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RECONSTRUCTION OF ENVIRONMENTAL CHANGES IN THE EEMIAN PALAEOLAKES ON THE BASIS OF ISOTOPIC DATA

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Abstract. Results of oxygen and carbon isotope analyses of Eemian lacustrine sediments from two sites from central Poland are presented. The Besiekierz palaeolake is located about 25 km north of Łódź at 130 m a.s.l. The 4 m thick sediments are represented by silty sands and clayey silts, overlain by gyttja and organic silts and peat. The Studzieniec palaeolake is located near Sierpc at 112 m a.s.l. The sediments above 19 m thick of Studzieniec core were analysed. The succession contains silty sands and clayey silts on the bottom, then gyttja, organic silts and peat in the upper part. Results of pollen analysis document that the sediments from Besiekierz and Studzieniec accumulated during the final part of the Wartanian Glaciation through to the Vistulian Glaciation. Based on the results of stable isotope analyses of sediments the isotopic horizons (Is) were defined and characterized for each succession. Results of isotopic analysis correlated with pollen data enabled reconstruction of both climatic and hydrological processes such: a lake deepening and/or an influx of groundwater enriched in light isotopes (at Besiekierz — Is 3-Be; at Studzieniec — Is 3-St); a warming of climatic conditions (at Besiekierz — Is 3–8-Be; at Studzieniec — Is 3–6-St); an increase of biological activity or existence of methanogenesis (at Studzieniec — Is 7-St). The positive correlation of $\delta^{18}O$ and $\delta^{13}C$ curves is characterized for the closed system of lake.

Key words: stable isotopes, Eemian Interglacial, palaeoenvironment, central Poland.

Abstrakt. Wykonano oznaczenia składu izotopów trwałych tlenu i węgla dla osadów jeziornych, zawierających węglan wapnia, z dwóch profili: Besiekierz i Studzieniec (centralna Polska). W Besiekierzu (ok. 30 km na północ od Łodzi) pod osadami piaszczysto-gliniastymi występuje seria osadów jeziorno-bagiennych złożona z gytii, mułków organicznych i torfów. W Studzieńcu k. Sierpca (112 m n.p.m.) osady jeziorne wykształcone są: w spągu — w postaci mułków słabo węglanowych, wyżej — gytii, a w stropie — mułków organicznych i torfów. Na podstawie wyników analiz palinologicznych stwierdzono, że badane osady były akumulowane od schyłku zlodowacenia warty, przez interglacjał eemski, do początku zlodowacenia wisły. Uzyskane wyniki oznaczeń izotopowych pozwoliły na wydzielenie i scharakteryzowanie horyzontów izotopowych (Is) dla każdego profilu. Korelacja danych izotopowych i palinologicznych umożliwiła rekonstrukcję zmian klimatycznych i hydrologicznych zachodzących w okresie interglacjału eemskiego, takich jak: pogłębienie zbiornika i/lub dopływ wód bogatych w lekkie izotopy (Besiekierz — Is 3-Be, Studzieniec — Is 3-St), ocieplenie klimatu (Besiekierz — Is 3–8-Be, Studzieniec — Is 3–6-St), wzrost aktywności biologicznej lub występowanie zjawiska metanogenezy (Studzieniec — Is 7-St). Ponadto zaobserwowana współkształtność krzywych izotopowych w obu profilach jest charakterystyczna dla zamkniętych systemów jeziornych.

Słowa kluczowe: izotopy stabilne, interglacjał eemski, paleośrodowisko, centralna Polska.

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INTRODUCTION

The results of isotopic investigations of Eemian lake sediments from two sites from central Poland are presented (Fig. 1).

The lacustrine sediments often contain authigenic carbonates and fossil shells whose oxygen and carbon isotope composition is measured. The oxygen isotope composition of authigenic carbonates is controlled by the isotopic composition of host water and water temperature at which carbonate precipitation took place (Craig, 1953; Hoefs, 1996; Schwalb, 2003). Two major processes may influence on this composition. The first is evaporation, intensification of which causes lake shallowing and enrichment in heavy isotopes. The second process is an influx of fresh water into the lake, which causes its deepening and relative depletion in the heavy isotope (Talbot, 1990). In addition the isotopic composition of lake water depends on the amount of precipitation in the catchment and the processes that affect the isotopic composition in the lake such as evaporation that changes with relative humidity, temperature, wind stress, relation of lake surface versus volume, and residence time (Schwalb, 2003). The oxygen isotope composition of the lake water is determined by the atmospheric component of the global hydrological cycle and reflects the mean oxygen isotopic composition of catchment precipitation, which is primarily a function of latitude, modified by orography and continentality (Hoefs, 1996; Różański *et al*., 1998; Schwalb, 2003) — Figure 2.

The carbon isotope composition of authigenic carbonates is determined by the isotopic composition of bicarbonate (HCO_3^-) — a form of dissolved inorganic carbon (DIC). The isotopic composition of lake water DIC is a complex function of isotopic exchange with atmospheric CO_2, water residence time, the volume of incoming groundwater and the influx of dissolved carbonates, the rate of photosynthesis and the CO_2 production during the decay of organic matter (Craig, 1953; Różański *et al*., 1998; Schwalb, 2003) — Figure 3.

Many of these factors are connected with climate conditions, thus the results of investigations of oxygen and carbon isotopes enable the interpretation of past climate (Stuiver, 1970). Numerous isotopic studies of lacustrine deposits demonstrated the usefulness of stable isotopes as a powerful tool in reconstructing past climatic and environmental changes (Litt *et al*., 1996; Drescher-Schneider, Papesch, 1998; Schwalb, 2003).

The isotopic record indicates an earlier response to climatic fluctuations and changes in the sedimentary than the pollen data (Nitychoruk, 2000).

Combining palaeobotanical results with isotope data helps to reconstruct more detailed palaeoclimate reconstruction for the Eemian Interglacial (Litt *et al*., 1996; Drescher-Schneider, Papesch, 1998).

Many of sites of Eemian deposits in Poland, were very well palynological documented (Mamakowa, 1988, 1989; Janczyk-Kopikowa, 1991, 1997; Krupiński, Morawski, 1993; Krupiński, in press; Kupryjanowicz, Drzymulska, 2002; Biñka, Nitychoruk, 2003). Some of them have been analysed as regards the diatoms (Kaczmarska, 1976; Marciniak, Kowalski, 1978) and Cladocera remains (Mirosław-Grabowska, Niska, 2005).

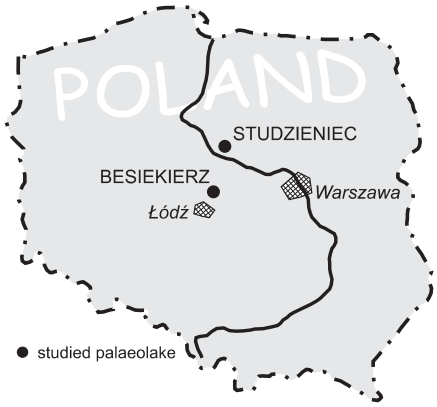

Fig. 1. Location of the studied palaeolakes

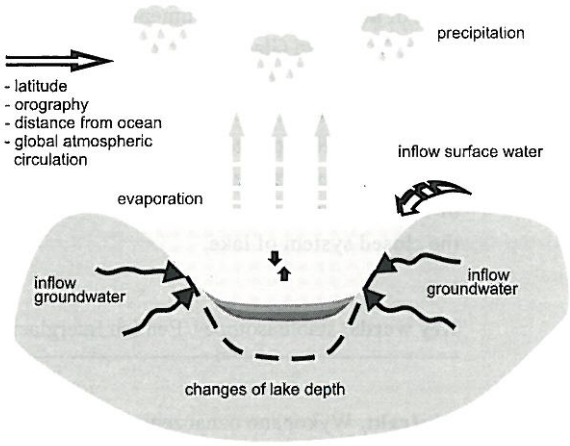

Fig. 2. Processes influence on the oxygen isotopic composition

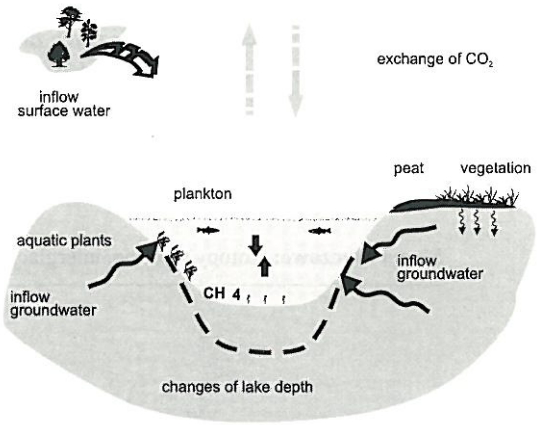

Fig. 3. Factors influence on the carbon isotopic composition

MATERIALS AND METHOD

The Besiekierz palaeolake is located about 25 km north of Łódź at 130 m a.s.l. (Klatkowa, 1972) — Fig. 1. The 4 m thick sediments of Besiekierz core were palynological investigated (Janczyk-Kopikowa, 1991). The lowest part (depth: 5.8–6.2 m) is represented by silty sand and clayey silt, containing below 10% of $CaCO_3$. Then (depth: 3.6–5.8 m) the bright brown and grey gyttja (25–87% of $CaCO_3$) appears (Fig. 4). The upper part (depth: 2.2–3.6 m) of this succession contains organic silts and peat. The published results of pollen analysis indicate that the sediments accumulated during the Late Wartanian Galciation, the Eemian Interglacial and the Early Vistulian Glaciation (Janczyk-Kopikowa, 1991).

The carbon and oxygen isotope composition was estimated for the carbonate sediments from the depth interval: 3.6–6.1 m. Stable isotope carbon and oxygen analyses were carried out on 53 samples of sediments (Fig. 4).

The Studzieniec palaeolake is located near Sierpc at 112 m a.s.l. (Fig. 1). Above 19 m thick sediments of Studzieniec core were analysed (Kotarbiński, Krupiński, 1995; Krupiński, in press). On the bottom (below 19.2 m) silty sand and clayey silt occur, containing below 20% of $CaCO_3$. Then (depth: 10.6–19.2 m) the bright brown and greyish gyttja appears (Fig. 5). The gyttja is characterized by increasing content of $CaCO_3$ to above 70%. The upper part (above 10.6 m) of this succession contains organic silts and peat. Based on the palynological data, the local pollen assemblage zones were distinguished and then correlated with regional pollen assemblage zones (R PAZ). Results of pollen analysis indicate that the sediments accumulated from the Late Wartanian to the Vistulian Glaciation (Kotarbiński, Krupiński, 1995; Krupiński, in press).

The carbon and oxygen isotope composition was estimated for the carbonate sediments from the depth interval: 10.8–19.3 m (79 samples) — Figure 5.

Stable isotope carbon and oxygen analyses are carried out on samples of carbonate sediments using the standard phosphoric acid method (McCrea, 1950). The isotopic composition was measured with a Finnigan MAT Delta $^+$ gas spectrometer at the Institute of Geological Sciences, Polish Academy of Sciences in Warsaw. The concentration of ^{18}O and ^{13}C isotopes in the samples are presented as $^{18}O/^{16}O$ and $^{13}C/^{12}C$ isotope ratios versus the V-PDB standard. The analytical error is ±0.1‰ for $\delta^{18}O$ and ±0.05‰ for $\delta^{13}C$. From the results of stable isotope analyses the isotopic horizons (Is) for each succession were distinguished (Fig. 4, 5).

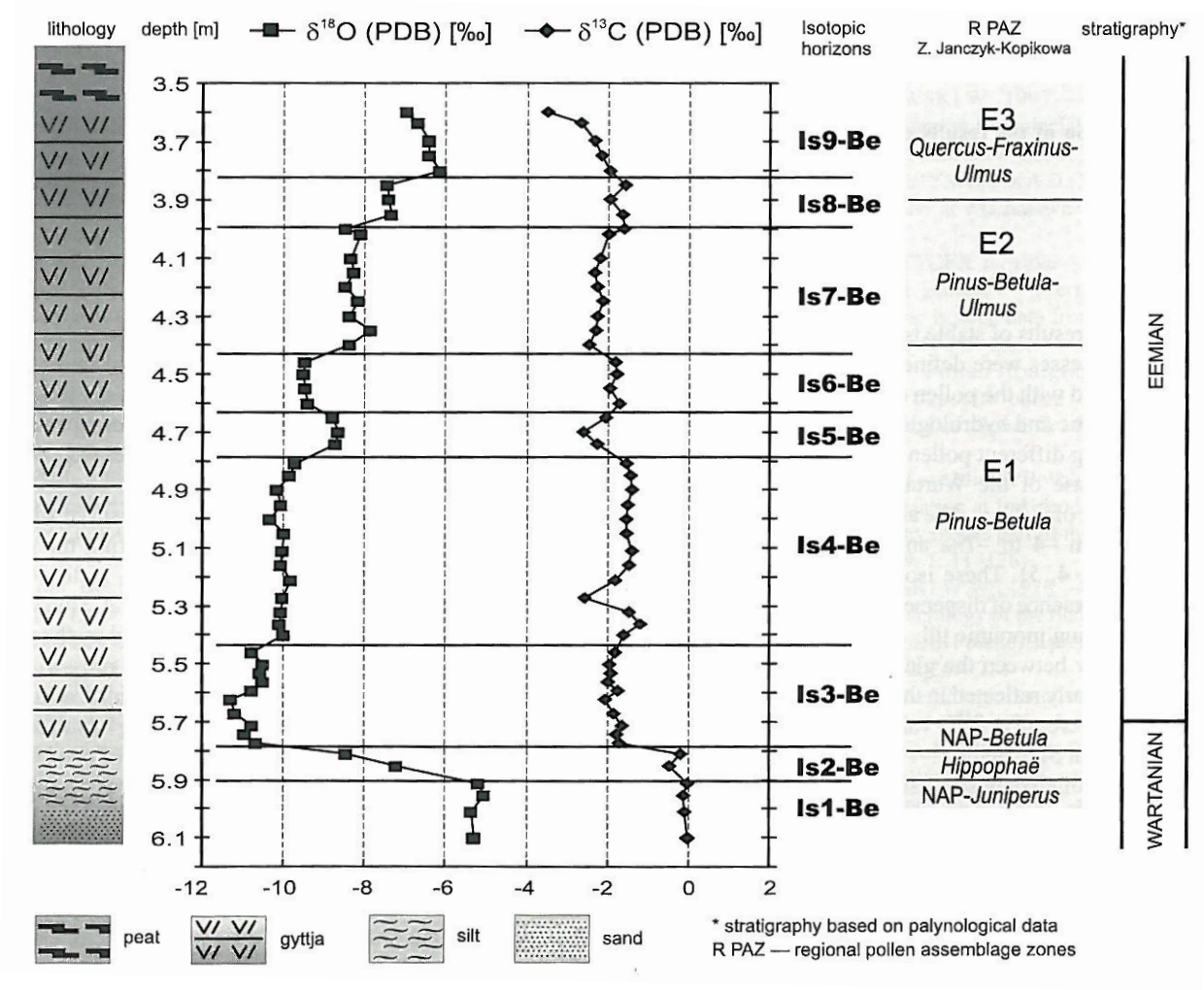

Fig. 4. Correlation of the results of isotopic and palynological analyses in the Besiekierz section

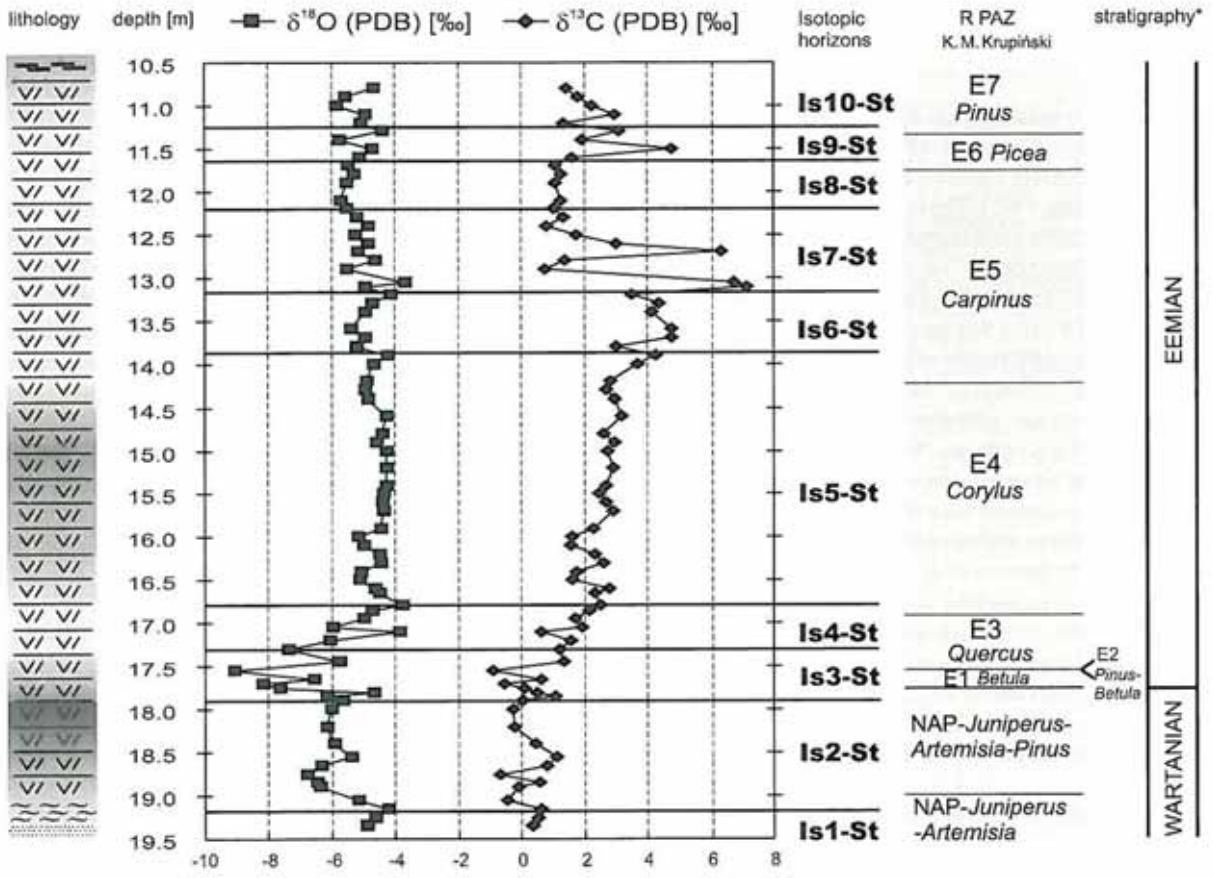

Fig. 5. Correlation of the results of isotopic and palynological analyses in the Studzieniec section (for explanations see Fig. 4)

RESULTS

Based on the results of stable isotope analyses some of environmental processes were defined and characterized. Isotopic data correlated with the pollen data enabled reconstruction both of the climatic and hydrological changes. These changes may repeat during different pollen zones.

The final phase of the Wartanian Glaciation is characterized by values: of $\delta^{18}O$ *c.* –5‰ and $\delta^{13}C$ *c.* 0‰ at Besiekierz and of $\delta^{18}O$ from –4 to –7‰ and $\delta^{13}C$ from 1 to –1‰ at Studzieniec (Fig. 4, 5). These isotopic values may be associated with the presence of dispersed allochthonous carbonates from the underlying morainic till.

The boundary between the glaciation and the interglacial period is very clearly reflected in the oxygen isotope curve and expressed by a decrease in $\delta^{18}O$ values (at Besiekierz: isotopic horizon Is 2-Be; at Studzieniec — Is 3-St). This event appears earlier than the pollen data suggest. It may be associated with faster change of the hydrological conditions in lake than the type of vegetation or/and the replacement the silts by gyttja (at Besiekierz palaeolake). At the transitional period the increase of precipitation of *c.* 200 mm/yr has been inferred (Cheddadi *et al*., 1998). The larger amount of meteoric water may have caused an increase of water level and relative depletion in heavy isotopes.

The constant values of $\delta^{18}O$ and $\delta^{13}C$ indicate stable climatic and hydrological conditions and/or the rapid rate of sedimentation (at Besiekierz palaeolake — Is 4-Be; at Studzieniec palaeolake — Is 5-St). At that time the isotopic composition of lake water unchanged and precipitated carbonates were characterized by similar isotopic ratios.

A gradual warming is expressed by a positive trend in $\delta^{18}O$ values and constant values of $\delta^{13}C$. During the pollen zones E1–E3 the $\delta^{18}O$ values increase from –11 to –6‰ at Besiekierz palaeolake and from –9 to –4‰ at Studzieniec palaeolake. This climatic warming documented by the pollen data (Janczyk-Kopikowa, 1991; Krupiński, in press).

A decrease in $\delta^{18}O$ and $\delta^{13}C$ values is coincided with an increase of precipitation leading to lake deepening by raised level of water and/or with an influx of groundwater enriched in light isotopes (at Besiekierz palaeolake — Is 3-Be; at Studzieniec palaeolake — Is 8-St).

The very high positive $\delta^{13}C$ values (to +7‰) noted at Studzieniec palaeolake (Is 7-St), may be caused by: an increase of biological activity in lake characterized by long residence time because aquatic plants prefer the light carbon isotope or a presence of CO_2 produced as a by-product of methanogenesis via acetate fermentation, relative enriched in ^{13}C (Schwalb, 2003).

The fluctuations of the isotopic curves in the upper part of the succession usually point to a shallowing of the lake through the infilling with the sediments, which caused enrichment in heavy oxygen isotope (at Studzieniec palaeolake — Is 10-St).

The positive correlation of $\delta^{18}O$ and $\delta^{13}C$ curves is characterized for the closed system of lake, then the change of water volume leads to change of isotopic composition both of the water and of precipitated carbonates.

CONCLUSIONS

The isotopic data correlated with results of pollen analysis enable reconstruction of the past climatic and environmental changes, and some of these changes may occur several times during different pollen periods:

- the constant values of $\delta^{18}O$ and of $\delta^{13}C$ show stable climatic and hydrological conditions and/or the rapid rate of sedimentation;
- a positive trend in $\delta^{18}O$ values and constant values of $\delta^{13}C$ may suggest the gradual warming of climate;
- the very high positive $\delta^{13}C$ values indicate an increase of biological activity in lake or a presence of CO_2 produced as a by-product of methanogenesis;
- the fluctuations of the isotopic curves in the upper part of the succession point to a shallowing of the lake through the infilling with sediments;
- the positive correlation of $\delta^{18}O$ and $\delta^{13}C$ curves is characterized for the closed system of lake.

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REFERENCE

BIŃKA K., NITYCHORUK J., 2003 — The Late Saalian, Eemian and Early Vistulian pollen sequence at Dziewule, eastern Poland. *Geol. Quart.,* **47**, 2: 155–168.

CHEDDADI R., MAMAKOWA K., GUIOT J., BEAULIEU de J.-L., REILLE M., ANDRIEU V., GRANOSZEWSKI W., PEYRON O., 1998 — Was the climate of the Eemian stable? A quantitative climate reconstruction from seven European pollen records. *Palaeogeogr., Palaeoclimatol., Palaeoecol.,* **143**: 73–85.

CRAIG H., 1953 — The geochemistry of the stable carbon isotopes. *Geochim. Cosmochim. Acta,* **3**: 53–92.

DRESCHER-SCHNEIDER R., PAPESCH W., 1998 — A contribution towards the reconstruction of Eemian vegetation and climate in central Europe: first results of pollen and oxygen-isotope investigations from Mondsee, Austria. *Veget. Hist. Archaeobot.,* **7**, 4: 235–240.

HOEFS J., 1996 — Stable Isotope Geochemistry. Springer-Verlag. Berlin-Heidelberg.

JANCZYK-KOPIKOWA Z., 1991 — Palynostratigraphy of the Pleistocene in Poland and the problem of the age of deposits from Besiekierz (Central Poland). *Ann. UMCS,* **46**, 6: 111–128.

JANCZYK-KOPIKOWA Z., 1997 — Analiza pyłkowa osadów interglacjału eemskiego w Ruszkówku na Pojezierzu Kujawskim [in Polish]. *Przegl. Geol.,* **45**, 1: 101–104.

KACZMARSKA I., 1976 — Diatom analysis of Eemian profile in fresh-water deposits at Imbramowice near Wrocław. *Acta Palaeobot.,* **17**, 2: 3–34.

KLATKOWA H., 1972 — Paleogeografia Wyżyny Łódzkiej i obsarów sąsiednich podczas zlodowacenia Warciańskiego (Paleographie du plateau de Łódź et de terrain avoisinant pendant la glaciation de Warta) [in Polish with French Sum.]. *Acta Geogr. Lodz.,* **28**: 1–220.

KOTARBIŃSKI J., KRUPIŃSKI K.M., 1995 — Osady interglacjału eemskiego w Studzieńcu i Babcu Piasecznym k.Sierpca. *Przegl. Geol.,* **43**, 7: 565–571.

KRUPIŃSKI K.M., in press — Młodoplejstoceńskie osady jeziorne Wysoczyzny Płockiej i ich zawartość paleobotaniczna.

KRUPIŃSKI K.M., MORAWSKI W., 1993 — Geological position and pollen analysis of Eemian Interglacial sediments of Warsaw-Wawrzyszew. *Acta Palaeobot.,* **33**, 1: 309–346.

KUPRYJANOWICZ M., DRZYMULSKA D., 2002 — Eemian and Early Vistulian vegetation at Michałowo (NE Poland). *Stud. Quatern.,* **19**: 19–26.

LITT T., JUNGE F.W., BÖTTGER T., 1996 — Climate during the Eemian in north-central Europe — a critical review of the palaeobotanical and stable isotope data from central Germany. *Veget. Hist. Archaeobot.,* **5**: 247–256.

MAMAKOWA K., 1988 — Pollen stratigraphy of the Eemian and adjoining glacial deposits based on continuous sequences in Poland. *Bull. Pol. Acad. Sc. Earth Sc.,* **36** , 3–4: 299–308.

MAMAKOWA K., 1989 — Late Middle Polish Glaciation, Eemian and Early Vistulian vegetation at Imbramowice near Wrocław and the pollen stratigraphy of this part of the Pleistocene in Poland. *Acta Palaeobot.,* **29**, 1: 11–176.

MARCINIAK B., KOWALSKI W.W., 1978 — Dominant diatoms, pollen, chemistry and mineralogy of the Eemian lacustrine sediments from Nidzica (northern Poland): a preliminary report. *Pol. Arch. Hydrobiol.,* **25**, 1–2: 269–281

McCREA J.M., 1950 — On the isotopic chemistry of carbonates and a paleotemperature scale. *J. Chem. Physics* **18**: 849–857.

MIROSŁAW-GRABOWSKA J., NISKA M., 2005 — Isotopic and Cladocera records of climate changes of Early Eemian at Besiekierz (Central Poland). *Geol.Quart.,* **49**, 1: 67–74.

NITYCHORUK J., 2000 — Climate reconstruction from stable-isotope composition of the Mazovian Interglacial (Holsteinian) lake sediments in eastern Poland. *Acta Geol. Pol.,* **50**, 2: 247–294.

RÓŻAŃSKI, K., KUC T., DULIŃSKI M., WACHNIEW P., 1998 — Oxygen and carbon isotope composition of authigenic carbonates in the Holocene part of the Lake Gościąż sediments. In:

Lake Gościąż. Central Poland a monographic study. (eds. M. Ralska-Jasiewiczowa *et al.*). Part 1: 229–232. W. Szafer Institute of Botany. Kraków.

SCHWALB A., 2003 — Third Invited D. G. Frey & E. S. Deevey Review: Lacustrine ostracodes as stable isotope recorders of late-glacial and Holocene environmental dynamics and climate**.** *J. Paleolimn.,* **29**, 3: 265–351.

STUIVER M., 1970 — Oxygen and carbon isotope ratios of freshwater carbonates as climatic indicators. *J. Geophys. Res.,* **75**: 5247–5257.

TALBOT M.R., 1990 — A review of the palaeohydrological interpretation of carbon and oxygen isotopic ratios in primary lacustrine carbonates. *Chem. Geol. Isot. Geosc. Sec.,* **80**: 261–279.