *Pinus* and *Betula* curve, 2 sub-zones were distinguished: *Betula-Pinus-Ulmus* (samples 49-51) and *Pinus-Corylus* (samples 44-47). The rise of the curve of *Corylus* pollen value and the start of the *Fraxinus* and *Tilia* curves mark the upper limit of the zone.

***Corylus-Pinus* LPAZ** (samples 37-43). The pollen curve of *Corylus* reaches its maximum values. Also a significant share of *Pinus* is recorded. *Ulmus*, *Quercus*, *Fraxinus*, *Tilia* and, initially, *Alnus* occur. Their amounts do not exceed several percents. The rise in the number of these trees and the appearance of the *Picea* pollen curve set the upper limit of the zone.

***Alnus-Quercus-Corylus* LPAZ** (samples 23-35). A slow but steady drop of the *Corylus* curve is observed in contrast with the growing presence of trees with higher thermal requirements, *Picea* and *Alnus*. In the bottom part of the zone, the proportion of *Ulmus* is the highest.

***Quercus-Alnus-Picea* LPAZ** (samples 13-22). The start of the continuous curve of *Carpinus* and *Fagus* marks the lower limit of the zone, while the rising share of these taxa marks its upper limit. The *Quercus* curve reaches its absolute maximum. The share of *Cyperaceae* rises in comparison with the lowest and highest zone. A marked growth in the share of *Sphagnum* spores is recorded.

***Picea-Alnus-Tilia* LPAZ** (samples 5-11). This zone sees the highest values of *Tilia* and *Fraxinus*. The *Corylus*, *Alnus* and *Quercus* curves stay on a similar level and do not exceed 20%. The continuous *Abies* curve starts there.

***Cerealia-Carpinus-Alnus* LPAZ** (samples 1-4). A marked rise in the share of *Carpinus* and the start of the *Cerealia* curve mark the lower limit of the zone. The share of *Quercus* and *Corylus* declines distinctly and the NAP curve increases, including *Cerealia*. The *Carpinus* and *Fagus* curve reaches its absolute maximum.

3.1. Chronostratigraphic division

The division of the diagram into chronozones was effected on the basis of C¹⁴ dating (MANGERUD *et al.* 1974), if dates were available. When no dates were available, the climatic-vegetation limits were set in some pollen assemblage zones on the basis of the traditional criteria of Holocene division (FIRBAS 1949).

The lowest three pollen assemblage zones (*Poaceae-Cyperaceae*, *Hippophaë-Juniperus*, *Pinus-Betula* and *Betula-Pinus* LPAZ) were classified into the Late Glacial. Gytja floor dating (325 cm in depth) established the age at 11880 ± 60 BP (KLOSS, ŽUREK 2005). A very close result ($11\,810 \pm 110$ BP) came from gytja floor dating from borehole 2/3 (MAROSIK, pers. comm.). This date marks the start of the Alleröd (MANGERUD *et al.* 1974). The bottom section of the pollen diagram (*Poaceae-Cyperaceae* LPAZ) can be classified into the Older Dryas. The Alleröd comprises *Hippophaë-Juniperus* and *Pinus-Betula* LPAZ. The pollen assemblage zone *Betula-Pinus*, found only in one sample, was correlated to the Younger Dryas. The start of the Holocene is marked by *Pinus* LPAZ which corresponds to the Preboreal Period. The start of the curves of the first taxa of higher thermal requirements (*Ulmus* and *Corylus*) recorded in the diagram mark the beginning of the Boreal Period. The rise in the share of these taxa and the appearance of the following thermophilous tree taxa (*Quercus*, *Fraxinus*, *Tilia*) was considered the start of the Atlantic Period. This limit was also confirmed by the radiocarbon date of 8200 ± 80 BP obtained for the gytja layer at a depth of 210 cm from borehole 2/3 (MAROSIK, pers. comm.). The appearance of the *Carpinus* and *Fagus* curves was considered the start of the Subboreal, while the start of the continuous curve for cultivated plants, mainly cereals, marks the lower boundary of the Subatlantic Period.

4. THE HISTORY OF VEGETATION

The development of the vegetation in the area under study started in the Late Glacial, during the Older Dryas, as indicated directly through C^{14} dating. This period was marked by forestless communities. On the other hand, the proportion of herb communities was high. In wet habitats, grasses, crowberry, cloudberry and dwarf birch grew, along with shrubs, such as willows, and among spore-producing plants – lesser clubmoss. The dryer and less humus-rich habitats were colonised by rock-rose, thrift, narrow-leaved fireweed and sage-brushes. Sedges grew around and *Pediastrum* inside the already then existing water body. The richness of herb taxa was very high. Never have herbs played such a prominent role in the study site ever since.

The start of the Alleröd is the time of dominance of shrub communities. The water level in the water body rose significantly. Around it, willow thickets developed, while juniper and sea-buckthorn occupied the habitats on the nearby dune. Also birch and then pine encroached on the dune, replacing the shrubs which had grown there before. In open habitats, wormwood communities continued to grow. Sedges and grasses communities shrank considerably. However, sage-brushes still occurred in open habitats, and pine was accompanied by heather. In the diagram from the Rąbień Mire, lack of the birch phase in the Older Alleröd is observed. It

is however recorded in a number of other sites, like Witów near Łęczysca (WASYLIKOWA 1964). The habitat conditions may have favoured the occurrence of sea-buckthorn and juniper followed by the pine phase of the Interstadial.

The Younger Dryas was reflected in the pollen diagram as another short episode of birch dominance.

The start of the Holocene is marked by the expansion of trees (*Pinus* LPAZ). Pine dominated – it may have colonized not only the sites on the dune. The share of shrub communities gradually decreased. Sea-buckthorn nearly disappeared; only few juniper communities remained. Willows continued to grow around the water body. Forest cover was not completely dense. It is confirmed by both the share of AP below 90%, and the presence of sage-brush.

As the climate became warmer, the study site was colonised by the first trees with higher thermal requirements. Sage-brush communities disappeared. The monotonous pine-birch forests were enriched with elm and hazel growing on the edges. This type of forest occurred throughout the entire Boreal Period (*Pinus-Corylus-Ulmus* LPAZ). Its decline phase was marked by the appearance of oak, ash and lime.

In the Atlantic period (*Corylus-Pinus* and *Alnus-Quercus-Corylus* LPAZ), pine initially grew on the dune. Hazel may have occurred in the pine forest undergrowth, or it may have formed independent communities on the edges of these forests. Alder encroached on the peatbog which was being formed on the bank of the water body. The development of mixed forests with oak, ash, lime, elm and spruce marks the next stage. The mild Atlantic climate also favoured the presence of ivy and mistletoe. After the likely slight water shallowing in the younger part of the Boreal Period, the water level in the lake rose slightly at the beginning of the Atlantic Period. Then, the water body shallowed and the overgrowing process began. The aquatic vegetation (communities with *Nuphar*, *Nymphaea alba*, *Potamogeton*) or reed vegetation (phytocoenoses *Typha angustifolia*, *T. latifolia*), which had been absent before, occurred throughout the entire Atlantic Period. The presence of *Pediastrum* decreased, to finally disappear completely.

In the older part of the Subboreal Period (*Quercus-Alnus-Picea* LPAZ), the composition of stands did not change significantly. Oak was the dominant species. The importance of elm gradually declined in favour of the growing role of spruce, hornbeam and beech in the younger part of the Subboreal Period. At the beginning of the Subboreal Period, the aquatic and reed vegetation disappeared almost completely. Sedges and mosses encroached upon the overgrown water body. This is reflected in the change of the deposit from gyttja to sedge-moss peat.

During the Subatlantic Period (*Cerealia-Carpinus-Alnus* LPAZ), the significance of forest communities declined in favour of cultivated plants, mainly cereals. Most of the stands of trees and hazel shrank, as a result of human activity. The areas covered by forests were turned into croplands. Only alder continued to dominate in the mire. The significance of trees which last encroached on the study site, like hornbeam, beech and fir, increases. The latter two however have never played a

larger role in this area. This can be explained by the fact that the north-eastern limit of their occurrence extends north of Łódź (SZAFFER and ZARZYCKI 1972).

5. CONCLUSIONS

1. The palynological analysis indicated that the examined deposit had developed during the Late Glacial and throughout the entire Holocene.
2. Absence of the birch phase in the Younger Alleröd is recorded.
3. The water body existed as early as in the Late Glacial and was deepest then. From the start of the Holocene, it underwent the process of gradual shallowing. It disappeared completely at the beginning of the Subboreal Period.

6. REFERENCES

- BALWIERZ, Z. 1980. Analiza palinologiczna późnoglacialnych i holocenijskich osadów z torfowiska w Napoleonowie [Pollen analysis of the Late Glacial and Holocene deposits from the peat-bog at Napoleonów]. *Acta Univ. Lodz.*, Ser. II 22: 151-157.
- BALWIERZ, Z., FORYSIAK, J., TWARDY, J. 2002. Cechy mineralnej i organicznej sedymentacji w zagłębieniach bezodpływowych w Polsce środkowej w świetle wstępnych wyników badań torfowiska „Żabieniec” k. Łodzi. Materiały konferencji „Roślinność a procesy erozji, transportu i depozycji” [Features of mineral and organic sedimentation in closed depressions in Middle Poland in the light of the preliminary results of the investigations of the Żabieniec peat-bog near Łódź. Conference papers “Vegetation versus erosion, transport and deposition processes”]. Sosnowiec, 21-22.03.2002, p. 13-17.
- BALWIERZ, Z., MAROSIK, P., MUZOLF, B., PAPIERNIK, P., SICIŃSKI, W. In press. Osadnictwo społeczeństw rolniczych i zmiany środowiska naturalnego nad środkową Krasówką (Kotlina Szczercowska). Wstępna charakterystyka [Settlement of agricultural communities and changes in natural environment upon middle Krasówka (Szczercowska Basin). Preliminary characteristics]. *Polish Botanical Studies*.
- BERGLUND, B. E., RALSKA-JASIEWICZOWA, M. 1986. Pollen analysis and pollen diagrams. In: B.E. BERGLUND (ed.), *Handbook of Holocene palaeoecology and palaeohydrology*. J. Wiley & Sons Ltd. Chichester-New York, p. 455-484.
- ERDTMAN, G. 1943. An introduction to Pollen Analysis. Waltham, Mass. Verdoorn.
- FAEGRI, K., IVERSEN, J. 1989. *Textbook of pollen analysis*. J. Wiley & Sons Ltd., Chichester-New York-Brisbane-Toronto-Singapore.
- FIRBAS, F. 1949-1952. Spät- und nachzeitliche Waldgeschichte Mitteleuropas nördlich der Alpen. *Gustav Fischer*. Jena. 1: 1-480, 2: 1-256.
- JANCZYK-KOPIKOWA, Z. 1987. Uwagi na temat palinostratygrafii Czwartorzędu [Remarks on Quaternary palynostratigraphy]. *Kwart. Geol.* 31: 155-163.
- KLOSS, M., ŻUREK, S. 2005. Geology of raised mire deposits. *Monogr. Bot.* 94: 65-80.
- MANGERUD, J., ANDERSEN, S.T., BERGLUND, B.E., DONNER, J.J. 1974. Quaternary stratigraphy of Norden, a proposal for terminology and classification. *Boreas* 3: 109-128.

- PAPIŃSKA, E. 1993. Podział regionalny i nazewnictwo geograficzne obszaru środkowej Polski [Regional division and geographical terminology of Central Poland territory]. In: S. PĄCZKA (ed.), Środowisko geograficzne Polski Środkowej [Geographical environment of Central Poland]. Wyd. Uniwersytetu Łódzkiego, Łódź.
- SZAFER, W. 1972. Szata roślinna Polski niżowej [Lowland vegetation of Poland]. In: W. SZAFER, K. ZARZYCKI (eds.), Szata roślinna Polski [Vegetation of Poland]. T. 1. PWN, Warszawa: 17-188.
- WALANUS, A., NALEPKA, D. 1999. POLPAL program for counting pollen grains, diagram plotting and numerical analysis. *Acta Palaeobot. Suppl.* 2: 659-661.
- WASYLIKOWA, K. 1964. Roślinność i klimat późnego glacjału w środkowej Polsce na podstawie badań w Witowie koło Łęczycy [Vegetation and climate of the Late Glacial in Central Poland based on the investigations carried out at Witów near Łęczycza]. *Biuletyn Peryglacjalny* 13: 261-417.

7. HISTORIA ROŚLINNOŚCI OKOLIC TORFOWISKA RĄBIEŃ (streszczenie)

Prowadzone przez Muzeum Archeologiczne w Łodzi w latach dziewięćdziesiątych XX w. badania archeologiczne na wydmie w Aleksandrowie Łódzkim były okazją do przeprowadzenia badań palinologicznych na sąsiadującym z wydumą torfowisku Rąbień. Wyniki analizy pyłkowej zostały przedstawione w postaci procentowego diagramu pyłkowego (Fig. 1).

W diagramie wydzielono 11 lokalnych poziomów pyłkowych (LPAZ). Podziału diagramu pyłkowego dokonano częściowo na podstawie datowania C^{14} , częściowo zaś na podstawie sukcesji roślinnej. Trzy dolne lokalne poziomy pyłkowe zaliczone zostały do późnego glacjału. Datowanie C^{14} pozwoliło wydzielić w obrębie późnego glacjału starszy dryas (LPAZ *Poaceae-Cyperaceae*), Alleröd (LPAZ *Salix-Hippophaë-Juniperus* i *Pinus-Betula*) oraz młodszy dryas (LPAZ *Betula-Pinus*). Kolejny poziom pyłkowy (*Pinus*) odpowiada okresowi preborealnemu a *Pinus-Corylus-Ulmus* okresowi borealnemu. LPAZ *Corylus-Pinus* i *Alnus-Quercus-Corylus* zaliczono do okresu atlantyckiego. Początek tego okresu potwierdza również data radiowęglowa 8200 ± 80 BP uzyskana dla warstwy gytyi z głębokości 210 cm. Do okresu subborealnego zaliczono kolejne dwa poziomy pyłkowe *Quercus-Alnus-Picea* i *Picea-Alnus-Tilia*, natomiast poziom *Cerealia-Carpinus-Alnus* do okresu subborealnego.

Rozwój roślinności na badanym obszarze zaczął się w późnym glacialu od zbiorowisk bezleśnych. W Allerödzie początkowo panowały zbiorowiska z dużym udziałem krzewów a następnie las sosnowy. Ochłodzenie młodszej dryasu spowodowało wycofanie się sosny a bujniejszy rozwój zbiorowisk z dominacją brzozy. Początek holocenu prowadzi do rozwoju zbiorowisk sosnowych, a następnie w miarę poprawy warunków klimatycznych, na badany teren wkracza wiąz i leszczyna. Dalsza poprawa klimatu powoduje wkraczanie na badany teren olszy, dębu, jesionu, lipy i świerka a na początku okresu subborealnego również graba i buka. Pojawienie się zbóż wyznacza początek okresu subatlantyckiego.

Zbiornik wodny istniał już w późnym glacie. W najwcześniejszym okresie jego istnienia odkładał się w nim piasek szary z humusem. Na początku Allerödu poziom wody w akwie znacznie się podniósł i zaczęła się w nim akumulować gytia. Zbiornik zaczyna się stopniowo wypłycać począwszy od okresu borealnego a u schyłku okresu atlantyckiego następuje jego zarośnięcie. Na jego teren wkraczają turzyce i mchy oraz następuje odkładanie torfu.

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**THE HISTORY OF THE ZIELENIEC MIRE
AND THE SURROUNDING AREAS
BASED ON THE PALYNOLOGICAL RESEARCH**

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ABSTRACT

Ewa MADEYSKA. *The history of the Zieleniec Mire and the surrounding areas based on the palynological research*. Monogr. Bot., Vol. 94, 145-157, 2005.

The paper presents the results of palynological investigations of a profile collected from the Zieleniec Mire (Sudety Mountains). The pollen analysis evidenced the development of a peat-bog and documented the character of the vegetation and its changes in this region from the end of the Preboreal Period to the present time. The succession of forest trees in the montane zones corresponds to the scheme of vegetation development in the mountains of Central Europe. The presence of *Betula nana* throughout the entire period till today has been confirmed. The main vegetation disturbances recorded from the prehistorical period have been caused by human activity in the submontane region.

Key words: raised mire; palynology; Holocene; vegetation history; Sudety Mts.; Poland.

1. INTRODUCTION

The Zieleniec Mire is located in the Kłodzka Valley (750-764 m a.s.l.), south of Duszniki Zdrój, in the watershed flattening of the Bystrzyckie Mountains. This mountain range is a part of the Central Sudety Mountains. Zieleniec is ranked among the largest (about 160 ha) raised bogs of the Sudety Mountains. Its northern part – Topielisko is a typical, open raised bog. Its southern part – Czarne Bagno is a transitional bog, with fragments of spruce forest. The Zieleniec Mire resembles the arctic tundra with small water bodies. Owing to the ombrophilous hydrological management of the mire, its recent vegetation is not too rich. There are many plant species which have survived since the Glacial Period, like dwarf pine (*Pinus mugo*). It is also Poland's second largest relic habitat of dwarf birch (*Betula nana* – 2-3 thousand specimens). Moreover, rhaetic pine (*Pinus x rhaetica*), the introgressive hybrid of common pine and dwarf pine grow there. Both, *Betula nana* and *Pinus x rhaetica* are listed in the Polish Red Data Book of Plants (KAŹMIERCZAKOWA, ZARZYCKI, eds. 2001). Thanks to the steady growth of *Sphagnum* species, peat thickness has increased continuously, although growth has been insignificant in recent times. Currently, the mire is in a stagnation phase.

Thanks to its exceptional natural values, the mire has acquired the status of a nature reserve. Thus, the destructive effects of man's activity have been halted. The mire has been and continues to be an excellent study site for naturalists. Both, the works of pre-war authors, like among others GÖPPERT (1859), LINGELSHEIM (1917), or HARNISH (1925), and many works by post-war authors, *i.e.* FABISZEWSKI (1965), FABISZEWSKI and KWIATKOWSKI (2002), KUŹNIEWSKI (1959), MAŁAŁSKI *et al.* (1961) or PROCHAZKA (1973, 1977), provide a lot of interesting data on contemporary vegetation. On the other hand, the origin and the history of development of the Zieleniec Mire were the subject of a study by P. STARK and OVERBECK (1929), L. STARK (1936), KUŹNIEWSKI (1962) and MADEYSKA (1989).

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2. MATERIAL AND METHODS

Four peat profiles were collected for palynological research - the main one (Z I), in the area of the Czarne Bagno Reserve and three additional ones in the area of

Topielisko. Profiles were extracted using an Instorf (Russian)-type borer, with a 10-cm core diameter. A full palynological analysis was carried out on the material from the main 7.5-m thick profile (Z I), besides profile Z II was used for pollen analysis of bottom samples only. This enabled comparing the time of inception and development of both parts of the mire.

In the lithological structure of the main profile (Z I) three layers were recognized: in the bottom – a very thin (ca. 5 cm) layer of grey-blue clay covered by a several centimetre thick layer of strongly humified peat and the overlain peat, mostly ombrogenous (with different degrees of humification), formed mainly of *Sphagnum* (differences occur in the contribution of the accompanying plants, such as sedge or cotton grass). A similar mire structure was presented in the works by both L. STARK (1936), and KUŹNIEWSKI (1958). According to MAREK (1998), the formation of a peatbog deposit in the Great Batorowskie Mire, located nearby, was also initiated on the underlying mineral bedding. He did not record the presence of gyttja in the bottom – the sediment typical for a lake.

Samples for physical and chemical analyses were taken at 10-cm intervals, while 1cm³ samples for pollen analysis were extracted at differentiated intervals. In each sample, about 3000 to 900 tree pollen grains (AP) were counted, as well as all the accompanying sporomorphs: pollen grains of herbs (NAP), aquatic and telmatic plants, as well as spores of pteridophytes and *Sphagnum*. The material was prepared for pollen analysis by modified Erdtman's acetolysis (FAEGRI, IVERSEN 1989). Tablets containing a fixed number of *Lycopodium* spores were added to each of the samples. This enabled calculation of sporomorph concentrations in the following stages of processing and helped to determine the rate of sedimentation. The palynological material appeared to be very rich in taxa and very well preserved. The results of the analyses were presented in the form of a percentage pollen diagram. The sum of tree and shrub pollen (AP) and herb pollen (NAP), except for pollen of aquatic and telmatic plants, was taken as a basis for calculation. Pollen diagrams were plotted using the POLPAL for Windows program (WALANUS, NALEPKA 1999). The diagrams (Fig. 1 and 2) include pollen curves of selected taxa. Some taxa, occurring only sporadically, yet of indicative character, were discussed exclusively in the text. The ordering of tree and shrub taxa was based on their sequence of appearance in the spectra. The other taxa were grouped in accordance with *e.g.* their ecological requirements (nitrophilous, acidophilous or aquatic plants), or their "phytosociological" rank (occurrence in crops or natural communities). In the diagram biostratigraphic units - so called local pollen assemblage zones (PAZ) were distinguished with a characteristic content (quantitative and qualitative) of sporomorphs in individual profile sections, thus illustrating the process of changes occurring in the vegetation cover (BERGLUND, RALSKA-JASIEWICZOWA 1986). Seven pollen assemblage zones were recognized. Their simplified description is presented in Table 1.

The preliminary, recognition palynological analysis of the main profile enabled selection of samples for ¹⁴C dating. Six samples were subjected to radiocarbon

dating at the Radiocarbon Laboratory, Institute of Physics, Silesian University of Technology in Gliwice.

The chronological division of the Holocene used below, refers to the classical division into chronozones (MANGERUD *et al.* 1974), as well as to the division used in the latest study on the history of Poland's vegetation based on isopollen maps (RALSKA-JASIEWICZOWA *et al.* 2004).

3. VEGETATION HISTORY

On the basis of the recognised pollen assemblage zones (Fig. 1 and 2, Table 1) it is possible to sketch the course of changes in mire vegetation and its closest vicinity since the beginning of its formation.

The initial period (Z1) recorded in the pollen profile features the predominance of forest communities including pine and birch (the presence of the glacial relic of *Betula nana* was recorded), a minor contribution of willow and aspen, and a low yet steadily growing proportion of elm and hazel. Drier areas, with the mineral bedding, were colonised by *Juniperus* and *Artemisia*, as well as plant taxa of the families of *Cichorioideae*, *Asteroideae*, or *Chenopodiaceae*. Forests were loose, well light-penetrated, with the significant proportion of herbs (mainly grasses) and the presence of many taxa, *i.e.* *Gypsophila fastigiata*, *Pleurospermum*, *Mercurialis*, *Polygonum bistorta/viviparum*-type, or *Sanguisorba officinalis* indicate that open communities, with variable moisture content of the soil, still covered quite large areas. The initial peat-forming communities colonised more wet areas. *Thalictrum* and *Ranunculus* grew besides grasses, sedges or ferns, while *e.g.* *Menyanthes*, *Typha angustifolia*, and *Myriophyllum verticillatum* occurred in shallow or only seasonal water bodies.

Therefore, it can be assumed that deposit sedimentation started at the transition between the Preboreal and Boreal chronozones, and the whole zone designated as Z1 (*Pinus-Salix*) corresponds to the Boreal Period. The above conclusion can also be confirmed by radiocarbon dating, as the age of the sample taken at a depth of 7.38-7.29 m was established at 8735 ± 100 BP.

The palynological analysis of the bottom clay layer of profile Z II (additional boring in the Topielisko area) showed that the composition of pollen spectra resembles the main profile. This may be indicative of a similar origin time for both parts of the mire.

During the Boreal Period (the top layer of zone Z1 and zone Z2 – *Corylus-Betula*), forest composition began to change in the surrounding of the site – expansive hazel encroached the areas covered formerly by pine and birch. This was the result of a major climatic change. Climate warming was also reflected in the gradual appearance of tree and shrub species with higher climatic and edaphic requirements.

Table 1
Zieleniec Mire (profile Z I) – description of pollen assemblage zones (PAZ)

PAZ	Zone description
Z-1 <i>Pinus-Salix</i>	<p>Among trees <i>Betula</i> (ca. 35%) and <i>Pinus</i> (ca. 20-30%) dominate. Presence of <i>Betula nana</i>-type is recorded. Highest proportion of <i>Salix</i> across the entire profile (3.9%). Start of continuous curves for <i>Ulmus</i> and <i>Corylus</i>, with an increase towards the zone top. Pollen curves appear for <i>Quercus</i>, <i>Tilia</i>, <i>Fraxinus</i>, <i>Picea</i> and sporadically for <i>Alnus</i>.</p> <p>Zone bottom records high values for NAP (ca. 60%) with dominant <i>Poaceae</i> (over 33%) and <i>Cyperaceae</i> (ca. 6-25%) and, to a lesser degree, <i>Asteroidae</i>, <i>Cichorioideae</i>, <i>Apiaceae</i> and <i>Ranunculus</i>-type (from 2-4%; highest values across the entire profile). Less numerous, yet present are e.g. <i>Chenopodiaceae</i>, <i>Filipendula</i>, <i>Humulus</i>, <i>Urtica</i>, <i>Thalictrum</i>, <i>Rubiaceae</i>, and <i>Pleurospermum austriacum</i>. Aquatic and telmatic plants are represented by <i>Menyanthes trifoliata</i>, <i>Myriophyllum verticillatum</i>, <i>Typha angustifolia</i>, and <i>Alisma plantago-aquatica</i>. Among spore-producing plants, <i>Filicales monoletae</i> and <i>Polypodium vulgare</i> show the highest values, ca. 12% and 2.9%, respectively.</p>
Z-2 <i>Corylus-Betula</i>	<p>The bottom layer boundary is marked by a sharp increase of <i>Corylus</i> curve (up to ca. 34%) and a quick decline of <i>Pinus</i> and <i>Salix</i>. The first <i>Corylus</i> maximum (up to ca. 39%). <i>Betula</i> values between 12-26% (the presence of <i>Betula nana</i>-type is recorded), <i>Pinus</i> drops to 6%. A slight rise of <i>Picea</i> (to ca. 3%). First pollen grains of <i>Sorbus</i>, <i>Sambucus</i>-type, <i>Viburnum</i>-type, <i>Frangula alnus</i>, <i>Hedera</i> and <i>Viscum</i>. The top-layer boundary is marked by a decline in <i>Corylus</i> (to 11%) and a simultaneous growth of <i>Picea</i> (to 11%). The proportion of <i>Alnus</i> and <i>Fraxinus</i> increases also. <i>Fagus</i> appear for the first time (values below 1%).</p> <p><i>Cyperaceae</i> and <i>Poaceae</i> show permanent dominance. Small quantities of <i>Menyanthes trifoliata</i> and <i>Typha angustifolia</i>. The declining frequency of <i>Filicales monoletae</i>, the importance of <i>Sphagnum</i> grows.</p>
Z-3 <i>Corylus-Picea</i>	<p>a – high contribution of <i>Picea</i> (to 21%) and <i>Corylus</i> (to ca. 29%). Marked growth of <i>Quercus</i> (10%), <i>Fraxinus</i> (4%), <i>Tilia</i> (10%), <i>Alnus</i> (9%) and <i>Fagus</i>. Beech forms a continuous curve below 1%. <i>Carpinus</i> (>1%) appears for the first time. Sharp oscillation of <i>Betula</i> curve with a maximum of about 40%. The highest values for <i>Betula</i> across the entire profile (presence of <i>Betula nana</i>-type). The first maximum for <i>Tilia</i> (ca. 10%) and <i>Picea</i> (21%). In the middle of the zone, the proportion of <i>Poaceae</i> declines; an oscillation for <i>Cyperaceae</i>, with two maxima of about 15%. In this and at the beginning of the next subzone, increased proportion of aquatic-telmatic plants, such as: <i>Typha angustifolia</i>, <i>Scheuchzeria palustris</i>, <i>Nuphar</i>, <i>Potamogeton</i>. The first maximum for <i>Sphagnum</i> up to 40%.</p> <p>b – another maximum for <i>Corylus</i> (ca. 34%) is accompanied by a temporary decline of <i>Picea</i> (to 2%). Start of the continuous curve for <i>Carpinus</i>. Decrease of NAP (to ca. 7%). Maximum of <i>Melampyrum</i> (ca. 1%). A single <i>Cerealia</i> pollen appears.</p> <p>c – absolute maximum for <i>Corylus</i> (to 45%), combined with <i>Picea</i> decline (to 7%). <i>Fagus</i> still high. Pollen values for <i>Fraxinus</i> and <i>Acer</i> rise. <i>Abies</i> curve appears for the first time (still below 1%). In comparison with the previous subzone, the proportions of <i>Tilia</i> and <i>Ulmus</i> are reduced (to 6%). Increased proportion of <i>Pteridium aquilinum</i> correlated with <i>Corylus</i> maxima. Sporadic cereals and <i>Plantago lanceolata</i>.</p>

<p>Z-4 <i>Picea-Fagus</i></p>	<p>A marked decline of <i>Corylus</i> (to 10%). The highest values for <i>Picea</i> (to over 30%), <i>Quercus</i> (to 16%) and <i>Fraxinus</i> (to ca. 5%) across the entire profile. <i>Fagus</i> rises slowly. The frequency of <i>Carpinus</i> grows, <i>Abies</i> forms a continuous curve below 1%. Herbs low. Sporadic cereals. <i>Plantago lanceolata</i> continuous from the top of zone.</p>
<p>Z-5 <i>Fagus-Carpinus-Abies</i></p>	<p>Marked rise of <i>Fagus</i> (to 26%), <i>Carpinus</i> (to 11%) and <i>Abies</i> (13%). <i>Corylus</i> decreases, like other tree taxa. <i>Calluna</i> reaches the highest values (to ca. 5%). <i>Poaceae</i>, <i>Artemisia</i> and <i>Urtica</i> increase.</p>
<p>Z-6 <i>Fagus-Abies</i></p>	<p><i>Fagus</i>, <i>Abies</i> and other trees remain on the same level. <i>Carpinus</i> slightly reduced. <i>Ulmus</i> at the top of zone below 1%. Higher values for <i>Calluna</i> at the top layer. The role of herbs increases (NAP about 11%), including <i>Poaceae</i> (4.5% in the top layer), <i>Artemisia</i> and <i>Plantago lanceolata</i>. Single cereals. The first <i>Centaurea cyanus</i> at the end of phase. High contribution of <i>Sphagnum</i> (max. ca. 40%) in the whole zone.</p>
<p>Z-7 <i>Fagus-Abies-Cereal</i></p>	<p>a – higher values for <i>Pinus</i> and <i>Betula</i> (presence of <i>Betula nana</i>-type), the other tree taxa at the same level. <i>Picea</i> shows a decrease, so does <i>Alnus</i> at the end of subzone. <i>Calluna</i> rise (with several maxima to 4%). <i>Urtica</i> up to 1.5%. Curve for Cerealia starts, the first <i>Secale cereale</i>. <i>Filicales monoletae</i> up to 2.2%. <i>Sphagnum</i> values increase (ca. 50%). b – <i>Pinus</i> and <i>Betula</i> decrease slightly (presence of <i>Betula nana</i>-type). Maxima for <i>Carpinus</i> (to 11%). <i>Abies</i> rises to ca. 20%, and <i>Picea</i> – to ca. 10%. Sharp increase in herbs (NAP. ca. 21%); <i>Poaceae</i>, <i>Cyperaceae</i>, <i>Artemisia</i>, <i>Urtica</i>, <i>Humulus</i> rise. Cerealia exceed 1%, <i>Secale cereale</i> is present. <i>Sphagnum</i> around 35%. c – short rise in <i>Fagus</i>, <i>Abies</i> and <i>Betula</i> (<i>Betula nana</i>-type recorded). At the top of zone <i>Picea</i> and <i>Pinus</i> rise (to ca. 17 and 23%, respectively), so does <i>Calluna</i>. The importance of herbs increases (NAP at ca. 32%), including the dominant <i>Poaceae</i> and <i>Cyperaceae</i>, and the taxa indicative of man's presence: <i>Chenopodiaceae</i>, <i>Humulus</i>, <i>Plantago lanceolata</i>, <i>Rumex</i>, <i>Urtica</i>, as well as cultivated plants.</p>

The representation of mesophilous tree species in forest communities increased, the proportion of oak and elm grew, and then ash and lime appeared. According to HUNTLEY and BIRKS (1983), the values of about 1-2% of lime pollen in the diagram indicate the local presence of lime. The above mentioned components of the mixed broadleaved forest, as well as the first, though sporadic shrubs, like *Viburnum*, *Sorbus*, *Rhamnus frangula* and *Sambucus*, and the presence of *Hedera* and *Viscum* indicate the beginnings of the Atlantic chronozone (decline of the Early Holocene acc. to RALSKA-JASIEWICZOWA *et al.* 2004).

During the climatic optimum of the Atlantic Period (Middle Holocene (Z3a, b – *Corylus-Picea*) the climate was warmer and moister than at present (STARKEL 1983). In the area surrounding the study mire, after hazel dominance, the presence of spruce in forests grew (in the higher elevations), and the improvement of climatic conditions had led to the enlargement of the areas overgrown by mixed, deciduous forest with thermophilous trees (at lower locations). Pollen of *Fagus* and *Carpinus* appear for the first time, along with sporadic *Abies* (this can be the effect of long-distance pollen transport, or – which seems more likely- of redeposition of the material from the younger layers). The declining diversity of herb pollen may be indicative of the consistent afforestation of the area around the mire and the likely increase of the canopy closure. The proportion of *Filipendula* in plant communities declined giving way to *Sphagnum* mosses. Thus, the stage of the raised bog began. In the study period, *Alnus* as a species of wetland or riparian forests and of poor competitive abilities (ELLENBERG 1996) used to build (with some exceptions) its own ecosystems.

Beginning from about 5370 ± 65 BP (Zone Z3c – *Corylus-Picea*), *Ulmus* and *Tilia* started to withdraw from the forest communities. The decline of the elm population in forest composition was the result of different factors. The Dutch elm disease was the main cause, but the anthropogenic factor also played a significant role. However, because of a less intensive human activity in the mountain areas, the disappearance of elm was slower there. In general, spruce predominated in forests covering vast areas, with a still large proportion of hazel.

Throughout the next period (Z4 – *Picea-Fagus*), spruce forests predominated. The growing forest density may have caused the retreat of hazel. Communities with beech gradually gain in importance. The climate change towards wetter and cooler, which started at that time, favoured the expansion of beech in the lower altitudes of the mountains (RALSKA-JASIEWICZOWA 1999; RALSKA-JASIEWICZOWA *et al.* 2004).

On the other hand, from about 3700 ± 60 BP (Zones Z5 – *Fagus-Carpinus-Abies*, Z6 – *Fagus-Abies*), a marked expansion of beech forests took place with the contribution of fir, whose proportion increased rapidly. Pollen grains of both species are not transported over long distances (HUNTLEY, BIRKS 1983), so the 15-20% of *Fagus* and 10-15% of *Abies* pollen contribution indicate that pollen of these trees, as recorded in the pollen diagram, arrived there from the nearby forests. During that time, the lower montane forest zone developed in the mountains, with beech and fir and some spruce becoming the main components of forests. Wetlands located along streams,

in the lower parts of foothills (to 800-900 m), were overgrown with alder (probably *Alnus incana*), producing large quantities of pollen carried by winds (this is reflected in the high frequency of this taxon in the pollen diagram). The marked decrease of the spruce forest area at the time is also a characteristic feature. Hazel shrubs covered only small areas. Due to their ecological adaptation, *Carpinus* communities occupied lower and drier areas with fresh and fertile soils. With the retreating spruce forests, *Calluna* and *Empetrum* heathlands expanded. A similar process was described by ZOLLER (1960 and later works). Most of the changes were undoubtedly caused by climatic factors. In the mire under study, peat accumulation decline was noted at that time. After 2715 ± 85 BP, the mire started to develop faster again, which may have been associated with moisture growth. Also a marked increase in the proportion of *Sphagnum* species is recorded.

The recognition of the first traces of human activity is based on the presence in the pollen diagram, of the taxa classified as anthropogenic indicators, as well as on the changes in forest composition and degree of site afforestation. In addition to the natural transformations of forest communities, also the introduction and development of animal breeding and then farming, had a great impact on the changes in the vegetation cover. Forest communities were strongly exploited by man (grazing in forests, harvesting of timber as fuel or construction material, uprooting for farming, etc.). The Late Holocene and, more precisely, its younger part, is the period of growing anthropopressure corresponding to the Subatlantic chronozone (Z7a, b, c – *Fagus-Abies-Cerealia*).

In the examined profile from Zieleniec, starting from about 4200 BP (interpolated date) pollen grains of the plants which are considered to be indicators of human presence appear regularly, e.g. *Plantago lanceolata* or Cerealia. This however is not indicative of any crops cultivated around the study site during that time, given the topographic conditions, but of a long distance transport. In the transformed communities of lower elevations, areas covered by herbs increased considerably, while in forests, the role of pine increased. In the youngest section (Z7c), the growing antropopressure is reflected in deforestation (decline in the proportion of beech and fir), animal grazing (increased proportion of nitrophilous and acidophilous plants), and plant cultivation (cereal and weed pollen records).

Around the study site, as well as in the areas located not far from it, the transition of the mixed beech-fir forest into spruce monocultures started in the Younger Subatlantic Period. It might have been the result of climate cooling (so called "Little Ice Age"), but first of all of the intensified human activity. *Fagus* (beech wood was commonly use for fuel) and *Abies* withdrew. This favoured the natural return, as well as reintroduction of spruce (RYBNIČEK, RYBNIČKOVÁ 2004). So, anthropopressure was the dominant factor determining the changes, which have led to the present status.

It also should be added, that the carbon and organic sulphur isotope analyses contributed to the acquisition of a deeper knowledge of the youngest changes in the palaeoenvironment of the Zieleniec region. On the basis of the $\delta^{13}\text{C}$ analyses

vegetation changes were recorded indicative of a shift in the hydrological regime and climate. The sedimentation rates and dating proved that peat deposition corresponding to a sharp change of the $\delta^{13}\text{C}$ curve had occurred around 1250-1350 AD, that is during the so called Little Climatic Optimum. The sharp decline of the curve is dated to around 1550-1850 AD, that is to the Little Ice Age (JĘDRYSEK *et al.* 1995; SKRZYPEK, JĘDRYSEK 2000).

4. CONCLUSIONS

The history of vegetation development recorded in the examined profile from the Zieleniec Mire is very similar to that reflected in the diagrams presented in the aforementioned studies. The only difference is that in the works by P. STARK and OVERBECK (1929), L. STARK (1936), as well as by KUŹNIEWSKI (1962), the origin of the mire is dated to the Boreal, while in this study at the turn of the Preboreal/Boreal Period. In the moist and quite warm climate, in the sandstone basin lined with impermeable margles where water accumulated, the paludification process occurred, and very shallow water bodies may have been formed at that time. They were overgrown by initial peat-forming communities with a high percentage of aquatic and telmatic plants. The sequence of appearance of individual trees corresponds to the generally adopted scheme for the Holocene.

At the study site, the permanent presence (from the Preboreal Period to the present time) of the glacial relic – dwarf birch is confirmed by both microscopic (pollen grains), and macroscopic remains (seeds and leaves).

Human activity is recorded only at the top of the diagram. One can speak about the cultivation of crops in the region not earlier than in the youngest section (from about 2000 BP) where a marked increase in the proportion of cultivated plants (cereals, including rye) is recorded, in addition to those indicative of human activity (plantain, sorrel, nettle, *etc.*).

The recent archaeological investigations show that the geographical environment of the study area, taking into consideration its mountainous character, had undergone only small anthropogenic transformations which lasted till the middle of the 13th century (WYTYCZAK 1981). However, the latest studies provide more and more new, significant data which point to human presence in the Sudety Mountains from as early as the Mesolithic (VALDE-NOWAK 1999).

5. REFERENCES

- BERGLUND, B.E., RALSKA-JASIEWICZOWA, M. 1986. Pollen analysis and pollen diagrams. In: B.E. BERGLUND (ed.), *Handbook of Holocene palaeoecology and palaeohydrology*. J. Wiley & Sons Ltd., Chichester, New York, p. 455-484.
- ELLENBERG, H. 1996. *Vegetation Mitteleuropas mit den Alpen*. UTB für Wissenschaft. Ulmer, Stuttgart.
- FABISZEWSKI, J. 1965. Nowe dane florystyczne z Dolnego Śląska. *Fragm. Flor. Geobot.* 9, 1: 7-12 (in Polish with English summary).
- FABISZEWSKI, J., KWIATKOWSKI, P. 2002. Threatened vascular plants of the Sudeten Mountains. *Acta Soc. Bot. Pol.* 71, 4: 339-350.
- FAEGRI, K., IVERSEN, J. 1989. *Textbook of Pollen Analysis*, 4th Edition. John Wiley & Sons. Chichester-New York-Brisbane-Toronto-Singapore.
- GÖPPERT, H.R. 1859. Über die Seefelder in d. Grafsch. Glatz und die Torfbildung auf denselben. *Jahresberichte der Schlesischen Gesellschaft für vaterländische Kultur* 32.
- HARNISH, O. 1925. Eine Wanderung durch die Seefelder. *Ostdeutscher Naturwart* 6.
- HUNTLEY, B., BIRKS H.J.B. 1983. *An Atlas of past and present pollen maps for Europe: 0-13000 years ago*. Cambridge University Press, Cambridge.
- JĘDRYSEK, M., SKRZYPEK, G., WADA, E., DOROSZKO, B., KRAL, T., PAZDUR, A., VIJARNSORN, P., TAKAI, Y. 1995. Analiza $\delta^{13}\text{C}$ i $\delta^{34}\text{S}$ w profilach torfowych a zmiany globalne [$\delta^{13}\text{C}$ i $\delta^{34}\text{S}$ analysis in peat profiles, and global change]. *Przegl.Geol.* 43, 12: 1004-1010 (in Polish with English summary).
- KĄŻMIERCZAKOWA, R., ZARZYCKI, K. (eds.). 2001. *Polska czerwona księga roślin* [Polish red data book of plants]. Instytut Botaniki im. W. Szafera, Polska Akademia Nauk, Kraków (in Polish with English summary).
- KUŹNIEWSKI, E. 1958. Torfowisko Zieleniec koło Dusznik. [The Zieleniec mire near Duszniki city]. *Rocznik Ziemi Kłodzkiej* 3, p. 169-211 (in Polish).
- KUŹNIEWSKI, E. 1962. Analiza palinologiczna torfowiska Zieleniec koło Dusznik [Palynological analysis of the bog in Zieleniec near Duszniki]. *Kwartalnik Opolski. Zeszyty Przyrodnicze* 2: 115-143 (in Polish with English summary).
- LINGELSHEIM, A. 1917. Bericht über einen Besuch des Hochmoores „die Seefelder” bei Reinerz. *Jahresberichte der Schlesischen Gesellschaft für vaterländische Kultur* 94.
- LOSERT, H. 1940. Beiträge zur spät- und nacheiszeitlichen Vegetationsgeschichte Innerböhmens. *Beihefte zum Botanischen Centralblatt* 50/B.
- MADEYSKA, E. 1989. Type Region P-f: Sudetes Mts. - Bystrzyckie Mts. *Acta Palaeobot.* 29, 2: 37-41.
- MANGERUD, J., ANDERSEN, S.T., BERGLUND, B.E., DONNER, J.J. 1974. Quaternary stratigraphy of Norden, a proposal for terminology and classification. *Boreas* 3, 3: 109-128.
- MAREK, S. 1998. Rozwój Wielkiego Torfowiska Batorowskiego w świetle badań biostratygraficznych [Development of the Great Batorowskie Peatbog in the light of biostratigraphy research]. *Szczeciniec* 2: 49-88 (in Polish).
- MĄDAŁSKI, J., KOWAL, T., KUŹNIEWSKI, E., MICHALAK, S., SERWATKA, J. 1961. Wyniki badań florystycznych Śląska za rok 1959. *Kwartalnik Opolski, Zeszyty Przyrodnicze* 1: 92-103 (in Polish).
- PROCHAZKA, F. 1973. Rare vascular plant species in the Góry Bystrzyckie Mountains (South Poland). *Fragm. Flor. Geobot.* 19: 411-413.
- PROCHAZKA, F. 1977. Květena. In: Z. ROČEK, (ed.), *Příroda Orlických Hor a Podorlicka* [Natural conditions of the Orlicke hory Mountains and their adjacent submontane area]. Praha (in Czech with English summary).
- RALSKA-JASIEWICZOWA, M. 1999. Ewolucja szaty roślinnej. In: L. STARKEL (ed.), *Geografia Polski. Środowisko Przyrodnicze*. Wyd. Naukowe PWN, Warszawa, 105-127.

- RAJSKA-JASIEWICZOWA, M., LATAŁOWA, M., WASYLIKOWA, K., TOBOLSKI, K., MADEYSKA, E., WRIGHT, H.E. JR., TURNER, CH. (eds.). 2004. Late Glacial and Holocene history of vegetation in Poland based on isopollen maps. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.
- RYBNÍČEK, K., RYBNÍČKOVÁ, E. 2004. Pollen analyses of sediments from the summit of the Praděd range in The Hrubý Jeseník Mts (Eastern Sudetes). *Preslia* 76: 331-347.
- SKRZYPEK, G., JĘDRYSEK, M.O. 2000. Climatic variation in the last Millenium in Poland: $\delta^{13}\text{C}$ peat profiles. *Prace Geograficzne UJ* 107: 131-136.
- STARK, L. 1936. Zur Geschichte der Moore und Wälder Schlesiens in postglazialer Zeit. *Botanische Jahrbücher* 67, 5: 493-640.
- STARK, P., OVERBECK, F. 1929. Zur Waldgeschichte Schlesiens. *Planta* 8, 3: 341-363.
- STARKEL, L. 1983. Paleogeografia i klimat późnego plejstocenu i holocenu. In: J.K. KOZŁOWSKI, S.K. KOZŁOWSKI (eds.), *Człowiek i środowisko w pradziejach*. PWN, Warszawa, p. 14-31 (in Polish).
- VALDE-NOWAK, P. (ed.). 1999. Początki osadnictwa w Sudetach [The beginnings of settlement in the Sudety Mountains]. Instytut Archeologii i Etnologii PAN, Kraków (in Polish with English summary).
- WALANUS, A., NALEPKA, D. 1999. POLPAL. Program for counting pollen grains, diagrams plotting and numerical analysis. *Acta Palaeobot.*, Suppl. 2: 659-661.
- WYTYCZAK, R. 1981. Rola osadnictwa w wylesianiu Sudetów w XIII i XIV w. na przykładzie międzyrzecza Bobru i Bystrzycy [The role of settlement in disafforestation of the Sudetes Mountains in the 13th and 14th cent. a case study of the region between the Bóbr and the Bystrzyca River]. *Czasopismo Geograficzne* 52: 31-43 (in Polish with English summary).
- ZOLLER, H. 1960. Pollenanalytische Untersuchungen zur Vegetationsgeschichte der insubrischen Schweiz. *Denkschrift der Schweizerischen Naturforschenden Gesellschaft* 83: 1-156.

6. PRZESZŁOŚĆ TORFOWISKA ZIELENIEC I TERENÓW PRZYLEGLYCH W ŚWIETLE BADAŃ PALINOLOGICZNYCH (streszczenie)

Opracowanie opiera się na wynikach analiz palinologicznych profili pobranych z jednego z największych sudeckich torfowisk wysokich – torfowiska Zieleniec w Górach Bystrzyckich (Sudety Środkowe). Pełną analizę pyłkową wykonano na materiale z profilu głównego (Z I), o miąższości 7.5 m. W diagramach (Fig. 1, 2) zamieszczono krzywe pyłkowe wybranych (istotnych do interpretacji) taksonów drzew, krzewów, krzewinek i roślin zielnych. Wyróżniono 7 lokalnych zespołów pyłkowych (Tabela 1). Analiza udziałów procentowych oznaczonych taksonów drzew oraz obecność ziarn pyłku roślin traktowanych jako wskaźnikowe pozwoliła na opisanie sukcesji szaty roślinnej tej części Sudetów. Badania wykazały, że odkładanie osadu torfowego w profilach z Zieleńca (Z I i Z II) rozpoczęło się już pod koniec okresu preborealnego. Wydzielone zostały wszystkie okresy holocenu: schyłek okresu preborealnego i okres borealny – panowanie lasów sosnowych i sosnowo-brzozowych, a następnie zwiększenie w nich udziału leszczyny i powolne, stopniowe rozprzestrzenianie się wiązu i świerka; okres atlantycki – charakteryzujący się wzrostem roli świerka, a także wzrostem udziałów składników lasów mieszanych (wiązu, lipy dębu), związanych z okresami cieplejszymi (lasy zajmują

ponad 80% powierzchni); obecność pyłku buka i jodły cechowała okres subborealny, w którym stale wysoka była frekwencja świerka; w okresie subatlantyckim stwierdzone zostały zaburzenia zbiorowisk leśnych, spowodowane obecnością człowieka, wyrażone powolnym spadkiem (choć w tej części Polski niewielkim) liczebności pyłku drzew, jak również obecnością pyłku roślin uprawnych i synantropijnych. Głównym powodem osiedlania się człowieka na tym terenie były surowce naturalne (np. kruszce czy drewno). Drzewa były karczowane prawie wyłącznie na budowę osad lub na opał w piecach hutniczych, nie wypalano ich pod uprawy czy pastwiska, tak więc spektra pyłkowe badanego profilu są ubogie w pyłek roślin wskaźnikowych dla działalności człowieka (zanotowane w diagramach ziarna pyłku pochodzą przede wszystkim z transportu).

Unikatową cechą torfowiska Zieleniec jest obecność szeregu gatunków roślin, które przetrwały od czasów epoki lodowej. Zachowała się np. kosodrzewina, zwana sosną górską *Pinus mugo*, jest też reliktowe stanowisko brzozy karłowatej *Betula nana*. Przeprowadzone analizy palinologiczne potwierdziły stałe występowanie *Betula nana* od okresu preborealnego po czasy współczesne (znalezione w profilu szczątki to zarówno ziarna pyłku, jak też nasiona i liście).

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