Contemporary Problems of Management and Environmental Protection
Vol. 2, 2009. Wetlands - Their Functions and Protection: 107-124

Chapter VI

Zbigniew Osadowski, Małgorzata Mazurek, Radosław Dobrowolski

Structure and development conditions of spring mires in the Parsęta basin (Western Pomerania)

INTRODUCTION

Spring mires are classified among the low soligenic mires (SUCCOW, JESCHKE 1986; SUCCOW 1988; DEMBEK 1992). The origin and development of these ecosystems are conditioned by a constant groundwater inflow. Because of that spring mires cover small areas; their total presence in Poland is assessed at less than 1% of the whole mire area (JASNOWSKI 1975). In the postglacial landscape of Pomerania the spring mires have been formed mainly in small stream valleys. An analogical situation occurs in the German part of Pomerania, as Wołejko (2001) emphasises. The author stresses that most mires in this area underwent transformation, mainly as a result of drainage and farming development (WOŁEJKO 1996, 2000a).

Spring mires have aroused the interest of many researchers for a long time. Numerous papers from Pomerania concerned the flora (including HERBICH 1982, 1994; JASNOWSKA et al. 1986; OSADOWSKI 2000, 2002, 2007). Wołejko (2000a) carried out a classification of the vegetation of spring ecosystems of north-west Poland. Among others Osadowski (1999, 2006), Osadowski, Fudali (2001), and Wołejko (2002) paid attention to the floristic values of spring ecosystems in the Parsęta basin. Because of the rarity of spring ecosystems, the presence of endangered and protected by law species of flora and fauna, and unique landscape values, these ecosystems have been the object of interest of persons who are engaged in nature protection in Pomerania, including: Łachacz (1999, 2001, 2006); Grootjans et al. (2006); Herbich (1998); Herbich, Stasiak (1971), and within the Parsęta basin among others Jasnowska, Markowski (1998), Osadowski, Wołejko (1997) and Wołejko (1996). Their role was appreciated as particularly important for nature protection with the creation of the European ecological network “Natura 2000”. The existing and planned areas for the “Natura 2000” programme that include the mire ecosystems in Pomerania are: “Parsęta Basin”, “Radwia, Chotla and Chociela Valley”, “Grabowa Valley”, “Wieprza and Studnica Valley”, “Słupia Valley”, “Łupawa Valley” and “Upper Łeba Valley” (OSADOWSKI 2007).

As it was stressed by Wołejko (2001), descriptions of distribution and structure of spring mires appeared at the beginning of the 20th century (among others HESS v. WICHDORF, RANGE 1906; HESS v. WICHDORF 1912; STEFFEN 1922, 1931). The only study from northern Poland had been for many years the paper of Kukla (1965). In recent years Wołejko (2001) studied the origin, typology and conditions of development of soligenic mires in north-west Poland. Recently Mazurek and Dobrowolski (2006) dealt with this issue in the Parsęta basin.

Considerably better recognised are the conditions of the development of spring mires in southern Poland (among others ALEXANDROWICZ et al. 1994; DOBROWOLSKI 1994, 1998, 2000; DOBROWOLSKI et al. 1999). The deposits of these mires were used for detailed palaeoenvironmental analyses, e.g. DOBROWOLSKI et al. (1996, 2002, 2005) and PAZDUR et al. (2002a, b). The calcareous tufa layers were analysed regarding to the participation of malacofauna (ALEKSANDROWICZ, ŻUREK 1996; ALEKSANDROWICZ 2005), which were then used to determine the development conditions of these mires.

Despite increasing recognition of the distribution and development of spring deposits forming the spring mires (WOŁEJKO 2000a, 2001), the data are used to a limited extent for further palaeoenvironmental analyses in Pomerania (MAZUREK, DOBROWOLSKI 2006). The purpose of this paper is to recognise the structure and development conditions of spring mires and main directions of vegetation successions based on the example of the chosen areas from the Parsęta basin.

STUDY AREA

The research was carried out in the Parsęta basin with an area of 3150.9 km^2 (Hydrological atlas of Poland 1987). The basin is located within the two macroregions of the West Pomerania Lakeland and the Koszalin Coastal Lowland (KONDRACKI 2000).

The Parsęta basin comprises three different morphogenetic zones (KARCZEWSKI 1998; SYLWESTRZAK 1978). The southern and south-eastern parts represent the marginal zone of the Pomerania phase of the Vistulian glaciation. Evidence of the areal deglaciation to which the investigated area was subjected to is present in the form of kame complexes and meltwater basins. In the southern part of the basin the small fragments of Piława and Gwda outwash plains are found. North of the marginal zone of the Pomerania phase the lakeland elevation descends towards the Baltic Sea, as a series of morainic plateau levels with diverse lithology (KARCZEWSKI 1998). Lakeland elevation is varied by the hills of end moraines and dead-ice moraines. Extensive erosion-accumulation glaciofluvial plains occur in the northern and central parts of the Parsęta basin.

The area is cut by river valleys of subglacial-trough origin or those using the marginal spillways (SYLWESTRZAK 1978). Basin-like sections of the valleys constitute of ice-dammed lakes or meltwater basins in the river's course. Within the basin there is a part of the Pomeranian Ice-Marginal Valley, whose latitudinal sections are used by the Parsęta and Radew rivers.

In the geological structure of the Parsęta basin a fundamental role is played by the complex of loose Pleistocene and Holocene deposits, from several dozen to over 200 m thick, which comprise tills, glaciofluvial sands and gravels, and river sands, as well as ice-dam silts and sands (Geological Map of Poland in the scale of 1:500000). The meltwater basins are filled with sands and silts, and organic formations: lacustrine chalk, gyttja and peat. The alternate arrangement of permeable and impermeable layers as well as their discontinuity and diverse thickness explains the occurrence of several aquifer levels that take part in supplying groundwater outflows and the spring mires associated with them.

The spring mire vegetation is represented by forest and non-forest communities, including numerous spring, rush and sedge, peat, meadow, as well as forest and shrub phytocenoses. Among others Jasnowska and Markowski 1998, Wołejko (2000a), Osadowski (2000, 2002, 2007), reviewed and systematized the knowledge about vegetation of the spring ecosystems in the Parsęta basin.

MATERIAL AND METHODS

Research was carried out within two selected spring mire complexes in the Parsęta basin (Western Pomerania), diverse in the geological and phytosociological respect (Fig. 1). Within the two sites the following features were analysed: (1) lithology of biogenic and mineral deposits, (2) species composition of peat-forming vegetation, (3) water supply and drainage conditions, as well as (4) physico-chemical properties of groundwaters in their outflow zones to the surface.

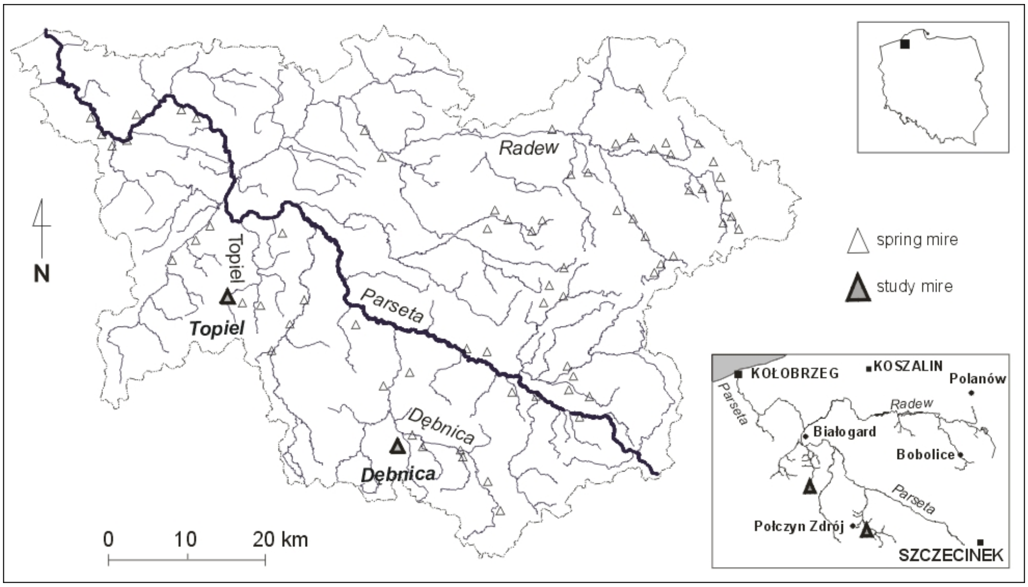

Fig. 1. Location map: A – General location in Poland; B – situation of the examined spring mires in the Topiel and Dębnica valleys; C – distribution of all spring mires in the Parsęta basin

The internal structure of the mires was determined on the basis of geological drillings performed along selected transects using the “Instorf” type bit (length of the box 0.50 m). The grade of peat decomposition was determined in the field and the recognition of its macroscopic remains was carried out in accordance with universally accepted methodology (GROSSE-BRAUCKMANN 1986). The chosen lithological profiles were analysed in terms of physical parameters (*nigror* darkness level, *stratificatio* layer stratification, *elasticitas* flexibility of the layer, *siccitas* dryness of the layer, *color* colour of the layer, *structura* structure of the layer and *limes* border between layers), the grade of decomposition and the presence of individual components of the deposit in accordance with Troels-Smith’s method.

Cores of undisturbed structure were taken for chronostratigraphic and palaeogeographic interpretations. Sedimentological and geochemical analyses (organic matter content, amount of $CaCO_3$) and AMS radiocarbon dating (samples of peat) were carried out for theses cores.

The natural development of spring mire vegetation was determined on the basis of genetic association between peat-forming vegetation communities and peat units on the basis of the study by Tołpa et al. (1967). In order to do that, representative peat samples were analysed regarding botanic composition by the simplified microscopic-net method (PRZYBYŁEK 1954). Peat classification was carried out according to scheme proposed by Tobolski (2000).

The present vegetation was investigated with Braun-Blanquet’s method (MATUSZKIEWICZ 2005). In total 105 phytosociological records used for further analyses on succession of present vegetation were taken within the studied areas. The list of the spring communities was based on the conception of Hinterlang (1992) and Zechmeister and Mucina (1994). Nomenclature and classification of independent bryophyte communities were taken after Hübschmann (1986). The list and nomenclature of rush, meadow and forest communities were taken after Matuszkiewicz (2005), Succow (1988) and Wołejko (2000a).

Samples for preliminary palynological analysis were taken from the depth of 470-475 and 475-480 cm in the mire in the Topiel River valley, site T4 (Fig. 2). Samples (1 cm^3 in volume) for pollen analysis were prepared according to standard Erdtman’s acetolysis method, after treating with HCl in order to remove carbonates and heating with 10% solution of KOH. The examined samples required additional treating with HF for 24 hours.

The pH and specific electrical conductivity (EC) of groundwater outflows (reference 25°C) were measured in the field using a CX-401 multifunctional portable meter. Water samples were immediately put through 0.45 µm membrane filters (Whatman) and stored in polyethylene bottles in the dark at approximately 4°C. For the purposes of cation analysis, the samples were acidified with HNO_3. Bicarbonate concentrations in the filtered samples were determined within a day of collecting by titration with 0.05 M HCl and a methyl orange indicator. The concentrations of Ca^{2+} (the absorption mode) were determined by atomic absorption spectrometry (AAS) using a Varian SpectraAA 20 Plus.

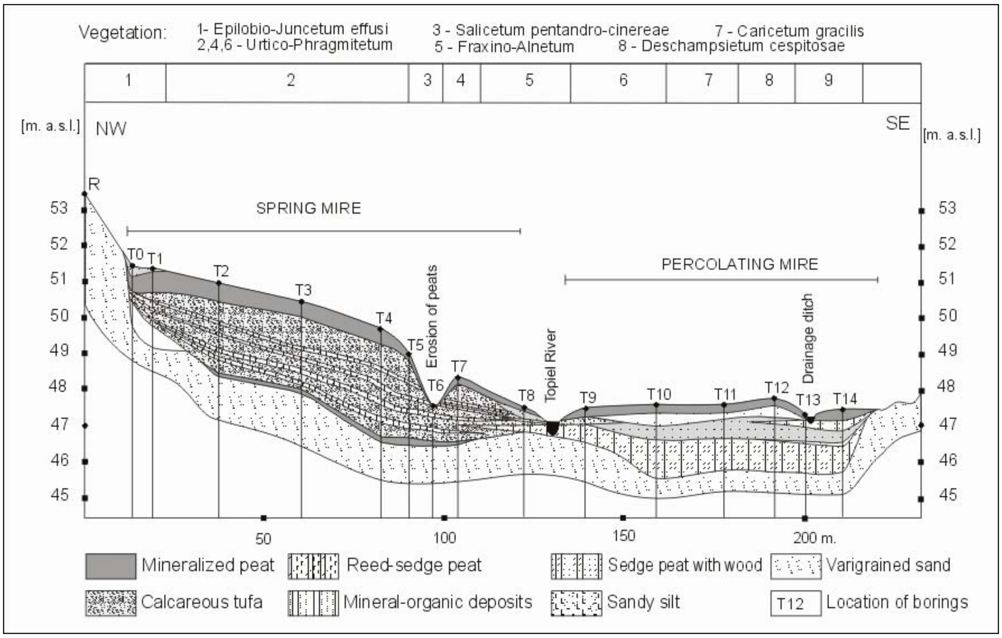

Fig. 2. Geological cross-section through the spring mire in the Topiel valley

RESULTS AND DISCUSSION

Distribution and hydrogeological conditions of spring mires

Hydrogeological conditions determine the occurrence of groundwater outflows in postglacial areas and result in specific lithological and morphological situations of spring mires. Groundwater outflows concentrate in the Parsęta basin, in areas with substantial height differences that is on scarps of morainic elevations, on slopes of kame hills, on slopes of valleys of marginal outflows, subglacial tunnel valleys and melt-out basins (MAZUREK 2006).

The mires are supplied by unconfined groundwaters from the local near-surface aquifer and by confined groundwaters from intermediate and regional intermorainic aquifers. Location of the recognised spring mires in the Parsęta basin is associated with the pattern of the valley network (Fig. 1). Among the privileged areas in terms of quantity and discharge of outflows there are valleys and fluvioglacial plains with a river terrace system, sections of the Pomeranian marginal spillways, and subglacial-trough and ravined valleys. Deep incisions of the valleys and high hydraulic gradients create beneficial conditions for groundwater drainage of local and regional range from the recharge areas, i.e. surrounding morainic plateau levels and fluvioglacial plains. Unconfined groundwaters supply layer outflows around which hanging spring mires were formed on the slopes of valleys. In the footslope zone where there are drainage conditions of intermorainic confined waters supplying efficient ascending springs, cupola spring mires developed. Mire complexes comprising different types of soligenic mires can develop in the drainage zones of a few aquifer levels, as stressed, among others, by Wołejko (2000).

Hydrochemical conditions of spring mires

Development of spring mires occurs in the case of a supply of groundwaters rich in calcium carbonates. The main source of calcium carbonate in the postglacial areas of Western Pomerania are morainic and fluvioglacial deposits in which the amount of $CaCO_3$ varies from a few to a dozen per cent or so (BUKOWSKA-JANIA 2003). The carbonates initially underwent redeposition within near-surface deposits in the conditions of permafrost. As a result of climate changes and the start of deep circulation of groundwaters, waters of intermorainic aquifers initiated the dissolution and migration of carbonates. On a large scale, the denudation processes developed in the early Holocene, and their high rate resulted from water balance and accessibility of material for leaching (BORÓWKA 1992). Precipitation of calcium bicarbonate contained in waters as a result of biochemical and physical processes occurs in the form of lacustrine chalk and calcareous gyttja in lake bodies, but also in the form of calcareous tufas in the groundwater outflow zones.

The present amount of calcium and bicarbonate ions in groundwaters of postglacial zones proves the intensive redeposition of calcium carbonate even today. The analysis of the basic physico-chemical parameters of groundwaters supplying the spring mires allows us to state that they are slightly alkaline, medium-mineralized waters (specific electrical conductivity within 300 – 500 µS/cm). Shallow groundwaters from layer springs on the morainic uplands belong to two hydrochemical types, HCO_3-SO_4-Ca and HCO_3-Ca, which are formed during infiltration of precipitation waters in the aeration zone. Infiltrating precipitation waters, with depth, are subjected to neutralisation and become enriched in the products of dissolution of calcium carbonate. Confined groundwaters in fluvioglacial sands and gravels (intermorainic aquifers) belong to two-ion type: HCO_3-Ca (MAZUREK 2007). Their physico-chemical properties result from higher amount of calcium carbonate in the aquifers and from a longer distance and time of groundwater flow. On the basis of isotope research, groundwater residence time in the analysed aquifers was determined for 20 to 50 years (WIŚNIOWSKI 1998).

The differences in water chemistry supplying the spring mires are not great; they also do not show anthropogenic transformation. The main natural component diversifying their composition is the amount of $CaCO_3$ in aquifers, as well as in the series of overlying deposits, and in waters of near-surface level – the intensity of biochemical processes. Therefore, in the ecological respect, the spring mires occurring in Western Pomerania represent two ecological types (SUCCOW 1988): eutrophic calcareous and mesotrophic calcareous (WOŁEJKO 2000).

Groundwaters drained in the Topiel valley (Fig. 1) are characterized by specific electrical conductivity from 302 to 371 µS/cm and slightly alkaline reaction. In the ionic composition there is dominant presence of calcium cations (average 61.50 Ca mg/dm^3), and bicarbonate anions (average 152.7 mg/dm^3). Waters of outflows in the Dębnica valley at Ogartowo (Fig. 1) have slightly higher specific electrical conductivity, approx. 430 µS/cm, with the amount of Ca cations of 80.6 mg/dm^3, and HCO_3 anions of 203 mg/dm^3. The investigated outflows supplying mires belong to the bicarbonate-calcareous type, whereas according to the ecological classification (SUCCOW 1988) these mires should be counted among eutrophic calcareous spring mires.

Diversity and structure of studied spring mires

The spring mire in the Topiel valley is located on the left slope of the valley where there are numerous efficient outflows supplied from the near-surface and intermorainic aquifers. The outflow from the mire is approximately 19 dm^3/s (2007). There are different hydrological conditions on the opposite slope of the valley, where percolating mires developed (Fig. 2). When analysing water discharge in an upper section of the Topiel river (25.7 dm^3/s) and in the hydrometric profile closing the area (81.1 dm^3/s) it is possible to state that the whole spring complex is characterized by an intensive underground supply (approx. 55.4 dm^3/s).

The spring mire in the Dębnica valley (Fig. 3) is characterized by the occurrence of more distinct spring cupola. Two cupolas formed around the springs functioning in the past, which are located in the Dębnica valley, at the foot of the edge of morainic plateau level (Fig. 4), were recognised in the structure of the mire. The mire domes are intensely dried up and consist of strongly decomposed peat. In the past this place was subjected to anthropogenic impact to a much higher extent. The deep dissection of the morainic plateau level created the conditions for the drainage of intermorainic confined waters. Several foothill efficient springs are supplied from the series of so-called lower glaciofluvial sand-gravel deposits. The total outflow from the spring mire area is approximately 10.5 dm^3/s (2006).

Deposits of the analysed spring mires are lithogenetically diverse: peat, humous peat, calcareous tufas and mineral-organic muds. In the profiles of the studied mires low peat occurs exclusively. The bottom beds are frequently composed of a layer of strongly decomposed sedge peat (*Cariceti*) and/or rush and sedge peat (*Carici-Phragmiteti*) (Figs. 2 and 3). In the floors there often occurs black amorphous humus (in the form of humus peat), without macroscopically distinguished structure. Strongly decomposed sedge peat (*Cariceti*), in places contaminated with amorphous calcareous tufa, occurs in the upper part of the spring domes. In many places, in near-surface layers, the occurrence of substantial additions of mineral components is found. These are usually fine-grained sands washed onto the surface of mires. In the profiles from the footslope parts of the spring mire in the Topiel valley (point TW and T1, Fig. 2) there are thicker layers of colluvial sands. This is probably the effect of increased erosion processes on the slopes of the valley which were deforested in the past.

A characteristic feature of vertical variability of deposits of the spring mires is the presence of substantial layers of calcareous tufa. Its thickness in the Topiel valley reaches 3 m. The layers of calcareous tufa occur with thin interbeddings of sedge peat or amorphous humus substance (Fig. 3). Sometimes tufa occurs with a substantial admixture of plant detritus and can be streaked with ferruginous precipitations.

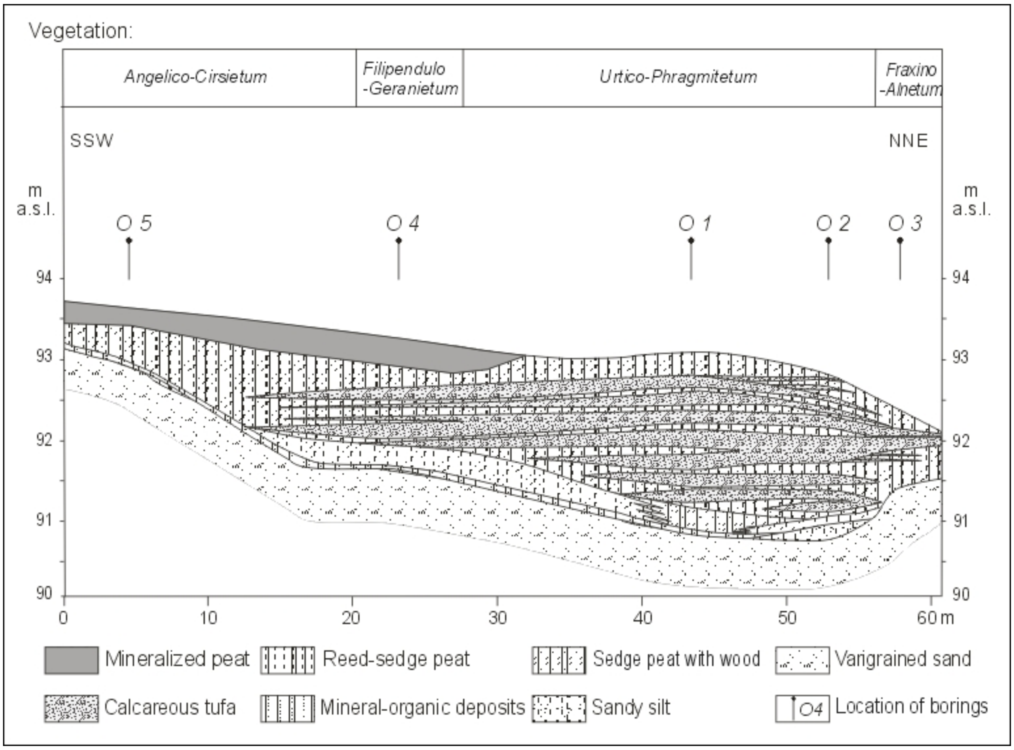

Fig. 3. Geological cross-section through the spring mire (Ogartowo site) in the Dębnica valley; explanations as in Fig. 2.

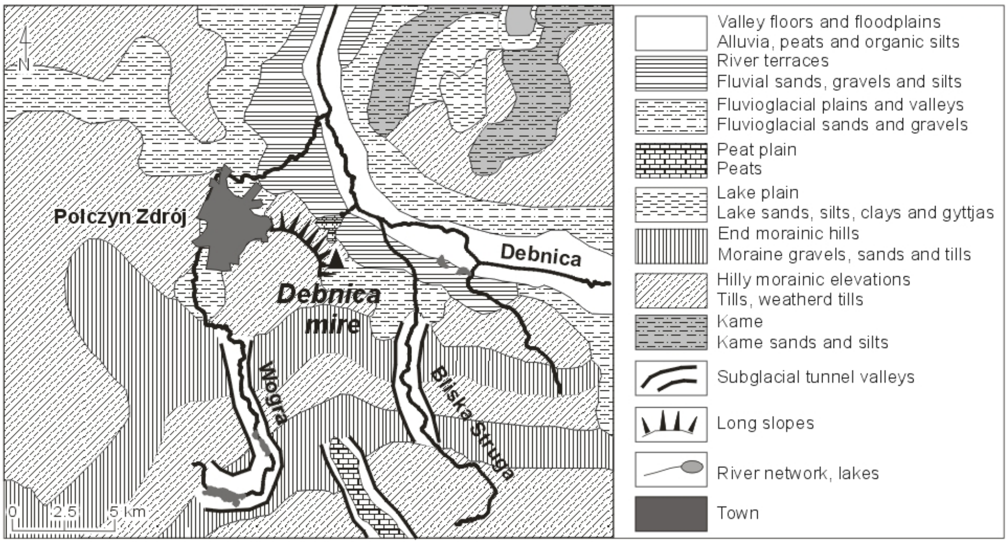

Fig. 4. Geological-geomorphological map of the surroundings of the Ogartowo spring mire

The calcareous tufa vary greatly in the granulometry respect, from large-grained, sharp-edged debris with a small amount of plant detritus, to fine-grained with a substantial amount of plant remains.

Silt tufa without plant detritus was noted in lower parts of the profile in the Topiel valley (at the depth of 2.65 – 3.30 m). Macroscopically it looks like calcareous gyttja, but is not plastic and to a small extent includes the remains of malacofauna (DOBROWOLSKI et al. 1999; WOŁEJKO 2001).

A different structure occurs in the percolating mires in the Topiel valley. The bottom layers consist of sedge peat with wood (*Alnetii*). In the upper part they are sharply separated from a thick layer of varigrained deluvial sands washed onto the mire; sedge moss peat (*Carici-Bryaleti*) is on their surface. Similarly to the case of the spring mires, surface layers of the percolating mires are composed of strongly decomposed sedge peat (*Cariceti*), often with considerable admixture of washed mineral components (point T9 - T14, Fig. 2).

Development of spring mires and vegetation in natural conditions

In the examined profiles (Figs. 2 and 3) it is possible to distinguish 3 main lithological units. They comprise: a) thin (up to 0.25 m), generally continuous layer of bottom sedge peat and/or sedge-reed peat; b) thick layer (up to 3 m) of calcareous tufa (diverse in the granulometric respect); c) discontinuous layer (up to 0.7 m) of strongly mineralised (decomposed) sedge peat, in parts contaminated with calcareous tufa and pieces of wood.

The main palaeogeographical conclusions resulting from the research carried out so far are as follows:

1) The development of the spring mires took place on the surface of thin peat, formed by sedge communities and rush communities of the *Magnocaricion* alliance. Preliminary palynological analysis shows that the peat accumulated in the Late Glacial period, in the conditions of the occurrence of permafrost in the substratum, without the presence of confined groundwaters.
2) In the Boreal period gradual disappearance of permafrost caused the reactivation of vertical circulation of groundwaters, which in consequence resulted in initiating of the spring mires development. From the very beginning these mires functioned as soligenic mires, supplied point-wise by confined waters (with growing pressure of groundwaters).
3) In the initial stage of development of the spring mires there occurred intensive accumulation of calcareous tufa in the presence of spring moss communities of *Montio-Cardaminetea* class, probably with the presence of mosses of *Cratoneuron*, *Drepanocladus* or *Calliergon* genus. Maximal deposition of calcareous tufas, similar as in other sites from southern (PAZDUR et al. 1988) and eastern Poland (DOBROWOLSKI et al. 1999, 2002, 2005), is correlated with the Atlantic climatic optimum of the Holocene (Fig. 5).

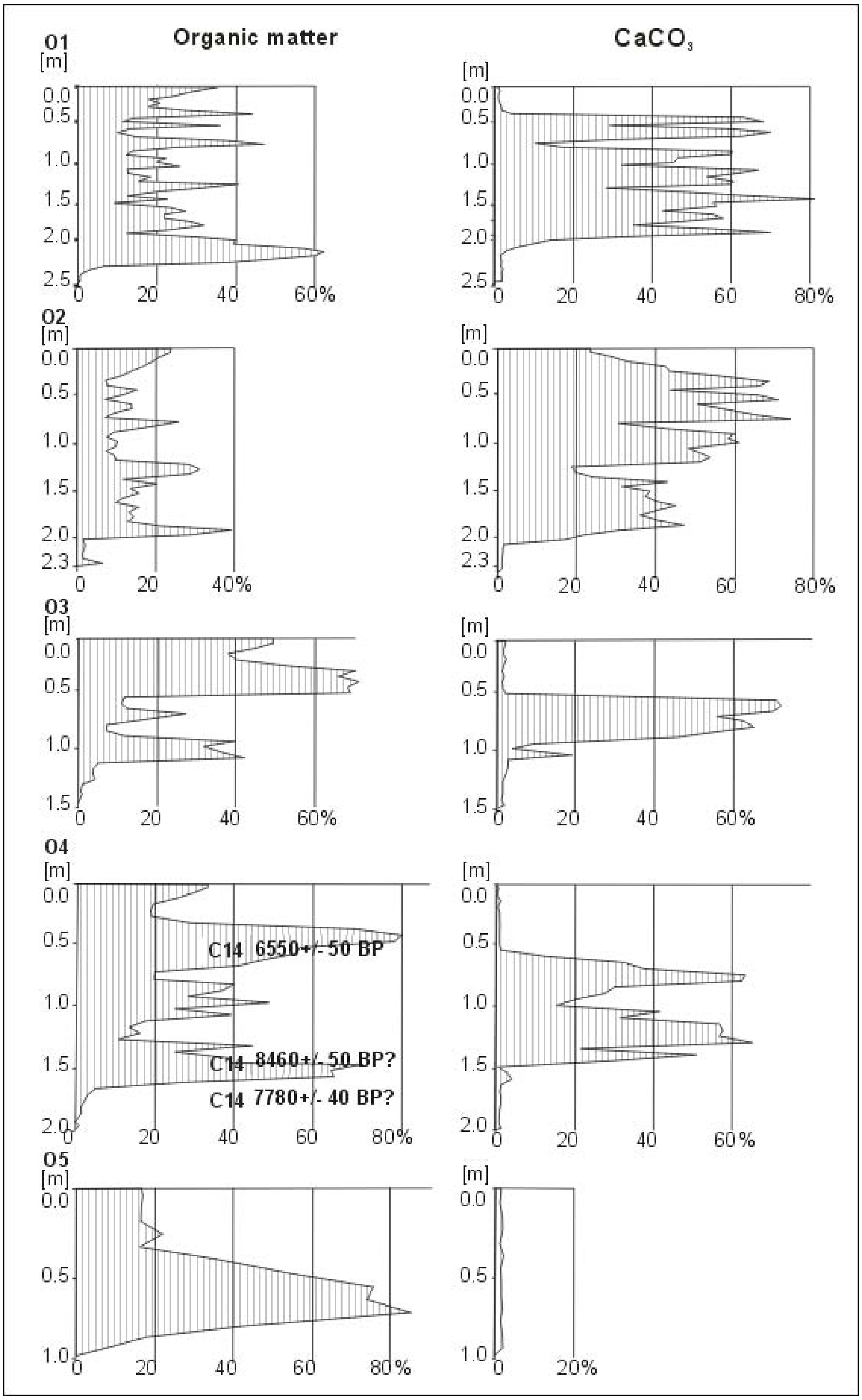

Fig. 5. Content of organic matter and $CaCO_3$ in the deposits from the Ogartowo spring mire profiles.

4) High efficiency of ascending springs supplying spring mires remained probably to the end of the Atlantic period. Probably close to the end of the Atlantic period the succession of the sedge vegetation of the *Magnocaricion* alliance occurred. The remains of wood in the sedge peat may show further succession towards alderwood communities *Cardamino-Alnetum glutinosae* or willow shrubs *Salicetum pentandro-cinereae* of the *Alnetea glutinosae* class.
5) Substantial deterioration in thermal and moisture conditions at the beginning of the Subboreal period caused considerable limitation of activity of ascending springs, decrease of organic accumulation rate and radical limitation of calcareous tufa deposition. Probably at the end of the Atlantic period and in the Subboreal period the natural development of mires could have been disturbed by the occurrence of the first Neolithic people.
6) There were different development conditions in the percolating mires in the Topiel valley. In the initial stage of mire development the area functioned as a small meltwater basin which was filled with water with time. Such hydrological conditions favour the development of eutrophic wood communities *Ribeso-nigri-Alnetum* of the *Alnetea glutinosae* class. Their long-term presence contributed to the creation of substantial layers of sedge peat with wood. In the further stage of the succession the development of moss vegetation of the *Scheuchzerio-Caricetea fuscae* class occurred, probably already formed under the influence of extensive farming practice (compare WOŁEJKO 2000a).

Present vegetation of spring mires and its transformation

Within the studied spring mires 29 types of vegetation of the rank of associations and communities, representing 6 classes of vegetation, were found: spring vegetation *Montio-Cardaminetea*, independent moss communities *Fontinaletea antipyreticae*, rush and sedge *Phragmitetea*, meadow *Molinio-Arrhenatheretea*, and shrub and forest *Alnetea glutinosae* and *Querco-Fagetea* (Table 1).

Typical spring communities of the *Montio-Cardaminetea* class occur in the spring niches formed in the outflow places of groundwaters. On the waterlogged and marshy substratum the most common is the *Cardamineto-Chrysosplenietum alternifolii* association. Small areas on the scarps and tree roots, constantly washed by water, are occupied by the *Pellieto-Conocephaletum* association. On the stony and sandy ground *Cratoneureto filicinae-Cardaminetum* and the community with *Pellia endiviaefolia* are often met.

The occurrence of numerous spring communities of the *Montio-Cardaminetea* and *Fontinaletea antipyreticae* class is dependent to a great extent on the activity of erosion processes in spring niches, as well as the spring mires themselves (compare WOŁEJKO 1996). Spring mires in the Topiel and Dębnica valleys are constantly eroded and make available new habitats for pioneer species of spring mosses. Calcareous tufa layers exposed as a result of erosion are often inhabited by communities of *Cratoneuron commutatum*. The *Pellieto-Conocephaletum* association often grows in places affected by human activity; in the Topiel valley these are concrete walls of former hydrotechnical appliances which are constantly washed by flowing waters.

Table 1

Systematic list of plant communities of the spring ecosystems in the Topiel and Dębnica valleys

	Spring vegetation
	Cl. *Montio-Cardaminetea* Br.-Bl. et R. Tx. 1943
	O. *Montio-Cardaminetalia* Pawł. 1928
	All. *Cratoneurion commutati* Koch 1928
1	Ass. *Cratoneureto filicinae-Cardaminetum* Maas 1959
2	Ass. *Cratoneureto filicinae-Lemnetum trisulcae* Woł. 1991
3	Comm. with *Pellia endiviaefolia*
4	Comm. with *Cratoneuron commutatum* (= *Palustriella commutata*)
	O. *Cardamino-Chrysosplenietalia* Hinterlang 1992
	All. *Caricion remotae* Kastner 1940
5	Ass. *Cardamineto-Chrysosplenietum alternifolii* Maas 1959
6	Ass. *Pellieto-Conocephaletum* Maas 1959, var. *Conocephalum conicum*
	Independent bryophytic communities
	Cl. *Fontinaletea antipyreticae* v. Hübschmann 1957
	O. *Leptodicyetalia riparii* Philippi 1956
	All. *Brachyhecion rivularis* Hertel 1974
7	Ass. *Brachythecium rivularis* Herzog 1943
	Rush vegetation
	Cl. *Phragmitetea* R. Tx. et Prsg 1942
	O. *Phragmitetalia* Koch 1926
	All. *Phragmition* Koch 1926
8	Ass. *Glycerietum maximae* Hueck 1931
9	Ass. *Eleocharitetum palustris* Sennikov 1919
	All. *Magnocaricion* Koch 1926
10	Ass. *Phalaridetum arundinaceae* (Koch 1926 n. n.) Libb. 1931
11	Ass. *Caricetum gracilis* (Graebn. Et Hueck 1931) R. Tx. 1937
12	Ass. *Caricetum acutiformis* Sauer 1937
	All. *Sparganio-Glycerion fluitantis* Br.-Bl. et Siss. in Boer 1942
13	Ass. *Glycerietum nemoralis-plicatae* Kopecky 1972
14	Ass. *Sparganio-Glycerietum fluitantis* Br.-Bl. 1925 n. n.
	Meadows and tall forb vegetation
	Cl. *Molinio-Arrhenatheretea* R. Tx. 1937
	O. *Molinietalia* W. Koch 1926
	All. *Filipendulion ulmariae* Segal 1966
15	Ass. *Filipendulo-Geranietum* W. Koch 1926
16	Ass. *Lysimachio vulgaris-Filipenduletum* Bal.-Tul. 1978
17	Ass. *Valeriano-Filipenduletum* Siss. in Westh. et all. 1946
	All. *Calthion* R. Tx. 1936 em. Oberd. 1957
18	Ass. *Angelico-Cirsietum oleracei* R. Tx. 1937 em Oberd. 1967
19	Ass. *Equisetetum palustris* Steffen 1931
20	Ass. *Deschampsietum cespitosae* (Horvatić) Grynia 1961
21	Ass. *Scirpetum silvatici* Ralski 1931
22	Ass. *Caricetum cespitosae* (Steffen 1931) Klika et Smarda 1940
22	Subass. Podzespół *Caricetum cespitosae phragmitetosum* Woł. 2000
23	Ass. *Epilobio-Juncetum effusi* Oberd. 1957

Table 1 continued

24	Ass. Zespół *Urtico-Phragmitetum* Succ. 1970
	Forests and bushwood vegetation
	Cl. *Alnetea glutinosae* Br.-Bl. et R. Tx. 1943
	O. *Alnetalia glutinosae* R. Tx. 1937
	All. *Alnion glutinosae* (Malc. 1929) Meijer Drees 1936
25	Ass. *Cardamino-Alnetum glutinosae* (Meijer-Drees 1936) Pass. 1968 typicum, var. *Poa trivialis*
26	Ass. *Salicetum pentandro-cinereae* (Almq. 1929) Pass. 1961
	Cl. *Qerco-Fagetea* Br.-Bl. et Vlieg. 1937
	O. *Fagetalia sylvaticae* Pawł. in Pawł., Sokoł. et Wall. 1928
	All. *Alno-Ulmion* Br.-Bl. et R. Tx. 1943
27	Ass. *Fraxino-Alnetum* W. Mat. 1952 typicum, var. *Cardamine amara*
27	Ass. *Fraxino-Alnetum* W. Mat. 1952 typicum, var. *Marcurialis perennis*
	All. *Fagion sylvaticae* R. Tx. et Diem. 1936
28	Ass. *Luzulo pilosae-Fagetum* W. Mat. et A. Mat. 1973
	All. *Carpinion betul*i Issl. 1931 em. Oberd. 1953
29	Ass. *Stellario holosteae-Carpinetum betuli* Oberd. 1957

Substitute communities of the spring and percolating mires active in the past are rush and sedge communities of *Phragmitetea* class and meadow communities of *Molinio-Arrhenatheretea* class. They occur often in the spring form, especially in places where confined waters escape on the surface. Abandoning the use of wet meadows of *Angelico-Cirsietum* type within the spring mires started a succession towards numerous other communities of *Calthion* and *Filipendulion* alliance. These are among other things wet forms of *Equisetetum palustris*, *Scirpetum silvatici* and *Deschampsietum cespitosae* and well developed forms of tall herbs: *Lysimachio vulgaris-Filipenduletum*, *Valeriano-Filipenduletum* and *Filipendulo-Geranietum*. The greatest role in the succession of vegetation after farming practice being abandoned is played by the *Urtico-Phragmitetum* association. It often covers deeply drained spring mires. Physionomically it looks like water reed-rush, but abounds in great numbers in meadow species as well as nitrophilous and heliophilous species, proving the mineralization of the upper layer of peat. It should be stressed that semi-natural meadow communities in the Topiel and Dębnica valleys used in the past are important biotopes for a few rare and endangered species, such as *Dactylorhiza majalis*, *Dactylorhiza fuchsii*, *Listera ovata* and *Ophioglossum vulgatum*.

Probably in the past the key association of eutrophic spring mire was typical alderwood *Cardamino-Alnetum glutinosae* of the *Alnetea glutinosae* class. Its small areas remained in the Topiel valley. They have the form of a subassociation of *Poa trivialis* (WOŁEJKO 2000b) and are characterized by the presence of species that indicate higher fertility of substratum: *Poa trivialis*, *Urtica dioica* and *Carex acutiformis*. Their presence is the result of substratum mineralization, triggered by the attempts of mire drainage whose tracks are visible until nowadays in the form of overgrown drainage ditches. In the Dębnica valley considerable areas are occupied by *Fraxino-Alnetum* (=*Circaeo-Alnetum*) associations. They have the form of a variant with *Mercurialis perennis* and clearly indicate the substantial dryness of spring mires domes (compare WOŁEJKO 2000).

Poor floristic composition of the willow shrubs *Salicetum pentandro-cinereae* and the presence of meadow species in studied patches clearly shows the initial character of those phytocoenoses on the spring mires.

CONCLUSIONS

The studied mires are eutrophic-calcareous spring mires supplied with bicarbonate-calcium waters from the near-surface aquifer and intermorainic aquifers. The occurrence of thick calcareous tufa layers in the profiles proves the intensive supply of these mires in the past with waters rich in calcium carbonate.

The deposit succession documented within the studied spring mires shows great variability (time and spatial) of sedimentation processes, being a consequence of changes of supply conditions (spring activity, physico-chemical features of groundwaters) and development of natural vegetation.

In the studied peat profiles the evidence of man's interference is registered, manifested as discontinuance of natural biogenic succession. Exact determination of the beginning of man's influence on the spring mire requires further palynological analysis.

Analysis of present vegetation showed the occurrence of 29 types of phytocoenosis belonging to 6 vegetation classes: *Montio-Cardaminetea*, *Fontinaletea antipyreticae*, *Phragmitetea*, *Molinio-Arrhenatheretea*, *Alnetea glutinosae* and *Querco-Fagetea*. It is the result of over 200-300 years of transformations of hydrological conditions by man and processes of spontaneous regeneration after abandoning farming practice. A great role in transformation of the spring and wood vegetation is played by erosion processes within the spring mires.

ACKNOWLEDGEMENTS

In the years 2006-2009 and 2008-2011, the research was financially supported by the Ministry of Science and Higher Education as research project 2PO4G 03530 and NN306279035.

REFERENCES

ALEKSANDROWICZ W. P. 2005. Late Glacial and Holocene malacocenoses in calcareous tufa in Southern Poland. Rozprawy, AGH, Kraków, 148: 1-255.

ALEXANDROWICZ S.W., BAŁAGA K., DOBROWOLSKI R. 1994. Etapy rozwoju torfowiska kopułowego Krzywice w okolicach Chełma Lubelskiego. Kwartalnik AGH, Geologia 20(3): 259-273. [In Polish with English summary: Stages of development of cupola mire in Krzywice near Chełm Lubelski].

ALEXANDROWICZ S.W., ŻUREK S. 1996. Geneza i malakofauna źródliskowego torfowiska w dolinie Tyśmienicy (Polesie Zachodnie). Kwartalnik AGH, Geologia 20(3): 259-273. [In Polish with English summary: Origin and malacofauna of a spring mire in the Tyśmienica River valley, Western Polesie].

Atlas hydrologiczny Polski. 1987. Stachŷ J. (Ed.), IMGW, Wydawnictwo Geologiczne, Warszawa [In Polish with English summary: Hydrological Atlas of Poland].

BUKOWSKA-JANIA E. 2003. Rola systemu lodowcowego w obiegu węglanu wapnia w środowisku przyrodniczym (na przykładzie Svalbardu i młodoglacjalnych obszarów Polski północno-zachodniej). Prace Naukowe Uniwersytetu Śląskiego, 2103. [In Polish with English summary: The role of glacier systems in the migration of calcium carbonate in the natural environment (with particular reference to Svalbard and the late-glacial areas in NW Poland)].

DEMBEK W. 1992. Soligenus peat lands in Poland nad some problems with their protection nad utilization, *Proc. 9th International Peat Congress*, Uppsala: 278-293.

DOBROWOLSKI R. 1994. Tektoniczne uwarunkowania rozwoju źródliskowego torfowiska kopułowego "Krzywice" koło Chełma. Przegląd Geologiczny, 7: 532-535 [In Polish].

DOBROWOLSKI R. 1998. Development conditions of calcareaous tufas from the karst area of the Chełm Hills (Lublin Upland). Kras i Speleologia, 9(18): 194-206.

DOBROWOLSKI R. 2000. Torfowiska węglanowe w okolicach Chełma – geologiczne i geomorfologiczne warunki rozwoju. In: Walory przyrodnicze Chełmskiego Parku Krajobrazowego i jego najbliższych okolic. Łętowski J. (ed.), Wydawnictwo UMCS, Lublin: 17-25. [In Polish with English summary: Carbonate mires in the environs of Chełm – geological and geomorphological conditions of development].

DOBROWOLSKI R., Alexandrowicz S.W., Bałaga K., Durakiewicz T., Pazdur A. 1999. Studies of tufa within spring cupola peatbogs in Eastern Poland. In: (A.Pazdur, A. Bluszcz, W. Stankowski, L. Starkel, Eds.) Geochronology of Upper Quaternary of Poland in the light of radiocarbon and luminescence dating. WIND- Wojewoda, Wrocław: 179-198.

DOBROWOLSKI R., DURAKIEWICZ T., PAZDUR A. 2002. Calcareous tufas in the soligenous mires of eastern Poland as an indicator of the Holocene climatic changes. Acta Geologica Polonica, 52(1): 63-73.

DOBROWOLSKI R., DURAKIEWICZ T., PAZDUR A., PAZDUR M. 1996. Chronostratigraphy and development stages of the spring peat – knoll at Krzywice near Chełm, Lublin Upland, SE Poland. Geochronometria 14: 19-29.

DOBROWOLSKI R., HAJDAS I., MELKE J., ALEXANDROWICZ W.P. 2005. Chronostratigraphy of calcareous mire sediments at Zawadówka (Eastern Poland) and their use in palaeogeographical reconstruction. Geochronometria, 24: 69-79.

GROOTJANS A., SWINKELS J, GROENEWEG M., WOŁEJKO L., AGGENBACH C. 1999. Hydro-ecological aspects of a Polish spring mire complex (Diabli Skok). Crunoecia, 6: 73-82.

GROOTJANS A.P., WOŁEJKO L., UTRACKA-MONKO B. 2006. Can we restore travertine forming spring mires in Poland?, 5th European Conference on Ecological Restoration, 21-25 August, Greifswald, Germany: 95-95.

HERBICH J. 1982. Zróżnicowanie i antropogeniczne przemiany roślinności Wysoczyzny Staniszewskiej na Pojezierzu Kaszubskim. Monographiae Botanicae, 63: 1-162. [In Polish with English summary: Differentiation and anthropogenic transformations of vegetation in the Staniszewo Upland in the Kashubian Lakeland].

HERBICH J. 1994. Przestrzenno-dynamiczne zróżnicowanie roślinności dolin w krajobrazie młodoglacjalnym na przykładzie Pojezierza Kaszubskiego. Monographiae Botanicae, 76: 1-175. [In Polish with English summary: Spatial and dynamical diversity of the vegetation in valleys in a young-glacial landscape exemplified by the Kashubian Lakeland (Northern Poland)].

HERBICH J. 1998. Staniszewskie Zdroje – ochrona szaty roślinnej źródlisk. In: Szata roślinna Pomorza – zróżnicowanie, dynamika, zagrożenie, ochrona. Przewodnik Sesji Terenowych 51. Zjazdu PTB 15-19 IX 1998, Herbich, J., Herbichowa, M. (eds.), Wydawnictwo Uniwersytetu Gdańskiego: 181–186. [In Polish with English summary: Staniszewskie Zdroje – protection of the vegetation cover of springs].

HERBICH J., STASIAK J. 1971. Roślinność projektowanego rezerwatu Staniszewskie Zdroje, Chronmy Przyrode Ojczystą, 27: 165-170. [In Polish with English summary: Vegetation in the nature reserve Staniszewskie Zdroje].
HESS v. WICHDORFF H. 1912. Zur weiteren Kenntnis der Quellmoore in Norddeutschland. Jahrbuch der Preussen Geologischen Landesanstalt, 33(2): 319-341.
HESS v. WICHDORFF H., RANGE P. 1906. Über Quellmoore in Masuren (Ostpreussen). Jahrbuch der Preussen Geologischen Landesanstalt, 27(1): 95-106.
HINTERLANG D. 1992. Vegetationsökologische der Weichwasser Quellgesellschaften zentraleuropaischer Mittelgebirge. Crunoecia 1: 5-117.
HÜBSCHMANN A. von. 1986. Prodromus der Moosgesellschaften Zentraleuropas. Bryophytorum Bibliotheca, Band 32. Gebrüder Borntraeger Verlagsbuchhandlung, Berlin – Stuttgart: 1-403.
JASNOWSKA J., MARKOWSKI S. 1998. Torfowiska dorzecza Parsęty. In: (A. Kostrzewski, ed.) Funkcjonowanie geosystemów zlewni rzecznych. Środowisko przyrodnicze dorzecza Parsęty – stan badań, zagospodarowanie, ochrona, UAM, Poznań: 73-94. [In Polish].
JASNOWSKI M. 1975. Torfowiska i tereny bagienne w Polsce. In: (N.J. Kac, ed.) Bagna kuli ziemskiej. PWN, Warszawa. [Peatlands and marshy areas in Poland, in: Marshes of the Earth].
JASNOWSKI M., JASNOWSKA J., FRIEDRICH S. 1986. Roślinność rzeczna, torfowiskowa i źródliskowa projektowanego Drawieńskiego Parku Narodowego. Gorzowskie Towarzystwo Naukowe: 69-94. [In Polish with English summary: The vegetation of rivers, mires and springs of the projected Drawa National Park].
KARCZEWSKI A. 1998. Układ przestrzenny stref morfologicznych dorzecza rzeki Parsęty. [W:]. Funkcjonowanie geosystemów zlewni rzecznych. 1. Środowisko przyrodnicze dorzecza Parsęty – stan badań, zagospodarowanie, ochrona. A. Kostrzewski (ed.), Wydawnictwo UAM, Poznań: 15-20. [Spatial composition of morphological zones in the Parsęta river basin, in: Functioning of river basin geosystems].
KONDRACKI J. 1978. Geografia fizyczna Polski. PWN, Warszawa. [Physical geography of Poland].
KUKLA S. 1965. Rozwój torfowisk źródliskowych na terenach północno-wschodniej Polski. Zeszyty Problemowe Postępów Nauk Rolniczych, 57: 395-483. [In Polish with English summary: Development of spring mires in the north-eastern Poland].
ŁACHACZ A. 1999. Torfowiska źródliskowe Polski północno-wschodniej. In: Źródła Polski – stan badań, monitoring i ochrona. E. Biesiadka, S. Czachorowski (ed.). WSP Olsztyn: 111-121. [In Polish with English summary: Spring-water bogs in north-eastern Poland].
ŁACHACZ A. 2001. Występowanie torfowisk źródliskowych na tle typów krajobrazu Pojezierza Mazurskiego. Zeszyty Problemowe Postępów Nauk Rolniczych, 476: 453-460. [In Polish with English summary: Distribution of spring mires against the background of the landscape types of the Mazurian Lakeland].
ŁACHACZ A. 2006. Transformations of spring mires in the Borecka Primeval Forest. Polish Journal of Environmental Studies, 15(5D): 199-206.
MAZUREK M. 2006. Wypływy wód podziemnych w południowej części dorzecza Parsęty. Badania Fizjograficzne nad Polską Zachodnią, Seria A, 57: 101-118. [In Polish with English summary: Groundwater outflows in the southern part of Parsęta drainage basin].
MAZUREK M., DOBROWOLSKI R. 2006. Budowa i warunki rozwoju źródliskowego torfowiska kopułowego Ogartowo (Pojezierze Drawskie). In: XIII Konferencja „Stratygrafia plejstocenu Polski” p.t. „Plejstocen południowej Warmii i zachodnich Mazur na tle struktur podłoża”. (W. Morawski, Ed.). Państwowy Instytut Geologiczny, Warszawa: 107-108. [The structure and conditions of development of the Ogartowo cupola-mire (Drawskie Lakeland)].

MAZUREK M. 2007. Chemizm wypływów wód podziemnych w dorzeczu Parsęty (Pomorze Zachodnie). In: (P. Jokiel, P. Moniewski, M. Ziułkiewicz, Eds) Źródła Polski. Wybrane problemy krenologiczne. Łódź: 242-252 [In Polish with English summary: Chemistry of groundwater outflows in the Parsęta catchment (West Pomerania)].

OSADOWSKI Z. 1999. Ginące i zagrożone rośliny naczyniowe Pomorza na obszarze górnej zlewni Radwi. Badania Fizjograficzne nad Polską Zachodnią, 8: 151-157 [In Polish with English summary: Endangered and threatened vascular plants of in the area of the upper Radew catchments (Pomerania)].

OSADOWSKI Z. 2000. Transformation of the spring-complexes vegetation on the area of the upper Parsęta catchment. In: (B. Jackowiak, W. Żukowski, Eds.) Mechanisms of anthropogenic changes of the plant cover. Publications of the Department of Plant Taxonomy of the Adam Mickiewicz University in Poznań, 10: 235–247.

OSADOWSKI Z. 2002. Materiały do flory naczyniowej kompleksów źródliskowych dorzecza Parsęty. Cz. I. Źródliska górnej zlewni rzeki Radwi. Słupskie Prace Przyrodnicze, Seria Botanika, 1: 7-48. [In Polish with English summary: Materials for the vascular flora of spring complexes of the Parsęta catchment. Part 1. Springs of the upper basin of the Radwia river].

OSADOWSKI Z. 2006. Threatened, protected, and rare species of vascular plants in spring complexes in the central part of Polish Pomerania. Biodiversity: Research and Conservation, 1-2: 174-180.

OSADOWSKI Z. 2007. The state of preservation and the needs of protection of spring vegetation in the Middle Pomerania. Oceanological and Hydrobiological Studies, 37(1): 81-90.

OSADOWSKI Z., FUDALI E. 2001. Materiały do brioflory kompleksów źródliskowych dorzecza Parsęty Cz. I Źródliska górnej zlewni Radwi. Badania Fizjograficzne nad Polską. Zachodnią, Poznań, 50: 149-168 [In Polish with English summary: Materials for the brioflora of spring complexes of the Parsęta catchment. Part 1. Springs of the upper basin of the Radew river].

OSADOWSKI Z., WOŁEJKO L. 1997. Możliwości optymalizacji ochrony ekosystemów źródliskowych doliny Chocieli koło Bobolic (Pomorze Zachodnie). Przegląd Przyrodniczy, 8(4): 23-35. [In Polish with English summary: Optimal nature management of spring-supplied ecosystems in the Chociel river valley near Bobolice (Western Pomerania)].

PAZDUR A., DOBROWOLSKI R., DURAKIEWICZ T., PIOTROWSKA N., MOHANTI M., DAS S. 2002. $\delta^{13}C$ and $\delta^{18}O$ time record and palaeoclimatic implications of the Holocene calcareous tufa from South-Eastern Poland and Eastern India (Orissa). Geochronometria, 21: 97-108.

PAZDUR A., DOBROWOLSKI R., MOHANTI M., DURAKIEWICZ T., PIOTROWSKA N., DAS S. 2002. Radiocarbon time scale for deposition of Holocene calcareous tufa from Poland and India (Orissa). Geochronometria, 21: 85-96.

PAZDUR A., PAZDUR M.F., STARKEL L., SZULC J. 1988. Stable isotopes of Holocene calcareous tufa in Southern Poland as paleoclimatic indicators. Quaternary Research, 30: 177-189.

PN-85/G-02500 1985. Torf. Genetyczny podział surowca. [Peat. Genetic division of raw material].

PRZYBYŁEK Z. 1954. Zagadnienia stopnia rozkładu i składu botanicznego torfu w świetle nowo opracowanej metody mikroskopowo-siateczkowej. Prace Instytutu Torfoznawstwa, 4: 71-97. [In Polish with English summary: The problem of the factorization and botanical composition of peat in the new microscopic-netmicroscope-reticle method].

STEFFEN H. 1922. Zur weiteren Kenntnis der Quellmoore des Preussischen Landrückens mit hauptsächlicher Berücksichtigung ihrer Vegetation. Botanisches Archiv, 1(5/6): 261-313.

STEFFEN H. 1931. Vegetationskunde von Ostpreussen. Pflanzensoziologie, Verlag von G. Fischer, Jena: 450.

SUCCOW M. 1988. Landschaftsökologische Moorkunde. Fischer Verlag. Jena – Berlin.: 340.

SUCCOW M., JESCHKE L. 1986. Moore in der Landschaft. Urania Verlag, Leipzig – Jena – Berlin: 268.

SYLWESTRZAK J. 1978. Rozwój sieci dolinnej na Pomorzu pod koniec plejstocenu. Gdańskie Towarzystwo Naukowe, Wydział V Nauk o Ziemi, Gdańsk. [In Polish with English summary: The development of the valley system in Pomorze towards the close of the Pleistocene].

TOBOLSKI K. 2000. Przewodnik do oznaczania torfów i osadów jeziornych. Wydawnictwo Naukowe PWN, Warszawa: 1-508. [In Polish].

TOŁPA S., JASNOWSKI M., PAŁCZYŃSKI A. 1967. System der genetischen Klassifizierung der torfe Mitteleuropas. Zeszyty Problemowe Postępów Nauk Rolniczych, 76: 1-99.

WIŚNIOWSKI Z. 1998. Objaśnienia do Mapy Hydrogeologicznej Polski w skali 1:50000, arkusz Barwice. (A. Sadurski, Ed.), Państwowy Instytut Geologiczny, MOŚZNiL, Warszawa. [In Polish].

WOŁEJKO L. 1996. Stan zachowania i potrzeby ochrony dolinowych kompleksów źródliskowych na Pomorzu Zachodnim. Zeszyty Naukowe AR Szczecin, Seria Przyrodnicza, 173(63): 127-138. [In Polish with English summary: State of preservation and needs for protection of the valley spring complexes in Western Pomerania].

WOŁEJKO L. 2000a. Dynamika fitosocjologiczno-ekologiczna ekosystemów źródliskowych Polski północno-zachodniej w warunkach ekstensyfikacji rolnictwa. Rozprawy AR Szczecin, 195: 1-112. [In Polish with English summary: Plant-sociological and ecological dynamics of spring ecosystems in NW Poland under conditions of decreasing intensity of agriculture].

WOŁEJKO L. 2000b. Roślinność leśna i zaroślowa (klasy *Alnetea glutinosae* i *Querco-Fagetea*) kompleksów źródliskowych Polski północno-zachodniej. Folia Universitatis Agriculturae Stetinensis: 298-319. [In Polish with English summary: Forest and willow carr vegetation (classes *Alnetea glutinosae* i *Querco-Fagetea*) in the spring complexes of north-western Poland].

WOŁEJKO L. 2001. Stratygrafia torfowisk soligenicznych Polski północno-zachodniej. Woda – Środowisko – Obszary Wiejskie, 1(1): 83-103. [In Polish with English summary: Stratigraphy of soligenous mires in north-western Poland].

WOŁEJKO L. 2002. Soligenous wetlands of North-western Poland as an environment for endangered mire species. Acta Societatis Botanicorum Poloniae, 71(1): 46-61.

ZECHMEISTER H., MUCINA L. 1994. Vegetation of European springs: High-rank syntaxa of the *Montio-Cardaminetea*. Journal of Vegetation Science, 5(3): 385–402.

Zbigniew Osadowski[1], Małgorzata Mazurek[2], Radosław Dobrowolski[3]
[1] Department of Botany and Genetics, Pomeranian Academy,
Arciszewskiego 22B; 76-200 Słupsk, Poland
e-mail: osadowsk@sl.onet.pl

[2] Institute of Palaeogeography and Geoecology, Adam Mickiewicz University,
Dzięgielowa 27; 61-680 Poznań, Poland
e-mail: gmazurek@amu.edu.pl

[3] Institute of Earth Sciences, Maria Curie-Skłodowska University,
Kraśnicka 2 C,D; 20-718 Lublin, Poland
e-mail: rdobro@biotop.umcs.lublin.pl