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RECONSTRUCTION OF CLIMATE AND ENVIRONMENT IN THE AUGUSTOVIAN INTERGLACIAL ON THE BASIS OF SELECT PLANT MACROFOSSIL TAXA

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Abstract: Lacustrine and fluviolacustrine organic deposits from the Czarnucha and Żarnowo profiles (NE Poland) have been examined by means of the analysis of macroscopic plant remains. The total of 264 samples have been examined, and a detailed analysis of species has shown that there are a dozen or so extinct species as well as those which are of a clear climactic and environmental significance. The location of the macroscopic plant remains which required a particular climate is associated with the warm and cold periods recorded by pollen analysis. It has been found out that such megaspores as *Azolla filiculoides* and *Salvinia natans*, fragments of nuts and thorns of *Euryale* cf. *ferox* and *Trapa natans* as well as some nuts of *Scirpus atroviroides* and *Carpinus betulus* occurred in the warm periods whereas *Betula nana* and *Selaginella selaginoides* existed in the cold periods. Both profiles abound in the species which tolerate an increased content of NaCl in their environment.

Key words: macroscopic remains of plants, Augustovian Interglacial, the Augustów Plain, northeastern Poland.

Abstrakt. Organiczne osady jeziorne i jeziorno-rzeczne z profili Czarnucha i Żarnowo (NE Polska) zostały zbadane metodą analizy makroskopowych szczątków roślin. Łącznie z obu profili przeanalizowano 264 prób, a szczegółowa analiza wyselekcjonowanych szczątków wykazała, że wśród licznie oznaczonych taksonów znajduje się kilkanaście gatunków wymarłych oraz takie, które mają wyraźną wymowę klimatyczną i ekologiczną. Analiza palinologiczna obu profili (H. Winter) wskazuje, że badane serie jeziorne powstały w interglacjale augustowskim. W profilach Czarnucha i Żarnowo udokumentowane są ciepłe i zimne okresy tego interglacjału. Obecność gatunków wskaźnikowych w wydzielonych lokalnych zespołach makroszczątków roślinnych obu profili pozwala na wydzielenie ciepłych i zimnych jednostek interglacjału augustowskiego. Oznaczone z drugiego okresu ciepłego megaspory *Azolla filiculoides, Salvinia natans* oraz szczątki *Euryale* cf. *ferox, Lemna trisulca, Trapa natans* wskazują, że temperatury letnich miesięcy musiały być wyższe niż obecnie, a temperatury miesięcy zimowych mogły być niższe. W zimnych okresach interglacjału stwierdzone szczątki *Betula nana, Selaginella selaginoides, Potamogeton pectinatus, P. vaginatus, P. filiformis* wskazują na klimat borealny. Osady badanych stanowisk obfitują w gatunki tolerujące zwiększoną zawartość NaCl w środowisku.

Słowa kluczowe: analiza makroszczątków roślinnych, interglacjał augustowski, Równina Augustowska, północno-wschodnia Polska.

INTRODUCTION

In connection with the geological and cartographic investigations carried out by the Polish Geological Institute in Warsaw about a dozen research core-holes were made on the Augustów Plain. The drillings went through the Holocene and Pleistocene deposits as deep as the Eocene and Paleocene ones (Kacprzak, Lisicki 2000; Włodek *et al*., 2002). A detailed analysis of the plant macroremains has been done for the sections representing an interglacial series of lacustrine and fluvio-lacustrine deposits in the Czarnucha (the sheet of Sztabin) and Żarnowo (the sheet of Woźna Wieś) profiles (Fig. 1). In both profiles, under the deposits in question there is a layer of glacial tills which, due to their geological position (*op. cit*.) as well as on the basis of a petrographic analysis (Gronkowska-Krystek, 2000, 2001), are referred to the oldest

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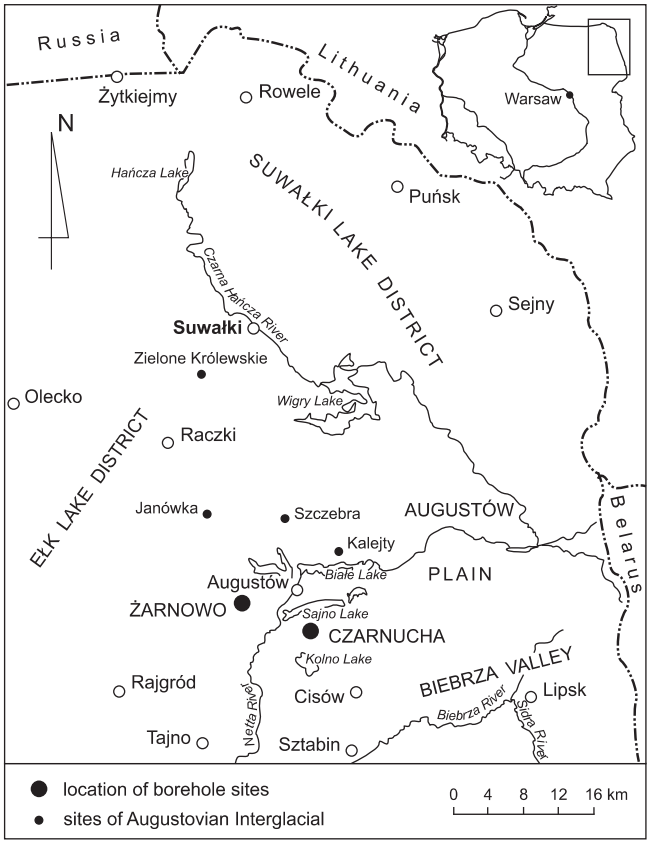

Fig. 1. Location map of the research area

glaciation, namely the Narew one. The organic series is covered with glacial tills which belong to the Nida glaciation.

A pollen analysis of those profiles records three cold periods and two warm ones in the interglacial deposits (Ber *et al*., 2002; Winter, Stachowicz-Rybka, 2002; Winter, 2003; Lisicki, Winter 2004). The pollen successions are correlated with the Augustovian succession which, on the Augustów Plain, was found in Szczebra (Ber 1996, 2000; Janczyk-Kopikowa, 1996) and Kalejty (Winter, 2001) sites.

Organogenic deposits at the depth of 100.25–129.95 m in the Czarnucha profile and at 113.15–143.55 m in the Żarnowo profile have been examined by means of macroscopic plant remains analysis.

A detailed plant remains analysis has shown that among numerous cosmopolitan species there are a dozen species or so which are of a distinct climatic and environmental significance as well as about a dozen extinct species or those which do not occur in Poland at present.

MATERIAL AND METHODS

Samples for macroscopic remains analysis from both profiles were taken in a strict correlation with the samples for pollen analysis. Each sample for pollen analysis is situated in the middle of the 10 cm section, from which the material for macroscopic analysis was taken.

127 samples from the Czarnucha profile and 137 from the Żarnowo profile have been analysed. All the samples have undergone maceration, using 10% KOH solution and detergents (in the case of very compact silts). Deposit samples of always the same capacity from a given site (Czarnucha 200 ml, Żarnowo 150 ml) were soaked in water for about 24 hours and then boiled, adding KOH. After the deposit was entirely cooked to rags, it was rinsed in a sieve with 0.2 mm mesh diameter. Tiny portions of the material left on the sieve were fingered under a stereoscopic microscope in order to fish out with a soft brush all markable plant remains which were then placed into a mixture consisting of glycerine, water and ethyl alcohol in the proportion of 1:1:1 and some thymol was added. Before marking, the remains were rinsed in a solution consisting of ethyl alcohol and water.

The macroremains were marked by means of keys, atlases and other publications, a camparative collection of contemporary seeds and fruits as well as fossil collections of museum floras which belong to the W. Szafer Institute of Botany, Polish Academy of Sciences in Kraków.

When it was possible and when the remains were in a good state, attempts were made to determine the excavated plant remains: seeds, fruits, nuts, needles, thorns and other vegetative parts up to the species level. All the remains are housed in the W. Szafer Institute of Botany Polish Academy of Sciences in Kraków.

RESULTS

THE TAXA OCCURRING IN THE WARM PERIODS OF THE AUGUSTOVIAN INTERGLACIAL

***Azolla filiculoides* Lam. foss. (Fig. 2)**

Megaspores with the dimensions of 0.43 × 0.34 mm. The upper, conical part includes 3 oval floats, situated within the ring embracing the megaspore. The ring separates the upper part from the almost spherical base (perisporium) abounding in appendices on its surphace. 732 megaspores from the Czarnucha profile and 1551 from Żarnowo have been found (some of them together with glochidia and microsporangia), both, in the first, colder period and in the second, warmer optimum of the interglacial. *A. filiculoides* is also present in the cold period separating the warm periods.

A. filiculoides is a water small fern, with small leaves. It is an American plant, mainly found in California, South America and Mexico, but in the northern part of its extent it reaches Alaska. It is a thermophilous plant, but able to stand freezing into a thin layer of ice which is formed on the surface of a basin. Late in spring it often forms dense congeneric concentrations on lake surfaces.

Fig. 2. *Azolla filiculoides* Lam., megaspores x 80

***Salvinia natans* L. (Fig. 3)**

Megaspores of average dimensions 0.5 × 0.4 mm, ovoid or round, the ending of the apex blunt, the apex being only slightly separated from the rest of the megaspore with a circular strand. Perisporium thick, off-white to brown. The surface covered with little round hollows. 674 megaspores from the Czarnucha profile and 605 megaspores from the Żarnowo profile have been found.

Fig. 3. *Salvinia natans* L., megaspore x 50

A water fern, often forming mass concentrations, similar to those of *Azolla*. It belongs to pleustonic communities. It prefers standing or slow flowing waters. *Salvinia natans* is almost a cosmopolitan species, existing in the temperature range between +7, –7°C for January and +17, +25°C for July (Mamakowa, 1997). It occurs together with *Azolla filiculoides* in both profiles.

***Carex paucifloroides* Wieliczk. (Fig. 4)**

Nuts of medium 2.3 × 0.9 mm, bilateral, protruded, narrow-oval outline, in part being the middle or the lower part. Arms frequently almost perpendicular with the style. The style quite long, tubular. The faces flat or slightly protuberant. 116 nuts in the Żarnowo profile and 279 in the Czarnucha profile have been marked. Typical for the periods preceding the climatic optima of older interglacials of Belarus (as far as the Alexandrian = Mazovian Interglacial). Known from the Lower and Middle Pleistocene. An extinct species, strongly represented in both profiles, especially in the Czarnucha profile.

Fig. 4. *Carex paucifloroides* Wieliczk., fruit x 20

***Carpinus betulus* L.**

In the second warm period of the Żarnowo profile two, heavily damaged nuts have been recorded. Nevertheless, their condition is good enough to decide that it belongs to this species. The palynological research carried out on the Augustovian Interglacial deposits points out to a very significant participation of this thermophilous tree in the woodland communities of the second warm period.

***Euryale* cf. *ferox* Salisb. (Fig. 5)**

Eight nut fragments have been found in the Czarnucha profile and 1 thorn in the Żarnowo profile. The species was found in the second younger warmer period of both profiles. The sculpture and the structure of the nut and the thorn fragments suggest that the remains belong to *E. ferox* , but it is not possible to determine it fully if a whole nut has not been found. In European Pleistocene fossil remains of *E. ferox* have been known so far from the Mazovian Interglacial (Holstein) as well

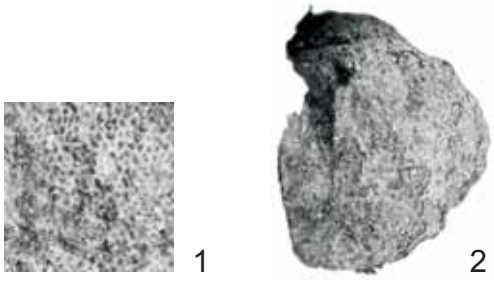

Fig. 5. *Euryale* cf. *ferox* Salisb.
1– fr. skulpture x 15, *2* – fr. seed x 5

as from Middle Pleistocene of south-eastern England (Aalto *et al*., 1996). In Poland this species was first found by Sobolewska (1970) from the Stanowice site near Rybnik, from the Mazovian Interglacial deposits. At present *E. ferox* Salisb. occurs in the tropical and subtropical zone of south-east Asia. Mean temperatures in which this species can occur are + 21°C in July and in extreme conditions it tolerates drops in temperature even to –18°C.

***Scirpus atroviroides* Dorof. (Fig. 6)**

Nuts of 0.9 × 0.55 mm, inversely ovoid, not evenly three-angular, narrow edged, oval, the dorsal wall wider than the two ventral ones, the style short and thick, round in the cross-section, the surface small-celled, lustrous. 270 nuts from the Czarnucha profile and 226 from the Żarnowo profile have been marked. Its plentiful occurence is noticed particularly in the second warm period of the interglacial, but it is also spotted sporadically in the first warm period of both sites under exploration. It is an extinct species, found between Late Pliocene and Neopleistocene (Velichkevich, Zastawniak, 2003) in the interglacial periods and serves as an indicator of warm temperate climate. Its closest relative is *S. atrovirens*, at present found in North America, between the Lake District and Florida.

Fig. 6. *Scirpus atroviroides* Dorof., fruit x 40

***Scirpus kreczetoviczii* Wieliczk. (Fig. 7)**

Average dimensions of the nuts 4.2 × 2.1 mm, inversely ovoid, three-angular, thick-walled. Ribs bluntly rounded off, often with a deep crack starting at the base. The style short, with a pyramid-like ending. It has only been found in the Czarnucha profile (26 nuts) in the second warm period. An extinct species, very typical for the Korczewo Interglacial (Velichkevich, 1982). Its climatic requirements are not known as it has no explicit equivalent in the present flora.

Fig. 7. *Scirpus kreczetoviczii* Wieliczk., fruit x 15

***Trapa natans* L.**

Fragments of nuts and thorns were found in the second, warm period in the Czarnucha and Żarnowo profiles. Optimal conditions for this species are warm basins with eutrophic waters and neutral reaction. At present it occurs in south Poland where is the northern part of its range of extent.

THE TAXA OCCURRING IN THE COLD PERIODS OF THE AUGUSTOVIAN INTERGLACIAL

***Selaginella selaginoides* (L.) P. Beauv. ex Schrank & Mart (Fig. 8)**

Macrospores with the dimensions of 0.35–0.50 mm, flat and convex with a tetraedric scar whose rays descend towards the base of the apical part. It occurs within the temperature range of –12, +7°C for January and +10, +20°C for July (Mamakowa, 1997). In the Czarnucha profile it occurs in the cold section separating the warm periods, and in the Żarnowo profile it is found in the cold section, after the second, younger, warm period.

Fig. 8. *Selaginella selaginoides* (L.) P. Beauv. ex Schrank & Mart, macrospore x 40

***Betula nana* L. (Fig. 9)**

Nuts with dimensions of 1.6 × 1.2 mm, ovoid, or irregularly round flat-convex, widened at the base, with a narrow wings. In all the three cold periods of the interglacial in both profiles nuts and fruit scales of this species were found. Its presence points to the boreal climate.

Fig. 9. *Betula nana* L., fruit x 20

***Potamogeton pusillus* L., *P. pectinatus* L., *P. vaginatus* L. (Fig. 10)**

Species preferring more severe climatic conditions. In both profiles these species occur together in the cold period which separates the warm periods of the Augustovian Interglacial.

Fig. 10. *Potamogeton pectinatus* L., endocarp x 20 (photo 1), *Potamogeton pusillus* L., endocarp x 20 (photo 2), *Potamogeton vaginatus* L., endocarp x 20 (photo 3)

SPECIES TOLERATING AN INCREASED CONTENT OF NaCl

***Zannichellia palustris* L.**

It occurs in large numbers here, especially in the Żarnowo profile, where 2029 seeds of this species have been marked. Its most plentiful occurrence is recorded in the first, warm period of the interglacial, as well as in the cold one, separating the warm periods. 334 seeds have been found in the Czarnucha profile and the largest number of them appeared in the cold period, after the second warm period. *Z. palustris* is found to settle down the most often in extreme eutrophic or slightly saline basins, strongly warmed up in summer.

Fig. 11. *Triglochin maritimum* L., fruit x 15

Apart from the above species, the plants tolerating an increased content of salt are: *Triglochin maritimum* (Fig. 11), *Najas marina*, *Schoenoplectus tabernaemontani*, *Rumex hydrolapatum*, *Potamogeton pectinatus*, *P. perfoliatus* and *P. filiformis*. These species are usually marked in both profiles in question and occur especially in the youngest, cold period and in the cold period separating the warm periods.

CONCLUSIONS

The presence of indicators species in selected local groups of plant macroremains of both profiles allows us to select warm and cold units of the Augustovian Interglacial.

The marked remains of *Azolla filiculoides*, *Salvinia natans*, *Euryale* cf. *ferox* and *Trapa natans* from the second, warm period show that the temperatures of the summer months must have been higher than at present, whereas the temperatures of the winter months might have been lower. In the cold periods of the interglacial the remains of *Betula nana*, *Selaginella selaginoides*, *Potamogeton pectinatus*, *P. vaginatus*, *P. filiformis* indicate the boreal climate.

The deposits of the sites where the research was carried out abound in species tolerating an increased content of NaCl in their environment. An extremely plentiful one from this group is *Zannichellia palustris* L. It appears the most plentifully in the first warm period of the interglacial, as well as in the cold one which separates the warm periods.

Apart from the above species, the plants tolerating an increased content of salt are: *Triglochin maritimum*, *Najas marina*, *Schoenoplectus tabernaemontani*, *Rumex hydrolapatum*, *Potamogeton pectinatus*, *P. perfoliatus* and *P. filiformis*.

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