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THE SUCCESSION OF INTERGLACIAL VEGETATION AT MOKRANY NOWE IN PODLASIE*

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ABSTRACT: The flora examined from Mokrany Nowe is sufficiently similar to that from Biała Podlaska to conclude that it represents the Mazovian Interglacial, the succession is of the Biała Podlaska or Komarno type.

KEY WORDS: pollen analysis, Mazovian Interglacial, vegetation succession, biostratigraphy

INTRODUCTION

Organic sediments with fossil interglacial flora were found at Mokrany Nowe in Podlasie (Krupiński & Nitychoruk 1990, 1991). This area is located within the extent of the ice sheet of the Odra (Rühle & Zwierz 1961, Różycki 1972, Rühle 1973, Lindner 1988) or the Warta Glaciations (Nowak 1973, 1974, 1977, Baraniecka 1984, Falkowski et al 1984–85, 1988). The site is a small undrained depression on a morainic plateau, 150 m long, 40 m wide and 4 m deep. The infilling sediments are not overlain by till. Preliminary palynological analyses of the distinctly deformed organic series made it possible associate them with the Mazovian Interglacial, a succession type of the Biała Podlaska (see: Krupiński 1984–85, 1988a, Krupiński et al 1986, 1988) or Komarno (Krupiński 1995a, Krupiński & Lindner 1991).

Various organic sediments there are up to 3 m thick and are composed of grey, strongly compressed and distinctly laminated or crumbled bituminous shales and peats; the latter are occasionally accompanied by sand. These sediments are underlain by clays or sands, beneath which there is grey till, highly saturated with water. The surface of the organic or organic-mineral sediments is considerably damaged, cut by numerous channels caused by erosion or by glaciotectonic deformations.

The poor cover of the preserved organic sediments, sandy at the top, is composed of occasional different-grained sands with gravel, silts, clayey fine-grained sands, medium-grained sands with gravel, clays and fine- and medium-grained sands of glaciofluvial origin. They are 1–2 m thick (Krupiński & Nitychoruk 1991).

The deformed organic sediments, underlying sands and clays are strongly saturated with water, and had not been sampled with a suitable auger. Therefore, a new core (MN 5/90) was collected with a Więckowski's corer, supplied with pipes affording protection from water from the overlying sediments. This core made possible the examination of the lithology, deformations, crumbling of shales and laminae within individual sets. The underlying clays and grey till were thermoluminescence dated.

The results of the palynological analyses of the organic and organic-mineral sediments from the core MN 5/90 are the main topic of this paper. They are obviously considered in relation to the earlier data too (Krupiński & Nitychoruk 1991). The varying lithology in this section is also described.

PALYNOLOGICAL STUDIES

The results of pollen analysis of the organic and organic-mineral sediments from core MN 5/90 made it possible to distinguish seven local pollen zones. They represent three main intervals in the development of forest communities.

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At the very base, no deposition had occurred or no sediments had persisted from the earlier non-forest phases (preceding the forest communities of the Mazovian Interglacial). Organic sediments could also have occurred beneath the bituminous shales but they were lost during drilling. The top of the underlying clays was located 15 cm below (depth 3.7 m) the base of the collected shales (depth 3.55 m). It also seems possible (but less probable) that between the bottom of the collected shales and the top of the underlying clays, there was a layer of silts or sands, 15 cm thick, but lost during drilling. The perceived picture of the first phases of vegetation development, recorded in sediments at bottom of the section, seems therefore to be incomplete.

PAZ – MN-5-A – *Betula-Picea-Alnus* (samples 38–31, depth 3.55–3.15 m). These are composed of dark grey, thick-laminated and slightly inclined laminae of strongly compressed bituminous shales. They contain much *Betula* (21–27%), *Alnus* (12–22%), *Picea* (10–15%), *Pinus* (21–27%), *Fraxinus* (3–8%), considerably less *Ulmus* (1–2%), *Quercus* (1%) and *Larix* (1–2%). There are low values of *Corylus, Tilia cordata* type and *Salix* (below 1%), occasionally *Acer*. Values of NAP are equal to 7–10%. Predominant is the pollen of Gramineae (3–5%), Cyperaceae (2–4%) and *Humulus* (0.3–0.9%). There are regular but low contents of *Artemisia* and *Viburnum*, an irregular or occasional presence of *Hedera, Frangula alnus, Juniperus, Urtica, Hippophaë*, Chenopodiaceae, Caryophyllaceae, Umbelliferae, Ranunuculaceae and Compositae Tubiflorae. The pollen of bulrushes (*Typha latifolia*), bur-reeds (*Sparganium* type), aquatic plants (*Myriophyllum spicatum* – about 1%) and spores of Polypodiaceae and *Equisetum* are of considerable significance. There are relatively high values of *Pediastrum* (20–40%). The spectrum has an undoubted Quaternary derivation. The pollen material shows a good frequency and is well preserved. The content of destroyed and non-determinable material does not exceed 0.5%. The upper boundary is defined by the converging of the curves of *Betula* and *Pinus*, a rise of *Alnus* and *Picea* and, to a lesser degree of *Tilia, Corylus* and *Quercus* and an insignificant drop of NAP.

PAZ – MN-5-B – *Alnus-Picea-(Pinus)*, samples 30–15, depth 3.15–2.35 m. These sediments are composed of dark grey, thick-laminated and slightly inclined layers of strongly compressed bituminous shales. Above the upper boundary of this horizon, the shales are badly crumbled. The spectrum is characterized by high values of *Alnus* (28–34%) and *Picea* (15–29%), much *Pinus* (20–25%), slightly less *Betula* (7–18%) and *Fraxinus* (2–6%). In comparison with the previous zone, this one contains slightly more *Tilia, Quercus* and *Corylus*. At its upper boundary, there are the first pollen grains of *Taxus*. The content of NAP is relatively low and gradually drops with decreasing depth, to about 3% at the top. There is occasional pollen of *Humulus, Viburnum, Frangula alnus, Hedera* and *Viscum*, and a single pollen grain of *Ephedra distachya* type (sample no. 26). *Myriophyllum spicatum* is present throughout. Its maximum values coincide with those of *Pediastrum*. The upper boundary of this zone is defined as the place where the pollen of *Taxus* and *Carpinus* first appeared, the curves of *Alnus* and *Pinus* declined and the high curve of *Pediastrum* was broken.

PAZ – MN-5-C – *Picea-Alnus-(Taxus)*, samples 14–12, depth 2.35–2.2 m. This section is represented by grey or dark grey, strongly compressed and crumbled bituminous shales. Their lower boundary with underlying non-crumbled shales is sharp and distinct. The spectra indicate the highest content in the whole diagram of *Picea* (36–39%) and a high concentration of *Alnus* (25–28%). Similar high values of *Picea* were noted in other sections or samples of organic sediments at this site, i.e. MN 4/90 (33%) and MN 2/89 (36%) (Krupiński & Nitychoruk 1991).

Besides *Picea* and *Alnus*, other important components in this zone, dominated by AP (over 98%), are: *Pinus* (17–22%), *Fraxinus* (1–3%) and *Tilia cordata* type (2–3%), and to a lesser degree, *Betula*, *Corylus*, *Quercus* and *Taxus*. The upper boundary of PAZ – MN-5-C is defined by a distinct rise of *Taxus* and a decreasing content of *Picea*. In the Mazovian succession of the Biała Podlaska or Komarno (Krupiński 1984–85, 1988a, 1995a, Krupiński & Lindner 1991, Krupiński et al 1986, 1988), this feature indicates the beginning of the main phase with yew (PAZ – BP-E or PAZ – KM-E – *Taxus-Picea-Alnus*). The *Picea* values are slightly or distinctly higher than those at other sites of this interglacial in mid-eastern Poland, for example, at Biała Podlaska (19%: Krupiński 1984–85, 1988a, Krupiński et al.

1986, 1988), Komarno (26%), Ossówka (22%) and Grabanów (24%: Krupiński 1984–90, 1985–92, 1991–92, 1995a, 1995b, Krupiński & Lindner 1991). Similar high contents were noted in sediments of similar pollen zones in the Poznań section near Adamów (Winter 1991) and Jamno Domaniewickie near Łowicz (Brzeziński & Janczyk-Kopikowa 1991).

PAZ – MN-5-D – *Picea-Alnus-Taxus* (samples 11–6, depth 2.2–1.9 m). These sediments are composed of grey or dark grey, strongly compressed and crumbled bituminous shales. There is a lithological change at the upper boundary. The pollen spectra indicate a similar taxonomic composition. They are dominated by *Picea* (25–37%) and *Alnus* (25–30%), with *Taxus* (5–10%) and *Pinus* (15–24%) numerous. The contents of each of *Corylus, Betula, Fraxinus, Ulmus* and *Carpinus* equal 2–3% or slightly less. *Larix* reappeared. Among the rare bushes and herbs (NAP 2–3%), the most abundant are Gramineae, Cyperaceae and plants of more exacting climatic demands such as *Viscum* and *Viburnum*. There is a relatively high content of *Nymphaea* and *Nuphar* and spores of *Sphagnum* are still present. More pollen within this and the previous zone, i.e. within the crumbled bituminous shales, has been destroyed (1–4%).

PAZ's – MN-5-E and **MN-5-F.** The lithology of sediments from the depths 1.9–1.75 m (sands with crumbled bituminous shales and peat at the top) made it necessary to treat each sample as two or three separate ones. The bituminous shales, sand and peat from the same depth were macerated separately. Pollen spectra from shales are marked 5b, 4b and 3c from peats 3b and 2a and from sands 5a, 4a, 3a and 2a (Fig. 1). Such an analysis made it possible to draw conclusions concerning the displacement of sediments and the possible occurrence of sedimentary or biostratigraphical hiatuses in this part of the section. The pollen spectra of sediments composed of crumbled, chaotically arranged pieces of grey and strongly compressed bituminous shales with sand (samples 5–4, depth 1.9–1.8 m) represent, depending on their lithology, two separate LPAZ's. The pollen spectra of the crumbled bituminous shales (samples 5b and 4b) represent PAZ – MN-5-E' – *Alnus-Picea-(Taxus)*, whereas the sands (samples 5a and 4a) correspond to PAZ – MN-5-E" – *Alnus-(Abies-Carpinus)*.

The spectra of the bituminous shales have high contents of *Picea* (20–24%), *Alnus* (25–27%), *Taxus* (17–19%) and *Pinus* (19%), and distinctly less *Fraxinus* (4–5%), *Quercus* (2–3%), *Corylus* (2%), *Carpinus* (1%) and *Betula* (2%). They do not contain *Abies*. The bituminous shales are therefore older than sands which occur with them. The pollen spectra from the sands contain much *Abies* (12–19%), *Carpinus* (8–13%), *Alnus* (16–22%) and *Pinus* (23–30%) and distinctly less *Picea* (9–11%) and *Taxus* (4–8%) than the spectra from bituminous shales. They represent a younger series having a similar or slightly higher content of *Quercus* (5%) and *Corylus* (5%), and less of *Fraxinus* (2–3%). The pollen spectra of the various sediments in samples 5 and 4, should be biostratigraphically correlated with those of the shales of PAZ – BP-E or PAZ – KM-E, but with those of the sands of PAZ – BP-G or PAZ – KM-G from the interglacial sediments at Biała Podlaska (Krupiński 1988a, 1995a, Krupiński et al 1986, 1988) or Komarno (Krupiński & Lindner 1991, Krupiński 1984–90, 1995a).

The sediments in section MN-5/90 that form the next, very thin bed (samples 3a, b, c, depth 1.80–1.75 m), consist of three different components: pieces of crumbled bituminous shale (sample 3c) and agglomerations of completely decomposed amorphous peat (sample 3b) that occur accompanied by sand (sample 3a). The pollen spectra of these three lithologically varied components are different. Totally distinct is the spectrum of the crumbled bituminous shales. Its composition corresponds to the spectra of the similar underlying sediments, although there are new floristic elements which are abundant in the overlying series. There is much *Pinus* (33%), *Alnus* (19%), *Picea* (14%) and *Abies* (8%) and slightly less *Carpinus* (5%), *Quercus* (5%) and *Corylus* (4%). The *Taxus* content is decidedly low (1%). The pollen spectra of the strongly decomposed peat and sand with dispersed organic matter are quite similar to each other. They contain much *Abies* (14–18%), *Alnus* (19–20%), *Pinus* (24%), *Carpinus* (8–9%), *Quercus* (5%) and *Corylus* (6%). There is much less *Picea* (6–9%) than in the bituminous shales and the values of *Pterocarya* and *Larix* are low. The content of other taxa does not differ significantly and contains the pollen of *Buxus*, *Viburnum* and *Stellaria nemorum*. In spite of such a diversity in the pollen spectra, the material in the decomposed peat and sand seems to represent a pollen zone (PAZ – MN-5-F – *Alnus-(Abies-Carpinus-Pinus*). The upper boundary of PAZ – MN-5-F is marked by a distinct drop in *Picea*, rises in *Abies* and *Carpinus*, and to a lesser degree, in *Quercus* and *Corylus*. The sediments change into more sandy ones, with peat but without crumbled bituminous shales.

PAZ – MN-5-G – *Abies-Carpinus-(Quercus)*, samples 2a, 2b and 1, depth 1.75–1.65 m, is very thin (0.1 m). Its sediments are not homogeneous and the top part consists of either an organic or organic-mineral series. In the bottom there are sands with peaty organic matter, completely decomposed at the top. These sediments are overlain with medium-grained sands with single gravel, over which there is grey-blue and slightly sandy clay (Fig. 1), covered with sand and peat that continue right up to the land surface.

The spectra of the palynologically analysed samples (2a, 2b and 1) of PAZ – MN-5-G indicate much *Abies* (16–31%), *Carpinus* (18–23%), *Alnus* (14–16%) and *Pinus* (22–31%), distinctly less (but still more than in the previous zone) of *Quercus* (7–9%) and *Corylus* (4–7%), and a little *Picea* (2–3%) and *Taxus* (0.4–0.9%). Among others, there are very small quantities of *Celtis* (0.2%), *Pterocarya* (0.2–0.4%), *Larix* (0.2%), *Buxus, Vitis* and *Viscum*. NAP does not exceed 3% and is mainly composed of Gramineae and Cyperaceae. No pollen of aquatic plants and algae of the genus *Pediastrum* were recorded.

The taxonomic-quantitative composition of the spectra makes possible the correlation of the sediments of this pollen zone to those of the older part of PAZ – BP-H (see Table 1), at the Biała Podlaska site (Krupiński 1984–85, 1988a, Krupiński et al 1986, 1988), and to that of PAZ – KM-H from Komarno (Krupiński 1984–90, 1995a, Krupiński & Lindner 1991).

SUCCESSION OF LOCAL AND REGIONAL VEGETATION

Several sections of organic sediments (mainly bituminous shales) at Mokrany Nowe in Podlasie have been analysed and subjected to palynological examination. The results are given in this and a previous paper (Krupiński & Nitychoruk 1991). Such sediments contain numerous sedimentary and post-sedimentary deformations, indicated by displacements (sand admixture in shales), gravity movements (varying subsidence of poorly consolidated or crumbling of consolidated series) and folds, as in the cores KM 2/85 and KM 2A/85 at Komarno (Krupiński 1995a). In any section analysed within this depression, the full sequence of organic sediments had been preserved and represented a complete record of the

Table 1. Correlation of local pollen zones in sections of the interglacial sediments at the Biała Podlaska, Komarno and Mokrany Nowe sites

Biała Podlaska* BP	Komarno* KM	Mokrany Nowe				
		MN.1/89	MN.2/89	MN.3/89	MN.4/89	MN.5/90
J	J	–	–	–	–	–
H	H	–	+	–	B	G
G	G	–	–	–		F
F	F	–	–	–	–	E
E	E	–	–	–	–	D
D	D	–	+	–	A	C
C	C	+	–	C	–	B
B	B	.	–	B	–	A
A	A	+	–	A	–	–

+ distinguished on the basis of a pollen spectrum of a single sample, – not found but may occur, absent.
*/ Simplified names of local pollen zones: BP – or KM: J – *Pinus-Picea-(NAP)*, H – *Carpinus-Quercus-Abies*, G – *Abies-Carpinus-Corylus-Quercus*, F – *Pinus-Picea-Alnus*, E – *Taxus-Picea-Alnus*, D – *Picea-Alnus-(Taxus)*, C – *Picea-Alnus-(Pinus-Betula)*, B – *Betula-Pinus-(Picea-Alnus)*, A – *Betula*-NAP – (*Salix*).

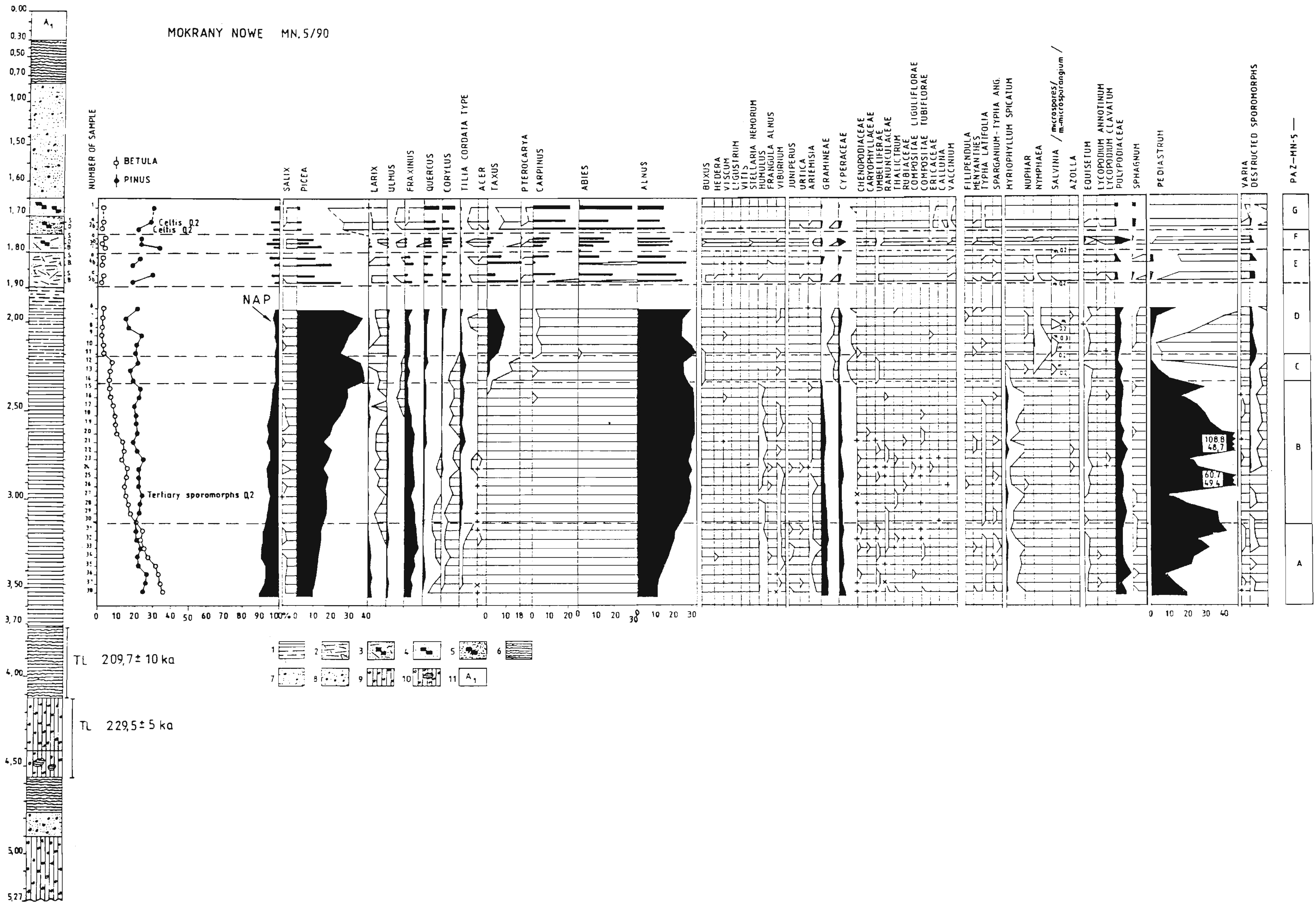

Fig. 1. Mokrany Nowe, pollen diagram of section MN 5/90. 1 – bituminous shales (solid line), partly crumbled (dashed line), 2 – crumbled bituminous shales with sand, 3 – different-grained sands with crumbled bituminous shales and peat, 4 – peat with sand, 5 – sand with peat, 6 – blue-grey clay, 7 – different-grained sands, 8 – sands with gravel, 9 – till, 10 – flow till with inserts of blue-grey clay, 11 – soil horizon A_1; B – bituminous shales, S – sand, O – agglomerations of amorphous peat; + – single, and x – two or more sporomorphs outside a total pollen content are indicated on the diagram.

Taxa not marked on the diagram (sample no. /%): NAP – *Ephedra distachya* type 26/+, *Hippophaë 31/+*, *Ledum* 2a/+, *Polygonum bistorta /viviparum* 24/+, *Polygonum persicaria/lapathifolium* 38/+, *Prunella* type 26/+, *Rhamnus cathartica* 6/0.2. Other taxa: *Comarum* 36/0.2, *Utricularia* 3b/0.2, *Stratiotes* 16/+, *Polygonum amphibium* 21/0.2, *Potamogeton* 24/0.2, 25/0.2, *Osmunda* 3a/0.6, *Botryococcus* 4a/0.2, 26/0.2, 31/0.2.

pre-integlacial, interglacial and post-interglacial evolution of the vegetation. The development of vegetation communities during the whole Masovian Interglacial near Mokrany Nowe is presented on the basis of a pollen diagram in this paper, previously published data (Krupiński & Nitychoruk 1991) and that from neighbouring sites with fossil flora of this interglacial at Biała Podlaska, Komarno and Hrud (Krupiński 1984–85, 1988a, 1995a, Krupiński & Lindner 1991, Krupiński et al 1986, 1988). The correlation of the compared local pollen zones at these sites and at Mokrany Nowe is shown in Table 1.

The results of pollen analysis of the sections and samples of the organic sediments from boreholes MN 1/89, MN 2/89, MN 3/89 and MN 4/90 (Krupiński & Nitychoruk 1991) and MN 5/90, contribute significantly to our understanding the development of the vegetation during the Mazovian Interglacial. The oldest organic sediments originate from a proto-interglacial, whereas the youngest ones come from the latter part of its optimum. No sediments from the climax of a yew phase were noted in any of the boreholes examined (PAZ – BP-E or PAZ – KM-E – *Taxus-Picea-Alnus-(Pinus)*). Nor were any found from the inner or mid-interglacial phase of rising contents of *Pinus* (PAZ – BP-F or PAZ – KM-F – *Pinus-Picea-Alnus-(Carpinus)*, Krupiński 1984–85, 1988a, 1984–90, 1995a, 1995b, Krupiński & Lindner 1991, Krupiński et al 1986, 1988). The organic sediments from Mokrany Nowe do not contain any remains of plants derived from the end of this interglacial or the beginning of the next glaciation.

DEVELOPMENT OF PROTO-INTERGLACIAL VEGETATION

This phase of the vegetation development is best illustrated by the spectrum of a single sample of silt with organic matter from borehole MN 1/89, and those of six samples of completely decomposed, amorphous and slightly clayey peats from the borehole MN 3/89 (Krupiński & Nitychoruk 1991), underlain by grey-blue silt almost devoid of floristic content. This interval is represented by two local pollen zones. In section MN 3/89, PAZ – MN-3-A – *Betula-Juniperus-(Salix-Pinus)* and PAZ – MN-3-B – *Betula-Pinus-Larix-(Picea-Alnus)* were distinguished. In section MN 1/89, this phase is represented by a single sample of silt, referred to as PAZ – MN-1-A – *Betula-NAP-(Juniperus)*. In other sections, no sediments were found which recorded this phase of succession or such sediments, if they exist, remain uncollected. Pollen spectra from this part of the section suggest that a depression filled with water and located on a morainic plateau, had already been present at the very beginning of this warming. Pollen spectra of this age, indicate first bushes or patches of forest communities, mainly composed of tree- or bush-like species with birch, and later with an admixture of pine. In between the patches of forest grew bushes and herbs, mainly composed of plants from the following genera and families: Gramineae, Cyperaceae, *Juniperus, Salix, Artemisia*, Chenopodiaceae, Umbelliferae, Ranunculaceae, Caryophyllaceae, Rosaceae, *Thalictrum and Hippophaë*. During warming, an increasing significance of forest communities was noted, in which *Picea* and *Alnus* appeared. Slightly later they formed their own forest communities with *Ulmus, Fraxinus* and *Quercus* appearing later still. At first, plants of non-forest communities with higher light demands such as *Juniperus, Hippophaë* and *Ephedra distachya* type persisted in the non-forest areas. However, they had to retreat with time, being replaced by forests containing *Larix* as their most important and constant component.

A very similar development of forest and non-forest communities during this time is represented by lithologically similar sediments from Biała Podlaska (Krupiński 1984–85, 1988a, Krupiński et al 1986, 1988), Komarno (Krupiński 1984–90, 1995a, Krupiński & Lindner 1991) and Krępiec (Janczyk-Kopikowa 1981).

DEVELOPMENT OF VEGETATION AT THE BEGINNING OF THE INTERGLACIAL

This is represented by spectra of peaty sediments from borehole MN 3/89 (PAZ – MN-3-C – *Picea-Alnus-(Pinus-Betula)*), peat from borehole MN 1/89 (PAZ – MN – *Alnus-(Picea-Betula)*, sand with organic matter from borehole MN 2/89 (PAZ – MN – *Picea-Alnus-(Taxus)* and 27 samples of bituminous shales from borehole MN 5/90 (PAZ – MN-5-A – *Betula-Picea-Alnus*, PAZ – MN-5-B – *Alnus-Picea-(Pinus)* and PAZ – MN-5-C – *Picea-Alnus-(Taxus)* –

Fig. 1). In the bituminous shales of numerous sections from Biała Podlaska (Krupiński 1984–85, 1988a, Krupiński et al 1986, 1988) and Komarno (Krupiński 1984–90, 1995a, Krupiński & Lindner 1991), there are two local pollen zones, defined as BP-C – *Picea-Alnus-(Pinus-Betula)* or KM-C – *Picea-Alnus-(Pinus)*, and BP-D – *Picea-Alnus-(Pinus-Taxus)* or KM-D – *Picea-Alnus-(Taxus)*.

This phase is represented by dense forest communities of a boreal zone. Non-forest vegetation did not play any significant role at that time, being replaced by trees. Well developed, species diverse forest communities of various habitats became dominant. Abundant *Alnus* indicates a considerable role for communities occupying wet habitats at Mokrany Nowe. They were composed mainly of alder, and, in areas with slightly lower ground water level, presumably with spruce, elm, ash, downy birch and finally also with yew. Dry areas were occupied by pine-birch and birch-pine forests which had persisted from a previous interval but were now more dense. Temperate wet and nutrient rich habitats seem to have been dominated by developing mixed forests, composed of numerous genera, including the previously mentioned trees with an admixture of oak, lime and hazel. Mid-forest open areas or margins of forest communities were occupied by bushes and herbs with more exacting climatic demands. Hop was abundant. New dense forest communities were already devoid of plants with higher light requirements. The existence of a wet and moderately mild climate at this time is also indicated by the presence of aquatic (shallow-water) plants of higher climatic demands, including *Typha latifolia* and *Stratiotes*. *Nymphaea* and *Nuphar* occurred during the later part of this phase. There were abundant *Myriophyllum spicatum* and algae of the genus *Pediastrum*, indicating stagnant or limited water circulation in this small lake.

The role of forest communities can also be interpreted in another way. A high *Alnus* content can result from a local superabundance of this taxon. In fact, the estimated role of alder communities in woods of this area should be considerably reduced.

The most important floristic transformations occurred during the final part of this interval. As at Biała Podlaska and Komarno, *Taxus* appeared at the described site and quickly gained ground. It became the main component of forests, playing a leading role in the type and composition of the next pollen zone that defined the beginning of the climatic optimum of this interglacial (vide Środoń 1957, Borówko-Dłużakowa 1981, Janczyk-Kopikowa 1981, Krupiński 1988a, 1995a, Brzeziński & Janczyk-Kopikowa 1991).

The presence of the water body at Mokrany Nowe is well confirmed by the occurrence of *Myriophyllum spicatum* (Tomaszewicz 1979). This species is typical for a community of Myriophylletum spicati, whereas its phytocoenoses usually form the association Myriophyllo-Nupharetum. The latter creates patches of subaquatic vegetation, developed in eutrophic waters, usually in habitats with mineral or slightly muddy substrate. This species is very vulnerable when growing in cloudy water with its low transparency. Therefore, phytocoenoses in deep water are asssociated with high water clarity. The depth seldom exceeds 1.5 m (reaching 2.5 m maximum). As well as growing in stagnant water, its well developed patches of high density occupy also clear and quite rapid streams. In the zonal vegetation pattern in lakes, it grows in plant communities with floating leaves (Nymphaeion) in places with mineral substrate. The deposition of organic sediments is accompanied by the replacement of the Myriophylletum spicati community by plants with floating leaves (very distinctly apparent in the diagram of MN 5/90) or by submerged plants which are more expansive, ecologically more widespread and demand more fertile habitats with organic substrate. Most frequently, the Myriophylletum spicati phytocoenoses are replaced by patches of Ceratophylletum demersi or Nuphareto-Nymphaeetum albae. Thus the community is a pioneer one and occurs mainly during the first phases of lake colonization (Tomaszewicz 1979). In Poland, this community is nowadays mostly restricted to areas north of Warsaw and to the Łęczyca-Włodawa Lakeland (see Tomaszewicz 1979: Fig. 17). Examination of macroscopic remains from the Mokrany Nowe site would provide extra data on local vegetation.

DEVELOPMENT OF RICH FOREST COMMUNITIES DURING THE INTERGLACIAL CLIMATIC OPTIMUM (SENSU LATO)

Sediments providing a vegetation record of this part of the Mazovian Interglacial are very poorly preserved in cores from Mokrany Nowe.

They describe the phase with forest hornbeam-fir communities quite well. There are only fragments of sequences, formed during the phase with communities dominated by *Taxus,* and the phase where yew was being gradually replaced by the occasionally more common pine. Determination of the composition of the vegetation during these two phases must therefore be based on palynological studies at neighbouring sites which include Biała Podlaska and Komarno. The absence of sediments of these two phases in sections from Mokrany Nowe indicates the intensity and efficiency of their destruction or post-sedimentary deformations.

The aforementioned relic sediments from a climatic optimum sensu lato of the analysed interglacial, are relatively well preserved in section MN 5/90 and in 5 samples of peat from section MN 4/90 (Krupiński & Nitychoruk 1991; vide Table 1). A sample of crumbled bituminous shales with sand from section MN 2/89 should also be associated with this interval. Vegetation developed in at least three phases. The first was dominated by rich forests, whose main component was yew (in sections from Biała Podlaska and Komarno defined as PAZ – BP-E or PAZ – KM-E – *Taxus-Picea-Alnus*). Less abundant were pine, ash, oak, elm and hazel. Also present were bushes and herbs with more exacting climatic requirements such as *Hedera, Viscum, Viburnum* and *Ligustrum* and possibly also *Ilex* and *Vitis*. At Mokrany Nowe this phase is partly represented by PAZ – MN-5-D – *Picea-Alnus-Taxus*, in crumbled bituminous shales, with an admixture of sand at the top. The sharp boundary of these sediments in the section suggests the presence of a significant sedimentary hiatus, so the record of vegetation development is incomplete.

The examined sections from Mokrany Nowe do not contain sediments from the second part of a climatic optimum of the interglacial, i.e. the phase of transitional mid-interglacial rise of pine, high content of spruce, the first expansion of hornbeam and finally, also of fir. Sediments of this phase are well preserved in sections from Biała Podlaska and Komarno, and represented by the spectra of PAZ – BP-F or PAZ – KM-F – *Pinus-Picea-Alnus*. A slightly drier climate (Krupiński 1994, 1995a, 1995b) caused a distinct reduction in the previously abundant yew and resulted in a transitional rise of pine (to about 50% in spectrum). The drier habitats were occupied by pine forests, possibly with a slight admixture of silver birch. These temperate wet habitats were mainly inhabited by spruce, pine with an admixture of hazel, oak, elm, ash, lime, hornbeam and possibly, also of yew. Wet areas had alder with an admixture of yew, spruce, elm and ash. The appearance of larch was mainly confined to nutrient rich wet and temperate wet habitats, in which spruce was abundant.

The transformations which occurred during the third phase of the development of plant communities during the climatic optimum were quite complex and varied. In most of the analysed sections from Mokrany Nowe, the sediments of this phase are not preserved and even in boreholes MN 4/90 and MN 5/90 where they contain a significant admixture of sand (Fig. 1) they provide only a fragmentary record of these transformations which must therefore be supplemented with further observations and conclusions, based on the examination of well preserved organic sediments from neighbouring sites.

The third phase of development of forest communities during the interglacial climatic optimum is represented by dense mixed forests, dominated by fir and hornbeam, with abundant hazel (particularly at the very beginning) and a rise of oak. Wet habitats were still occupied by alder, possibly with an admixture of yew and the already rare elm and ash. However, such a picture of these transformations is incomplete. The pollen spectra of this interval indicate additional dynamics of the transformations. Within these communities at Biała Podlaska and Komarno occurred three maxima of *Abies*, separated by two maxima of *Carpinus*. This suggests distinct competition between these two trees in particular, to occupy existing and developing dense species diverse forests. It is, however, uncertain whether the varying content of these two taxa reflects competition between them or minute climatic changes, especially as this process has also been recorded at several other sites in Poland and in other countries (e.g. Rossendorf – Erd et al 1977). Numerous bushes, herbs and aquatic plants of more exacting climatic demands (*Hedera, Viscum, Ligustrum, Buxus, Viburnum, Frangula alnus, Vitis, Salvinia, Nuphar* and *Nymphaea*) were present too. Their stabile content suggests that this phase of vegetation development took place in a warm, wet and mild climate.

A fourth phase in the development of forest communities during the interglacial climatic optimum is indicated by the frequent occurrence of oak and hornbeam. At the end of the phase, the roles of spruce and fir increased thus giving rise to the only part of this interglacial during which abundant spruce and fir occurred. This fourth phase is partly recorded by the spectra from a sample of deformed sands with peat or peats with sand, in section MN 5/90 or possibly, in the upper part of the spectra-diagrams of two samples of sand with crumbled pieces of bituminous shales and organic matter from borehole MN 2/89 (Krupiński & Nitychoruk 1991, Fig. 4). In other boreholes, no sediments of this phase were noted. The considerable similarity of the results of the palynological examinations of sediments of the same interglacial from the neighbouring sites at Biała Podlaska and Komarno indicates that the Mokrany Nowe area was also occupied by similar forests whose composition was distinctly transformed during that time. In the first part of this phase, forest communities were dominated by the gradually disappearing fir and slightly increasing oak. The second part is indicated by the continued dominance of hornbeam with abundant oak and fir. The third part was also dominated by hornbeam but fir had already become more common. The contents of oak and alder distinctly decreased but spruce reappeared and was abundant, mostly during the later part of the fourth phase of the interglacial climatic optimum. The well-developed and dense forest communities of this phase gradually thinned out. Pine began its late interglacial expansion. The content of bushes and herbs with more exacting climatic requirements were limited at first to *Buxus* and *Viscum* but then even these plants disappeared completely. The approaching cooling determined the final phase of forest development during the interglacial climatic optimum. It was followed by the development of boreal forests, representing the end of the interglacial.

DEVELOPMENT OF BOREAL FORESTS AT THE END OF THE INTERGLACIAL

No organic sediments from the decline of the interglacial were noted in any borehole within the depression at Mokrany Nowe. Their absence seems to result from earlier sedimentary processes or from post-sedimentary destruction. The structure, particularly at the top of the deformed organic sediments, points to the latter. The small size of the described depression at Mokrany Nowe prevented the creation of favourable conditions for the persistence of sediments during the post-interglacial disappearance of forests and the development of permafrost (freezing at first seasonal), and through at least one advance of the ice sheet in this area, and resulted in immense stress being placed on the slightly consolidated and considerably saturated organic sediments. In such circumstances, sapropelic sediments were subjected to diagenesis and became bituminous shales (see Krupiński 1984–85).

The development of boreal forests at the end of this interglacial near Mokrany Nowe can be reconstructed if they are regarded as similar to synchronic ones near Biała Podlaska and Komarno. They were represented first of all by still dense pine, pine-spruce and spruce-fir forests with an admixture of hornbeam, oak and occasionally *Pterocarya*. Later on, these communities became relatively less dense. Slightly thinner pine forests with spruce then formed, containing a decidedly lower admixture of trees which had previously been common or has always been infrequent to rare (*Alnus, Abies, Carpinus, Quercus, Corylus, Tilia cordata* type, *Ulmus* and *Fraxinus*). Larch appeared in the forests for the third time during this interglacial, suggesting that the climate was becoming increasingly continental with a cooler shorter growing season and also more severe and longer winters. Such climatic changes resulted in poorer taxonomic composition, thinner forest communities, and the retreat of infrequent to rare taxa. In this way, favourable conditions were created for the colonization of new habitats with bushes and herbs, associated with the transformation and disappearance of dense forests at the end of this interglacial.

AGE OF VEGETATION AND DEPOSITION

Palynological studies of organic sediments from Mokrany Nowe, presented both in previous papers (Krupiński & Nitychoruk 1990, 1991) and here, make possible a detailed description of transformations of plant communities during the Mazovian Interglacial in this part of Poland.

Floristic changes during this interval include the:

– development of proto-interglacial vegetation,

– development of boreal forest at the beginning of the interglacial,

– development of rich forests during the optimum of the interglacial,

– development of boreal forests at the end of the interglacial.

Therefore, the depression with examined sediments was in existence quite early, almost at the beginning of the interglacial or during its initial phases, when the first pioneer bush-like plant communities or boreal-forest patches occurred. The succession of forest communities and their probable taxonomic composition undoubtedly point to an interglacial vegetation. The fossil flora examined from Mokrany Nowe is sufficiently similar to that from Biała Podlaska or Komarno for similar conclusions to be drawn. As at these sites, the vegetation can be ascribed to the Mazovian Interglacial, represented by a succession of the Biała Podlaska or Komarno types (Krupiński 1988a, 1995a, Krupiński et al 1986, 1988, Krupiński & Lindner 1991).

The phases of pollen succession recorded in the interglacial sediments from Mokrany Nowe are represented by:

– primarily very common *Betula*, followed by the coexistence of abundant *Betula* and *Pinus*;

– the early, almost synchronic, occurrence and rise of *Picea* and *Alnus*;

– *Alnus* and *Fraxinus* which appeared slightly later. Elm did not play a significant role. There were two maxima of *Fraxinus*: firstly during the first maximum of *Picea* and *Alnus*, and then during the high content of *Taxus*;

– *Quercus* and *Corylus* which appeared slightly before or during the first peak of *Fraxinus* but whose maximum appeared considerably later;

– *Tilia*, which occurred at the same time as *Quercus* and *Corylus*, but was not significant in forests in Polish territory during this interglacial, was also the case as during the Ferdynandów Interglacial;

– *Taxus*, which, during this interglacial in Podlasie, formed a separate biostratigraphical unit, i.e. R PAZ – *Taxus-Picea-Alnus* (Krupiński 1995a, 1995b); rapid fluctuations in its incidence are evident in the diagram – at relatively low values, this taxon occurred almost until the end of the interglacial;

– *Carpinus* which appeared at the maximum of *Taxus* and rose quite slowly;

– *Abies* which appeared slightly later than *Carpinus* and whose content rose very rapidly (vide Środoń 1984);

– a transitional mid-interglacial rise of the content of *Pinus* (to about 50%) created an important element during this part of the pollen succession was the slow rise of *Carpinus* and the rapid drop of *Taxus*;

– a first maximum of *Carpinus* and *Abies* which was preceded, during this interglacial at least, by the greatest content of *Corylus* (10–15%) and by the retreat from forests of first spruce and later pine;

– a high *Abies* and *Carpinus* content and the demise of *Quercus*. The overall picture of pollen spectra within this interval is very complex. There were three maxima of *Abies*, separated by two of *Carpinus*; maximum of *Quercus* occurred during the second peak of *Carpinus* or slightly earlier. The contents of *Abies* fell during that time to about 10%. During the third peak of *Abies*, there was a higher value of *Picea* and small quantity of *Pterocarya;*

– a final very rapid rise of *Pinus* and a stabile high content of *Betula* and *Picea*; sediments of this phase of the pollen succession are very poorly preserved, due to destruction or distinct deformation.

In addition to the above features of the pollen succession, the interglacial sediments from Mokrany Nowe possess pollen of abundant important indicator taxa representing plants with more exacting climatic requirements, including *Hedera, Viscum, Ligustrum, Frangula alnus, Viburnum, Buxus, Vitis, Humulus, Typha latifolia,* microspores and microsporangia of *Salvinia* and *Azolla filiculoides* (massulae). The phases of their occurrence were revealed together with details of the local and regional vegetation by the local pollen zones.

DISCUSSION

The results of pollen studies of the interglacial sediments from Mokrany Nowe do not support the previous opinion of Nitychoruk (in:

Krupiński & Nitychoruk 1991: p. 241) that the organic sediments at this site were deposited in two phases – during two different interglacials. The bituminous shales of the first phase were associated by Nitychoruk (Krupiński & Nitychoruk 1990, 1991) with an interglacial optimum, represented by a succession of the Biała Podlaska, Krępiec and Komarno type. The deposition of silts and peats (underlain by the aforementioned shales) during the second phase, was associated by him with the beginning of an interglacial, represented also by a succession of the Biała Podlaska, Krępiec and Komarno type, i.e. of the same interglacial. Between these sediments, he noted a sedimentary hiatus, during which the shales had been eroded, and later deposition of sands with gravel and crumbled bituminous shales had occurred. Such an interpretation cannot be accepted, however, as it postulates the earlier deposition of sediments from the interglacial climatic optimum, represented by a succession of the Biała Podlaska, Krępiec and Komarno type, and followed by the deposition of sediments from the initial part of an interglacial with the same succession, i.e. of the same interglacial Nitychoruk neglects, however, the possibility of stratigraphical inversion.

The aforementioned sediments from the initial part of the interglacial, should be considered as a secondary deposit. This is proved by their varied lithology and the palynological analyses of the individual components of sediments from this bed (see Fig. 1 and Krupiński & Nitychoruk 1991: Fig. 4). The pollen spectra of the shales are directly associated with the warm phases of this interglacial (its optimum), whereas the spectra of mineral sediments or ones with an admixture of sand or other mineral material correspond to its considerably cooler phases. The considerable variations in the composition of pollen spectra from the different lithological components of the same sample, suggest that they are of different age and therefore, occurred as a secondary deposit. It seems probable that at Mokrany Nowe sediments of varying age (bituminous shales and peats) were broken down and deposited with sands at the organic sediments.

The processes associated with deposition in the described depression, could have occurred in a manner quite different from that described by Nitychoruk. At first, sediments of varied lithology and spatial distribution were deposited in a depression filled with water. A fen existed by the lake shore. Deposition of occasionally sandy and peaty material occurred (see Krupiński & Nitychoruk 1991: Fig. 3.5). In the deeper part of the lake, sapropelic sediments were deposited; after diagenesis, they became bituminous shales (see Krupiński 1984–85). Such sediments form the deepest deposits in sections MN 4/90 and MN 5/90. Therefore, the relation of the lithology of sediments to the time or phase of their deposition seems highly uncertain, although the lithology of the examined series itself is very important for the evaluation of plant communities when used in conjunction with palynological examination. The occurrence of peat, sandy peat or silt above or within the bituminous shales at Mokrany Nowe could also have resulted from their displacement during the final phase of the existence of this small depression, already almost filled with organic sediments. The nature of these processes is clear from the destroyed or deformed upper layers of persistent bituminous shales in section MN 5/90, in association with the crumbling of strongly compressed hard layers formed by individual sets of laminae, the dipping of layers, the admixture of sand and last, but not least, presence of shale pieces within the overlying sandy sediments. Material from higher altitudes reaching the lake littoral could have been deposited within the deep erosive channels in the surface of the organic sediments. As a result, sediments from the initial part of the interglacial overlie sediments from the climatic optimum of the same interglacial There is insufficient palaeobotanical evidence for concluding the existence of two asynchronic interglacial warmings and successions of the Biała Podlaska, Krępiec or Komarno type within the organic sediments from Mokrany Nowe (Krupiński & Nitychoruk 1991: p. 241). The sampling method of Nitychoruk, applied to the first palynological examination (Krupiński & Nitychoruk 1991), seems to have been inadequate and only by further examination could changes of earlier palynological results at this site be justified.

Deformations or sedimentary hiatuses within compressed and deformed bituminous shales can be detected in non-disturbed sediment cores only. The collecting of sediments from rotary drills does not comply with these requirements. The only section from this site suitable for palaeobotanical examination is MN 5/90 and the results are presented in this paper. Detailed lithological changes in the sediments in this core have been described for every local pollen zone. Sediments collected with a window auger did not comply with these requirements and cannot constitute the basis for any important conclusions. It seems worth mentioning that within the interglacial sediments of this site there is a tree trunk, 20 cm in diameter. However, it is unclear how Nitychoruk could have determined its diameter (see Krupiński & Nitychoruk 1991: Fig. 2).

The palynological studies of organic sediments from the section MN 5/90 were completed with TL data from the underlying silty clay and the still deeper underlying till. The upper part of this till at a depth 4.12–4.56 m was dated at 229 ± 5 ka (Wa-45/90) in the Warsaw laboratory. On the other hand, silty clay (coming from a depth of 3.72–4.12 m) between the top of this till and the bottom of the overlying bituminous shales was dated at 209.7 ± 10 ka (Wa-44/90). The datings of these sediments from Mokrany Nowe are very similar to the those from the same laboratory, carried out on similar sediments (clayey silts) at the bottom of the interglacial shales at the Biała Podlaska site, i.e. 209 ± 10 ka (Wa-5/85) and the older till, known from a borehole in the vicinity (Krupiński 1988b, Prószyński & Stańska-Prószyńska 1987). Silts older than the interglacial sediments (namely bituminous shales) from Komarno received similar dates. In the Komarno section 3/86, silts (under a till, from a depth of 8.7–8.9 m) were dated at 211 ± 32 ka (Wa-74/87, Prószyński & Stańska-Prószyńska 1987, Krupiński & Lindner 1991).

These data are close to previous (unpublished) ones, for two samples of sand and till that occur just below the youngest interglacial series at the Hrud site (Wa-76/91 and Wa-77/91, Prószyński & Stańska-Prószyńska 1992, see Lindner et al 1991). Four samples of till that overlie interglacial carbonate sediments (Krupiński 1989–91) were dated at from 161 ± 24 ka to 174 ± 25 ka in the TL Laboratory of Lublin (Lindner et al 1991). If these data are correct, the till should be associated with the Warta Glaciation or with a suggestion of Lindner et al (1991: p. 358) as to whether the Odra Glaciation is not an older stage of the Warta Glaciation. This sounds probable and a larger extent of the Warta Glaciation should be expected, at least as far as the confluence of the Vistula and Bug rivers (Nowak 1977, Baraniecka 1984, Żarski 1990). Such an interpretation of the age of the tills suggests a considerable rejuvenation of the youngest glacial sediments in this area, as well as calling into question the role of the interglacial sediments and flora (of the Biała Podlaska and Komarno type, and thus also from Mokrany Nowe) in the stratigraphical setting of any of the interglacials within the Middle Polish Glaciations (Lindner et al 1991: p. 359). This biostratigraphical interpretation of interglacial flora with the Biała Podlaska type of succession, has already been postulated by Prószyński in 1986, who set it between the Odra and Warta Glaciations. The palaeofloristic contents of numerous and well preserved sediments of the Mazovian (Holstein, Likhvin, Butenai) Interglacial from Central Europe, primarily from southern Podlasie, do not provide sufficient palaeobotanical evidence for the occurrence of sediments of the Mazovian Interglacial with a succession at two different stratigraphical settings (Krupiński 1995a).

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