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DEVELOPMENT OF THE PEATBOG AT LAKE BRZEZICZNO (ŁĘCZNA-WŁODAWA LAKELAND) BASED ON THE ANALYSIS OF SUBFOSSIL PLANT MACRO REMAINS

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Summary. The studied peatbog is located in the Łęczna-Włodawa Lakeland constituting a part of the Polesie Lubelskie Region. Three drillings were performed with an „Instorf" type drill, and 64 samples were taken for further laboratory analyses. In the samples, subfossil plant macro remains, as well as the ash content and reaction (pH in H_2O, and KCl) were determined. The studied deposit is located on gyttja beds, which documents its lake origin. Fragments of the peatbog occurring in the peripheral parts of the lake-peatbog complex were formed as a result of paludification of the mineral bedrock. The succession of plant communities occurred according to the following patterns: water phytocoenoses from *Potametea* and *Charetea* class → rush phytocoenoses from *Phragmitetea* class and peatbog phytocoenoses from *Scheuchzerio-Caricetea nigrae* class → transitional peatbog phytocoenoses from *Scheuchzerio-Caricetea nigrae* class → high peatbog communities from *Oxycocco-Sphagnetea* class (on a fragment of the peatbog); rush phytocoenoses from *Phragmition* association → rush phytocoenoses from *Magnocaricion* association.

Key words: peatbog, subfossil plant remains, Łęczna-Włodawa Lakeland

INTRODUCTION

The Łęczna-Włodawa Lakeland is a region with an exceptionally large number of peatbogs. Almost 800 fen, raised, and transitional peatbogs occur here [Borowiec 1990]. Many of them are characterised by high natural values. Due to their significance for the natural environment and man, peatbog habitats should be carefully studied and included in various land protection systems. Research on peatbogs under protection or planned to be protected should be conducted in a complex manner. The knowledge of their geology and history is of particular importance, as „they are the key to recognize the level of naturalness of peatbogs" [Tobolski 1999]. The sequence of subfossil plant macro remains accumulated in the peat deposit is a source of information on the succession of plant communities and changes in hydrologic conditions in the peatbog.

The purpose of the research was to trace the history of the development of the peatbog at Lake Brzeziczno on the one hand, and on the other hand to specify, based on the analysis of subfossil plant macro remains, the composition of subfossil peat-forming phytocenoeses.

STUDY AREA, MATERIALS AND METHODS

The studied object is located in the Lublin district, in the commune of Ludwin, to the South-West of village Piaseczno. In physiographic terms, it is located in the Łęczna-Włodawa Lakeland constituting the mesoregion of Polesie Lubelskie. The described object is located in the area of the nature reserve „Lake Brzeziczno" and the Łęczna Lakeland Landscape Park.

In the studied peatbog, according to methods applied in peat science research [Tobolski 2000], three drillings with a „Instorf" type drill were performed. Full cores of sediment were taken from the profiles (from the ground surface to the mineral bedrock) for laboratory analyses. The material for analyses of subfossil plant macro remains (samples with volume of 50 cm^3) was taken from the peat at every 10 cm, and from gyttja at every 50 cm (64 samples in total). Separation of plant remains was carried out according to the methodology compiled by Tobolski [2000]. Identification of subfossil plant communities was carried out with the application of available keys and atlases [Dombrowska *et al*. 1969, Grosse-Brauckmann 1972, 1974, Grosse-Brauckmann and Streitz 1992, Tobolski 2000], as well as reference slides of contemporary plants. Results of the analyses of botanical composition of the peat samples were treated as „paleophytosociological pictures of the fossil macro remains" [Kloss 2007]. Taxonomy of vascular plants was adopted after Mirek *et al*. [2002], and that of mosses according to Ochyra *et al*. [2003]. In 64 gyttja and peat samples, also reaction (pH in H_2O and KCl), and ash content were determined by means of incineration of the samples in a muffle furnace at the temperature of 560°C [Sapek and Sapek 1997].

RESULTS

In the peatbog Brzeziczno, the occurrance of two types of deposits were found: one built of peat and gyttja, and the second built exclusively of peat. The conducted research indicates that profiles Br2 (Tab. 2) and Br3 (Tab. 3) represent the first type of the sediment, and the studied fragment of the peatbog is of

Table 1. Stratigraphic profie Brzeziczno 1 (Brz1)

Depth in cm	Deposit	Ash in %	pH		% share of plant macrofossils	Subfossil communities
			H_2O	KCl		
0–20	Fen peat *Magnocaricioni Carici-Phragmiteti*	16.1	4.3	3.6	*Carex elata* 40%, *Carex rostrata* 3%, *Carex caespitosa* 3%, *Carex lasiocarpa* 5%, *Phragmites australis* 25%, *Equisetum fluviatile* 15%, *Menyanthes trifoliata* 4%, *Bryales* 2%, nn. 5%	*Caricetum elatae phragmitetosum*
20–40		15.5	4.7	3.8	*Carex elata* 35%, *Carex rostrata* 3%, *Carex caespitosa* 3%, *Carex lasiocarpa* 5%, *Phragmites australis* 30%, *Equisetum fluviatile* 15%, *Menyanthes trifoliata* 4%, *Bryales* 2%, nn*. 3%,	
40–45		36.3	5.3	4.6	*Carex sp.* 20%, *Carex rostrata* 3%, *Carex caespitosa* 3%, *Phragmites australis* 38%, *Equisetum fluviatile* 10%, *Menyanthes trifoliata* 4%, *Bryales* 2%, nn 10%	*Phragmitetum australis caricetosum*
45–50	Sand with humus	84.2	5.6	4.8	-	-

* indeterminate

limnogenic origin. Originally, clay gyttja was deposited at the bottom of the reservoir, and later detritus gyttja. At the contact with the mineral bedrock, a layer of sphagnum peat was found. Lake formations were covered with a layer of transitional sphagnum – sphagnum-scheuchzeria peat – (profile Br3), or sphagnum-sedge peat (profile Br2). In the uppermost section of the profile Brz2, sphagnum-hollow peat was found. In the second case, sedge-reed peat, silted at the lowest section of the profile, deposited directly on the mineral bedrock (profile Br1). The uppermost section (0–10 cm) constituted a muck horizon [Urban 2009].

Based on the analysis of subfossil plant remains, two stages of development of the peatbog were distinguished (lake and peatbog stage). In the first stage (540–150 cm Br2, 500–150 cm Br3), moss phytocoenoses occurred at the bottom of the lake. Among subfossil plant communities, brown mosses *Bryales* prevailed, most of them constituted by *Warnstorfia exannulata* remains (50%). There were also some rush plants: *Carex sp.* (3%), *Phragmites australis* (1–2%), and *Menyanthes trifoliata* (2%). A well developed layer of sphagnum peat with a significant amount of gyttja was also fund in the gyttja layer in profile Br3 (at the depth of 340–360 cm). Among the preserved subfossil remains, *Drepanocladus sp*. and *Scorpidium scorpioides* dominated. In profile Br2, the layer was vaguely visible and had the thickness of a few millimetres. Moss layers were of very acid and acid reaction (pH in KCl from 4.3 to 5.3), and ash content ranged from 42.7 to 10.5%.

In the next stage, sediments of organic (detritus), or organic-mineral gyttja accumulated in the lake. The reaction of the sediments was very acid or acid (pH in KCl from 4.2 to 4.5), and the ash content ranged from 65.2 to 81.2%. Communities typical of floating mat, mainly *Menyanthes trifoliata* and *Comarum palustre*, *Carex sp.*, as well as mosses, developed (profile Br 2), and so did water communities from the *Potametea* class (profile Br 1). Among the preserved subfossil remains, the presence of *Nymphaea* remains was found.

In the next phase of the lake stage, detritus gyttja sediments deposited in the reservoir. The reaction of these sediments was acid (pH from 4.5 to 5.3), and the ash content ranged from 4.2 to 8.1%. Water vegetation from *Potametea* class developed in the reservoir. In the profiles Br2 and Br3, bioindicators of the limnic accumulative environment occurred. The following water plant subfossil remains were identified: *Nymphaea* sp., *Nuphar lutea* and *Chara sp.* At the end of this stage, the strongly hydrated gyttja organic sediments were colonised by the floating mat vegetation. Plant remains accumulated under this quagmire carpet.

In accordance with the analysis of subfossil plant communities, the beginning of stage II (the peatbog stage) in profiles Br2 and Br3 is indicated by the vaguely visible in the analysed sediments rush phase. It is evidenced by the presence of the remains of species from *Phragmitetea* class (*Carex rostarata*, *Equisetum fluviatile*, *Phragmites australis*, *Schoenoplectus lacustris*). In the next phase, while peat developed and separated from the lake mineral-trophic waters, *Caricetum lasiocarpae* or *Caricetum lasiocarpae sphagnetosum* phytocoenoses

Table 2. Stratigraphic profie Brzeziczno 2 (Brz2)

Depth in cm	Deposit	Ash in %	pH		% share of plant macrofossils	Subfossil communities
			H_2O	KCl		
0–10	Highmoor peat *Ombro-Sphagnioni Cuspidato-Sphagneti*	3.4	4.4	3.3	*Sphagnum* s. *Cuspidata* 45%, *S. Acutifolia* 40%, *Oxycoccus palustris* 10%, *Eriophorum vaginatum* 5%, *Menyanthes trifoliata* +, *Pinus sylvestris* +,	*Eriophoro-Sphagnetum*
10–30		5.0	4.3	3.3	*Sphagnum* s. *Cuspidata* 35%, *S. Acutifolia* 30%, *Oxycoccus palustris* 25%, *Eriophorum vaginatum* 5%, *Menyanthes trifoliata* 3, *Polytrichum sp.* 1%, *Pinus sylvestris* +, nn* 1%	*Eriophoro-Sphagnetum*
30–35	Transition bog peat *Minero-Sphagnioni Sphagno-Scheucherieti*	5.0	4.3	3.3	*Oxycoccus palustris* 45%, *Sphagnum sp.* 30%, *Polytrichum sp.* 15%, *Bryales* 10%,	*Oxycoccus palustris-Sphagnum*
35–80		6.5	4.4	3.4	*Oxycoccus palustris* 45%, *Sphagnum* s. *Cymbifolia* 30%, *Bryales* 5%, *Eriophorum angustifolium* 2%, nn. 18%	*Oxycoccus palustris-Sphagnum*
50–150	Strongly hydrated gyttja	-	-	-	-	-

150–170	Detritus gyttja with peat	5.1	5.3	4.4	*Carex lasiocarpa* 50%, *Carex sp.* 35%, *Phragmites australis* 8%, *Sphagnum sp.* 2%, *Menyanthes trifoliata* 1%, *Equisetum fluviatile* 1%, nn. 3%	*Caricetum lasiocarpae*
150–250		5.5	5.5	4.5	*Carex sp.* 28%, *Carex lasiocarpa* 22%, *Menyanthes trifoliata* 15%, *Equisetum fluviatile* 10%, *Phragmites australis* 10%, *Carex rostarata* 5%, *Sphagnum sp.* 2%, *Bryales* 2%, *Schoenoplectus lacustris* 1%, *Nymphaea* 4%	*Caricetum lasiocarpae* *Phragmitetea* *Potametea*
250–275	Detritus gyttja	4.0	5.7	4.7	*Nymphaea* 10%, *Nuphar lutea* 2%, *Chara sp.* +, *Phragmites australis* 6%, *Equisetum fluviatile* 8%, *Carex sp.* 5%, *Carex rostrata* +, *Menyanthes trifoliata* 1%, *Comarum palustre* +, *Sphagnum sp.* 2%, *Bryales* 2%, *Warnstorfia exanulata* +, *Calliergon cordifolium* +, *Scorpidium scorpioides* +	*Potametea*
275–350		8.5	5.8	4.7		
350–450		6.2	5.8	4.7		
		8.1	5.8	4.8		
450–500	Mineral-detritus gyttja	81.2	6.2	4.8	*Menyanthes trifoliata* 10%, *Bryales* 10%, *Sphagnum sp.* 3%, *Carex sp.* 2%,	*Menyanthes trifoliata*
500–540	Detritus gyttja	64.0	4.7	4.2	*Bryales* 10%, *Menyanthes trifoliata* 5%, *Carex sp.* 5%, *Comarum palustre* +, *Sphagnum sp.* +	*Menyanthes trifoliata*
540–570	Fen peat *Bryalo-Parvocaricioni Bryaleti*	17.0	5.3	4.3	*Warnstorfia exanulata* 50%, *Bryales* 40%, *Menyanthes trifoliata* 2%, *Phragmites australis* 1%, nn. 7%	*Warnstorfia exanulata*
570–580	Sand	-	-	-	-	-

* indeterminate

Table 3. Stratigraphic profie Brzeziczno 3 (Brz3)

Depth in cm	Deposit	Ash in %	pH		% share of plant macrofossils	Subfossil communities
			H_2O	KCl		
0–20	Transition bog peat *Minero-Sphagnioni Sphagno-Scheucherieti*	3.5	4.2	3.1	*Sphagnum* s. *Cuspidata* 60%, s. *Cymbifolia,* 20%, *Oxycoccus palustris* 10%, *Scheuchzeria paustris* 10%	*Scheuchzerio-Caricetum limosae*
20–50		3.5	4.5	3.2	*Sphagnum* s. *Cuspidata* 38%, s. *Cymbifolia,* 20%, *Oxycoccus palustris* 15%, *Menyanthes trifoliata* 15, *Scheuchzeria paustris* 5%, *Bryales* 5%, *Carex limosa* 2%,	*Scheuchzerio-Caricetum limosae*
50–80	Transition bog peat *Minero-Sphagnioni Sphagno-Cariceti*	3.5	4.5	3.2	*Carex lasiocarpa* 45%, *Carex sp.* 15%, *Bryales* 10%, *Sphagnum sp.* 8%, *Menyanthes trifoliata* 8%, *Phragmites australis* 8%, *Equisetum fluviatile* 3%, nn. 3%	*Caricetum lasiocarpae*
80–150	Strongly hydrated gyttja	-	-	-	-	-
150–200	Detritus gyttja	8.0	6.0	5.1	*Nymphaea sp.* 5%, *Sphagnum cuspidatum* 1%, *Sphagnum sp.* 2%, *Carex sp.* 2%, *Carex canescens* (n**) +, *Menyanthes trifoliata* 2%, *Phragmites australis* +, *Meesia triquetra* 1%, *Warnstorfia exanulata* 1%,	*Potametea*

* indeterminate, ** seeds

200–340	Detritus gyttja	4.2	6.2	5.3	*Nymphaea sp.* 10%, *Ceratophyllum* 2%, *Potamogeton* +, *Najas sp.* (n) +, *Najas flexilis* (n) +, *Sphagnum cuspidatum* 5%, *Sphagnum* s. *Acutifolia*, *Carex sp.* 2%, *Carex lasiocarpa* 1%, *Carex limosa* 1%, *Carex acutiformis* (n) +, *Rhynchospora alba* 1%, *Menyanthes trifoliata* 5%, *Comarum palustre* 1%, *Eriophorum angustifolium* (n) +,*Bryales* 3%, *Calliergon cordifolium* 1%, *Warnstorfia exanulata* +, *Schoenoplectus lacustris* +, *Typha sp.* +, *Phragmites* +, *Equisetum fluviatile* +, *Juncus effusus* (n) +	*Potametea*
340–360	Fen peat *Bryalo-Parvocaricioni Bryaleti* with gyttja	10.5	6.2	5.3	*Sphagnum cuspidatum* +, *Bryales* 40%, *Drepanocladus sp.*30%, *Scorpidium scorpioides* 30%	*Scorpidium scorpioides*
360–500	Mineral-detritus gyttja	65.2	6.6	5.5	*Nymphaea sp.* 10%, *Menyanthes* 2%, *Sphagnum sp.* +, *Bryales* 1%, *Warnstorfia exanulata* +, *Fontinalis antipyretica* +,	*Potametea*
500–540	Fen peat *Bryalo-Parvocaricioni Bryaleti*	42.7	6.4	5.1	*Warnstorfia exanulata* 50%, *Bryales* 40%, *Phragmites australis* 2%, *Carex sp.* 3%, nn. 5%	*Warnstorfia exanulata*
540–550	Sand	-	-	-	*Bryales* +	-

appeared. This community in the fossil state is characterised by a large content of *Carex lasiocarpa.* Among other components, species from *Scheuchzerio-Caricetea nigrae* class were often noted, like e.g.: *Eriophorum angustifolium*, *Menyanthes trifoliate*, and sphagnum from *Acutifolia* section, as well as *Bryales* brown mosses.

The next phase of the peatbog (transitional peatbog phase) is indicated by the occurrence of *Scheuchzerio-Caricetum limosae* (profile Br3) or *Oxycoccus palustris-Sphagnum* (profile Br2) phytocoenoses. The transitional peat developing at this stage is characterised by strong acid reaction (pH in KCl from 3.1 to 3.3) and low ash content (from 3.5 to 6.5%). The presence of e.g. *Sphagnum sp.*, as well as *Eriophorum angustifolium* and *Carex limosa* indicates increasing impoverishment and acidification of the habitat. The next phase (the raised peatbog phase) was noted at the top of profile Br2. It is determined by the *Eriophoro-Sphagnetum* phytocoenosis characterised by large content of species from *Oxycocco-Sphagnetea* class. A large content of sphagnum, as well as *Oxycoccus palustris* and the presence of *Eriophorum vaginatum* indicate a high degree of oligotrophy of the habitat. The reaction of the peat developed in this phase was very acid (pH = 3.3). The ash content ranged between 3.4 and 5.0%.

The fen peat (profile Brz1) developed by means of paludification. The peat accumulation process in the peripheral parts of the studied peatbog was initiated by the *Phragmitetum australis caricetosum* phytocoenosis. In the next phase, a *Caricetum elatae phragmitetosum* community occurred (Tab. 1).

DISCUSSION

Biogenic sediments of the studied peatbog are diversified. In the lowest parts of profiles Bi2 and B3, at the contact with the mineral bedrock (sand), the presence of a well developed layer of sphagnum peat was found. According to research by Okruszko *et al*. [1971], Bałaga *et al*. [2002], Gawlik and Urban [2003], such layers occur also at the bottom of other lake-peatbog formations of the Łęczna-Włodawa Lakeland. The peat is considered to be of Allerod age [Bałaga 1991]. In the lower part of the discussed deposit, also limnic accumulation sediments (gyttja) occur, lying directly on the thin sphagnum peat layer. At the bottom it is usually clay gyttja, transforming upwards into organic-mineral gyttja, and then into detritus gyttja – algae or detritus-algae gyttja. Research by other authors [Okruszko *et al*. 1971, Bałaga *et al*. 2006, Kloss 2007, Urban 2009] proves that gyttja sediments usually lie on mineral bedrock.

The thickness of gyttja in the analysed profiles reaches 5 m. According to research by other authors, the thickness of gyttja deposits in certain lakes of the Łęczna-Włodawa Lakeland is considerably greater, and reaches the thickness of as much as 12–14 m. The water level in the reservoir was changing, which is indicated by peat interlayers occurring in the analysed profiles, as well as in other lake sediments of the Łęczna-Włodawa Lakeland [Bałaga *et al*. 2006]. The thickness of these individual layers was between a millimetre and a few millimetres. According to Okruszka *et al*. [1971], the peat formation process on the lakes of the Łęczna-Włodawa Lakeland began at the moment of sliding of the floating vegetation carpet over the lake water surface. Research by Bałaga *et al*. [1995] indicates that the process began in the subboreal period. For example, the development of the peatbog in the Moszne reservoir started about 4300+/-120 BP. Similarly as on other objects [Pacowski 1967, Kloss 2007], a change in the character of communities and accumulated sediments occurred. The lowest sediment layer was constituted by fen sedge peat characterised by small degree of decay, and vivid large content of gyttja at the bottom, as well as significant hydration. In the top part (with thickness of 50 to 80 cm), the sediments of the nearby Lake Brzeziczno were occupied by very scarce (5–15%) sphagnum peat.

Succession of plant communities in the case of the peatbog of lake origin occurred, like on other lake-peatbog objects in the Łęczna-Włodawa Lakeland and in other regions in Poland [Pacowski 1967, Okruszko *et al*. 1971, Bałaga *et al*. 1995, 2002, Noryśkiewicz and Kowalewski 2002, Drzymulska 2009, Urban 2009], according to the pattern: water phytocoenoses → floating mat-forming phytocoenoses (rush and sphagnum phytocoenoses from *Scheuchzerio-Caricetea nigrae* class) → transitional peatbog phytocoenoses from *Scheuchzerio-Caricetea nigrae* class. In the case of certain fragments of the peatbog (profile Brz2), the next succession stage was noted, i.e. the beginning of the development of raised peat communities from *Oxycocco-Sphagnetea* class.

Apart from a peatbog of lake origin, the studied complex includes also a peatbog which developed in the process of paludification of mineral soils. The development of such a peatbog began at the moment when the depression curve of rising ground water covered the near surface layer of the ground. According to Gawlik and Urban [2003], as reservoirs were becoming overgrown, and the thickness of sediments increased, ground water levels increased, which led to paludification of all hollows in the area. The deposit (profile Brz1) is constituted solely of peat, and it is formed by reed-sedge peat. At the top of the studied profile, muck horizon occurs (thickness of up to 20 cm).

CONCLUSIONS

1. The studied deposits are located on thick gyttja, which documents their lake origin. The exception constitute fragments of the peatbog occurring in the peripheral sites of the lake-peatbog complex which developed as a result of paludification of the mineral bedrock.

2. Alterations of vegetation in the studied peatbog include the following stages: stage I – lake stage, stage II – fen peatbog stage, stage III – transitional peatbog stage, and beginning of stage IV – raised peatbog stage.

3. Succession of plant communities occurred according to the following patterns:

– water phytocoenoses → floating mat-forming phytocoenoses (rush phytocoenoses from *Phragmitetea* class and peatbog phytocoenoses from *Scheuchzerio-Caricetea nigrae* class) → transitional peatbog phytocoenoses from *Scheuchzerio-Caricetea nigrae* class → raised peatbog communities from *Oxycocco-Sphagnetea* class (on a fragment of the peatbog);

– rush phytocoenoses from *Phragmition* association (*Phragmitetum australis caricetosum* phytocoenosis) → rush phytocoenoses from *Magnocaricion* association (*Caricetum elatae phragmitetosum* phytocoenosis).

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ROZWÓJ TORFOWISKA PRZY JEZIORZE BRZEZICZNO (POJEZIERZE ŁĘCZYŃSKO-WŁODAWSKIE) W ŚWIETLE ANALIZY MAKROSZCZĄTKÓW ROŚLINNYCH

Summary. Badane torfowisko znajduje się na Pojezierzu Łęczyńsko-Włodawskim, wchodzącym w skład Polesia Lubeskiego. Wykonano tu świdrem torfowym typu Instorf trzy wiercenia, z których do dalszych analiz laboratoryjnych pobrano 64 próbki. W pobranych próbkach oznaczono makroszczątki roślinne, a także popielność i odczyn (pH w H_2O i KCl). Badane złoże jest podścielone pokładami gytii, co dokumentuje ich jeziorną genezę. Fragmenty torfowiska wstępujące w peryferyjnych fragmentach kompleksu jeziorno-torfowiskowego ukształtowały się wskutek zabagniania podłoża mineralnego. Sukcesja zbiorowisk roślinnych przebiegała według następujących schematów: fitocenozy wodne z klasy *Potametea* i *Charetea* → fitocenozy szuwarowe z klasy *Phragmitetea* i torfowiskowe z klasy *Scheuchzerio-Caricetea nigrae*) → fitocenozy torfowisk przejściowych z klasy *Scheuchzerio-Caricetea nigrae* → zbiorowiska torfowisk wysokich z klasy *Oxycocco-Sphagnetea* (na fragmencie torfowiska); fitocenozy szuwarowe ze związku *Phragmition* → fitocenozy szuwarowe ze związku *Magnocaricion*.

Key words: torfowisko, zbiorowiska subfosylne, Pojezierze Łęczyńsko-Włodawskie