Kwartalnik Geologiczny, t. 35, nr 1, 1991 r., str. 27–36

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Deposits and pollen analysis of the Eemian Interglacial section at Sokolniki Stare (Płock Upland)

During the geological mapping to SW of Raciąż the Eemian Interglacial deposits were recorded. The pollen analysis of the samples from Sokolniki Stare allowed the authors to distinguish six pollen assemblage zones which illustrate the evolution of vegetation during the interglacial period. The geological setting of the Eemian lake area is strictly connected with the deformations of Quaternary deposits and their basement. The lake and bog depressions are concentrated along the edge of the Płock Upland slope which dips to the north toward Raciąż Depression.

Geological mapping for the *Detailed Geological Map of Poland* in the scale of 1:50 000 generally contributes great amount of data on the Quaternary of the Polish Lowlands concerning both superficial and burrowed deposits. Nevertheless uniquely there are more than important geological sites within small area of one map section.

During the geological mapping for the Raciąż sheet lacustrine, lacustrine-bog and bog sediments were found in more than ten sites.

The Sokolniki Stare profile (Fig. 1) revealed the best results in palynologic analysis. The profile was choosed after selection of prepared samples due to the preliminary palynologic expertise which indicated the Eemian spectrum. Besides the possibilities of palynologic dating of Eemian the Maliszewko profile provided well developed upper part of the sequence which represents the declining period of the interglacial and possibly of younger periods. The upper part of the profile was dated by ^{14}C method (M.F.Pazdur, M.D.Baraniecka, in print).

The present study deals mainly with the results of investigations on Sokolniki Stare profile. The profile was described as follows:

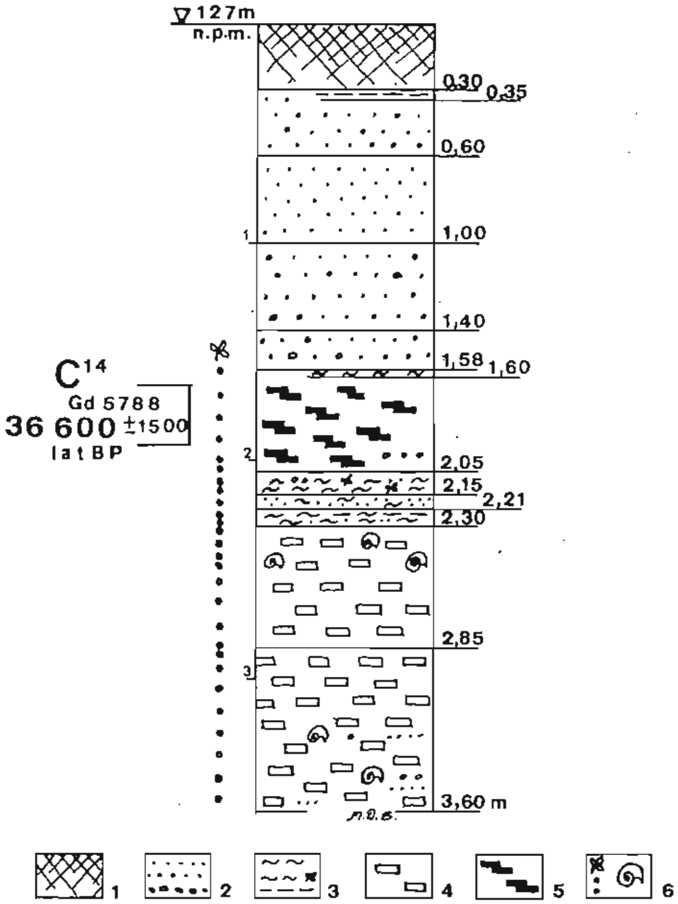

Fig. 1. Geological profile from Sokolniki Stare (probe 650)

1 – soil; 2 – fine- and vari-grained sands, gravels; 3 – silts, peaty silts, clays; 4 – gyttjas; 5 – peats; 6 – sites of sampling for pollen analyses, moluscs remnants recorded

Profil geologiczny Sokolniki Stare (sonda 650)

1 – gleba; 2 – piaski drobno- i różnoziarniste, żwiry; 3 – mułki zatorfione, iły; 4 – gytie; 5 – torfy; 6 – miejsca pobrania próbek do analiz pyłkowych, obecność okruchów mięczaków

Depth in m	**Lithological profile**
0.00–0.30	Black peat-meadow soil;–HCl.
0.30–0.35	Grey-black clay;–HCl.
0.35–0.60	Vari-grained, rusty-yellowish sand, mostly fine;–HCl.
0.60–1.00	Light grey, fine-grained sand;–HCl.
1.00–1.40	Light grey, yellowish, vari-grained sand, with admixture of gravel up to 2 cm;–HCl.
1.40–1.58	Light grey, medium- and coarse-grained sand, moderately graded, with admixture of gravel at the bottom;–HCl.
1.58–1.60	Brown silt, slightly humic;–HCl.
1.60–2.00	Black peat, well decomposed;–HCl.

2.05–2.15	Blue-blaek, vari-grained peaty silt, with lenses of sand and gravel;–HCl.
2.15–2.21	Blue-grey sandy silt;–HCl.
2.21–2.30	Grey clayey silt, tight, sandy in the lower part with thin layers of humic matter;-HCl.
2.30–2.85	Beige gyttja, with gastropods remnants, + + +HCl, similar to chalk (white if desiccated).
2.85–2.90	Beige-pink gyttja; + +HCl (white if desiccated).
2.90–3.20	Greenish-grey gyttja; +HCl.
3.20–3.60	Green-grey gyttja, dark grey in the lower part, in places with intercalations of sand, thin lenses of humic matter or gastropods remnants, darker in the lower part; brittle and lumpy, with stripes of silt and single fine gravels.

The lower part of lake deposits represents the bottom sedimentation which resulted in clayey, silty and admixtures, gravel grains content and lumpy structure. Compared with the relevant results of palynologic investigations the above data indicate the beginning of interglacial sedimentation in the lake. In adjoining sites similar lake deposits especially gyttjas of different $CaCO_3$ content were found at comparable depths of 2–4 meters. In other sites where the above deposits were pierced through the admixture of organic matter (wood, other flora remnants and fauna elements) steeply disappear at the depth of about 9 m in underlying silts e. g. at Maliszewko where silts are underlain with medium- and coarse–grained sands (or in clays e. g. at Rogotwórsk about 4 m below level (where they are underlain with till).

The results of a pollen analysis carried out for the deposits from Sokolniki Stare are illustrated in a pollen diagram (Fig. 2). The sum of tree and shrub pollen (AP) and terrestrial herbs pollen (NAP) was assumed as the basic sum constituting 100% to be used in percentage computation. 100% = AP + NAP. Pollen of aquatic plants, spores and plankton were excluded from this basic sum; their percentages were calculated in relation to it. The variability of successive pollen spectra permitted us to trace the changes in vegetational history and to distinguish local pollen assemblage zones. These zones are designated with the capital S and Arabic numerals from the bottom to the top of the interglacial series. The picture of the vegetational history with such characteristic features as high proportions of oak (*Quercus*) and hazel (*Corylus*), a significant percentage of hornbeam (*Carpinus*), a late culmination of alder (*Alnus*) and the simultaneous occurrence of fir (*Abies*) and spruce (*Picea*), made it possible to refer the deposits from Sokolniki Stare univocally to the Eemian Interglacial. Particular local pollen assemblage zones could be correlated with the regional zones distinguished by K.Mamakowa (1989*a, b*) for the Eemian Interglacial. The zones were united in three pollen periods.

Z o n e S 1 — *Pinus–Betula*. Samples 19–21; depth: 3.35–3.55 m. In the zone pine (*Pinus*) and birch (*Betula*) are dominant trees. Pine prevails in the older part of the zone, reaching an absolute maximum of 80.8%, while birch predominates in its younger part, where it, too, attains its absolute maximum of 54.2%. The sum of herbaceous plant pollen (NAP) does not exceed 7%, which indicates the great closeness of forest, which is in the nature of boreal forest starting an interglacial succession.

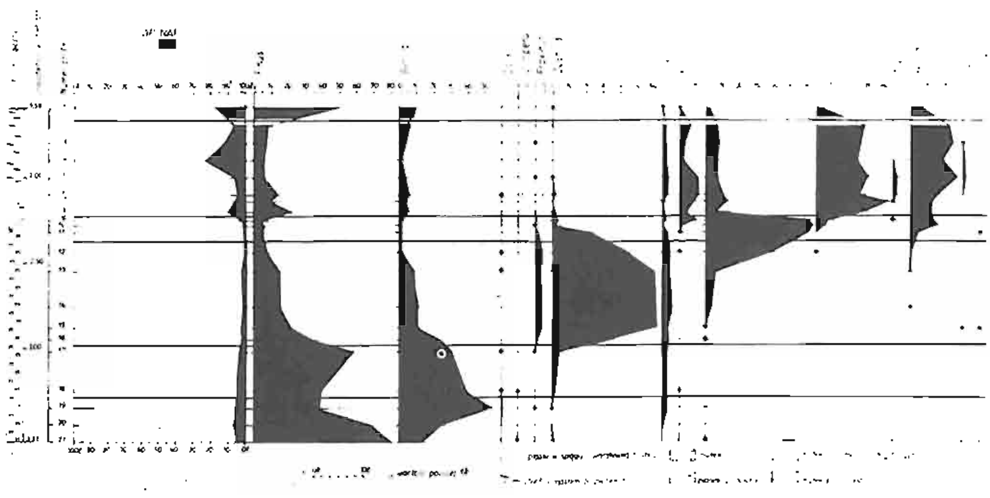

Fig. 2. Pollen diagram of the profile at Sokolniki Stare

Zone S 2 — *Pinus-Betula-Ulmus*. Samples 17–18; depth: 3.05–3.25 m. Pine (*Pinus*) and birch (*Betula*) are still dominant (55.8 and 44.0%, respectively). However low, the curves of elm (*Ulmus*), 3.0% and oak (*Quercus*), 3,6% are continuous. Lime (*Tilia*) also appears; *Sambucus* and *Viburnum* are present. The appearance of thermophilous elements (*Quercus, Ulmus* and *Tilia*) leads to a change in the forest structure. The climatic conditions become those of a temperate climate.

Zone S 3 — *Quercus-Fraxinus-Ulmus*. Samples 12–16; depth: 2.44–2.95 m. Thermophilous deciduous trees prevail in this zone. Characteristic of it is oak (*Quercus*) with a maximum pollen value of 62.0%. Also elm (*Ulmus*) attains its maximum pollen value of 6.0% here. This is, in addition, true of ash (*Fraxinus*), whose curve is continuous, the pollen value being 4.0%. Towards the end of this zone the proportion of hazel (*Corylus*) rises to 37.6%.

The originally prevalent coniferous forests gave way to oak forests. Ash (*Fraxinus*) and elm (*Ulmus*) played an important role in them. Besides, there were xerothermic thickets with privet (*Ligustrum*). A rapid expansion of hazel (*Corylus*) took place at the decline of this zone. The climate ranged from temperate to moderately warm.

Zone S 4 — *Corylus-Quercus-Tilia*. Samples 9–11; depth: 2.25–2.32 m. Hazel (*Corylus*), with its pollen values reaching 62.6%, is a characteristic taxon of this zone. Oak (*Quercus*) attains marked pollen values merely in its older part. Lime (*Tilia*), hornbeam (*Carpinus*) and alder (*Alnus*) grow in importance and reach higher values at the decline of the zone. Yew (*Taxus*) appears. The vegetation of this period, in addition to mixed oak forests, may have been composed of thickets or hazel woods. Generally speaking, the vegetation is clearly of a thermophilous nature and together with the vegetation of zone S 3 reflects a broadly conceived interglacial climatic

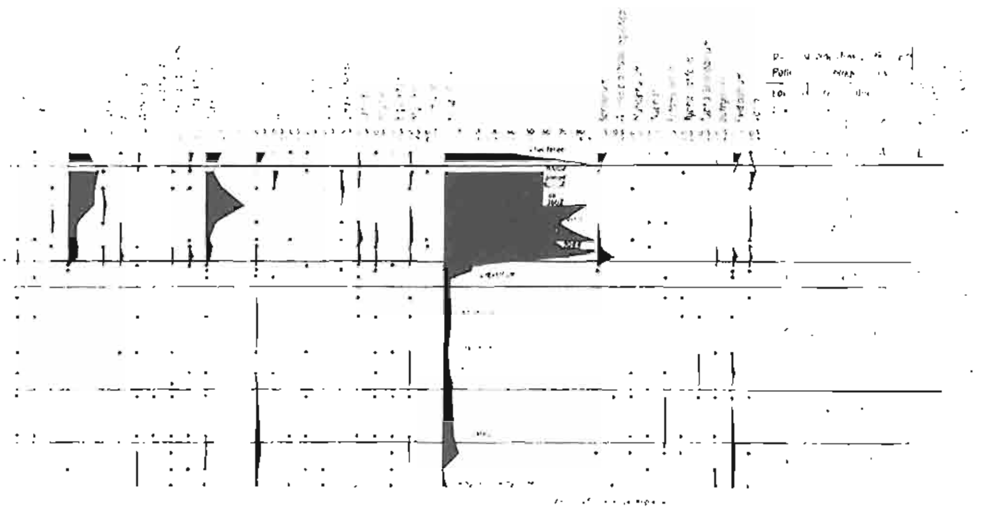

Diagram pyłkowy z profilu Sokolniki Stare

optimum. The role of pine (*Pinus*) and birch (*Betula*) is slight and the NAP values are the lowest in the whole profile (2.0%).

Z o n e S 5 — *Carpinus–Corylus–Alnus*. Samples 2–8; depth: 1.70–2.20 m. Hornbeam (*Carpinus*), with its maximum pollen values reaching 42.4%, is the — tree by which this zone is distinguishable. Alder (*Alnus*) also reaches its maximum pollen value of 26.4%. A fall in the pollen values of hazel (*Corylus*) is noted. On the other hand, it is not but here that lime (*Tilia*) has its peak of 11.0%. Yew (*Taxus*) appears in this zone, with its pollen value of 1.5%. Vine (*Vitis*) is present and so is the frequent ivy (*Hedera helix*). In the younger part of the zone spruce (*Picea*) grows in significance and fir (*Abies*) appears.

Hornbeam (*Carpinus*), which becomes dominant, brings changes in the nature of the forest. Forming communities of an oak-hornbeam forest type, it succeeded in ousting hazel (*Corylus*) and, partly, lime (*Tilia*).

At the onset of this zone the climate was still warm and oceanic but it underwent a cooling in its younger part. This is evidenced by the expansion of spruce (*Picea*) and fir (*Abies*).

Z o n e S 6 — *Picea–Abies–Alnus*. Sample 1; depth: 1.59 m. The pollen spectrum of this sample has been referred to the regional *Picea–Abies–Alnus* zone in view of the rise of pine (*Pinus*) pollen values and the distinct decrease in the proportion of hornbeam (*Carpinus*) pollen. Spruce (*Picea*) pollen values come to 10.4% and those of alder (*Alnus*) to 5.2%. The climate underwent a further cooling. The pollen spectrum of the sample from a depth of 1.59 m terminates the interglacial pollen sequence at Sokolniki.

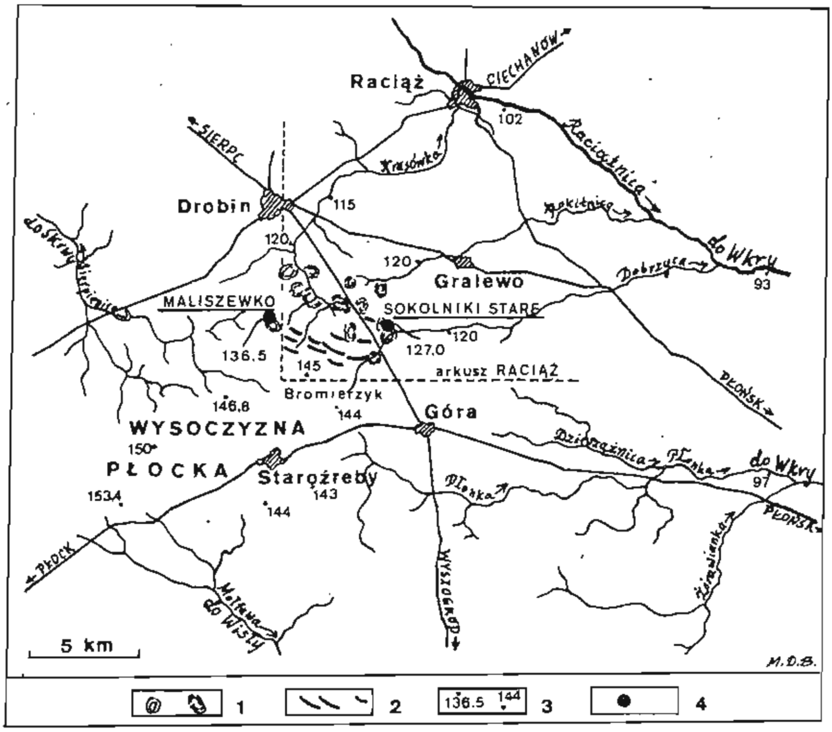

Fig. 3. Eemian lake depressions at the background of the drainage basin in the north part of Plock Upland

1 – Eemian lake depression; 2 – area of Tertiary and Older Quaternary uplifted deposits; 3 – elevation in meters a.s.l.; 4 – selected sites of investigations

Położenie obniżeń — pozostałości kopalnych jezior z interglacjału eemskiego — na tle sieci rzecznej odwadniającej północną część Wysoczyzny Płockiej

1 – obniżenia — pozostałości po kopalnych jeziorach eemskich; 2 – strefy wypiętrzeń osadów trzeciorzędowych i starszego czwartorzędu; 3 – wysokości w m n.p.m.; 4 – wybrane stanowiska badawcze

The state of preservation of pollen grains and spores also calls for discussion. In the case of pollen grains obtained from the profile starting from its bottom to a depth of 2.10 m the state was very good and the frequency of grains very high. However, the samples from depths of 1.70 to 2.00 m showed a very low frequency of pollen grains. In these samples only spores of *Polypodiaceae* occurred in huge quantities. This may be explained by a local expansion of ferns, which has found its reflection in the pollen spectra. Besides the low frequency of pollen, the grains from the samples from 1.70 to 2.00 m were heavily deteriorated, which may have been caused by the weathering of deposits owing to the lowering of the water level. This fact put an end also to further accumulation of peat. Indirect evidence of this is provided by the fragmentary development of the *Picea–Abies–Alnus* zone and the lack of deposits from the decline of the interglacial in the profile.

The age of peat from the interval 1.6–1.9 m is determined at 36 600±1500 BP due to ^{14}C dating (M.F.Pazdur, 1990) and differs from the results of pollen analyses. According to the pollen diagram (see Fig. 2, zone S 5) the same interval of deposits represents the period of *Carpinus* forest with *Corylus* and *Alnus* which are typical of the transition between Eemian Interglacial optimum and its declining stage. Although concerning general data the above period is much more older. That allows to suppose some reasons which "rejuvenated" the peat layer. Low content of weathered pollen grains in this section of the profile indicates possible soil formation factors which caused also "rejuvenation" of humic matter. Thus the date of 36 600 BP represents rather the age of alteration deposits connected with illuvial accumulation of younger humic matter within the older, weathered peat. Another possibility considered is the indirect influence of Holocene processes. But in that case humic matter would have penetrated into Eemian deposits through permeable layer of barren deluvial sands (about 1.3 m thick) which underlie the soil cover and overlie Eemian deposits in the depression described. Consequently the radiometric date would derive from different age humic elements.

The closest recorded and comprehensively described sites of Eemian Interglacial deposits are located at Główczyn (H.Ruszczyńska-Szenajch, 1964; J.Niklewski, 1968) about 40 km to SE and at Nidzica (Z.Borówko-Dłużakowa, 1976; B.Marciniak, W.W.Kowalski, 1978 — pollen analysis by J.Niklewski) about 80 km to NNE from Sokolniki Stare. Less carefully examined sites of Eemian were found at Bylice (J.Nowak, 1967; Z.Borówko-Dłużakowa, 1959, 1973) and at Falbogi (M.D.Baraniecka, 1974; Z.Janczyk-Kopikowa, 1966).

Occurrence now the lacustrine deposits have not been reported on the general geological maps of the area (A.Bałuk, 1978). The region described is a part of relatively high glacial upland (Fig. 3). It mounts toward the south at Góra, Bromierzyk and Staroźreby up to 140 m a.s.l. This part of the area — the center of Płock Upland — is situated on the watershed. Several small watercourses which compose the entire drainage basin begin in the vicinity of it. Waters outflow by Żurawianka and Płonka to SE, by Dzierzążnica to E, by Dobrzyca to NE, by Krasówka to N, by Sierpienica to NW and W, and by Mołtawa to SW and S. The described part of the upland is located between watersheds of Krasówka and Dobrzyca. There are many depressions of pothole character there. They are barely connected with the surface drainage system by small streams or dug up water rows. Most of the potholes represent buried Eemian lakes and bogs. At Sokolniki Stare the pothole is linked by a water row with Dobrzyca which inflows Raciążnica river toward theeast and 20 km further contributes Wkra river. The Depression at Maliszewko is almost an isolated pothole without any perennial drainage, and the periodic outflow directs mostly toward the west to Sierpienica river. The latter inflows Skrwa river about 40 km from the investigated area. Other potholes at Setropie and Olszyny are linked by drainage rows with Krasówka watercourse in the north, which in turn inflows Raciążnica river at Raciąż about 15 km to the north.

According to the results of mapping on the Raciąż sheet the assemblage of potholes occupies the area of deformed Quaternary deposits and their basement. Probably the same processes influenced the area of Staroźreby, Bulkowo and Drobin.

In the Raciąż vicinity all potholes representing lakes and bogs of Eemian are very clearly recognizable both in the landscape and in deposits. Lake basins are situated among or close to elevations of Older Quaternary and its basement. During geological survey on the Raciąż sheet, in several outcrops, boreholes and waterwell profiles many sections revealed deformed deposits. They have been reported by A.Bałuk (1979) from the neighbourhood of Gralewo due to relatively high position of Pliocene deposits and anomalous within Pliocene and Miocene basement.

On the surface around Eemian lake basins there are stripes of Older Quaternary varved clays, Pliocene silts and variegated clays as well as Miocene (possibly also Oligocene) sands, clays and brown coals. Especially white sands and quartz sands with admixture of kaolin are elevated and exploited in few outcrops. The pattern of these deposits suggest either anticlinal or thrust-like structure of the zone limiting the post-lake area from the south. Deformational structures (considerable dip of layers) are observed in some outcrops e.g. at Wrogocin and Bromierzyk—Pieńki as well as in the described Gralewo borehole where laminated Pliocene deposits are inclined vertically.

Deformations of structure, and particularly uplifts were formed preasumably in few phases. Actually it is not possible to precise neither their origin nor age. However, undoubtedly they influenced both the transgression and the decay of the ice sheet during the last stages of glaciation in described area. On the north slope of Płock Upland the ice sheet disintegrated by cracks upon the uneven, deformed basement. The network of cracks became the area of potholes after the ice blocks decayed. No valleys or outwash plains were formed. Shallow lakes and bogs started to occupy depressions and continued to exist during Eemian Interglacial. Their location on the slope of the upland (from 140 m a.s.l. in the South to 120 m a.s.l. in the North) was unfavourable to accumulate any deposits during the Last Glaciation and Holocene. Ice-dammed lakes in front of the last ice margin did not reach them and any thicker river sequence was not found there although known from broader valleys. Some of the Eemian lake depressions were being filled with fine material and organic matter during the Last Glaciation (e.g. Maliszewko), the others (e.g. Sokolniki Stare) accumulated deluvial material upon Eemian deposits. In Holocene according to the water saturation, meadow soils and peats and alluvial deposits were being accumulated in the former lake basins. It is supposed that nowadays the processes of soil and peat forming are declining because of artificial drainage and general deepening of the upper pool elevation.

Further geological investigations, pollen analyses, dating of deposits and lithologic expertises at Sokolniki Stare, Maliszewko and in other sites increase knowledge on Eemian lake area at the northern slope of Płock Upland.

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Received: 27.02.1991

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OSADY I ANALIZA PYŁKOWA INTERGLACJAŁU EEMSKIEGO Z PROFILU SOKOLNIKI STARE (WYSOCZYZNA PŁOCKA)

Streszczenie

Podczas badań potrzebnych dla sporządzenia *Szczegółowej mapy geologicznej Polski* na SW od Raciąża stwierdzono szereg profili z kopalnymi osadami organicznymi. Do badań wybrano w pierwszej kolejności profil Sokolniki Stare (fig. 1) i profil Maliszewko. Kopalne osady reprezentowane są przez facje jeziorne, jeziorno-bagienne i bagienne. Są to gytie, kredy jeziorne i łąkowe, torfy i mułki o różnej, częściowo znacznej zawartości humusu, ze szczątkami skorupek ślimaków. W wytypowanych profilach przeprowadzono częściowo badania palinologiczne i oznaczenia wieku metodą radiowęgla ^{14}C.

Najlepszy do analizy pyłkowej okazał się profil Sokoliniki Stare. W diagramie pyłkowym (fig. 2) stwierdzono 6 poziomów zespołów pyłkowych interglacjału eemskiego. Są to od dołu: S 1 — *Pinus–Betula*, S 2 — *Pinus–Betula–Ulmus*, S 3 — *Quercus–Fraxinus–Ulmus*, S 4 — *Corylus–Quercus–Tilia*, S 5 — *Carpinus–Corylus–Ulmus* i S 6 — *Picea–Abies–Alnus*. W stropowej części warstw organicznych stwierdzono niską frekwencję oraz zniszczenie ziarn pyłku, spowodowane zapewne obniżeniem poziomu wody i wietrzeniem.

Datowanie osadów metodą radiowęgla ^{14}C nie pozostaje w zgodzie z wynikami analizy pyłkowej. Doszukiwać się można przyczyn "odmłodzenia" substancji humusowej.

Stwierdzenie w Sokolnikach Starych obecności i następstwa sześciu kolejnych poziomów zespołów pyłkowych charakterystycznych dla interglacjału eemskiego pozwala określić, że niecki jeziorne występujące na powierzchni omawianego obszaru są pozostałością pojezierza z interglacjału eemskiego. Niecki i osady tych jezior zostały częściowo zasypane osadami mineralnymi w okresie ostatniego zlodowacenia. Na nich rozwinęły się holoceńskie torfowiska, bagniska lub procesy glebotwórcze. Obecnie obserwuje się przejawy zaniku reliktowych jezior, obniżenia wód gruntowych i degradacji roślinności wodnej w obniżeniach i zabagnieniach.

Położenie kopalnego pojezierza związane jest z obszarem stoku Wysoczyzny Płockiej (fig. 3) opadającej od około 140 m n.p.m. koło Starożrebów ku północy na obszar niżej położonej wysoczyzny i dalej ku Kotlinie Raciąskiej. Występowanie reliktowych niecek jeziornych związane jest z obszarem załamania stoku, a równocześnie strefą zaburzeń osadów czwartorzędowych i ich podłoża.

Badania podobnych profili kopalnych osadów organicznych będą dalej prowadzone dla rozszerzenia znajomości przebiegu zaniku jezior eemskich i zmiennych procesów z okresu ostatniego zlodowacenia i holocenu.