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Biogenic sediments of the Eemian Interglacial on the Nidzica Plateau, southwestern Mazury Lakeland

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Biogenic deposits of small lakes and bogs of the Eemian Interglacial were found in kettle holes on the Nidzica Plateau, southwestern Mazury Lakeland. Absence of any glacigenic cover of these deposits proves that the plateau developed during the Mława Stadial of the Wartanian Glaciation. It has located therefore outside the ice sheet limit of the Vistulian Glaciation.

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Key words: Mazury Lakeland, Pleistocene, Eemian Interglacial, pollen analysis.

INTRODUCTION

Southwestern boundary of the Mazury Lakeland runs along the northern edge of the Nidzica Plateau (after S. Z. Różycki, 1972*b*) and coincides with a maximum ice sheet limit of the Vistulian Glaciation (Fig. 1). Principal significance for stratigraphy of the Quaternary in this area is played by occurrence of sites with deposits of the Eemian Interglacial.

Lake sediments of the Eemian Interglacial have been known from a vicinity of Nidzica already in the twenties of this century (F. Kaunhowen, 1923). Then, they were also known from boreholes in a southern part of Nidzica (Fig. 1; J. Niklewski, unpubl.; Z. Michalska, B. Marciniak, 1974). A research drilling was done to the north of Nidzica (Fig. 1) for the *Geologic Map of Poland* in scale of 1:200 000, sheet Olsztyn (A. Mańkowska, W. Słowański, 1980). Biogenic sediments from this drilling were scarcely pollen-analyzed and referred to the Eemian Interglacial (Z. Borówko-Dłużakowa, 1976; B. Marciniak, W. W. Kowalski, 1978). They were gyttjas, lake marl, silts and clays, with admixture of shales and peat, in total to 29 m thick. Among the lake sediments there were inserts of slope deposits and the whole series was underlain by sands and gravels that filled a glacial channel, meridionally cut into the Nidzica Plateau and about 80 m deep. The channel developed presumably during the Mława Stadial of the Wartanian Glaciation. During the Eemian Interglacial the lake was an overflow one what resulted in sedimentary hiatuses within a biogenic sequence, and numerous interbeddings of fluvial and slope deposits. The Eemian sequence is covered by outwash sands, over 20 m thick, formed during ice sheet retreat of the Vistulian Glaciation. This meltwater valley is used by the Nida River, i.e. an up-stream part of the Wkra River.

Previously examined sections of interglacial deposits from Nidzica are incomplete, interrupted with slope and fluvial deposits, and partly eroded. For a regional stratigraphic investigation, a significant role is played by interglacial deposits, known from deep pits and boreholes in a past brick-yard at Sewerynów to the west of Nidzica. Basing on plant macrofossils and palynologic analysis, these deposits were correlated with the Eemian Interglacial (K. Szczepanek, 1962).

Four new sites of organic sediments of the Eemian Interglacial have been drilled through in the Nidzica Plateau recently (W. Morawski, in print).

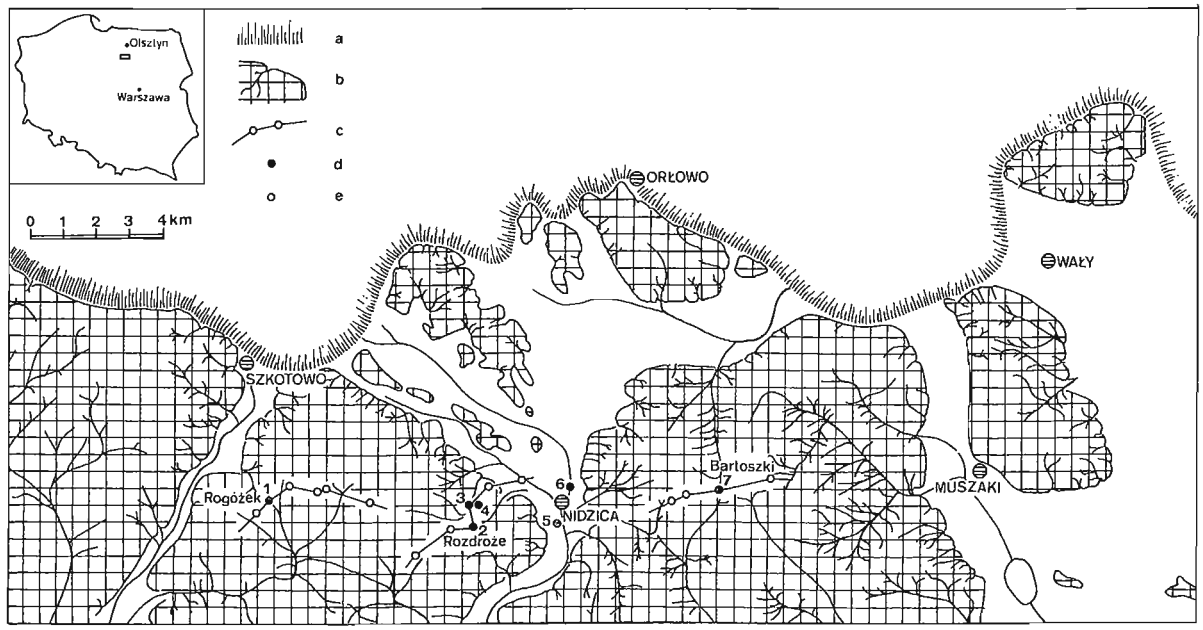

Fig. 1. Sites with biogenic deposits of the Eemian Interglacial on the Nidzica Plateau

a — maximum ice sheet limit of the Vistulian Glaciation, b — Nidzica Plateau and erosive outliers, c — geologic sections (*cf.* Fig. 2), d — boreholes with biogenic sediments of the Eemian Interglacial with original numbers: 1 — Rogóżek (SM 10), 2 — Rozdroże South (SM 37), 3 — Rozdroże North (SM 38), 4 — Sewerynów, 5 — Nidzica South, 6 — Nidzica North, 7 — Bartoszki (SM 121); e — other boreholes

GEOLOGIC SETTING

The surface of the Nidzica Plateau, occurring at 190–215 m a.s.l., is denuded. Its highest fragments are covered with patches of till of the Mława Stadial of the Wartanian Glaciation (W. Morawski, 1999, in print). A till is commonly thin, and only occasionally to a dozen metres thick (Fig. 2). It gets locally even thinner, passing into a stony residual cover. A till or residual stones are underlain by glaciofluvial sands with gravel, from several to about 20 m thick. Beneath there is a till of the Wkra Stadial of the Wartanian Glaciation, from several to a dozen metres thick. It forms a continuous layer in a prevailing part of the Nidzica Plateau. This till outcrops at plateau slopes and inside erosive incisions.

The plateau is occupied by a complex drainage pattern which connects all kettle holes (W. Morawski, 1999). This pattern is composed of dry valleys that are incised into the plateau to depth of several metres. Their slopes are gentle and bottoms are flat. The valleys are filled partly with colluvial deposits, and thin local alluvia of the Holocene occur in axes of the largest meridional valleys only. In bottoms of such dry valleys in the Nidzica Plateau, four sites with biogenic sediments of shallow water reservoirs have been found recently (Fig. 1).

Rogóżek. This site is located at a termination of a narrow dry valley, in a vicinity of two small lakes to the south-east of Szkotowo (Fig. 1). Slopes of the valley are covered with a thin till or its residuum. In the section of the borehole SM 10 there is a decalcified colluvium to depth of 4.5 m; it is sandy-clayey with gravel and boulders in the bottom, sandy-clayey in the middle and silty-clayey in the top. At depth 4.5–5.5 m there are brown-black peaty muds, underlain by grey-blue lake muds to depth of 7 m. These lake sediments are underlain by glaciofluvial sands (Fig. 2).

Rozdroże. Two sites, about 700 m apart, are located in a wide valley to the west of Nidzica (Fig. 1). Valley slopes in the upper part are composed of till of the Mława Stadial of the Wartanian Glaciation, and in the lower part there glaciofluvial sands. A southwestern, relatively steep slope is composed of till and its residuum. In the north-east, the northern site (borehole SM 38) contacts with a kame, and presumably comprises sediments of the same reservoir as the site at Sewerynów (K. Szczepanek, 1962). To a depth of 3 m there is a decalcified sandy-silty or clayey colluvium (Fig. 2), underlain by peaty muds (1 m thick) and peats (2 m thick). Below there are grey-blue silty clays and grey lake muds. The lake sediments are underlain by a till of the Wkra Stadial of the Wartanian Glaciation. At the southern site (borehole SM 37) near a present bog, biogenic sediments occur just beneath a soil, i.e. without any colluvial cover (Fig. 2). They are brown peaty muds, 5 m thick, with a peat layer. Below there are calcareous grey-bluish clays, passing downwards into clayey muds, and then into a till.

Bartoszki. This site is located in a wide flat-bottom meridional valley to the east of Nidzica (Fig. 1). Very gentle slopes of the valley are composed of thin patches of a till of the Mława Stadial, underlain by glaciofluvial sands. In a borehole SM 121 there are colluvial decalcified clayey muds to depth of 4 m, locally with sandy-gravel and boulder inserts

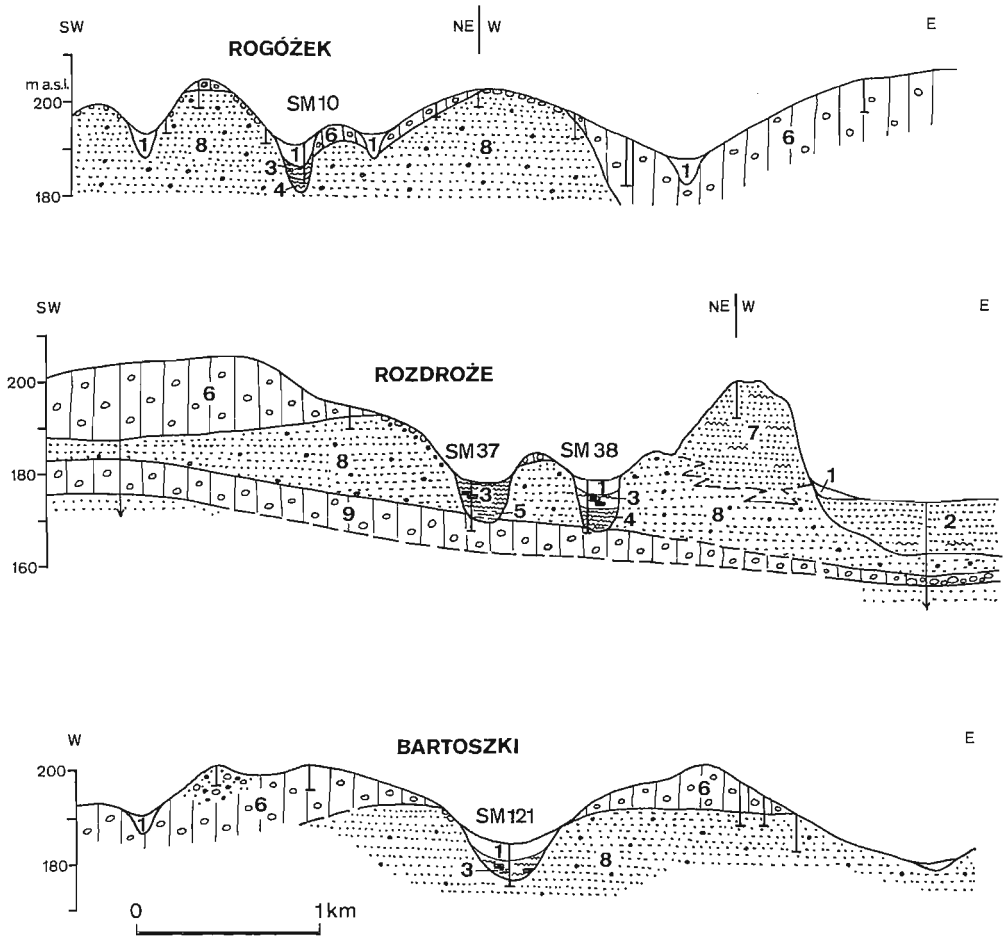

Fig. 2. Geologic sections of the sites with deposits of the Eemian Interglacial

Holocene and Vistulian Glaciation: 1 — colluvium; **Vistulian Glaciation**: 2 — outwash sands; **Eemian Interglacial**: 3 — peats and peaty muds, 4 — lake muds, 5 — lake clays; **Wartanian Glaciation: Mława Stadial**: 6 — till, 7 — kame sands and silts, 8 — glaciofluvial sands and gravels, **Wkra Stadial**: 9 — till

(Fig. 2). Under a colluvium there are (to depth of 7.5 m) peaty-gyttja muds, muddy silts with pieces of wood and peaty muds. Biogenic sediments are underlain by glaciofluvial sands with fine gravel.

Geologic setting (Fig. 2), detailed geomorphologic and palaeogeographic analysis indicate that depressions were formed during ice sheet retreat of the Mława Stadial of the Wartanian Glaciation, filled with deposits of the Eemian Interglacial, and that this area have not been covered by any glacial deposits. The plateau between Mława and Nidzica seems therefore to have been occupied by the Eemian lakeland (S. Z. Różycki, 1972*a*; Z. Michalska, 1975) and similar sites probably occur also in many other places.

PALYNOLOGY

A preliminary palynologic examination of biogenic sediments from Rogóżek and Rozdroże (K. M. Krupiński, 1995), as well as Bartoszki (H. Winter) has been done only. In spite of this, pollen spectrum enabled reconstruction of type and composition of vegetation, and determined time of deposition of individual samples.

Rogóżek. Palynologic examination focused on two samples (SM 10). Pollen spectrum of the sample 1 (depth 6.5 m: clayey silt) presents (Fig. 3) high content of *Pinus silvestris* type (37%) and *Betula* (33%), some *Juniperus* (2.4%) and *Salix* (0.7%). Abundant pollen of shrubs and herbs (26%) is represented mainly by *Artemisia* (7%), Gramineae (8%) and Cyperaceae (6%). There are abundant *Pediastrum* (50%) and *Botryoccocus* (15%). Spectrum of this sample resembles a beginning of development of birch-pine and pine-birch forest with juniper and willow. In undergrowth of these loose or patch-like communities and outside them there were motherworts, grasses, Cyperaceae, and several plants with higher light demands as *Ephedra*. Development of such vegetation communities should be correlated with the zone E-1 — *Betula-Pinus* of a pollen stratigraphy of the Eemian Interglacial from Poland (K. Mamakowa, 1989) or the zone WW-4 — *Betula-Pinus*-NAP from Warsaw (K. M. Krupiński, W. Morawski, 1993).

Pollen spectrum of the sample 2 (depth 5.5 m: peaty mud) contains much *Corylus* (30%) and *Quercus* (23%), less *Fra-*

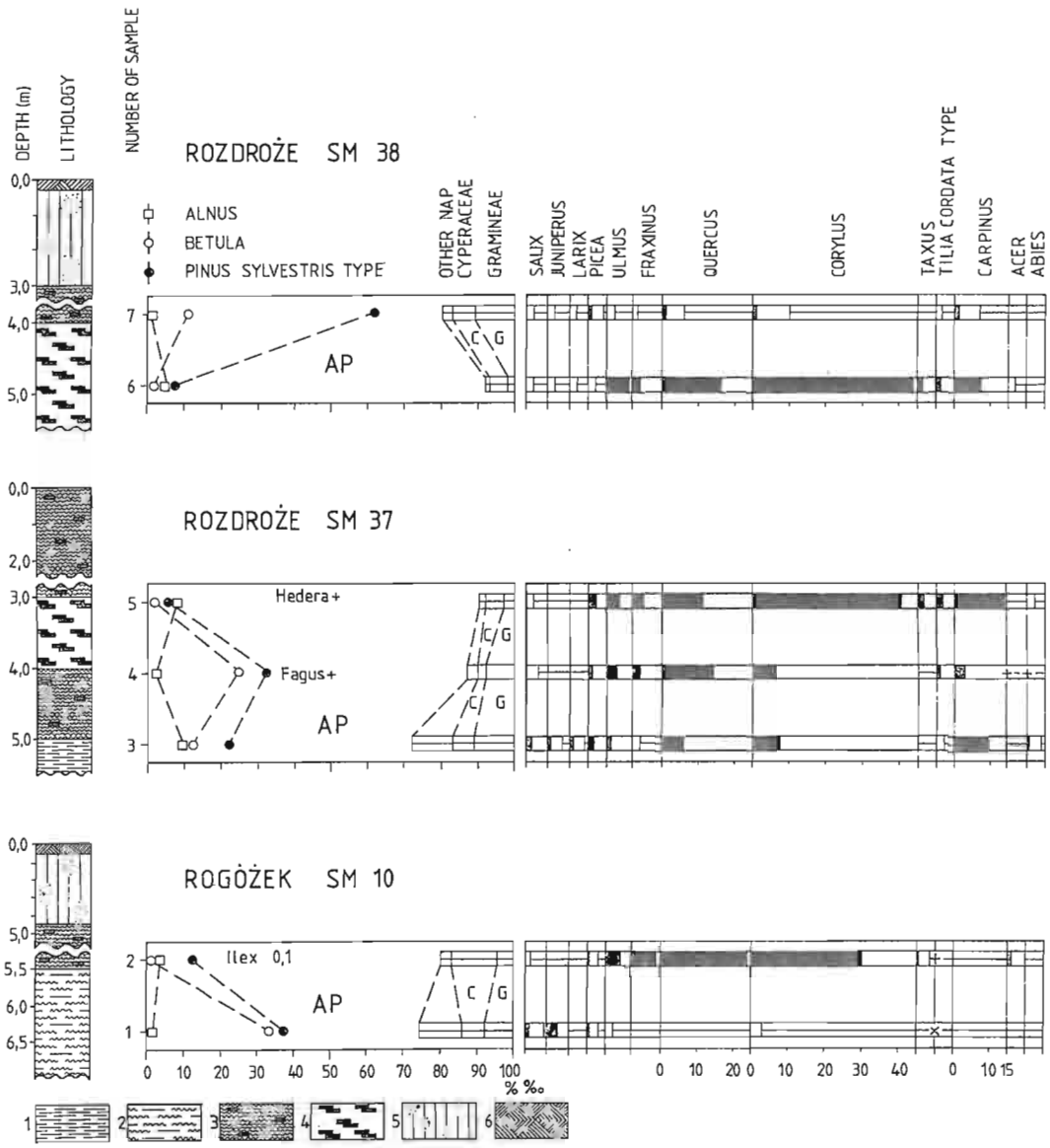

Fig. 3. Simplified pollen diagrams of the sections Rogóżek (SM 10) and Rozdroże (SM 37 and SM 38)

1 — lake clays, 2 — lake muds, 3 — peaty muds, 4 — peat, 5 — colluvium, 6 — soil

xinus (7%) and *Ulmus* (4%), and some *Alnus* (2%), *Acer, Taxus, Tilia, Ilex, Viscum* and *Humulus* (Fig. 3). Considerable content of NAP (20%) results from local over-representation of Cyperaceae. Compact forest communities predominated, with oak as the main tree and abundant hazel. Wet habitats were occupied by compact elm-ash communities, possibly also with hazel and hop. Stagnating water was covered by floating moss. Pollen spectrum of this sample can be correlated with the upper part of the zone E-3 — *Quercus-Fraxinus-Ulmus* from Poland (K. Mamakowa, 1988, 1989) or with the subzone WW-6c — *Quercus-Corylus-Alnus* from Warsaw (K. M. Krupiński, W. Morawski, 1993).

Deposition of grey silts (sample 1) should be connected with an older part of the Eemian Interglacial, comprising a beginning of the north-boreal forest. The overlying peaty muds (sample 2) correspond to replacement of oak forest with hazel — by hazel-dominated forest communities.

Rozdroże, southern site (SM 37). Palynologic analysis of three samples was done (Fig. 3). The sample 3 (depth 5.5 m: organic mud) contains rare and considerably destructed sporomorphs. There are also redeposited sporomorphs of the Tertiary plants (18%) and marine plankton Hystrichosphaeridae. The spectrum is predominated by pollen of *Pinus* and *Betula*. Significant contents of meso- and oligocratic trees as *Carpinus, Alnus, Corylus, Quercus, Picea* and *Abies*, abundant in overlying sediments, seem to be due to a secondary deposit or — what seems more probable — could be an effect of contamination during sampling. Very good conservation of sporomorphs speak for the second possibility.

However, if elements of secondary deposit and sampling contamination are neglected, the spectrum seems to reflect a

phase with loose pine-birch forest. In its undergrowth or in open areas there were abundant motherworts, grasses and Cyperaceae, with occasional crowberry and other heliophylous plants as *Ephedra, Polemonium* and rock-rose. Deposition of sediments occurred in the late glacial environment of a preceding glaciation (see K. M. Krupiński, 1992).

Spectrum of the sample 4 (depth 4 m: peat) contains strictly the Quaternary pollen, abundant and well preserved. Predominant is pollen of *Pinus silvestris* type (32%), *Betula* (24%) and *Quercus* (14%), much more rare are *Corylus* (6%), *Ulmus, Fraxinus* and *Alnus*. Relatively abundant is pollen of shrubs and herbs (13%), represented almost exclusively by Gramineae (8%) and Cyperaceae (3%). There is much *Humulus* and microsporangium of *Salvinia*. This spectrum reflects compact pine-birch forest with abundant oak and occasional hazel. Wet habitats were gradually occupied by elm-ash communities, with first specimens of alder and presumably also of hazel and hop. The whole spectrum should be correlated with a youngest part of the zone E-2 — *Pinus-Betula-Ulmus*, the oldest zone E-3 — *Quercus-Fraxinus-Ulmus* from Poland (K. Mamakowa, 1988, 1989) or with the subzone WW-5b — *Pinus-Quercus-Ulmus-(Fraxinus)* from Warsaw (K. M. Krupiński, W. Morawski, 1993).

Spectrum of the sample 5 (depth 3 m: peat which passes gradually into peaty mud) contains the Quaternary pollen only, with abundant *Corylus* (40%), less *Carpinus* (14%) and *Quercus* (11%), distinctly lower content of *Alnus, Ulmus, Fraxinus, Tilia, Taxus, Pinus, Betula* and *Picea* (Fig. 3). There is also pollen of *Hedera, Buxus, Humulus, Stellaria holostea* and *Lemna,* as well as spores of *Salvinia* and *Isotes*. This spectrum reflects occurrence of well developed and compact mixed deciduous forest, composed mainly of hazel, with hornbeam and more and more rare oak. Insignificant admixture in this forest is created by first specimens of linden and probably, also of yew. Warm, mild and wet climate favoured development of ivy, box and hop. The spectrum can be correlated with the youngest part of the zone R PAZ E-4 — *Corylus-Quercus-Tilia* from Poland (K. Mamakowa, 1988, 1989) or with the subzone WW-7d — *Corylus-Carpinus-Tilia* from Warsaw (K. M. Krupiński, W. Morawski, 1993).

Rozdroże, northern site (SM 38). Palynologic analysis was done for two samples of peat (depth 5.5 and 4.5 m). Pollen spectrum of the lower sample (6) is very similar to the one of the sample 5 from the site Rozdroże SM 37, and insignificant difference suggests slightly earlier deposition. Forest communities were similar, and the only difference was a slightly larger participation of hazel and oak, and smaller of hornbeam and alder.

Spectrum of the sample 7 (depth 4 m) is predominated by pollen of *Pinus* (62%), abundant *Betula* (11%), and also presence of *Juniperus* (2.8%), *Quercus, Corylus, Carpinus, Tilia, Ulmus* and *Fraxinus*. There is high content of microspores of *Isotes* (50%). Content of NAP reaches about 20%. Loose forest communities are predominated by pine. There is small admixture of birch and juniper, decidedly less abundant are trees with higher climatic demands (hornbeam, oak, hazel). Loose character of these communities is indicated by abundant herbs: mainly grasses, Cyperaceae and motherworts. Waters were full of quillwort. Deposition should be connected with a final part of the Eemian Interglacial. The spectrum speaks for its correlation with the zone R PAZ E-7 — *Pinus* (K. Mamakowa, 1989) or with the youngest subzone R PAZ WW-10b — *Pinus-Betula*-NAP from Warsaw (K. M. Krupiński, W. Morawski, 1993).

Bartoszki. Three samples from the section Bartoszki (SM 121) were pollen-analyzed. Pollen spectrum of the sample 3 (depth 7 m) is predominated by AP. Trees are mainly represented by *Pinus* (32%) and *Betula* (18%). Among thermophilous trees and shrubs, *Corylus* (14%) and *Quercus* (2.7%) are prevailing. Other trees (*Ulmus, Tilia cordata* type, *T. platyphyllos* type) are limited to 1.5%. There is a very low content of *Alnus* (4%) and *Picea* (1.6%). Content of NAP is equal to less than 20%. *Artemisia* (10.5%) and Gramineae (5.5%) are predominant. There is single pollen of heliophytes as *Helianthemum* and *Hippophaë*. Such pollen spectrum is typical for loose mixed forest with pine, birch, oak, linden and hazel, and in wet area with alder, spruce and elm.

The sample 2 (depth 6 m) is predominated by pollen of AP, with lower frequencies of *Pinus* and *Betula*. Share of *Corylus* reaches over 45%. Values of pollen of *Carpinus* (15%), *Quercus* (6%) and *Alnus* (8%) are rising. Therefore, the vegetation is represented by dense deciduous forest with predominant hazel.

The sample 3 (depth 5 m) is predominated by *Pinus* (47%), with *Picea* to over 10%. Contents of *Corylus, Carpinus* and *Quercus* are decreasing. Changing pollen spectrum indicates transformation of a deciduous forest into a mixed pine-spruce-hornbeam forest with admixture of birch. Wet areas are occupied by alder and elm. Presence of pollen of *Calluna vulgaris* (2%), high content of spores of *Sphagnum* and presence of peat indicate development of peatbogs.

Basing on palynological examination, the pollen spectra can be referred to a pollen succession of the Eemian Interglacial. Typical features are high contents of *Corylus* and relatively high of *Quercus*, occurrence of *Carpinus, Picea* and *Abies*. Similar pollen spectra occur in deposits of the Eemian Interglacial in a pollen diagram from Nidzica (Z. Borówko-Dłużakowa, 1976).

CONCLUSIONS

Depressions on the Nidzica Plateau, incorporated into a drainage pattern, are filled with biogenic deposits. Palynologic analysis speaks for deposition during the Eemian Interglacial. Pollen spectra were correlated with pollen zones of this interglacial in Poland (K. Mamakowa, 1989) and in Warsaw (K. M. Krupiński, W. Morawski, 1993).

Geologic setting of the Eemian series without any cover of glacial sediments proves that the Nidzica Plateau has developed during the Mława Stadial of the Wartanian Glaciation. During the Eemian Interglacial, this area was occupied by lakes which have been gradually drained. Shallow depressions on the plateau were filled with several metres thick series of biogenic sediments.

Ice sheet of the Vistulian Glaciation has not advanced onto the Nidzica Plateau which was all the time subjected to intensive denudation. Slope processes resulted in deposition of colluvial covers on biogenic series of the Eemian Interglacial.

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NOWE STANOWISKA INTERGLACJAŁU EEMSKIEGO NA WYSOCZYŹNIE NIDZICKIEJ

Streszczenie

W ramach badań geologicznych dla opracowania arkuszy Nidzica i Muszaki *Szczegółowej mapy geologicznej Polski* w skali 1:50 000 zbadano cztery nowe stanowiska osadów biogenicznych na Wysoczyźnie Nidzickiej stanowiącej bezpośrednie przedpole maksymalnego zasięgu zlodowacenia wisły (fig. 1).

Wszystkie cztery stanowiska to wypełnienia niewielkich jeziorek lub bagienek w lokalnych zagłębieniach, stanowiących fragmenty sieci drenażu na wysoczyźnie. Osady biogeniczne występują tuż pod powierzchnią terenu lub są przykryte jedynie osadami deluwialnymi (fig. 2). Powierzchnia wysoczyzny i zbocza dolinek są pokryte płatami gliny zwałowej stadiału mławy zlodowacenia warty lub kamienistymi rezyduami po tej glinie. Pod serią osadów biogenicznych występują piaski wodnolodowcowe ze żwirami, a pod nimi glina zwałowa stadiału wkry zlodowacenia warty, która miejscami odsłania się w zboczach wysoczyzny i dolinek ją rozcinających.

Stanowisko Rogóżek znajduje się ok. 9 km na zachód od Nidzicy. Pod odwapnionymi deluwiami występują namuły torfiaste, które podściela mułek ilasty. Wyniki analizy pyłkowej wskazują, że sedymentacja tych osadów przebiegała w czasie występowania luźnych lasów sosnowo-brzozowych, a następnie zwartych, mieszanych zbiorowisk dębowych z leszczyną, wiązem i jesionem (fig. 3). Cechy spektrum pozwalają wiązać sedymentację tych osadów ze starszą częścią interglacjału eemskiego.

Dwa stanowiska Rozdroże są położone ok. 3 km na zachód od Nidzicy. W stanowisku południowym pod torfami i namułami torfiastymi występują iły jeziorne, podścielone gliną zwałową stadiału wkry zlodowacenia środkowopolskiego. W stanowisku północnym pod deluwiami występują namuły torfiaste i torf, niżej leży ił mułkowaty oraz mułek ilasty, a pod nim glina zwałowa. Spektra pyłkowe 3 próbek z profilu południowego wskazują na akumulację w czasie występowania umiarkowanie zwartych lasów sosnowych z brzozą, dębem i leszczyną, a w górnej części zwartych, mieszanych zbiorowisk dębowo-leszczynowych z domieszką wiązu, jesionu, cisa i lipy (fig. 3). Spektra pyłkowe 2 próbek osadów ze stanowiska południowego wskazują, że ich akumulacja przebiegała w czasie występowania lasów dębowych z obfitą leszczyną, a w górnej części umiarkowanie zwartych lasów sosnowych z nieliczną domieszką innych drzew. Cechy spektrów próbek z obu profili pozwalają wiązać akumulację tych osadów z interglacjałem eemskim.

Stanowisko Bartoszki jest położone ok. 5 km na wschód od Nidzicy. Pod deluwialnymi namułami piaszczystymi występują namuły torfiaste oraz torf z kawałkami drewna. Osady biogeniczne są podścielone piaskami ze żwirami stadiału mławy zlodowacenia środkowopolskiego. W wyniku analizy pyłkowej trzech próbek stwierdzono spektra charakterystyczne dla interglacjału eemskiego.

Zbadane stanowiska świadczą, że zagłębieniach na powierzchni Wysoczyzny Nidzickiej występowały w interglacjale eemskim jeziorka i bagienka, w których zachodziła akumulacja osadów biogenicznych. Ten wyniesiony obszar wysoczyzny nie został przykryty żadnymi osadami glacigenicznymi w okresie zlodowaceń północnopolskich. Powyższe dane wskazują, że Wysoczyzna Nidzicka została uformowana w stadiale mławy zlodowacenia warty.