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Biogenic sediments of the Eemian Interglacial at Krzyżówki near Koło, central Poland

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Biogenic sediments at Krzyżówki were subjected to lithologic, palynologic and palaeozoologic analyses which determined palaeoclimatic and palaeoecologic conditions during deposition. The climate was temperate and the water reservoir shallow and gradually overgrowing, being inhabited by molluscs, ostracods and fish.

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Key words: central Poland, Pleistocene, Eemian Interglacial, lithology, pollen analysis, molluscs, ostracods, fish.

INTRODUCTION

Field works during mapping of the sheet Koło of the *Detailed Geologic Map of Poland* in scale 1:50 000 were supplemented in 1995 with a research borehole at Krzyżówki V, about 2 km to the north-west from Koło, on the right bank of the Warcica River (Fig. 1). This borehole supplied with samples of the biogenic deposits, known previously from several archival drillings, e.g. Krzyżówki I and Krzyżówki II (described by E. Ciuk in 1955), Budki Stare (described by J. Cieślak in 1949), and Zagaj IIIM (described by H. Galon in 1956). In publications dealing with the Konin region, peats and gyttjas of this biogenic series are commonly connected with the Mazovian (Holsteinian) Interglacial (W. Stankowski, D. Krzyszkowski, 1991; W. Stankowski *et al.*, 1995).

GEOMORPHOLOGIC AND GEOLOGIC SETTING

Archival boreholes and the research borehole Krzyżówki V with peats, gyttja and faunistic remains are located within the area occupied by ice sheet of the Vistulian Glaciation.

These boreholes occur on an outwash plain, composed of vari-grained sands and gravels, and with inserts of a till. The plain is full of dead-ice depressions, meltwater channels (at present used by lakes and rivers) and small river valleys with oxbows, filled with mineral-organic muds and peats. End moraines in this area are composed of sands, gravels and boulders, and form a distinct arc from Drążek–Drzewce Kolonia–Lipiny–Lichenek to Babiak (Fig. 2). These end moraines indicate ice sheet advance of the Poznań Phase of the Vistulian Glaciation to the north-west of Koło. The Quaternary sediments are about 30–50 m thick on marls or gaizes of the Upper Cretaceous, and are preserved in erosive depressions of the Mesozoic bedrock. If on the Miocene brown coal-bearing series, the Quaternary sediments are decidedly thinner, to 20 m only. The Pleistocene is represented by deposits of the Sanian, Wartanian and Vistulian Glaciations, and the Eemian Interglacial (Fig. 4). The Sanian Glaciation series comprises a till at 50–60 m a.s.l. The Middle Polish Glaciations are represented by tills of the Wartanian Glaciation, pebbles, and glaciofluvial sands and gravels at 60–70 m a.s.l. Fluvial and lake sediments of the Eemian Interglacial fill the erosive depressions at 60–75 m a.s.l. They are overlain by 15–20 m thick sandy-gravel series of the Vistulian Glaciation.

The section of the research borehole Krzyżówki V is as the following:

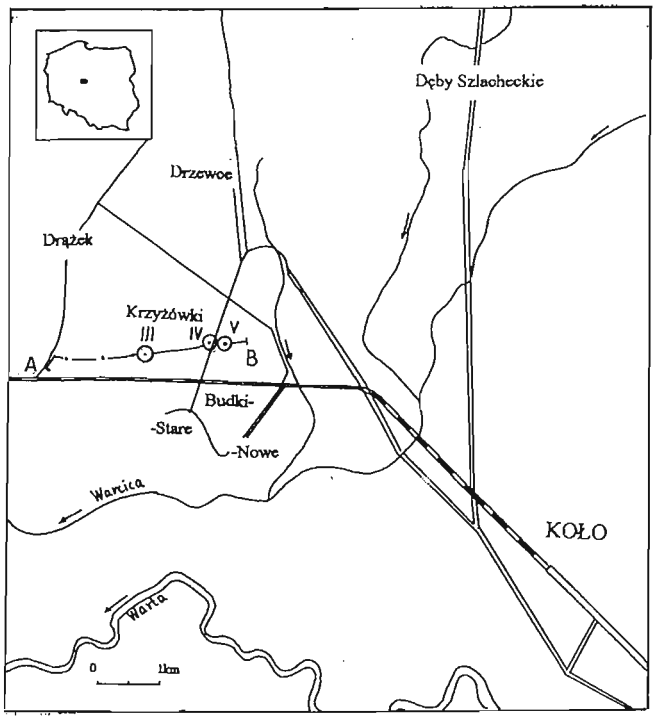

Fig. 1. Location sketch with the boreholes Budki Stare (III), Krzyżówki (IV and V) and geologic cross-section A–B (*cf.* Figs. 2–4)

Depth in m	Lithology
0.30–2.30	Vari-grained sands, yellow (HCl+).
2.30–2.40	Pebbles (2–7 cm in diameter) of Scandinavian rocks.
2.40–20.60	Fine- to coarse-grained sands with gravel in the bottom, grey-yellow and grey.
20.60–22.50	Brown peat, sandy in the top and in the bottom.
22.50–23.50	Medium-grained sands, grey, laminated with organic matter (HCl–).
23.50–24.30	Brown peat.
24.30–25.05	Gyttja with mollusc shells, grey (HCl+).
25.05–25.60	Grey-green silts.
25.60–28.20	Grey silts and sands (HCl+).
28.20–30.00	Pebbles of Scandinavian rocks.
30.00–35.10	Cretaceous marls.

The Quaternary sediments were subjected to standard lithologic (B. Szałamacha, 1996) and palynologic (B. Noryśkiewicz, 1996) analyses, and to a rough palaeozoologic examination (S. Skompski, 1997). Besides, R. Tarkowski (1997) examined microfossils from bedrock marls and, basing on numerous forams: *Arenobulimina conica* Marie, *Ataxophragmium depressum* (Perner), *Lenticulina comptoni* Reuss, *Cibicides excavantus* (Reuss) and *Spiroplectamina dentata* (Alth), ascribed them to the Upper Cretaceous, i.e. the Campanian/Maestrichtian.

A bottom part of the Quaternary series is composed of pebbles of Scandinavian rocks, 1.8 m thick. It is a residuum of glacial sediments of the Middle Polish Glaciations, most probably the Wartanian Glaciation. Lithologic examination indicated within the sands a sequence of fluvial, glaciofluvial, lake and fluvioperiglacial deposits. In a bottom of the biogenic series there are vari-grained light grey sands with single gravel and interbeds of sandy silts and fine-grained sands. This layer has quite a stabile content of heavy minerals: garnets 58.0–52.3%, amphiboles 13.7–11.8%, staurolite 6.2–5.3%, pyroxene 4.2–5.3%, and sillimanite 5%. Quartz grains are well rounded (R = 0.34). Content of $CaCO_3$ is quite significant and increases towards the bottom to 19.8%, presumably due to close contact with marls and limestones of the bedrock. This bed is a fluvioperiglacial deposit, transported by a river from a single alimentary area, what is indicated by uniform content of heavy minerals and good roundness of quartz grains.

The biogenic series occurs at depth of 25.0–20.6 m. It starts with grey-blue lake silts (depth 25.0–25.6 m) with well rounded quartz grains (R = 0.27), and heavy minerals are predominated by non-transparent components. It indicates at least partly a deposition of a river-transported material. Content of $CaCO_3$ is equal from 3.51 to 8.25%. The silts are overlain by grey-green gyttja (depth 24.3–25.0 m) with faunistic remains examined at depth 24.6–24.75 m (S. Skompski, 1997). At depth of 23.5–24.5 m there is a lower peat, separated from the upper one at depth of 20.6–22.5 m by sands. The whole biogenic series was subjected to a palynologic analysis (39 samples) by B. Noryśkiewicz (1996).

The biogenic series is overlain by vari-grained sands, light yellow, with a medium sorting (sorting coefficient $\delta = 0.68$). Roundness of quartz grains is bad (R = 0.46) and content of $CaCO_3$ low (about 0.41%). Spectrum of heavy minerals is mostly composed of garnets 70%, andalusite 10.9%, topaz 3.5%, amphiboles 2.9%, sillimanite and staurolite. Basing on this examination, the sands seem to be of glaciofluvial origin. A top part of the section from a depth of 0.3–17 m is composed of vari-grained sands and gravel agglomerations. Lithologic examinations proves their fluvial origin as quartz grains are well rounded (R from 0.18 to 0.26). Heavy minerals are mostly garnets 48.7%, amphiboles 8.1%, andalusite 7.1% and chlorite 6.4%, but in single samples a content of garnets increases even to 87%.

PALYNOLOGIC AND PALAEOZOOLOGIC ANALYSIS

Palynologic analysis of biogenic deposits from depth of 20.6–25.0 m resulted in determination of several local pollen zones L PAZ (B. Noryśkiewicz, 1996, 1998, 1999): K-1 — *Artemisia-Betula nana-Juniperus*, K-2 — *Betula*, K-3 — *Quercus-Corylus* and K-4 — *Pinus*, that correspond to the late glacial period with a tundra vegetation, and to the Eemian Interglacial succession: birch forest with pine and multi-species deciduous forest with oak and hazel from a climatic optimum, to pine forest with spruce of a terminal part of the interglacial. The pollen zones can be correlated with regional pollen zones R PAZ 1, 3 and 7 in the Konin region (K. Tobolski, 1991). Results of a pollen analysis of the lower peat from Krzyżówki indicate sedimentary hiatuses in the palynologic sequence. If comparing with a classic section at Jóźwin

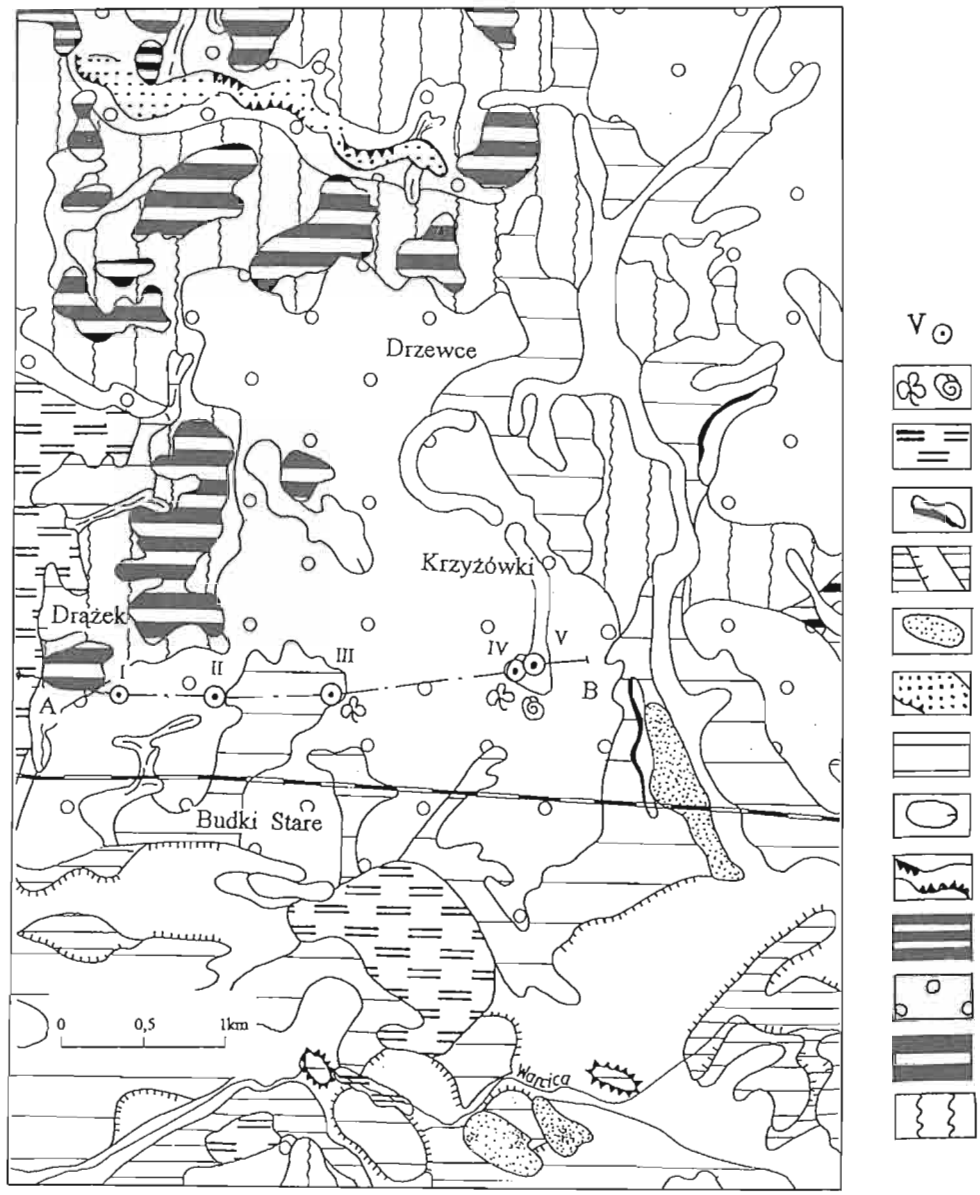

Fig. 2. Geomorphologic sketch of the Koło region (after G. Szałamacha, 1996)

Vistulian Glaciation: 1 — wavy morainic plateau, 2 — end moraines, 3 — outwash plains, 4 — kames, 5 — meltwater channels, 6 — thaw depressions, 7 — supra-inundation terrace, 8 — lake bottom; **Holocene**: 9 — dunes, 10 — floodplain and valley beds, 11 — oxbow lakes, 12 — peat plains, 13 — sites with fossil fauna and flora, 14 — boreholes, A–B — geologic cross-section (Fig. 4)

1976, the pollen zones R PAZ 2 and 4–6 are absent. In the other sites: Jóźwin 1984, Kazimierz and Władysławów, sedimentary hiatuses of indeterminate origin are indicated by K. Tobolski (1991) in the palynologic sections for the telocratic, protocratic and mesocratic periods. However, these hiatuses do not result in disturbations in the pollen zones. In the section Krzyżówki V there is no geologic evidence for sedimentary hiatuses or erosion within the lower peat. The latter is overlain by medium-grained grey sands with admixture of a silty organic matter, what presumably indicates a renewed overflow in the lake. A bottom of the lower peat (depth 22.5–20.6 m) indicates a pollen succession K-5 — *Betula*-NAP, corresponding to distinct predominance of aqueous plants and birch forest with admixture of pine. This succession is similar to the one of the zone Wła-2 at the site Władysławów (K. Tobolski, 1991), therefore deposition could occur during the Brörup Interstadial. The pollen zones K-6 — *Pinus*, K-7 — *Corylus* and K-8 — *Pinus* represent pine and deciduous forests with predominant hazel, what indicates temperate climate, and then the interglacial optimum with renewed cooling. Inconsistent succession in pollen zones of the upper peat at Krzyżówki cannot be explained by disturbances of geologic strata or by drilling errors. Some inconsistences in deposition of the pollen zones in top parts of the sections of the Eemian Interglacial in the Konin region were already noted by K. Tobolski (1991) at Kazimierz, Jóźwin 1976 and

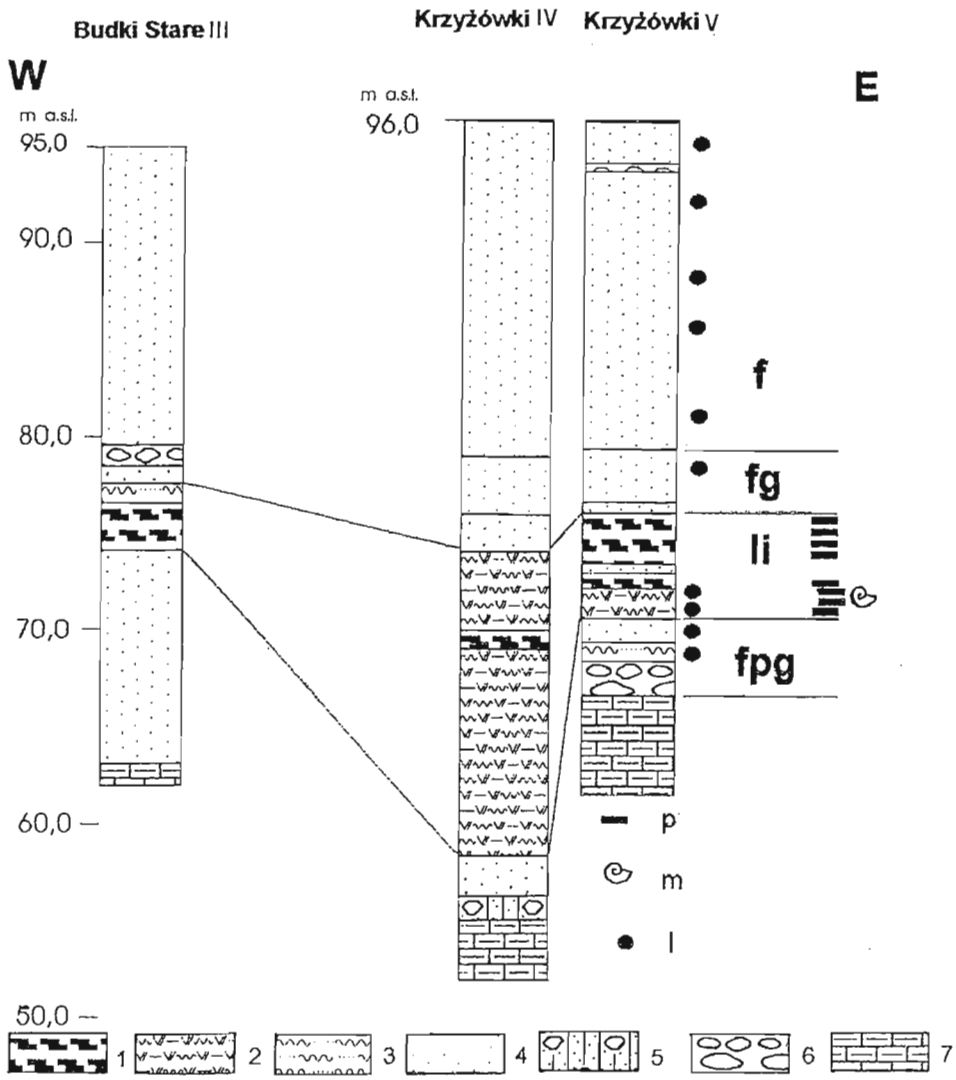

Fig. 3. Sampling of a core of the research borehole Krzyżówki V and correlation of deposits with the archival data

1 — peat, 2 — gyttja, 3 — sandy silts, 4 — sands, 5 — tills, 6 — pebbles, 7 — marls; sampling for: p — palynologic, m — mollusc, l — lithologic analyses; f — fluvial, fg — glaciofluvial, fpg — fluvioperiglacial, li — lake

Jóźwin 1984. However, neither palynologic nor macrofossil analyses have not explained univocally their stratigraphic setting.

The sample for palaeozoologic analysis was collected from the borehole Krzyżówki V at depth 24.60–24.75 m, from a green-grey gyttja with remains of plants and fragments of mollusc shells. 20 species of snails and 6 species of bivalves were determined (Table 1). Except for the molluscs, there were also several species of ostracods: *Candona candida* (O.F. Müller), *C. compressa* (Koch), *C. levanderi* Hirschmann, *C. neglecta* Sars, *C. protzi* Hartwig, *C. weltneri* Hartwig, *Candoniella albicans* (Brady), *Candoniella subellipsoida* Sharapova, *Cyclocypris ovum* (Jurine), *Cyprideis torosa* (Jones), *Cyprinotus salinus* (Brady), *Darwinula stevensoni* (Brady et Robertson), *Herpetocypris* sp., *Limnocythere inopinata* (Baird), *L. sanctipatricii* Brady et Robertson, and *Metacypris cordata* Brady et Robertson, single covers of cockchafers (*Coleoptera*) and various fragments of fish (*Pisces*), firstly teeth of pike (*Esox lucius*), rud (*Scardinius erythrophthalmus*), roach (*Rutilus rutilus*) and bream (*Abramis brama*), and scales of perch (*Perca fluviatilis*), i.e. a most common species of fresh-water fish in Poland. There were also other fragments of fish skeletons, e.g. vertebra and otoliths. Similar faunistic remains were found also at Ruszkówek, to the north of Sompolno (Z. Kozydra, S. Skompski, 1995).

The molluscs from Krzyżówki throw light on palaeoecology, palaeoclimate and stratigraphy. Most species are typical for stagnant fresh-water reservoirs: *Acroloxus lacustris* (Linnaeus), *Anisus contortus* (Linnaeus), *A. vortex* (Linnaeus), *Armiger crista* (Linnaeus), *Planorbis planorbis* (Linnaeus), *Segmentina nitida* (Müller), and *Valvata cristata* Müller with

Table 1

Molluscs from the site Krzyżowki V

	Molluscs	Number of shells*	Environment**
Snails	*Acroloxus lacustris* (Linnaeus)	52	S
	Anisus contortus (Linnaeus)	2	SB
	Anisus vortex (Linnaeus)	1	SB
	Anisus vorticulus (Troschel)	1	S
	Armiger crista (Linnaeus)	125	S
	Belgrandia marginata Michaud	19	Z
	Bithynia tentaculata (Linnaeus)	77(154)	SR
	Discus sp.	1	I
	Gyraulus albus (Müller)	54	S(R)
	Gyraulus laevis (Alder)	115	S
	Lymnaea peregra (Müller)	54	SR
	Lymnaea stagnalis (Linnaeus)	9	S(R)
	Lymnaea truncatula (Müller)	3	SR
	Planorbis carinatus (Müller)	4	S(R)
	Planorbis planorbis (Linnaeus)	1	BS
	Segmentina nitida (Müller)	5	S
	Vallonia costata (Müller)	1	I
	Valvata cristata Müller	83	SB
	Valvata pisicinalis (Müller)	1250	SR
	Perpolita sp.	1	I
Bivalves	*Pisidium casertanum* (Poli)	2	RSB
	Pisidium nitidum Jenyns	3	RS
	Pisidium sp.	6	–
	Pisidium subtruncatum Malm	1	SR
	Sphaerium sp.	d	–
	Unio sp.	d	–
	Anodonta anatina (Linnaeus)	1	SR

*number of snail or bivalve shells (in brackets number of covers of *Bithynia tentaculata*): d— shell detritus; environment: B — boggy, I — inland, R — running water, S — stagnant water, Z — spring

dense vegetation. Some species as *Bithynia tentaculata* (Linnaeus), *Valvata piscinalis* (Müller), and *Gyraulus albus* (Müller) (Table 1) are common also in running water, but prefer stagnant ones and rich in water plants.

Worth-mentioning is abundant occurrence of the snail *Valvata piscinalis* (Müller) (1250 specimens) and, at well preserved non-destructed specimens, predominance of shell height over its width what speaks for their a lake habitat of *Valvata piscinalis* f. *antiqua* Sowerby (A. Piechocki, 1979). There is also another common (125 specimens) species *Armiger crista* (Linnaeus) as *A. crista* f. *nautileus* Linnaeus and *A. crista* f. *cristatus* Draparnaud (16 specimens). Another peculiarity of this species is indicated by occasional shell deformations, with the last coil which does not adhere to the other ones. Such single specimen was found too, but at other sites these anomalies are common, e.g. at Bogdanów to the north of Poznań (S. Skompski, 1994). Single species of inland snails: *Discus* sp., *Vallonia costata* (Müller) and *Perpolita* sp. indicate a close location of a shore.

The lake environment is indicated by abundant ostracods, although the environmental conclusions drawn from ecology of individual species, should be treated in a general way — that it was a reservoir with stagnant water. However, details on depth, temperature, salinity, etc. can result in an incorrect interpretation because the species, due to their wide range of living, can result in controversial conclusions. Such examples are known from literature, in which the species *Candona candida* (O. F. Müller) and *C. neglecta* Sars are put into the ecologic group of "cool waters" (R. Fuhrmann, E. Pietrzeniuk, 1990, p. 204–205), and *Metacypris cordata* Brady et Robertson from the same sample is connected with warm intervals only (T. Sywula, E. Pietrzeniuk, 1989, p. 98).

A past climate resembles interglacial conditions, due to presence of the snail *Belgrandia marginata* Michaud, at present living in springs of France and Catalonia, and which occurred as far to the north as the July isotherm of 18°C. Brachlewo is the northernmost site of this snail in Poland during the Eemian Interglacial (S. Skompski, 1983).

Stratigraphic conclusions are also based on occurrence of the species *Belgrandia marginata* Michaud, which is known only from 5 sites of the Eemian Interglacial in Poland (Z. Kozydra, S. Skompski, 1995; S. W. Alexandrowicz, 1987). Therefore, these deposits are to be referred to this interglacial (S. Skompski, 1996, p. 24), what fully corresponds to results of a palynologic analysis (B. Noryśkiewicz, 1996, 1998).

RECAPITULATION

The borehole Krzyżówki V indicates stratigraphic setting of biogenic deposits which have been previously connected with the Mazovian (Holsteinian) Interglacial (W. Stankowski, D. Krzyszkowski, 1991).

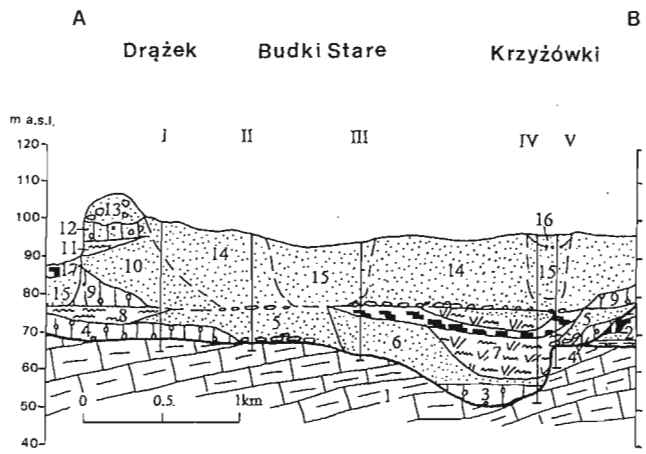

Fig. 4. Geologic cross-section A–B from Drążek to Krzyżówki

Cretaceous (Campanian–Maestrichtian): 1 — Cretaceous marls; **Tertiary** (Miocene): 2 — brown coal, clays, sands; **Quaternary: Sanian Glaciation**: 3 — till; **Wartanian Glaciation**: 4 — till, 5 — glaciofluvial vari-grained sands; **Eemian Interglacial**: 6 — fluvial vari-grained sands with gravels, 7 — gyttja, peat, lake sands and silts; **Vistulian Glaciation**: 8 — ice-dam silts, 9 — till; **Leszno Phase**: 10 — glaciofluvial vari-grained sands, 11 — ice-dam silts, 12 — till; **Poznań Phase**: 13 — sands, gravels and boulders of end moraines, 14 — glaciofluvial vari-grained sands, 15 — fluvial vari-grained sands and gravels; **Holocene**: 16 — silty sands of kettle holes, 17 — peat

Basing on palynologic and palaeozoologic analysis, the Eemian age of the lower part of biogenic deposits seems obvious. It excludes therefore the Holsteinian age of the series Budki Stare–Zagaj–Krzyżówki, which occurs within the same sedimentary basin. The pebbles above this series cannot be an equivalent of glacial sediments of the Middle Polish Glaciations (Saalian), and the sediments under the biogenic series cannot be younger than the South Polish Glaciations (Elsterian; *cf.* W. Stankowski, D. Krzyszkowski, 1991).

Palaeozoologic analyses determine characteristics of the sedimentary basin with the Eemian deposits. It was a stagnant water reservoir with rich vegetation as indicated firstly by molluscs but also abundant ostracods and fish, particularly a pike that feeds amidst the aquatic plants.

Results of lithologic analysis determined the origin of some fluvial, glaciofluvial, lacustrine and fluvioperiglacial beds.

Preliminary analysis of the upper biogenic series at Krzyżówki can be supplied with more detailed conclusions if this series becomes exposed in a pit, due to a brown coal exploitation at Drzewce.

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NOWE STANOWISKO EEMSKICH OSADÓW ORGANICZNYCH W KRZYŻÓWKACH W REJONIE KONIŃSKIM

Streszczenie

Osady interglacjalne w Krzyżówkach zostały odwiercone w związku z pracami geologiczno-kartograficznymi na arkuszu Koło *Szczegółowej mapy geologicznej Polski* w skali 1:50 000 (G. Szałamacha, 1996). W profilu geologicznym zbadanego otworu wiertniczego Krzyżówki V (fig. 1–4) bezpośrednio nad marglami kredowymi, których wiek określono mikropaleontologicznie na kampan/mastrycht (R. Tarkowski, 1997), leżą osady czwartorzędu o miąższości 30 m, które zostały poddane badaniom litopetrograficznym (B. Szałamacha, 1996), palinologicznym (B. Noryśkiewicz, 1999) i paleozoologicznym (S. Skompski, 1997).

W dolnej części osadów czwartorzędowych (głęb. 28,2–30,0 m) znajduje się bruk skał skandynawskich, stanowiący pozostałość po osadach lodowcowych zlodowaceń środkowopolskich (i ewentualnie starszych). Nad brukiem (głęb. 25,6–28,2 m) występują piaski różnoziarniste z przewarstwieniami mułków, o cechach osadu fluwioperyglacjalnego. Roślinność najwyższej warstwy tej serii, w postaci mułków (głęb. 25,0–25,6 m), ma charakter późnoglacjalnych zbiorowisk tundry krzaczastej (B. Noryśkiewicz, 1999). Nad tą warstwą leży seria osadów interglacjalnych, w której można wyróżnić część dolną (głęb. 23,5–25,0 m) i górną (głęb. 20,6–22,5 m), rozdzielone

bezwapienną warstwą piasków średnioziarnistych (głęb. 22,5–23,5 m) smugowanych substancją organiczną. Dolną część serii interglacjalnej wyrażonej gytią (głęb. 24,3–25,0 m) i torfem (głęb. 23,5–24,3 m) można zaliczyć do interglacjału eemskiego, co wynika zarówno z badań palinologicznych (B. Noryśkiewicz, 1999), jak i faunistycznych (S. Skompski, 1997), a co potwierdza przede wszystkim obecność ślimaka *Belgrandia marginata* Michaud (S. Skompski, 1983, 1991, 1996; S. W. Alexandrowicz, 1987). Górna część, w której spągu początkowo występują ziarna pyłku schyłkowej części interglacjału, zaś ku stropowi pojawiają się znów ziarna pyłku lasu liściastego, może mieć interpretację dyskusyjną. Pyłek ten, być może, oznacza ocieplenie lub znajduje się na wtórnym złożu.

Warunki paleoekologiczne w czasie powstawania gytii w dolnej części serii interglacjalnej, określone na podstawie mięczaków, małżoraczków i ryb, można krótko scharakteryzować w sposób następujący. Osady z fauną tworzyły się w płytkim zbiorniku wody stojącej, na co wskazuje większość znalezionych gatunków ślimaków (tab. 1) i małżoraczków. O bogatej roślinności świadczą natomiast ryby (szczupak, wzdręga, płoć i leszcz) i gatunki ślimaków preferujące zbiorniki o charakterze bagiennym: *Valvata cristata* Müller, *Planorbis planorbis* (Linnaeus) i *Anisus contortus* (Linnaeus), a o bliskości brzegu zbiornika informują lądowe gatunki ślimaków: *Discus* sp., *Vallonia* sp. i *Perpolita* sp.

Nad serią organiczną w profilu Krzyżówki leży warstwa piasków średnioziarnistych (głęb. 17,0–20,6 m) o stosunkowo słabym obtoczeniu (R = 0,46), zaliczonych do osadów wodnolodowcowych. Wyżej znajduje się miąższa warstwa (głęb. 0,3–17,0 m) piasków różnoziarnistych ze żwirem o dobrym obtoczeniu (R = 0,18–0,12), co wskazuje na ich genezę rzeczną.