Multi-proxy study of anthropogenic disturbance and climate change in a small mire in central Poland

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Summary

The Żabieniec kettle-hole mire is situated in central Poland. Peat and limnic deposits were studied with several proxies. There are also geomorphological and archeological studies being carried out in the mire surroundings. The main part of the sequence of lake sediments and peat accumulated under natural conditions. In the top part of the peat an anthropogenic disturbance was recognized as the signal of agricultural development extending from the Middle Ages to the present day.

Key index words: anthropogenic changes, climate change, kettle-hole mire, central Poland

Introduction

Żabieniec mire is situated near Łódź (25 kilometres to the east) in the area of Wzniesienia Łódzkie Landscape Park (central Poland). The peatland is located on the morainic upland in the watershed area with the Mrożyca River to the west and Mroga River to the east. The peatland area is stretched over 2 hectares (4.9 acres) and it is situated in the central part of the oval, 1.5 km long depression (without out-flow). The interdisciplinary research carried out during the past few years focused on peat archives and lake sediments. They were accumulated during the late Vistulian and the Holocene. This peatland is a kettle-hole mire, which is unusual for this part of the Polish Lowland.

The research work is being carried out by a team of experts in geomorphology, palaeobotany (pollen analysis, plant macrofossils analysis, and diatom analysis), palaeozoology (Cladocera, Chironomidae), protistology (testate amoebae) and archaeology. Laboratory work on the biogenic sediments is in progress. Age-depth model was constructed for the peat part of the profile (0.0 – 3.8 m). This paper demonstrates the results of the Holocene part of the profile.

Results

Sediments

The bottom sediment of Zabieniec mire consists of sand that was at the end of the Upper Plenivistulian. From 16.10 to 12.40 metres, mineral silt can be found and, placed directly above 12.40 m, is gyttia with silt. From 10.75 to 8.30 metres, the basin is filled with light-brown detrital – clay gyttia (accumulated in the Late Vistulian). In the layer between 8.30 and 3.8 metres, detritus brown gyttja was accumulated (with two layers of brown moss peat). Telmatic sediments can be found at 3.80 metres and upwards. The bottom of the peat has been dated at 2100 BC.

Plant macrofossil

Peat and detrital gyttja were analyzed with palaeobotanical methods (Kloss *et al.,* 2004). From 10.75 m to 8.30 m the basin is filled with light-brown detrital – clay gyttja. Fine-detrital gyttja with a low mineral content can be located between 8.3 and 6.05 metres. It also includes substantial remains of *Potamogeton natans* and *Ceratophyllum demersum.* Two layers of moss peat composed mainly of

Drepanocladus sendtneri were revealed between 6.05 and 5.2 metres. It includes also the remains of *Potamogeton natans*. Coarse-detrital gyttja can be found again at the levels of 5.2-3.8 metres. A thin layer of moss peat from *Drepanocladus sendtneri* and *Pseudocalliergon trifarium* was recorded at 4.05-4.1 metres.

Between 3.8 and 3.6 metres sedge-moss peat was found that was dominated by *Drepanocladus sendtneri* and *Pseudocalliergon trifarium*. Rootlets and sedge epiderms such as *Carex lasiocarpa, C. nigra, C. rostrata, C. elata* prevailed among herbaceous taxa. Between 3.2 and 2.15 metres, there was bog-moss peat. Its botanical composition included *Scheuzcheria palustris*, *Carex lasiocarpa*, *Carex nigra* and sometimes *Carex rostrata*. In the layer between 2.15-1.20 m sedge-moss peat was recorded, that was composed of: *Scheuzcheria palustris*, *Carex lasiocarpa*, *Carex limosa* and *Sphagnum subsecundum, S. fallax* and *Sphagnum* sec. *Sphagnum*. At 1.20-0.65 m the macrofossils composition was dominated by bog mosses of the *Sphagnum* section, mainly by *Sphagnum magellanicum*. At 0.65-0.38 m sedges remains (with *Carex elata*) appeared among *Sphagnum* . At 0.38-0.15 m sedge peat was recorded. Its botanical composition was dominated by: *Carex nigra, C. lasiocarpa, C. rostrata* and *C. elata.* Peatmosses, brown mosses were very scarce. In the top (up to 0.15 m) a thin layer of sedge-moss peat accumulated.

Pollen analysis

The pollen analysis was used to carry out an initial study of a part of a core from 0 to 8.05 metres. Four local pollen assemblage zones (LPAZ) were distinguished: *Ulmus-Corylus-Alnus* (8.05–4.55 m), *Quercus-Alnus-Corylus* (4.55–3.25 m), *Carpinus-Fagus-Abies* (3.25–0.45 m – 1541 BC to 1330 AD), Cerealia-Poaceae (0.45-0 m). *Corylus-Ulmus-Alnus-Quercus* LPAZ was correlated with the Atlantic period, while *Quercus-Alnus-Corylus, Carpinus-Fagus-Abies* and Cerealia-Poaceae were correlated with the Subboreal and Subatlantic periods.

The first signal of human activity can be found in the lower part of the *Ulmus-Corylus-Alnus* LPAZ in the form of *Plantago lanceolata* and *Rumex acetosella* pollen grain (at 6.95 m). *Plantago lanceolata* is an indicator of pasture land (Behre, 1981). However the presence of this pollen grain does not entail other changes in the plant cover. It is also possible that it comes from long distance transport.

In the top of the pollen zone *Quercus-Alnus-Corylus* (above the sample from 3.75 m, which was dated in 2075 BC) *Plantago lanceolata* and *Rumex acetosella* pollen were recorded along with the first pollen grains of cereals, and also *Polygonum lapathifolium.* Human indicators suggested the presence of crops and grazing. In this episode hazel and oak percentage decreased, but pine increased. Single pollen grains of plants connected with human activity were observed in the entire pollen zone *Carpinus-Fagus-Abies,* and changes in plant cover were very small in this period.

Cladocera

The Żabieniec mire development was reconstructed on the basis of species composition of Cladocera and their developmental phases. Subfossil Cladocera fauna in peat deposits is represented by 17 Cladocera species, belonging to 4 families. The most numerous were littoral species of the Chydoridae family (over 90%). Two phases have been identified and subsequently subdivided into subphases. Phase I (depth 3,80-0,90 m) is the phase of development of the littoral species of the Chydoridae family. At 0.90 m Cladocera disappeared. Phase II (between 0.90-0.30 m – 765AD to 1590AD) is the phase characterized by the presence of very few species. The species composition (particularly between 0.40-0.50 m – 1213 AD - 1420 AD) shows that the conditions were unfavorable for the Cladocera development. Cladocera disappeared at 0.3 m.

Chironomidae

Sub-fossil remains of dancing midges in the Żabieniec mire were analyzed to evaluate pressure of decreasing pH in the reservoir and their ecosystem and to reconstruct the main factors forming character of their assemblages. Whenever possible, 180 chironomid head capsules were taken. All the same, at least 64-taxa assemblage was maintained despite a low pH for a long time. From 5.51 to 3.51 m a typical assemblage for mesotrophic lake was formed. Specific for this zone is the abundant presence of *Ablabesmyia*, *Microtendipes chloris/pedellus* – group and *Polypedilum nubeculosum*-group, which gradually replace each other as dominants from the bottom to the upper part of the zone. It was relatively colder period. There was a noticeable change in chironomid remains stratigraphy up to 3.41 m (ca 1700 BC). Probably, it was caused by lake acidification and climate warming. At first, conditions oscillated between those favourable for fauna associated with macrophyte habitat (*Lauterborniella agralyoides*) and those for *Paratendipes nudisquama* which is typical for bogs and springs. It may reflect the large oscillation between atlantic and continental climatic conditions and influence of gradual acidification on assemblage structure. The rapid change occurs at 1.31 m (ca 470 AD), where pH drop below 5.0 and most taxa wane. Also a number of head capsules decreased. Shortly afterwards, they are replaced by three genera typical for Sphagnum bogs and soils – *Limnophyes*, *Pseudorthocladius* and *Pseudosmittia*. This storage remains until today and only the short event of human activity pressure on the mire in Middle Ages (0.41-0.26 m, i.e. 1400 to 1610 AD) caused c. 20 taxa less tolerant for low pH to come back.

Diatoms

The presence of diatoms in the sediments of the Żabieniec mire was recorded between the bottom and 8.0 metres depth. In peat bed and in upper part of limnic deposits diatoms are almost absent. Standard diatom analyses of the core from 8.0 to 11.8 metres revealed the presence of diatoms of tychoplanktonic, epontic and benthic origin with the absence of typically euplanktonic taxa, which is indicative of a low water level in the basin. The layer between 8.8 and 8.0 metres is dominated by diatom taxa characteristic of acid, oligotrophic waters, largely of the genus: *Pinnularia*, *Eunotia,* and *Tabellaria flocculosa* (Roth)

Kützing types. Between 10.00 and 9.0 meters over 70% of *Staurosira pinnata* Ehrenb. and *Staurosira venter* (Ehrenb.) Cleve and Moeller were noted in a sample. These taxa belong to the meso-eutrophic species and prefer circum-neutral-alkaline waters.

Testate amoebae

Quantitative palaeohydrological reconstruction was performed on the basis of updated training set consisting of 230 surface samples taken from natural *Sphagnum* mires in Pomerania (Lamentowicz and Mitchell, 2005; Lamentowicz, unpublished data), western Poland (Lamentowicz *et al.*, 2007; Lamentowicz *et al.*, 2008) as well as those collected in Żabieniec peatland in 2005. Testate amoebae reveal hydrology and local habitat changes occurring over the last 1400 years since *Sphagnum* appeared in the mire. It is intriguing how fast the first assemblages with *Archerella flavum* were established on the boundary between telmatic and peat sediments (1.30 m). The period of AD 1600 – AD 1350 was characterized by a relatively stable water table. A significant change in species composition was recorded in AD 1350 (0.45 m). Ca AD 1450 water table was lowered from 0.10 to ca 0.50 m (DWT – depth to the water table). Species characteristic of mineral soil and generally dry conditions – *Centropyxis aerophila* tend to dominate. Ca AD 1550 water table raised again and it was fluctuating around 0.20 m (DWT) until AD 1800 when it abruptly was lowered below 0.60 m (DWT). This dry shift may be interpreted as the sign of the local peat cutting. Testate amoebae inferred wet shifts, correlate with *Botryococcus* appearance in the pollen diagram as well as landscape openness caused by deforestation.

Geochemistry

In the analysed part of the peat core two main geochemistry zones were determined. Deposits of P-I zone (lower, 0.50-2.50 m) have very small content of mineral matter (2 to 4%, medium 2.82%). There was recorded a high content of: sodium, copper, manganese and significantly lower content of: potassium, magnesium, iron, zinc and lead. These results show 4 phases of changes of peat accumulation. The deposits of upper geochemistry zone (P-II – 0-0.50 m i.e. 1200 AD) have higher than P-I content of mineral matter. These deposits contain more potassium, magnesium and iron. Concentration of zinc and lead show almost permanent increase of deposition.

Archaeology

In the Żabieniec mire surroundings, the archaeological research has been undertaken. So far, only two points have been documented with 6 and 2 fragments of pottery dated late Middle Ages or Modern Period. Within 350 metres of the Żabieniec mire, the archaeological site Syberia Dolna, was registered as site one during the surface survey. At this site, only three fragments of pottery dated from the Bronze Age were found. In the Żabieniec vicinity the geochemistry survey has been undertaken as well. By means of a field method of estimating phosphorus (P) quantity in the ground, we have registered a few areas with an increased quantity of phosphorus, probably due to anthropogenic influence. The archaeological survey documents some very rare evidence of human activity in Prehistoric and Early Historic Periods. The first historical mention of Bielanki village situated west of the mire comes from 1392.

Conclusions

Żabieniec mire provides an interesting palaeoenvironmental record. Despite of many archeological sites documented since the Neolithic period in central Poland, the Zabieniec surroundings remained free from human impact until the Middle Ages. From the level of 0.65 m (ca AD 925), an increase in the habitat trophy has been observed. Significant changes in natural plant community, caused by human activity, were found at 0.45 m (ca AD 1300) (LPAZ: *Cerealia-Poaceae*). In this period considerable deforestation occurred accompanied by the appearance of agriculture. Mineral character of the peat connected with mineral matter deposition (aeolian and slope transport) on the mire surface that can be interpreted as caused by Medieval deforestation and then climatic instability related to the Little Ice Age. Chironomid stratigraphy in Żabieniec confirms their high tolerance of low pH (Brodin and Gransberg, 1993) but acidity under 5 strongly influenced their assemblages. It seems that rising temperature coincided with decreasing pH. Temporary neutralisation of water's pH caused by human impact was associated with eutrophication, which may reflect high percentage of *Chironomus* h.c. (Brooks *et al.,* 2007). Testate amoebae inferred wet periods correlate with *Botryococcus* appearance in the pollen diagram as well as landscape openness caused by deforestation. Intense changes of water conditions are also marked in the species composition of Cladocera. Changes content of mineral matter and potassium and magnesium in geochemistry zone P II indicate increase mechanical denudation rate (0.25-0.50 m).

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References

Behre, K.E. (1981). The interpretation of Anthropogenic Indicators in Pollen Diagrams. *Pollen and Spores* **23**, 225-245.

Brodin, Y-W. and Gransberg, M. (1993). Responses of insects, especially Chironomidae (Diptera), and mites to 130 years of acidification in a Scottish Lake. *Hydrobiologia* **250 (3)**, 201-212.

Brooks, S.J., Langdon, P.G. and Heiri O. (2007). *The Identification and Use of Palearctic Chironomidae Larvae in Paleoecology*. Quaternary Research Association, London, 276 pp.

Kloss, M., Kucharski, L. and Żurek, S., (2004). Palaeobotanical study as a basis for the protection of raised bogs in Poland. In J. Päivänen (ed.), *Proceedings of 12th International Peat Congress*: *Wise Use of Peatlands,* 875 – 880, vol. 2. *Tampere, Finland.*

Lamentowicz, Ł., Gąbka, M. and Lamentowicz, M. (2007). Species composition of testate amoebae (Protists) and environmental parameters in a *Sphagnum* peatland. *Polish Journal of Ecology* **4**, 749-759.

Lamentowicz, Ł., Lamentowicz, M. and Gąbka, M. (2008). Testate amoebae ecology and a local transfer function from a peatland in western Poland. *Wetlands* **28**, 164-175.

Lamentowicz, M. and Mitchell, E.A.D. (2005). The ecology of testate amoebae (Protists) in *Sphagnum* in north-western Poland in relation to peatland ecology. *Microbial Ecology* **50**, 48-63.