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Pollen and diatom stratigraphy of the lacustrine-fluvial-swamp deposits from the profile at Domuraty, NE Poland

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Fluvio-lacustrine deposits from a boring core drilled at Domuraty, NE Poland have been examined by pollen and diatom analyses. These studies allow characterization of the development of vegetation in a long pollen sequence, and of palaeoenvironmental changes in the former basin based on quantitative and qualitative changes in diatom assemblages along the profile studied. The pollen record shows a sequence of phases with forest communities separated by phases of open vegetation. It demonstrates the impact of rapid, of lesser climate changes, as well as climatic fluctuations on terrestrial ecosystems. The age of the succession can be related to the Cromerian Complex Stage *s.l.* (early Middle Pleistocene).

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Key words: northeastern Poland, Cromerian Complex Stage, Małopolanian Interglacial, pollen analysis, diatom analysis.

INTRODUCTION

In the stratigraphical subdivision of the Pleistocene of Poland, seven interglacials have been distinguished (Ber, 2005, 2006; Lindner *et al*., 2004, 2006). Five of these: the Augustovian (Cromerian I), Ferdynandovian (Cromerian III/IV, Voigtsted), Mazovian (Holsteinian), Zbójnian (Dömnitz) and Eemian interglacials have been recognized on the basis of palynological data and have been documented by complete pollen successions. Their palynological characteristic show different patterns of vegetational development (Janczyk-Kopikowa, 1991*a*). The stratigraphical position of the deposits of these interglacials have been established by lithological and petrographic analysis and by thermoluminescensce (TL) dating of associated tills and of other glacigenic deposits as well as by geological setting. Diatom successions have been reported from the deposits of the Augustovian (Marciniak, 2004; Khursevich *et al*., 2005), Ferdynandovian (Khursevich *et al*., 1990; Marciniak, 1991*a*, *b*; Marciniak and Lindner, 2003), Mazovian (Marciniak, 1998; Khursevich *et al*., 2003) and Eemian (Kaczmarska, 1976; Marciniak and Kowalski, 1978; Marciniak, 1994) interglacials.

The Lubavian (Schöningen) Interglacial is represented by an incomplete pollen succession very similar to the Eemian pollen succession (Janczyk-Kopikowa, 1991*a*) and its stratigraphical position is still debated. The Małopolanian (Cromer II) Interglacial has been determined only by faunistic data (Głazek *et al*., 1976) recorded in cave clays at Kozi Grzbiet and by dating of mammal bones using the FCL/P method (Lindner, 1984; Lindner *et al*., 2004). The palynological data recorded in lake deposits at Łowisko (Kolbuszowa Upland; Stuchlik and Wójcik, 2001) and from the Jasionka section near Rzeszów (Lindner, 1984) probably represent this interglacial. This documentation is fragmentary, and the pollen succession, could not be correlated with any known interglacial succession.

SITE DESCRIPTION

Geological surveying of the Sztabin sheet of the Detailed Geological Map of Poland at 1:50 000 scale included drilling a borehole at Domuraty. This borehole was drilled on the northern slope of the Sokólskie Hills, about 0.5 km SE of the present Biebrza River bed (Fig. 1).

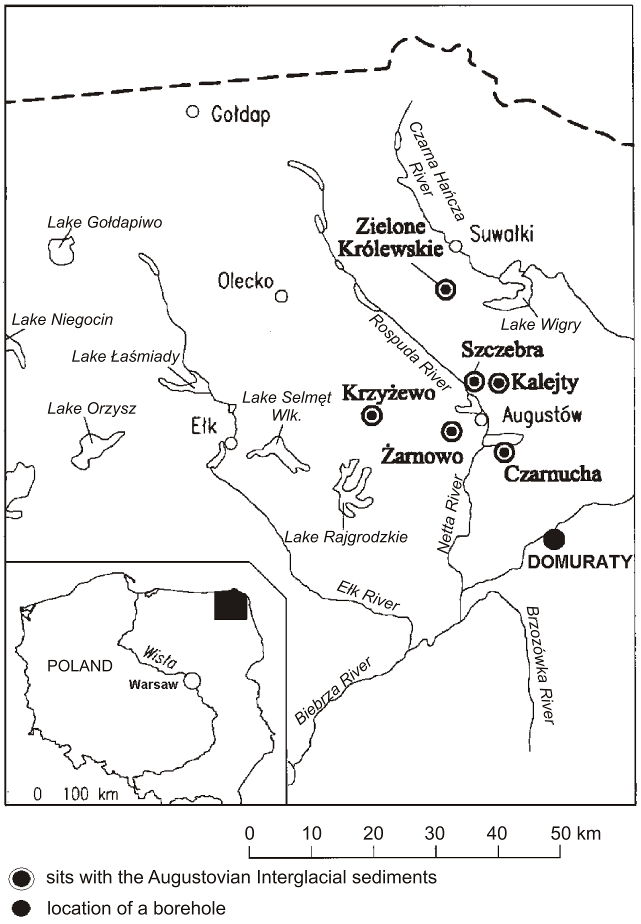

Fig. 1. Location of the Domuraty section

The thickness of Quaternary deposits in the Domuraty borehole, that rest on upper Cretaceous rocks (Campanian), makes up 225.6 m (Fig. 2). Lacustrine-fluvial-swamp deposits occur in the depth range from 137.2 to 97.2 m. This series of deposits is underlain by a thick unity of till apparently belonging to the Narevian Glaciation and it is overlain by four tills which can be correlated with the Liviecian Glaciation, the older stadial of the Odranian Glaciation, the younger stadial of the Wartanian Glaciation, and the older stadial of the Vistulian Glaciation (Lisicki, 2003; Lisicki and Winter, 2004; Winter and Lisicki, 2005).

The deposits examined are represented by fine-grained sands, silty sands, clayey silts with peat intercalations and sandy silts with a fossil flora (Fig. 2).

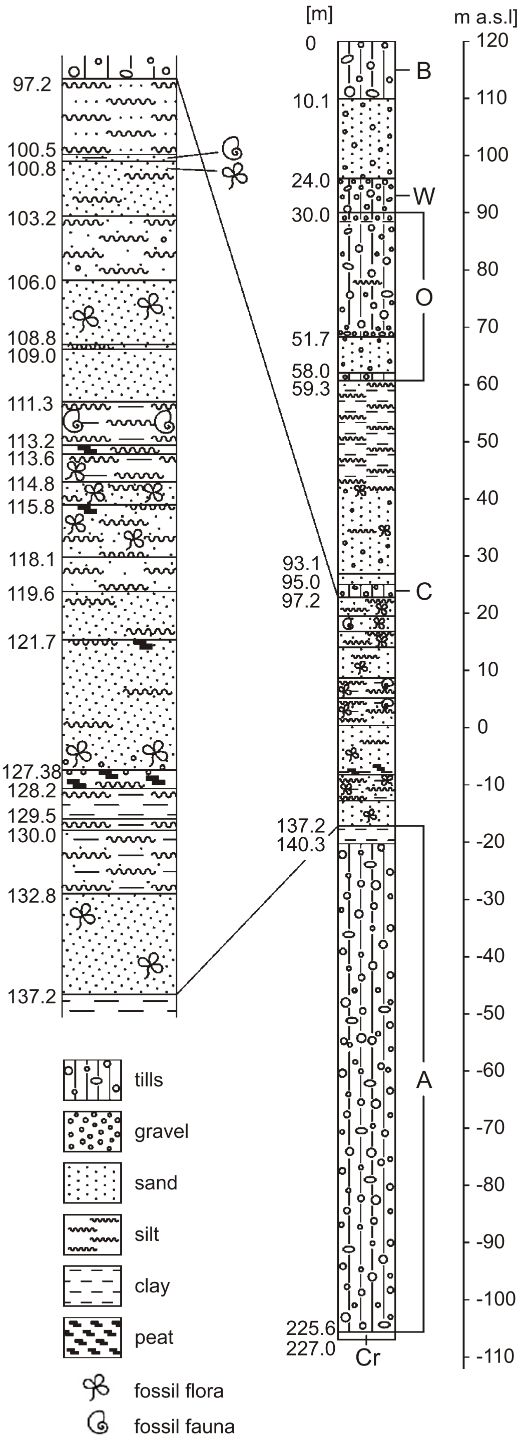

Fig. 2. Lithological profile of the studied deposits

Glaciations: A — Narevian; C — Livecian; O — Krznanian; W — Wartanian; B — Vistulian

MATERIALS AND METHODS

Deposits from the depth interval 118.9–114.3 m have been analysed by means of pollen and diatom analyses. Both methods provided insight into environmental changes and also elucidated the relationships between terrestrial events and events in the lake.

POLLEN ANALYSIS

85 samples investigated by pollen analysis were covered with 10% HCl and after that boiled in 10% KOH. To remove the mineral fraction the sediments were treated with heavy liquid and than subjected to the Erdtman's acetolysis method. At least 250 pollen grains were counted per sample. The calculation of percentages is based on the total terrestial pollen sum (AP+NAP) excluding pollen of aquatic plants, spores, and reworked sporomorphs. Sporomorphs of pre-Quaternary age were considered as reworked. Varia were represented by indeterminable pollen, frequently very deteriarated Pine pollen, and crumpled and broken

pollen grains. The presence of these and of dinoflagellate cysts suggests redeposition connected with erosion.

Results of the pollen analysis were plotted using the *POLPAL* programme (Walanus and Nalepka, 1996).

DIATOM ANALYSIS

51 samples were taken for diatom analysis from the depth interval 128–111m. However, diatoms were found only between 118.9 and 114.3 m. The samples were cleaned using hydrochloric acid and hydrogen peroxide. After washing with water, samples were treated with heavy liquid (KJ and CdJ_2) following the standard procedure which separates diatom valves from mineral sediment by centrifuging. The cleaned valves were mounted in Elyashev's aniline-formaldehyde and observed with a *Zeiss-Jena Amplival* light microscope with an oil immersion objective (100 , NA = 1.25). The results, after counting about 500 diatoms per sample, are presented in a diatom diagram, constructed using the *TILIA* computer programme.

A classification of diatoms proposed by Round *et al*. (1990) has been used in the paper. Taxonomic transformations and data on diatom ecology given in many monographic reports (Krammer and Lange-Bertalot, 1986, 1988, 1991*a*, *b*; Lange-Bertalot and Metzeltin, 1996; Bukhtiyarova, 1999; Lange-Bertalot, 2001) were taken into consideration.

RESULTS

POLLEN ANALYSIS

The pollen diagram from Domuraty section has been divided into 22 local pollen assemblage zones L PAZ (Fig. 3). Description of each zone is given in Table 1.

The pollen sequence recorded here is discontinuous, but within it can be distinguished several warm/wet and cold/dry stages.

The sequence from Domuraty started with a cold stage documented by a pollen spectrum from 129.05 m depth. It shows a high percentage of *Pinus* pollen, redeposited miocene pollen, pollen of thermophilous taxa and dinoflagellate cysts.

The beginning of **I warm stage Do I (Do 1–6 L PAZ)** shows high proportions of *Betula* species accompanied by *Larix* and *Picea*. This trees formed a pioneer forest. The presence of *Hippophaë*, *Juniperus* and *Salix* pollen suggests patches of shrub tundra vegetation. Open communities of herbaceous plants with Poaceae, Cyperaceae, *Artemisia* and Chenpodiaceae also existed.

The spread of *Pinus* and *Alnus* forests was a signal of climatic amelioration. Deciduous, thermophilous trees such as *Tilia cordata* typ, *Quercus* and *Ulmus* occurred, but with low percentages. This indicates that development of mixed forest corresponds to the climatic optimum of this stage. Subsequently a major expansion of *Picea* correlated with a decrease of *Alnus, Pinus* and thermophilous trees suggest the presence of a post-temperate conifer forest of taiga type.

The vegetational features of a **cold stage Do I/II (Do 7–8 L PAZ)** is characterized by deforestation and increasing NAP values. An expansion of herb pollen can be related to high value of Poaceae and a slight increase of *Artemisia* and Cyperaceae. Nevertheless the relatively high percentage of *Betula* pollen suggests the presence of birch forest with patchy Poaceae–Cyperaceae communities. Steppe elements such as *Artemisia* and Chenopodiaceae may indicate steppe vegetation. The occurrence of *Betula nana* and Ericaceae pollen indicates the presence of tundra.

A sharp increase in *Pinus* pollen indicates the beginning of **temperate stage II (Do 9 L PAZ)**. This stage **Do II** (**Do 9–12 L PAZ**) is characterized by the domination of pine in forest communities. The vegetation has mixed forest character with *Betula, Picea* and *Alnus*. Very low frequencies of deciduous trees point to cool climatic conditions, though overall the floristic composition documents an interstadial type of vegetation.

The vegetation of the **cold period Do II/III** (**Do 13 L PAZ**) is dominated by non-arboreal taxa such as Poaceae, Cyperaceae and *Artemisia*, as well as by *Betula*. This cold stage can be attributed to deforastation indicated by the expansion of herb plants. The higher percentages of *Betula* pollen may be connected with the development of very patchy birch forest.

The onset of **warm stage III** (**Do III — Do 14–18 L PAZ**) is indicated by a sharp expansion of *Pinus* and very fast re-immigration of the themophilous taxa *Quercus, Ulmus* and *Corylus* into the area. This stage is characterised by a spread of *Carpinus*, that had not been present in the local vegetation until this stage. This particular feature indicates development of a temperate mixed forest dominated by *Pinus, Quercus, Carpinus* with the occurrence of *Ulmus, Corylus* and *Acer*. The early re-occurrence of thermophilous deciduous trees and the presence of *Carpinus* suggest that the climatic optimum of stage III occurred very early and also that the refugia for these trees must have persisted close by. Warm climatic conditions are indicated by the presence of *Buxus, Ligustrum* and *Sambucus,* as well as by *Trapa* pollen.

Within this stage a short-lived rise in *Quercus* and *Ulmus* corresponding with a decrease in *Carpinus* and *Abies* pollen implies the development of a mixed oak forest. These changes in pollen data correlate with a change in deposits that document climatic oscillation expressed by much drier climatic conditions. A parallel increase in frequencies of *Picea* and to a slight extent in *Abies* pollen during the climatic optimum may indicate that climatic conditions as regards temperature should be assigned to a warm interstadial or a cool interglacial.

Transition to next **cold stage III/IV (Do 19 L PAZ)** is shown by a short-lived spread of *Pinus* followed by a broad peak of *Alnus* and the reappearance of NAP. The percentage of herbaceous especially Cyperaceae and Poaceae, pollen shows a sharp rise pointing to a marked opening of the landscape caused by climatic cooling. The pollen records indicate that tundra and, to a smaller degree, steppe vegetation developed. The more favourable climate conditions in **warm stage IV** (**Do 20–21 L PAZ**) are indicated by a decline of non-arboreal pollen and a spread of *Pinus*. The relatively high percentage of NAP suggests open *Pinus–Betula* forest.

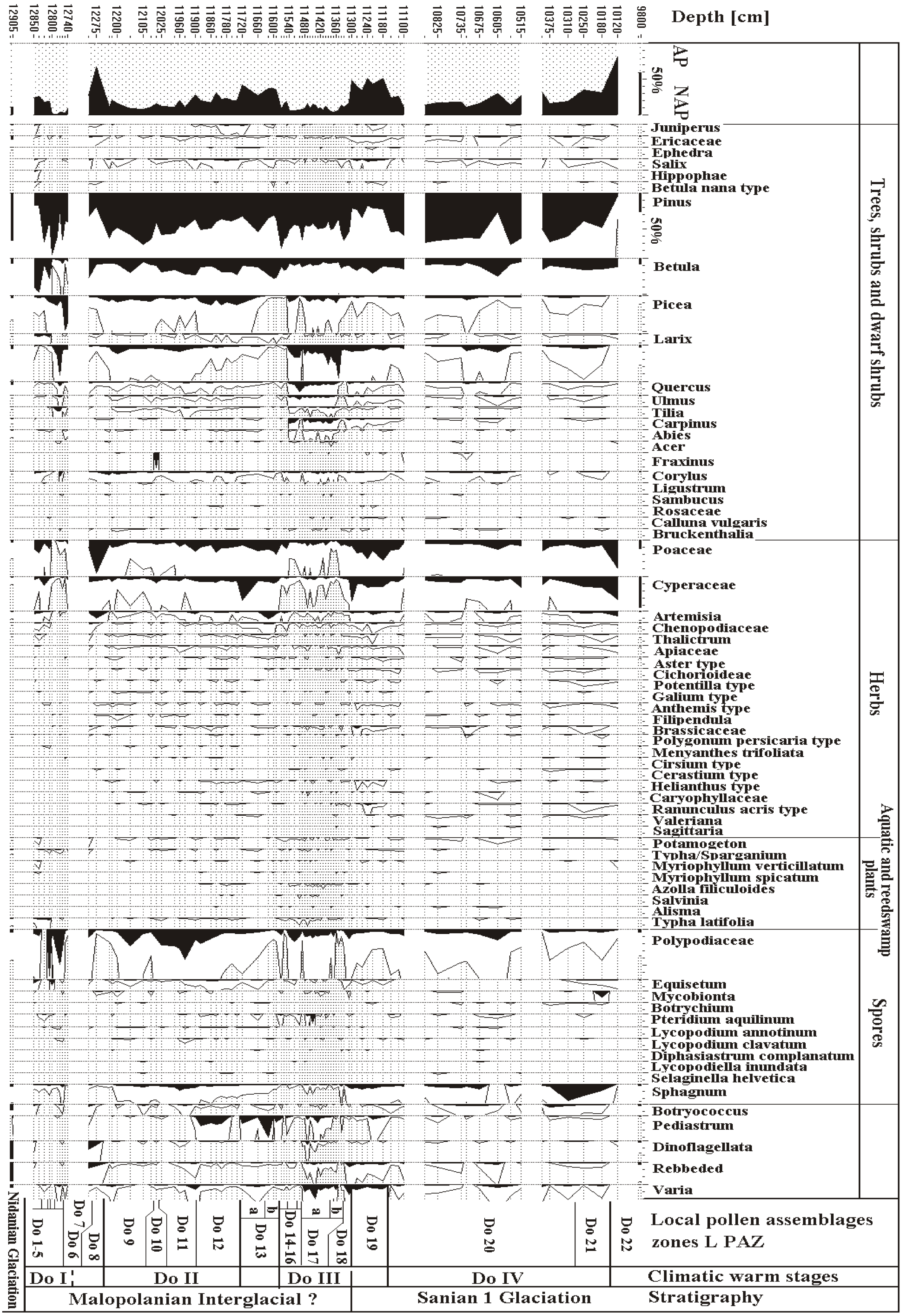

Fig. 3. Domuraty — pollen diagram

Table 1

Description of the local pollen assemblage zones from Domuraty section

Local pollen assemblage zones L PAZ		Depth [m]	Description of L PAZ
Do 22 Cyperaceae		101.2– 98.0	Domination of NAP, high maximum of Cyperaceae pollen (max. 47%) associated with Poaceae and *Artemisia*.
Do 21 *Pinus*–NAP		101.8–101.2	*Pinus* and *Picea* pollen values fall, rise in NAP represented by Poaceae, Cyperaceae and *Artemisia*.
Do 20 *Pinus–Picea–Betula*		108.75–103.1	Domination of AP, mainly *Pinus*, *Betula*, *Alnus* and *Picea*.
Do 19 Poaceae–Cyperaceae–*Salix*		113.0–111.0	Rise in NAP, particulary Poaceae (8.2–27.2%). Cyperaceae (9.7–34.0%) and *Artemisia*. Increase in *Salix* values to 3.9% (max.).
Do 18 *Pinus–Betula–Alnus*		113.4–113.1	Decline of *Alnus*, *Picea*, *Abies*, *Carpinus* and *Quercus* pollen. Increase of *Pinus* and slightly of *Betula* values.
Do 17 *Carpinus–Alnus–Abies*	Do 17b *Alnus*	114.8–113.5	The highest values of *Carpinus* (max.7.1%). Increase in *Picea* and *Abies* as well as thermophilous taxa. Do 17a with relatively high proportions of NAP (20%) and *Picea*. Do 17b with maximum values of *Alnus* (45.6%).
	Do 17a *Picea–Carpinus*–NAP		
Do 16 *Quercus–Ulmus*		115.0–114.9	Maximum values of *Quercus* (13.9%) and *Ulmus* (6%). *Carpinus* and *Picea* pollen disappeared.
Do 15 *Picea–Carpinus–Quercus*		115.4–115.2	AP values persist high. *Quercus*, *Ulmus*, *Tilia cordata* type and *Corylus* percentages rise, maximum value of *Carpinus* (6.6%). The contribution of *Alnus*, *Picea* and *Abies* reach up 16.7%, 9.2% and 2.4%. Pollen of *Viburnum* and *Sambucus* is present.
Do 14 *Pinus*		115.7–115.5	Domination of *Pinus*, associated with *Betula*.
Do 13 Poaceae–Cyperaceae–*Betula*	Do 13b Poaceae–*Artemisia–Betula*	117.2–115.9	High values of NAP, and *Pinus* share distinct. This zone is divided into two subzones: older Do 13a Cyperaceae–*Picea* marked by high proportion of Cyperaceae (32.6%) and decreasing in values of *Picea* and Do 13b Poaceae–*Artemisia–Betula*. This zone is characterised by an increase in Poaceae and *Artemisia* (4.3–11.2%), as well by *Betula* (23.5–28.1%).
	Do 13a Cyperaceae–*Picea*		
Do 12 *Pinus–Picea*–NAP		118.8–117.4	Still *Pinus*, *Betula*, *Alnus* and *Picea* prevail among trees, NAP rises. Herbs attend great variety, and are dominated by Poaceae (5.4–17.1%) and Cyperaceae (4.8–7.9%) with *Artemisia*, Apiceae, Brassicaceae, *Thalictrum*, *Aster* typ, *Anthemis* typ and others.
Do 11 *Betula–Pinus–Alnus*		120.25–118.8	*Pinus*, *Betula*, *Alnus* and *Picea* prevail in AP. Thermophilous elements in low percentages.
Do 10 *Fraxinus–Betula*		120.43	Sharp increase in *Fraxinus* (20%) and slight in *Betula*.
Do 9 *Pinus–Picea–Calluna vulgaris*		122.3–120.8	Alternating percentage of *Pinus* (47–71.6%), *Betula* (5.1–19.4%) and *Alnus* (3.5–11.7%). Pollen of *Quercus*, *Ulmus*, *Tilia cordata* typ and *Corylus* is recorded.
Do 8 *Artemisia*–Poacae		122.75	Domination of NAP, an increasing in *Artemisia* (10.2%) and max. share of Poaceae (45.8%).
Do 7 *Betula–Salix*–Ericaceae		123.0	*Betula* pollen values fall (29%), maximum value of *Salix* (3.6%) and Ericaceae (2.2%). *Betula nana* pollen is present.
Do 6 *Picea–Abies*		127.5–127.4	An decrease *Quercus*, *Tilia cordata* typ, *Ulmus* and *Corylus* proportions. High values of *Picea* (48.5%) and max. share of *Abies* (1.5%).
Do 5 *Alnus–Quercus–Tilia*		127.8–127.6	In the zone AP dominations, *Alnus* reaches high values, above 42%, more abundant pollen of thermophilous taxa *Quercus* (5.8%), *Tilia cordata* typ (max. value 5.5%), *Ulmus* (2.7%) and *Corylus* (up to 6%). Pollen of *Acer* and *Tilia platyphyllos* is present. The proportion of *Picea* is distinct (13%).
Do 4 *Pinus–Picea*		128.0	An abrupt rise of *Pinus* (86.3%) and slight *Picea* (9.5%).
Do 3 NAP–*Betula–Larix*		128.1	This zone is marked by an increase in *Betula* (28.7%) and *Picea* (8.7%). Maximum values of *Larix* (4.8%).
Do 2 *Pinus–Betula*		128.15	A decrease in *Betula* precetange to 10%, *Pinus* values increase to 68%, NAP falls, *Artemisia* disappears.
Do 1 *Betula–Hippophaë–Juniperus*		128.5–128.3	This zone corresponds to the maximum values of *Betula* (46.7%), *Hippophaë* (3.5%) and *Juniperus* (2.3%). *Larix* and *Picea* up to 4.5% and 2.9% respectively.

The following stadial stage (**Do 22 L PAZ)** is characterized by high percentages of herb pollen that indicates deforestation resulting from the severe climate deterioration.

DIATOM ANALYSIS

The diatom flora studied from the profile at Domuraty consists of 133 species and intraspecific taxa belonging to 45 genera, 23 families, 11 orders and 3 classes. Qualitative and quantitative changes in species composition allow distinction of 7 local diatom assemblage zones (L DAZ D-1–D-7) in the diatom diagram (Fig. 4) reflecting changing palaeoecological and sedimentary conditions in the ancient basin.

The first, sparce diatoms (21 taxa) appeared in the depth interval 118.9–118.6 m (L DAZ D-1). This zone is dominated by species of *Staurosirella* often occurring attached to sand grains. The most common taxon is *Staurosirella* sp. 1 (up to 6.8%). The epiphytic species *Pseudostaurosira brevistriata* and the planktonic species *Stephanodiscus* sp. aff. *S. raripunctatus* are present in small quantity. The palaeobasin was of oliogotrophic type and shallow at the initial stage of its development.

The next L DAZ D-2 (118.6–117.2 m) is recognized by increase in the frequency and diversity of diatoms (to 50 taxa). This diatom zone contains two subzones. Subzone D-2a (118.6–118.1 m) is defined by the highest values (72–74.4%) of the freshwater epithytic diatom *Fragilariforma hungarica* in the profile. Subzone D-2b (118.1–117.2 m) is distinguished not only by a considerable content of the *Fragilariforma* mentioned above (to 54–66%), but also by the maximum amounts of the cold-water brackish planktonic species *Fragilariforma heidenii* (up to 31%), as well as of the freshwater epiphytic taxa of *Staurosirella pinnata* et var. *lancettula* (13.3%) and *Punctastriata ovalis* (8%). The above data indicate the improvement of palaeoecological conditions in the ancient basin (a slight rise of water level and influx of mineral matter) at this stage. The palaeobasin was oligotrophic, as before. L DAZ D-1 and L DAZ D-2 correspond to L PAZ Do 12 *Pinus–Picea*–NAP.

L DAZ D-3 (117.2–116.5 m) is marked by a sharp decrease in the percentage of all ecological diatom groups, and only to the end of this zone does the abundance of diatoms again increase by virtue of the epiphytic taxa (*Martyana martyi* — up to 47%, *Cocconeis pediculus* — 5.6% and *C. placentula* with varieties — 4.2%). At this depth interval fossil chrysophyte cysts preferring generally cold water were found in great number. This suggests general changes in lacustrine or lacustrine-fluvial biota caused by environmental (primarily climate) shifts, in agreement with the results of palynological investigations (L PAZ Do 13a Cyperaceae–*Picea*) obtained by Winter.

L DAZ D-4 (116.5–115.6 m) is identified by the maximum taxonomic diversity of diatoms in this profile (up to 90 species and intraspecific taxa) and by the abundance of many planktonic and some benthic/epiphytic taxa. This diatom zone includes two subzones. Subzone D-4a (116.5–116.1 m) is dominated by various planktonic taxa of *Stephanodiscus* (*S. rotula* — to 17%, *S. niagarae* var. *insuetus* — to 8%, *S. parvus* — to 10%, *Stephanodiscus* sp. aff. *S. raripunctatus* — 2.8%) and *Fragilaria* cf. *capucina* — to 13%, as well as by benthic species of *Tryblionella angustata* (8.6%), *Amphora libyca* (4.4%), *Cymatopleura solea* (2.8%), and the epiphytic species

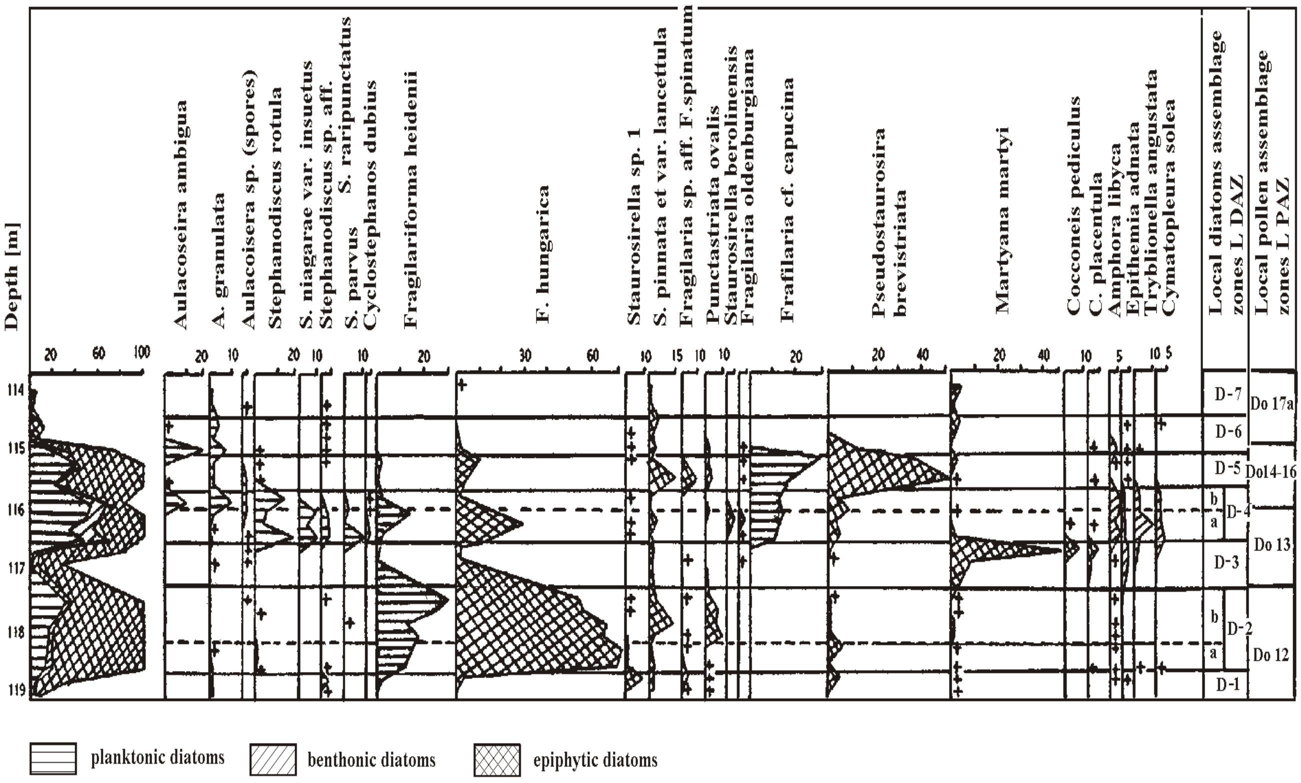

Fig. 4. Diatom succession and the sedimentary record from the Domuraty section

Fragilariforma hungarica (to 30%). Subzone D-4b (116.1–115.6 m) differs by the prevalence not only of *Stephanodiscus rotula* (14.2%) and *Fragilaria* cf. *capucina* (to 12%), but also of certain planktonic species of *Aulacoseira* (*A. ambigua* — to 10.4% and *A. granulata* — to 9.8%). Proportions of benthic and epiphytic diatoms decreased. The constant predominance of planktonic taxa in L DAZ D-4 reflects a higher water level of the palaeolake at this stage than in the previous one. The appearance and a generally high content of the temperate warm-water taxa of *Aulacoseira* mentioned above together with some cold-water diatom species in subzone D-4b testify to a meso-oligotrophic or even mesotrophic regime in the fossil lake. Diatom subzones D-4a and D-4b correspond to L PAZ Do 13b Poaceae–*Artemisia*–*Betula* and L PAZ Do 14 *Pinus*.

L DAZ D-5 (115.6–115.1 m) is characterized by the absolute maximum of the epiphytic species *Pseudoaulacosira brevistriata* (as much as 55%) and of the planktonic taxon *Fragilaria* cf. *capucina* (as much as 35%) in this profile. Moreover, *Staurosirella pinnata* et var. *lancettula* shows a second peak (up to 13%). The diatom assemblage described suggests a lowering of water level in the ancient lake in the comparison with the previous stage. This diatom zone corresponds to L PAZ Do 15 *Picea–Carpinus–Quercus*.

The next L DAZ D-6 (115.1–114.5 m) is marked by decrease in the amount of diatoms, especially to the end of this zone. The quantities of many species represented by *Staurosira*, *Synedra*, *Gomphonema*, *Achnanthes*, *Sellaphora* and other taxa are insignificant. The values of *Pseudoaulacosira brevistriata* abruptly reduce to 12–0.4%, and only *Aulacoseira ambigua* has a maximum occurrence in the profile (17.2%) at the beginning of this zone. The changes noted in the diatom composition are indicative of shallowing and apparently eutrophication of the ancient lake. L DAZ D-6 corresponds to L PAZ Do 16 *Quercus–Ulmus* and partly to L PAZ Do 17 *Carpinus–Alnus–Abies*.

Deposits, corresponding to L DAZ D-7 (114.5–114.3 m), contain a very poor diatom flora (14 taxa) with few valves of *Aulacoseira*, *Synedra*, *Martyana*, *Epithemia*, and so on. The palaeolake remained shallow.

Hence, the diatom succession revealed in the lacustrine-fluvial-swampy deposits from the profile at Domuraty can be represented as follows: *Staurosirella*, *Pseudostaurosira* *Fragilariforma*, *Staurosirella*, *Punctastriata* a small number of diatoms except *Matryana* and *Cocconeis* *Stephanodiscus*, *Aulacoseira*, *Fragilaria* cf. *capucina*, *Fragilariforma*, *Tryblionella*, *Amphora* *Pseudostaurosira*, *Fragilaria* cf. *capucina* *Aulacoseira*, *Pseudostaurosira* a very low frequency of diatoms. Generally, this diatom succession reflects lake changes from a not very deep, oligotrophic basin (L DAZ D-1–L DAZ D-3) to a lake of medium depth and meso-oligotrophic or mesotrophic type (L DAZ D-4–L DAZ D-5), and finally to a shallow and slightly eutrophic lake (L DAZ D-6 — partly L DAZ D-7).

DISCUSSION

The Domuraty sequence is a long pollen sequence recording alternations of forest and open vegetation communities in response to climate changes.

The interpretation of the Domuraty pollen sequence in terms of the vegetation development is difficult due to the lack or scarcity of pollen in the sand layers, which could be related to fluvial activity (Winter and Lisicki, 2005). Nevertheless the general pattern of vegetational change is clear.

The two stages Do I and Do III are associated with warm climate conditions which led to the expansion of deciduous forests with *Quercus, Tilia cordata* and *Ulmus* dominating, as well as *Corylus* in stage Do I, and also with the parallel presence of *Carpinus, Picea* and *Abies* in Do III. The characteristic feature of Do III is the continuous presence of *Azolla filiculoides*. The first stage Do I was briefly interrupted by a rapid spread of *Picea* before the onset of stadial conditions. The prevailing boreal pollen taxa of stages Do II and Do IV suggests that they represent cold interstadials.

In Poland interglacial pollen succesions of the Augustovian (Janczyk-Kopikowa, 1996; Ber *et al*., 1998; Winter, 2001; Lisicki and Winter, 2004; Ber, 2005) and the Ferdynandovian interglacials (Janczyk-Kopikowa, 1975; Janczyk-Kopikowa, 1991*b*; Mamakowa, 2003; Pidek, 2003) represent complex sequences with records of glacial?/interglacial cycles (perhaps, cold/warm cycles), within each of which *Carpinus* appears to be characteristic only during the second interglacial. Comparisons have been made between these pollen successions. The pollen records from Domuraty show a similar pattern of vegetation development and appearance of *Carpinus*. The lack of *Carpinus* pollen in older interglacials and its presence in the younger ones is characteristic of Augustovian and Ferdynandovian sequences, as well as of the Domuraty succession. In the Domuraty sequence the different behaviour of *Picea*, which increases with *Carpinus* and other thermophilous trees, is distinct. Moreover the *Abies* pollen curve parallels that of *Carpinus*.

The vegetational succession of the warm stages of the Domuraty sequence indicates a climate shift to cooler conditions reflected by more open character of the forest and lower proportions of thermophilous taxa. More detailed inspection of the first warm phase Do I shows very substantial differences between it and the first interglacial of the Ferdynandovian succession. The main ones are: a continuous *Picea* pollen curve at the beginning of Do I, very low proportions of thermophilous trees and the absence of *Celtis, Ilex, Buxus, Taxus* and *Vitis* pollen. The Domuraty sequence does not include the *Abies* phase observed in diagrams of the Ferdynandovian succession. The pollen sequence from Domuraty is more similar to the Augustovian than to the Ferdynandovian one.

Therefore the pollen record indicates that Domuraty succession cannot be correlated with Augustovian and

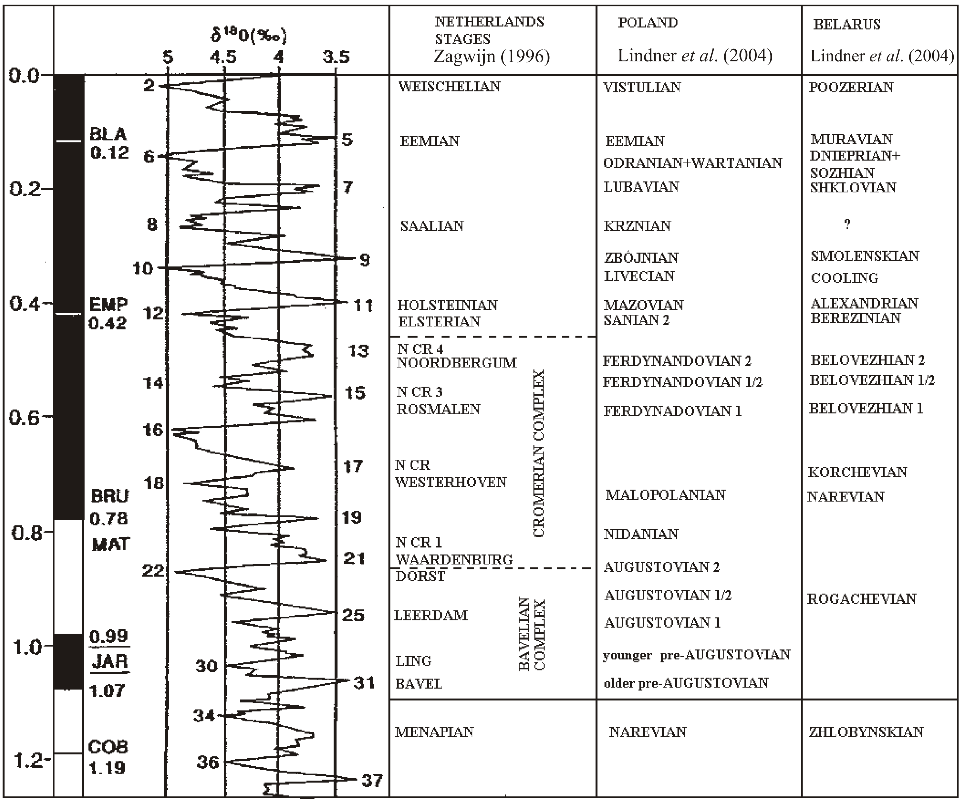

Fig. 5. Scheme of the upper Early, Middle and Late Pleistocene stratigraphy of Poland

Ferdynandovian pollen sequences. The Augustovian and Ferdynandovian interglacials are attributed to the early Middle Pleistocene in Polish stratigraphy (Ber *et al.*, 1998; Lindner and Astapova, 2000; Lisicki and Winter, 2004; Ber, 2005; Winter and Lisicki, 2005; Lindner *et al.*, 2006; Fig. 5).

The stratigraphical position of the Augustovian Interglacial has been determined by palaeomagnetic studies (Ber, 2000). The deposits investigated were deposited at the Matuyama–Bruhnes magnetic polarity reversal. Based on this result the second warm stage/interglacial of the Augustovian Interglacial could be correlated with Marine Isotope Stage 19, and the first one with Marine Isotope Stage 21, i.e. with the Cromer I (Waardenburg Interglacial) of Dutch stratigraphy (Zagwijn, 1985, 1996).

On the basis of the palaeomagnetic studies, deposits belonging to the Ferdynandovian Interglacial have been placed in Bruhnes chronozone (Krzyszkowski *et al.*, 1996). Lindner *et al.* (2004) attributed the first warm stage/interglacial of the Ferdynandovian pollen succession to MIS 15 (Cromerian III Interglacial), and the second one was referred to MIS 13 (Cromerian IV Interglacial).

Lindner *et al.* (2004) suggest that the Małopolanian Interglacial corresponds to the MIS 17. Therefore the composition of the pollen flora and the general pattern of the vegetation development in the Domuraty section indicate also its relation to the early Middle Pleistocene and it could be a palynological equivalent of the Małopolanian Interglacial (Lindner *et al.*, 2000; Kacprzak *et al.*, 2002; Winter *et al.*, 2005; Lindner *et al.*, 2006). Nevertheless the lack of chronological control of the pollen-bearing deposits makes chronostratigraphical correlation difficult.

In Poland, deposits attributed to the Małopolanian Interglacial have been recognized at Łowisko (Stuchlik and Wójcik, 2001). The fragmentary pollen succession represents the decline of a warm period characteristic of interglacial successions, and a considerable part of this succession is referred to glacial conditions. Because of the lack of *Carpinus* it might be correlated with the final part of the warm stage Do I (Do 5 L PAZ) distinguished in the Domuraty pollen diagram.

The sequence from Domuraty appears to share a great similarity with Göttingen, Otto-Strasse (Grüger, 1996) in terms of the character of the pollen flora and the palynological record of warm/cold cycles. In the pollen floras from both profiles exotic elements are represented only by *Azolla filiculoides.* The vegetational development of Do I resembles that recorded in GOS II (the second warm period) at Göttingen. In both periods *Picea* is a very important forest component, and *Carpinus* is absent. Forest phase Do III could be correlated with GOS III. The similarity is expressed by the occurrence of *Carpinus* pollen and massulae of *Azolla filiculoides* a water fern.

In terms of the chronostratigraphical position the Göttingen, Otto-Strasse sequence, on the basis of palynological investigations and palaeomagnetic studies, has been ascribed to the Cromerian Complex Stage *s.l.* (Grüger, 1996).

The Cromerian Interglacial III from Rosmalen has been distinguished in the Cromerian Complex Stage of the Netherlands (Zagwijn, 1996). Despite some differences, the dominance and development of vegetation are similar for this interglacial and the Do III warm stage. Both successions are characterized by the occurrence of *Carpinus* and *Picea* pollen from the beginning of these stages, relatively high percentages of *Carpinus* and *Picea* pollen and low values of thermophilous trees.

COMPARISON OF THE DOMURATY DIATOM SUCCESSION

A comparative analysis of diatom successions revealed in the profiles at Domuraty and Komorniki showed the following shared peculiarities. In the profile at Komorniki two intervals with a relatively high content of planktonic species of the genera *Stephanodiscus* and *Aulacoseira*, corresponding to L DAZ K-2 and L DAZ K-6, are present (Khursevich *et al*., 2005), while in the profile at Domuraty only one interval with an increased percentage of those (L DAZ D-4 — the lower part of L DAZ D-6) has been noted. Moreover, the planktonic species *Fragilaria* cf. *capucina* is abundant in L DAZ D-4–L DAZ D-5 in the Domuraty profile. The cold-water littoral planktonic species of *Fragilariforma heidenii* that preferred brackish water (Krammer and Lange-Bertalot, 1991*a*) generally rather high values in L DAZ K-4 and L DAZ K-6b at Komorniki, and in L DAZ D-2 and L DAZ D-4a at Domuraty.

Among the *Aulacoseira* taxa, both species *A. ambigua* and *A. granulata* are characteristic of these profiles. However, in the profile at Komorniki spores of *Aulacoseira* belonging apparently to several species of this genus were occurred in great number in subzone K-6d. In the profile at Domuraty *Aulacoseira* spp. represented by spores were not numerous.

Species of *Stephanodiscus* are more diverse in the profile at Komorniki as compared with that at Domuraty. Both profiles contain the following common taxa of *Stephanodiscus*: *S. niagarae* var. *insuetus* and *S. rotula* (with some morphological peculiarities), *Stephanodiscus* sp. aff. *S. raripunctatus*, as well as the small species *S. hantzschii*, *S. parvus* and *S. minutulus.* But certain unidentified, apparently new diatom representatives, such as *Stephanodiscus* sp. 1 (small specimens with thin areolation of valves) and *Stephanodiscus* sp. 2 (large specimens with narrow fascicles of areolae), found in the diatom succession at Komorniki (Khursevich *et al*., 2005), are absent from that at Domuraty.

Benthic/epiphytic species in diatom successions of both profiles are represented mainly by the dominant taxa *Fragilariforma hungarica*, *Staurosirella pinnata* et var. *lancettula*, *Staurosirella* sp. 1 (small specimens with short coarse striae and oval axial area), *Pseudostaurosira brevistriata*, *Punctastriata ovalis*, *Martyana martyi*, *Tryblionella angustata* and some other members. They are abundant in those local diatom assemblage zones which reflect a not very deep, oligotrophic type of ancient basin. Additionally, three unidentified, apparently new species of *Staurosirella*, characterized by different shapes of valves and their ends, different shapes of the axial area and by the character of apical pore fields, as well as one unidentified species of *Pseudostaurosira*, were found in the profile at Komorniki. Moreover, some intermediate forms between *Staurosira* and *Staurosirella* (on the structure of areolar striae) occurred in the lacustrine-swamp-fluvial sequence at Komorniki.

On the whole, the taxonomic composition of diatoms from the profile at Domuraty differs by lesser diversity as compared with that at Komorniki (133 taxa in the Domuraty profile against 216 species and intraspecific taxa in the Komorniki profile). This may be caused by the dilution of diatom valves with sandy material at Domuraty, or by palaeoenvironmental conditions affecting the development of diatoms.

Diatom successions from the Komorniki and Domuraty profiles are similar in many aspects as shown above (the presence of many common dominant species belonging not only to *Stephanodiscus* and *Aulacoseira*, but also to *Fragilariforma*, *Staurosirella*, *Pseudostaurosira*, *Punctastriata* and *Martyana*). Among extinct members of diatoms, recorded in both profiles, *Stephanodiscus niagarae* var. *insuetus* (with some morphological peculiarities), *Stephanodiscus* sp. aff. *S. raripunctatus* and *Staurosirella* sp. 1 should be noted. But the assemblage of apparently extinct species in the diatom succession at Komorniki is more diverse, and is represented also by several unidentified members of *Stephanodiscus*, *Staurosirella* and *Pseudostaurosira* noted above. This is indicative of an older age of the diatom flora from Komorniki, belonging to the Augustovian Interglacial (Khursevich *et al*., 2005), in the comparison with that from Domuraty.

On the other hand, successions of diatoms at Komorniki and Domuraty essentially differ from diatom successions known from many profiles of the Ferdynandovian Interglacial in Poland (Khursevich *et al.*, 1990; Marciniak, 1990; Marciniak and Lindner, 2003) and of the Byelovezhian Interglacial in Belarus (Khursevich and Loginova, 1986; Velichkevich *et al.*, 1997; Khursevich, 1999). First of all, absent from the lacustrine-swamp-fluvial sequences from both profiles studied are stenochronous taxa of the Byelovezhian/ Ferdynandovian Interglacial, such as *Cyclotella reczickiae*, *Stephanodiscus determinatus*, *S. styliferum* and *S. peculiaris* var. *ferdynandoviensis*. The latter is known from profiles at Ferdynandów (Przybyłowska-Lange and Khursevich, 1991) and Popioły (Marciniak and Lindner, 2003) in Poland. As far as the nominate variety of *Stephanodiscus peculiaris* is concerned, this taxon was first described from the profile of the Byelovezhian Interglacial at Krasnaya Dubrova in the territory of Belarus (Khursevich, 1987), and later it was found in other coeval profiles not only in Belarus, but also in Russia and Poland (Khursevich *et al.*, 1990; Antsiferova, 1991; Marciniak and Lindner, 2003).

Furthermore, the absence of the apparently extinct *Stephanodiscus raripunctatus*, originally described from the Byelovezhian Interglacial lacustrine deposits at Krasnaya Dubrova (Khursevich and Loginova, 1986; Khursevich, 1999) is characteristic of the Komorniki and Domutary profiles. *Stephanodiscus* sp. aff. *S. raripunctatus*, revealed in the Komorniki and Domuraty sequences, differs from the typical *S. raripunctatus* (Khursevich, 1999: 594, fig. 33) by the presence of valves with a strongly concave or convex central area which is commonly structureless, as well as in the number of areolae and hyaline strips (or costae) in 10 μm on the valve surface.

Some morphological peculiarities of *Stephanodiscus niagarae* var. *insuetus* in the Komorniki profile have already been noted by Khursevich *et al*. (2005). *Stephanodiscus rotula* abundantly represented in both profiles studied, is distinguished by the specific external expressions of marginal fultoportulae on the valve mantle.

An insignificant participation of the *Cyclotella* species is also distinctive feature of diatom successions from the lacustrine-swamp-fluvial sequences at Komorniki and Domuraty as compared with those known from many profiles of the Byelovezhian Interglacial in Belarus and the Ferdynandovian Interglacial in Poland. Only the long-lived taxa *Cyclotella atomus*, *C. meneghiniana* and *C. distinguenda* were infrequent in the sedimentary records obtained from both studied sections, while generally high values show many *Cyclotella* members, including the extinct *C. comta* var. *pliocaenicus*, *C. comta* var. *lichvinensis* and *C. reczickiae* var. *diversa*, in the deposits of the Byelovezhian/Ferdynandovian Interglacial. The extinct *Cyclotella* taxa mentioned above belong to those dominating also in the Alexandrian Interglacial sequences of Belarus (Loginova, 1979; Khursevich and Fedenya, 1998; Khursevich, 1999), and some of these (*C. comta* var. *pliocaenicus* and *C. comta* var. *lichvinensis*) are typical of the profiles of the Mazovian Interglacial from Poland (Marciniak, 1998).

The diatom successions at Komorniki and Domuraty are similar in the abundance of planktonic species of *Stephanodiscus* and *Aulacoseira*, as well as in the small amounts of *Cyclotella* with the succession of diatoms studied in the Mogilevian Interglacial deposits from the Krasnaya Dubrova profile (the borehole 13B) in Belarus (Khursevich *et al.*, 1990). Nevertheless the taxonomic composition of diatoms in the Komorniki sequence is characterized by the presence of certain important, apparently extinct species of *Stephanodicus* (in particular, several unidentified taxa of this genus noted above, and *Stephanodiscus* sp. aff. *S. raripunctatus* — the latter is present also at Domuraty) which are absent both from the diatom assemblages of the Byelovezhian/Ferdynandovian and the Mogilevian interglacials. The same is also characteristic of some small, unidentified *Staurosirella* and *Pseudostaurosira* representatives, as well as of certain intermediate forms between *Staurosira* and *Staurosirella* found in the profile at Komorniki. The abundant occurrence of *Fragilariforma heidenii* and *F. tumida* is typical of both diatom successions studied.

Thus, a comparative analysis of diatom successions revealed in the lacustrine-swamp-fluvial sequences at Komorniki and Domuraty showed that they belong apparently to different age intervals. According to geological, palynological, diatomological and malacological investigations, the deposits of this sequence in the Komorniki profile proceeded mainly in the Augustovian Interglacial (Ber, 2000, 2005; Khursevich *et al.*, 2005). The results of palynological and petrographic studies of the lacustrine-fluvial-swamp succession in the Domuraty section suggest its accumulation apparently during on interstadial not connected with the Augustovian and Ferdynandovian interglacials (Winter and Lisicki, 2001, 2005; Lisicki and Winter, 2004). With regard to the complicated character of the pollen succession and the uncertain stratigraphic position of the tills the sequence from Domuraty may tentatively be related to the Małopolanian Interglacial of the early Middle Pleistocene (Winter and Lisicki, 2005).

The data derived from diatom analysis also indicate that the diatom succession from the profile at Domuraty apparently occupies a transitional position between the Augustovian and Ferdynandovian interglacials. But it is similar to the Augustovian succession of diatoms studied from the Czarnucha (Marciniak, 2004) and Komorniki sections (Khursevich *et al.*, 2005), and is distinct from the Ferdynandovian diatom succession in Poland (Khursevich *et al.*, 1990; Marciniak, 1990; Marciniak and Lindner, 2003) and from both the Byelovezhian and the Mogilevian Interglacial successions in Belarus (Khursevich and Loginova, 1986; Velichkevich *et al.*, 1997; Khursevich, 1999).

As a result of the new palaeobotanical investigations the Domuraty sequence might be regarded as a new warm stage in the Pleistocene. In conclusion palynological and diatom data, as well as through the stratigraphical position of tills underlying and overlying the deposits examined, their stratigraphical position could be assigned to the Cromerian Complex Stage situated in the upper part of the early Pleistocene and the lower part of the Middle Pleistocene succession (Gibbard and Van Kolfschoten, 2004). The chronostratigraphical position of the Domuraty sequence as the time equivalent of the Małopolanian Interglacial could support Müller's opinion (1986) that this complex contains more warm stages than previously recognized.

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REFERENCES

ANTSIFEROVA G. A. (1991) — The diatom flora of the Lower Pleistocene interglacial (Muchkapian) deposits (in Russian with English summary). Algologia, **1** (1): 104–108.

BER A. (2000) — Pleistocene of north-eastern Poland and neighbouring areas against crystalline and sedimentary basement (in Polish with English summary). Pr. Państw. Inst. Geol., **170**.

BER A. (2005) — Polish Pleistocene stratigraphy — a review of interglacial stratotypes. Netherl. J. Geosc., Geol. en Mijnbouw, **84** (2): 61–76.

BER A. (2006) — Pleistocene interglacials and glaciations of northeastern Poland compared to neighbouring areas. Qutern. Internat., **149**: 12–23.

BER A., JANCZYK-KOPIKOWA Z. and KRZYSZKOWSKI D (1998) — A new interglacial stage in Poland (Augustovian) and the problem of the age of the oldest Pleistocene till. Quatern. Sc. Rev., **17**: 761–773.

BUKHTIYAROVA L. (1999) — Diatoms of Ukraine Inland waters. M. G. Kholodny Institute of Botany, Kyiv.

GIBBARD P. and VAN KOLFSCHOTEN T. (2004) — The Pleistocene and Holocene Epochs. In: A Geologic Time Scale (eds. Gradstein, J. Ogg and A. Smith): 441–452.

GŁAZEK J., KOWALSKI K., MŁYNARSKI M., STWORZEWICZ E., TUCHOŁKA P. and WYSOCZAŃSKI-MINKOWICZ T. (1976) — Cave deposits at Kozi Grzbiet (Holy Cross Mts., Central poland) with verterbrate and snail faunas of the Mindelian I/ Mindelian II Interglacial and their stratigraphic correlation. Proc. 7th Internat. Speleolog. Congress: 211–214.

GRÜGER E. (1996) — Palynostratigraphy of the Middle Pleistocene sequence from Göttingen, Otto-Strasse. In: The Early Middle Pleistocene in Europe (ed. Ch. Turner): 173–180. A. A. Balkema, Rotterdam, Brookfield.

JANCZYK-KOPIKOWA Z. (1975) — Flora interglacjału mazowieckiego w Ferdynandowie. Biul. Inst. Geol. **290**: 5–94.

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

JANCZYK-KOPIKOWA Z. (1991*b*) — The Ferdynandów Interglacial in Poland. Geol. Quart., **35** (1): 71–80.

JANCZYK-KOPIKOWA Z. (1996) — Ciepłe okresy w mazoplejstocenie północno-wschodniej Polski. Biul. Państw. Inst. Geol., **373**: 49–66.

KACPRZAK L., LISICKI S. and WINTER H. (2002) — Stratigraphical position of the Czarnucha, the Cisów and the Domuraty sections in the Middle and Lower Pleistocene, NE Poland. Abstract Volume of the Field Symposium on Quaternary Geology and Geodynamics in Belarus, May 20–25, 2002, Grodno. Inst. Geol. Sc., Minsk. P.: 19–21.

KACZMARSKA I. (1976) — Diatom analysis of Eemian profile and freshwater deposits at Imbramowice near Wroclaw. Acta Palaeobot., **17**: 3–33.

KHURSEVICH G. K. (1987) — Morphology of new species of the genus *Stephanodiscus* and their stratigraphic significance. Dokl. Akad. Nauk. BSSR, **31** (4): 355–357.

KHURSEVICH G. K. (1999) — Diatom communities from the Middle Pleistocene deposits of Belarus. In: Proc. 14th Diatom Symposium (eds. Sh. Matyama, M. Idei and I. Koizumi): 591–602. Koeltz Scientific Books, Koenigstein.

KHURSEVICH G. K. and FEDENYA S. A. (1998) — Microstratigraphy of the Alexandrian Interglacial deposits on the data of diatom analysis (in Russian with English summary). Dokl. Akad. Nauk. Belarusi, **42** (5): 107–112.

KHURSEVICH G. K. and LOGINOVA L. P. (1986) — Vozrast i paleogeographicheskiye usloviya phormirovaniya drevneozernykh otlozheniy Rechitskogo Pridneproviya (po dannym diatomovykh issledovanij). In: Pleistotsen Rechitskogo Pridneproviya Byelorussii (ed. R. A. Zinova): 76–142. Nauka i tekhnika, Minsk.

KHURSEVICH G., NITA M., BER A, SANKO A. and FEDENYA S. (2005) — Palaeoenvironmental and climatic changes during the early Pleistocene recorded in the lacustrine-boggy-fluvial sediments at Komorniki, NE Poland. Pol. Geol. Inst. Spec. Pap., **16**: 35–44.

KHURSEVICH G. K., PIDEK I. A. and FEDENYA S. A. (2003) — Environment changes in a fossil lake at Brus (Lublin Polesie — SE Poland) based on palaeoalgological data. Ann. UMCS Sect. B, **58** (4): 107–120.

KHURSEVICH G. K., PRZYBYŁOWSKA-LANGE W. and LOGINOVA L. P. (1990) — Coeval diatom floras from the Pleistocene profiles of Krasnaya Dubrova (Belarus) and Ferdynandów (Poland) (in Russian with English summary). Dokl. Akad. Nauk. BSSR, **34** (2): 179–183.

KRAMMER K. and LANGE-BERTALOT H. (1986) — *Bacillariophyceae*. 1: *Naviculaceae*. Fischer, Stuttgart.

KRAMMER K. and LANGE-BERTALOT H. (1988) — *Bacillariophyceae*. 2: *Bacillariaceae*, *Epithemiaceae*, *Surirellaceae*. VEB Gustav Fischer Verlag, Jena.

KRAMMER K. and LANGE-BERTALOT H. (1991*a*) — *Bacillariophyceae*. 3: *Centrales*, *Fragilariaceae*, *Eunotiaceae*. VEB Gustav Fischer Verlag, Jena.

KRAMMER K. and LANGE-BERTALOT H. (1991*b*) — *Bacillariophyceae*. 4: *Achnanthaceae*, Kritische Erganzungen zu *Navicula* (*Lineolatae*) und *Gomphonema* Gesamtliteraturverreichnis. VEB Gustav Fischer Verlag, Jena.

KRZYSZKOWSKI D., BÖTTGER T., JUNGE F. W., KUSZELL T. and NAWROCKI J. (1996) — Ferdynandovian Interglacial climate reconstructions from pollen successions, stable-isotope composition and magnetic susceptibility. Boreas, **25** (4): 283–296.

LANGE-BERTALOT H. (2001) — *Navicula* sensu stricto. 10 genera separated from *Navicula* sensu lato. *Frustulia*. A. R. G. Gantner Verlag K. G.

LANGE-BERTALOT H. and METZELTIN D. (1996) — Oligotrophie-Indicatoren 800 taxa repräsentativ rei diverse Seen-Typen. Iconographia Diatomologica, **2**. Koeltz Scientific Book, Konigstein.

LINDNER L. (1984) — An outline of Pleistocene chronostratigraphy in Poland. Acta Geol. Pol., **34**: 27–49.

LINDNER L. and ASTAPOVA S. D. (2000) — The age and geological setting of Pleistocene glacigenic beds around the border between Poland and Belarus. Geol. Quart., **44** (2): 187–197.

LINDNER L., BOGUTSKY A., GOZHIK P., MARKS L., ŁANCZONT M. and WOJTANOWICZ J. (2006) — Correlation of Pleistocene deposits in the area between the Baltic and Black Sea, Central Europe. Geol. Quart., **50** (1): 195–210.

LINDNER L., GOZHIK P., MARCINIAK B., MARKS L. and YELOVICHEVA Y. (2004) — Main climatic changes in the Quaternary of Poland , Belarus and Ukraine. Geol. Quart., **48** (2): 97–114.

LISICKI S. (2003) — Lithotypes and lithostratygraphy of tills of the Pleistocene in the Vistula drainage basin area, Poland (in Polish with English summary). Pr. Państw. Instyt. Geol., **177**.

LISICKI S. and WINTER H. (2004) — Rewizja pozycji stratygraficznej osadów dolnego i środkowego plejstocenu północno-wschodniej Polski. Geneza, litologia i stratygrafia utworów czwartorzędowych, 4. Ser. Geogr., **68**: 259–283.

LOGINOVA L. P. (1979) — The palaeogeography of the Likhvin Interglacial of the central part of the East-European plain (in Russian) (ed. A. P. Jousé). Nauka i tekhnika, Minsk.

MAMAKOWA K. (2003) — Plejstocen. In: Palinologia (eds. S. Dybova-Jachowicz *et al.*): 235–266. Wyd. Inst. Bot. PAN, Kraków.

MARCINIAK B. (1990) — Dominant diatoms in the interglacial lake sediments of the Middle Pleistocene in Central and Eastern Poland. Hydrobiologia, **214**: 253–258.

MARCINIAK B. (1991*a*) — Diatoms of the Ferdynandovian Interglacial in the Bełchatów region, Central Poland (preliminary report). Fol. Quatern., **61/62**: 85–92.

MARCINIAK B. (1991*b*) — Okrzemki w osadach organogenicznych interglacjału ferdynandowskiego w Podlodowe (Polska środkowa). Prz. Geol., **39** (5–6): 280–284.

MARCINIAK B. (1994) — Diatoms from the Eemian lacustrine sediments at Zbytki, Leszno Upland, Western Poland. Fol. Quatern., **65**: 99–110.

MARCINIAK B. (1998) — Diatom stratigraphy of the Mazovian Interglacial lacustrine sediments in southeastern Poland. Stud. Geol. Pol., **113**: 7–64.

MARCINIAK B. (2004) — Diatoms from Lower Pleistocene lacustrine sediments of Poland. In: 18th Internat. Diatom Symp., September 2–7, 2004, Międzyzdroje, Poland (eds. A. Witkowski *et al.*). University of Szczecin, Szczecin.

MARCINIAK B. and 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**: 269–281.

MARCINIAK B. and LINDNER L. (2003) — Diatoms and geology of the Ferdynandovian Interglacial lake sediments in Poland (in Polish with English summary). Botanical Guidebooks, **26**: 199–215.

MÜLLER H. (1986) — Altquartäre Sedimente im Deckgebirge des Salzstockes Gorleben. Zeitschrift der deutschen geologischen Gesselschaft, **137**: 85–95.

PIDEK I. A. (2003) — Mesopleistocene vegetation history in the northern foreland of the Lublin Upland based on palaeobotanical studies of the profiles from Zdany and Brus sites. Maria Curie-Skłodowska University Press. Lublin.

PRZYBYŁOWSKA-LANGE W. and KHURSEVICH G. K. (1991) — *Stephanodiscus peculiaris* Khurs. (Bacillariophyta) from Ferdynandów Interglacial. Acta Palaeobot., **31** (1–2): 245–259.

ROUND F. E., CRAWFORD R. M. and MANN D. G. (1990) — The diatoms. Biology and morphology of genera. Cambridge University, Cambridge.

STUCHLIK L. and WÓJCIK A. (2001) — Pollen analysis of Małopolanian Interglacial deposits at Łowisko (Kolbuszowa Upland, southern Poland). Acta Palaeobot., **41** (1): 15–26.

VELICHKEVICH F. JU., KHURSEVICH G. K., RYLOVA T. B. and LITVINYUK G. I. (1997) — Stratigraphy of the Middle Pleistocene of Belarus (in Russian). Strat. Geol. Correl., **5** (4): 68–84.

WALANUS A. and NALEPKA D. (1996) — POLPAL. Palinologiczna Baza Danych. Inst. Bot. PAN, Kraków.

WINTER H. (2001) — New profile of Augustowski Interglacial in north-eastern Poland (in Polish with English summary). UAM, Ser. Geogr., **64**: 439–450.

WINTER H. and LISICKI S. (2001) — The Domuraty pollen succession — vegetation and its stratigraphical position in the Middle Pleistocene of northeastern Poland. The Ukraine Quaternary Explored: the Middle and Upper Pleistocene of the Middle Dnieper Area and its importance for the East-West European correlation. Abstracts: 102–103. Kiev, Ukraine.

WINTER H. and LISICKI S. (2005) — Sukcesja pyłkowa z Domurat (Wzgórza Sokólskie) i jej znaczenie dla plejstocenu Polski północno-wschodniej. Biul. Państw. Inst. Geol., **416**: 115–131.

ZAGWIJN W. H. (1985) — An outline of the Quaternary stratigraphy of Netherlands. Geol. en Mijnbouw, **64**: 17–24.

ZAGWIJN W. H. (1996) — The Cromerian complex stage of the Netherlands and correlation with other areas in Europe. In: The early Middle Pleistocene in Europe (ed. C. Turner): 145–172.