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POST-GLACIAL VEGETATIONAL CHANGES IN THE MIDDLE ROZTOCZE (E POLAND)

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ABSTRACT. Palynological studies at three sites (Tarnawatka, Krasnobród and Kosobudy) together with fourteen radiocarbon datings have greatly increased our understanding of the history of the vegetation in the Middle Roztocze from the Alleröd up to the present day. Thirteen local pollen assemblage zones have been distinguished; 2 from the Late Glacial and 11 from the Holocene. They suggest that the vegetational succession in the vicinity of the examined sites varied according to the different habitat conditions: soil, relief and water supply.

KEY WORDS: pollen analysis, Roztocze, vegetational history, Late-Glacial, Holocene

INTRODUCTION

The Roztocze vegetation is one of the richest and most interesting in Poland due to the occurrence of vast and diverse forest communities. A lowland group of the Central-European subelement, with the presence of plants of the lower montane zone, is dominant. About 20 alpine species whose optimum developmental conditions occur in the Carpathians and Sudety Mts are found there (Izdebski 1967b). *Abies alba, Fagus sylvatica, Ulmus glabra, U. laevis, Acer pseudoplatanus, Tilia platyphyllos* and *Taxus baccata* reach the north-eastern limit of their continuous extent. Polish larch (*Larix decidua* ssp. *polonica*) occurs in isolated stands, beyond its continuous extent there. Despite their occurrence near their limit of distribution these species show great vitality. Many of them, especially beech and fir, reach monumental size. Although the history of the vegetation of the Roztocze region is very interesting, there are no sites there which have been the subject of detailed pollen analysis and ^{14}C datings. One can learn about the history of the Roztocze vegetation only from the results of old palynological studies of the Lublin Upland by Macko (1946) and Scherwendtke (1939) – an unpublished, simplified pollen diagram presented by Środoń (1967), and from research carried out in the Sandomierz Basin by Mamakowa (1962).

PRESENT-DAY ENVIRONMENT OF THE ROZTOCZE

Situation and division

The Roztocze is a range of hills about 180 km long (about 110 km of it belonging to Poland) and 15–25 km wide extending south-east from Kraśnik to beyond Lvov in the Ukraine (Fig. 1). Its height increases south-eastwards from 300 m near Kraśnik to 414 m near Lvov. Geobotanically the Roztocze belong to the Middle Polish Uplands and the Baltic Watershed (Szafer 1972). To the west, north and north-east it adjoins subregions of the Lublin Upland, to the east the Nadbuże, and to the south-west it is separated from the Sandomierz Basin by a steep escarpment 50–100 m high.

Because of its widely differing geological structure, relief and vegetation the Roztocze can be divided into three parts called the West, Middle and South Roztocze (Chałubińska & Wilgat 1954) or the Goraj, Tomaszów and Rawa Roztocze (Maruszczak 1972).

The West (Goraj) Roztocze is characterized by a typical loess relief. Deep, dry valleys and eroded gullies dissect here not only the loess cover but also the underlying Cretaceous rocks. The extremely varied relief of the

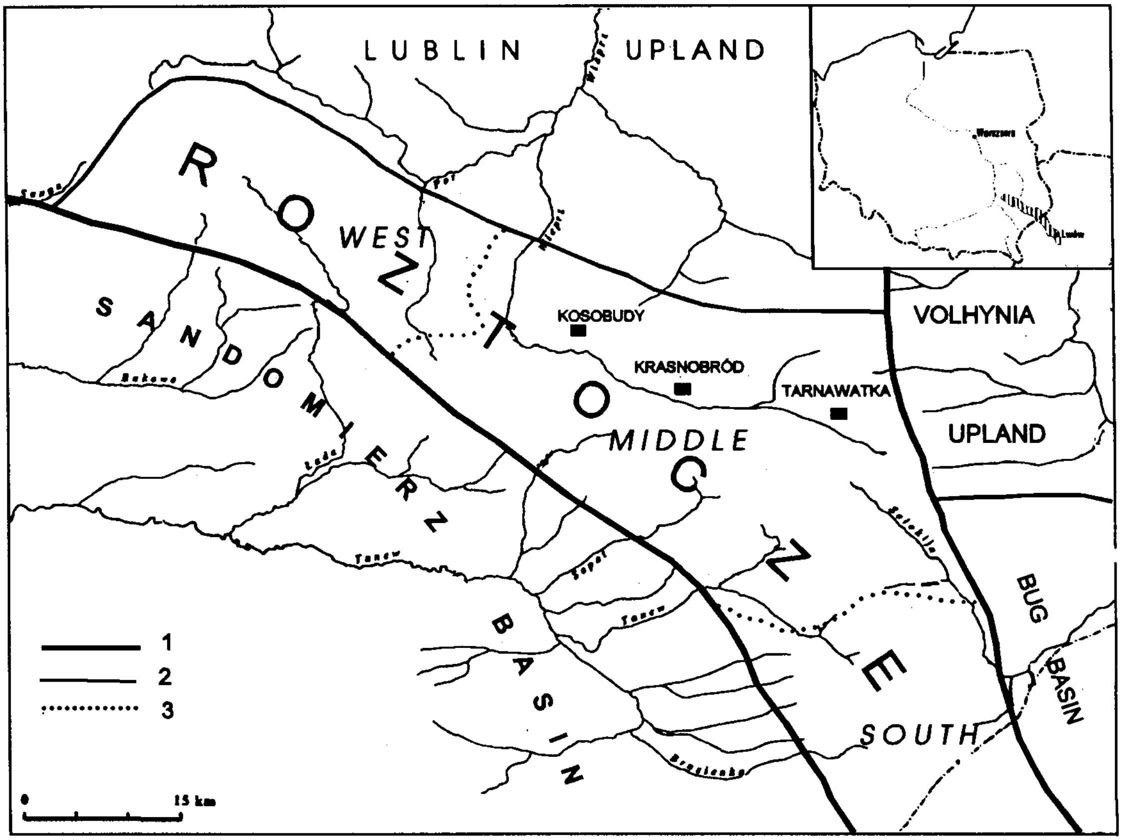

Fig. 1. Location of the examined sites. 1 – province boundary, 2 – macroregion boundary, 3 – mesoregion boundary

Middle (Tomaszów) Roztocze has developed in the Cretaceous and Tertiary deposits. Two planes at different levels form a contrast with the diversified relief of the edge zone. The South (Rawa) Roztocze is the highest part of the Polish Roztocze with elevations up to 390 m. Tertiary deposits predominate on the surface and the relief is characterized by isolated hills separated by valleys.

Geology

The Roztocze hills are composed of Upper Cretaceous rocks: opokas, marly opokas and gaizes, with Maestrichtian rocks possessing the greatest thickness (about 500 m) (Krasowska 1976). During the Tertiary these were covered by diversified marine deposits: detritus, lithothamnium and reef limestones, sands and sandstones. The thickness of these deposits is usually less than 100 m (Areń 1962, Jaroszewski 1977). Because of intensive erosion in this area during the upper Tertiary and Pleistocene, these deposits are preserved only as remnants and are confined to the escarpment zone. Especially intensive erosion occurred in the Middle Roztocze and the Miocene deposits there have their least thickness (Areń 1962). Tertiary and probably subsequent tectonic movements caused the formation of many blocks of rock separated by depressions; these blocks occur in the channels of the Tanew, Sopot, Jeleń and Szum rivers as rock rapids (Buraczyński 1974, 1984, Harasimiuk 1980). Terrestrial sedimentation and phases of erosion and chemical denudation alternated during the Quaternary. The Roztocze area was probably under the direct influence of the ice sheet twice (Harasimiuk 1980, 1994). The Quaternary deposits (mainly sands and loesses) form a thin cover on summits and slopes. In valleys their thickness reaches 50–70 m.

Relief

The Middle Roztocze has a gentler relief than the West and South Roztocze; we can find here two planation levels: a lower one reaching 310–320 m, and a higher one at 340–350 m (Jahn 1956, Maruszczak & Wilgat 1956, Maruszczak 1972). The flat and monotonous planation landscape contrasts sharply with the diversified relief of the escarpment zone. In places, single residual hills with remnants of Tertiary deposits on their summits rise above the planation surface. It is here where the Cretaceous deposits are usually exposed. Valley bottoms are most often covered with sands, mainly of Quaternary origin. In some places, their thick layers form dunes. Loess occurs rarely (Maruszczak 1991).

Climate

The climate of the Roztocze, just like that in other areas of eastern Poland, has many continental features but is also subject to some oceanic influence (Gumiński 1948, Romer 1949, Zinkiewicz & Zinkiewicz 1973, Warakomski 1994). The Roztocze is a rather cool region protruding above the surrounding lower lying areas delimited by a mean annual isotherm of 7°C (Warakomski 1994). January is the coldest month and July the warmest. The mean annual temperature range is about 22–23°C and the mean annual precipitation about 710 mm, i.e. 110 mm higher than the mean value for Poland (Michna & Paczos 1972, Warakomski 1994). The rainfall distribution is very variable and conditioned by relief. Western and south-western slopes receive more rain than slopes exposed to the east and north-east, and those to the lee of hills. This is due to the dominance of westerly winds. Snow cover persists for about 80 days, i.e. 22 days longer than the average values for Poland. The growing season usually lasts for about 203 days (Michna & Paczos 1972).

Hydrological conditions

The Roztocze is a rather dry region with a low groundwater table (Michalczyk 1986, Michalczyk & Wilgat 1994). Water conditions depend mainly on tectonics, lithology and relief. Sands and loesses covering the Roztocze are easily permeable deposits. Water infiltrates also into the fissured Cretaceous deposits and aquifers occur only at great depths. Thus, surface water is almost absent here. On the other hand, the Roztocze are distinguished by abundant precipitation, higher than in neighbouring regions, so its water resources are greater (Wojciechowski 1965). The main river is the Wieprz flowing longitudinally through the Roztocze. The valleys of the Szum, Sopot and Tanew rivers have created gaps in the escarpment through which their fast flowing waters pass before being discharged into the San.

Soils

The different soil types which formed in the Roztocze as a result of differences in the bedrock, relief, water conditions and vegetation have been described by Dobrzański et al. (1969), Uziak et al. (1978), Turski et al. (1993) and Uziak (1994).

Peaty soils occupy the dampest places in the valleys of rivers and forest streams, and between dunes in local depressions with impeded outflow. Raised and transition bogs (Ledo-Sphagnetum magellanicum, Rhynchosporetum albae), alder carr (Circaeo-Alnetum), and meadow communities occur on these soils.

Brown soils occurring on loesses, loess-like deposits, Cretaceous gaizes and loamy sands form meso- and eutrophic habitats for forest communities such as Dentario glandulosae-Fagetum, Querco-Potentilletum albae, Tilio-Carpinetum and, more rarely, Abietetum polonicum and Pino-Quercetum.

Chalk rendzinas occur on slopes, mainly in the northern part of the Roztocze. Forest communities of Dentario glandulosae-Fagetum and Querco-Potentilletum albae occur on these soils.

Podsolic soils occupy large areas covered by forest in the Middle Roztocze. They usually occur in depressions or on hill tops and show different degrees of podsolization depending not only on the topography and water table, but also on the bedrock. Leucobryo-Pinetum,

Molinio-Pinetum, Querco-Piceetum, Querco roboris-Pinetum and Abietetum polonicum forests occur on these soils.

Alluvial soils can be found in the Wieprz river valley. They are mainly covered by meadow communities.

Vegetation

In the Middle Roztocze forest occupies about 60% of the area. The Roztocze National Park is situated in the western part of the Middle Roztocze. Its plant communities have been thoroughly described (Izdebski 1961, 1962a, b, 1963a, b, 1964, 1966, 1967a, Szynal 1962, Izdebski & Popiołek 1969, Izdebski et al.

1992, Fijałkowski 1993). As stressed in those studies the distinctive feature in the distribution of the forest communities is their zonal pattern caused by relief and soil-habitat conditions. Alder carr (Circaeo-Alnetum) and alder swamp (Ribo nigri-Alnetum) occur in the depressions of river and stream valleys. They are usually surrounded by a narrow band of wet oak-spruce wood (Querco-Piceetum). If the area is flat or slightly undulating a complex of *Sphagnum* and transition bogs are often formed in depressions. Bog pine wood (Vaccinio uliginosi-Pinetum) and wet pine wood (Molinio-Pinetum) are found on bogs or in their surroundings. Dry pine forest (Leucobryo-Pinetum) occurs on plains or dunes. On the slopes of Cretaceous hills this community usually changes gradually into mixed fir wood (Abietetum polonicum) occupying most often the middle parts of the slopes. Carpathian beech wood (Dentario glandulose-Fagetum) usually occurs in the upper parts and on the summits of hills where habitats are rich. Mixed forest communities (Querco roboris-Pinetum, Tilio-Carpinetum, Potentillo albae-Quercetum) form a mosaic pattern on the flat or slightly undulating terrain lying above the pine forest habitat and below the Carpathian beech wood.

Meadow communities form the greatest complex in the Wieprz river valley. Meadow vegetation grows also in forest clearings (Izdebska 1959, Popiołek 1994).

Archaeology

In the Mesolithic Period the Roztocze was probably populated by hunting tribes mainly occupying the dunes in the river valleys (Libera 1995).

At the beginning of the Early Neolithic Period an agricultural population from the south appeared in the loess areas of the Lublin Upland. At first they were tribes of the Linnear Pottery Culture, but later followed those of the Volhynia-Lublin White-Painted Pottery Culture. Traces of these cultures have also been found in the Roztocze near the studied sites (Balcer 1991, archival materials of the Department of Archaeology, Maria Curie-Skłodowska University). As the southern cultures declined, the Funnel-Beaker Culture appeared (Gurba 1960, Balcer 1991). The inhabitants of a settlement were divided into groups engaged either in cultivating the land near the settlement, or in stock raising in valley meadows situated at shorter or greater distances from the permanent mother settlement. The seasonal camps of these herdsmen were usually set up on dry sandy dunes in valley bottoms. Dunes were also the place of temporary settlement of stock raising populations of the Globular Amphora Culture but, in the Roztocze, settlements of this culture were rather sparse (Ścibor 1991). More abundant are traces of tribes of the Corded Ware Culture (Machnik 1959, 1961, Bargieł 1991) which appeared at the end of the New Stone Age and developed until the early Bronze Age. At first these populations were nomadic and semi-nomadic, mainly engaged in stock raising and hunting. Later groups of this culture began to cultivate the soil leading to a more settled way of life.

In the Early Bronze Age the Roztocze saw the arrival of the Mierzanowice Culture, followed by the Trzciniec Culture, traces of the latter being found more often. Settlements of the Trzciniec Culture formed two centres in the Roztocze : on the upper Wieprz and Sołokija rivers. Dunes occurring along the Wieprz river were typical settlement places for this culture – about 70% of their sites have been found on sandy terrain (Wróbel 1991).

Starting from the third period of the Bronze Age, the Lusatian Culture, based on the Trzciniec Culture, began to develop. It is here defined as an eastern group (the Ulwówek subgroup) developing mostly in the fourth and fifth periods of the Bronze Age. Settlements were established on the high river terraces, and the population was engaged in soil cultivation and stock raising (Gurba 1978). In the early and middle La Těne period the Pomeranian Culture reached the Lublin region, but its settlements are not recorded in the Roztocze, probably because it has been poorly investigated by archaeologists. Pottery from the period of Roman influence has been found in only one site (Sumin) near the examined Tarnawatka profile (archival materials of the Department of Archaeology, Maria Curie Skłodowska University). Part of this area was certainly exploited during hunting and gathering migrations (Kokowski 1991).

Evidence of settlement in the early Middle Ages is quite strong in the Roztocze and has been found mainly in the valleys of the Por, Wieprz and Sołokija rivers (Nosek 1957, Gajewski & Gurba 1977). Numerous artefacts have been discovered in the neighbourhood of the sites examined.

DESCRIPTION OF SITES AND PROFILES

Three sites (Fig. 1) were cored using a Russian "Instorf" corer 5 cm in diameter.

Tarnawatka

This site is situated in an extensive basin of the upper Wieprz river. A boring was made in a meadow which had been cut by many drainage ditches.

0.00–0.16 m	Sedge peat, brown, moderately decomposed
0.16–0.21 m	Moss-sedge peat, brown, slightly decomposed
0.21–0.73 m	Moss-sedge peat, brown, moderately decomposed
0.73–1.00 m	Moss-sedge peat, dark brown, moderately decomposed
1.00–1.37 m	Moss-sedge peat, brown, moderately decomposed
1.37–2.30 m	Sedge peat, dark brown, moderately decomposed, pieces of *Alnus* wood
2.30–2.55 m	Detritus-algae gyttja, dark brown, fine-grained
2.55–3.24 m	Detritus-algae gyttja, grey-brown, fine-grained
3.24–3.45 m	Detritus-algae gyttja, grey-yellowish, fine-grained, HCl+
3.45–3.65 m	Silt, dark grey, with plant detritus and mollusc shells, HCl+

Krasnobród

The site is situated in a depression without outflow on the Pleistocene terrace of the Wieprz river. The profile was collected from a *Sphagnum* bog with a hummock structure, covered by pine and birch scrub and dwarf shrubs of the Ericaceae family.

0.00–0.10 m	*Sphagnum* peat, brown, slightly decomposed, overgrown by Ericaceae dwarf

shrubs

0.10–0.50 m	*Sphagnum* peat, dark brown, moderately decomposed, with Ericaceae rootlets
0.50–3.00 m	*Sphagnum* peat, black-brown, moderately decomposed, with Ericaceae rootlets and pieces of wood at 2.50 m
3.00–3.20 m	*Sphagnum* peat, black-brown, strongly decomposed, with some gyttja content,

Ericaceae rootlets less abundant

3.20–3.85 m	*Sphagnum* peat, black-brown, moderately decomposed, fibrous, with Ericaceae rootlets
3.85–4.20 m	*Sphagnum* peat, black-brown, strongly decomposed, with gyttja
4.20–4.50 m	Sedge-*Sphagnum* peat with black-brown gyttja
4.50–5.17 m	Algae-detritus gyttja, black-brown, of nodular structure
5.17–5.33 m	Algae-detritus gyttja, brown-grey, with dark band at 5.20–5.21 m
5.33–5.50 m	Sand, grey

Kosobudy

The profile was collected from a high sedge swamp (*Caricetum elatae*). Such phytocoenoses usually occur in closed depressions of differing origin. Their habitats often contain stagnant water and *Carex elata* is a dominant species. Hummocks may reach 0.6 m in diameter and height. Rush, meadow and swamp plants are also abundant, and moss patches occur in places.

0.00–0.15 m	*Sphagnum*
0.15–0.21 m	Sedge peat, brown, moderately decomposed
0.21–0.27 m	Sedge peat, with thin clay interbedding
0.27–0.65 m	Sedge peat, brown, moderately decomposed
0.65–0.75 m	Clay interbedding, grey, with plant remains
0.75–0.95 m	Sedge peat, black-brown, moderately decomposed
0.95–1.00 m	Sedge peat, black-brown, moderately decomposed, with sand

MATERIALS AND METODS

Samples for palynological analyses were taken from the cores at 5 and 10 cm intervals. The samples were prepared by standard procedures: calcareous gyttja was treated with 10% HCl and silica was removed with hydrofluoric acid. All samples were prepared by the Erdtman method and stained with basic fuchsin. An average of ca 1000 AP was counted in each sample. In the case of very low frequencies smaller numbers were counted.

Percentage values were calculated from the pollen aggregate including trees, shrubs and herbaceous plants. The total excluded spores and pollen of aquatic and swamp plants. In a few of the bottom samples from the Tarnawatka profile diatoms found were examined by B. Bogaczewicz-Adamczak.

RADIOCARBON DATINGS AND THE ACCUMULATION RATE OF BIOGENIC SEDIMENTS

Six samples from Tarnawatka, six from Krasnobród and two from the Kosobudy profiles were radiocarbon dated.

The datings were done in the ^{14}C Laboratory of the Silesian Technical University in Gliwice. All the dates are given in uncalibrated radiocarbon years BP (Tables 1, 2 and 3).

water table was low. The state of preservation of the pollen grains (many had been destroyed) is also evidence of a low water table and the mineralization of the top peat layers. According to Żurek (1986) an accumulation rate below 0.5 mm/year is typical for fens. A higher accumulation rate (0.72 mm/year) was found in the 143–107 cm profile section, i.e. from 3540 to 3100 years BP, together with a greater proportion of mosses, and a change from sedge peat to moss-sedge peat. This change could have been the result of the presence of increased moisture. The accumulation rate for the top part of the profile was determined to be 0.35 mm/year.

Table 1. Radiocarbon dates of the Tarnawatka profile

Lab. No. of sample	Depth of sample (cm)	Age BP	Description
Gd 6080	104–111	3040±100	peat, decrease of *Carpinus*, appearance of Cerealia
Gd 6079	139–146	3540±110	peat, beginning of *Carpinus* increase, fall of *Ulmus*
Gd 6078	169–176	4950±120	peat, decrease of *Ulmus*, appearance of *Plantago lanceolata*
Gd 6077	214–221	6980±140	peat, fall of *Corylus*, increase of *Quercus*
Gd 6075	269–276	8610±150	detritus-algae gyttja, rise of *Corylus* and *Quercus*
Gd 4456	318–324	10,750±210	detritus-algae gyttja, increase of NAP

Table 2. Radiocarbon dates of the Krasnobród profile

Lab. No. of sample	Depth of sample (cm)	Age BP	Description
Gd 6482	55–65	1800±80	peat, fall of *Carpinus*, occurrence of *Plantago lanceolata*
Gd 5953	135–145	3540±60	peat, beginning of *Carpinus* increase, occurrence of Cerealia
Gd 6483	255–265	5970±120	peat, fall of *Corylus* and rise of *Tilia*
Gd 6484	365–375	8570±150	peat, increase of *Corylus, Tilia* and *Fraxinus*
Gd 6490	435–445	9430±160	peat, beginning of peat accumulation
Gd 6493	515–525	11,780±180	detritus-algae gyttja, beginning of organogenic accumulation

In the Tarnawatka profile the accumulation rate of lacustrine deposits was calculated at 0.22 mm/year in the 332–327 cm section, and at 0.33 mm/year in the 327–273 cm section. The higher accumulation rate in the upper part of the gyttja probably resulted from a hiatus in the sedimentation of the lacustrine deposits (see chapter Changes...). The mean accumulation rate of peat was rather low (0.29 mm/year). In the 272–143 cm section comprising the period from 9610 to 3540 years BP, it fluctuated between 0.22 and 0.33 mm/year. The rate depended on the type of sedge-reed community forming the peat layers when the

In the Krasnobród profile the mean accumulation rate of the lacustrine deposits was 0.34 mm/year and that of peat 0.44 mm/year. The highest accumulation rate of peat (0.81 mm/year) was found at a depth 440–400 cm corresponding to the interval 9430–8750 years BP, i.e. to the first stage of mire formation. In the overlying profile section (400–60 cm) the accumulation rate was fairly stable and fluctuated from 0.41 to 0.49 mm/year, but was somewhat lower (0.33 mm/year) in the top section.

Table 3. Radiocarbon dates of the Kosobudy profile

Lab. No. of sample	Depth of sample (cm)	Age BP	Description
Gd-6952	55–65	1060±100	peat above mineral layer, increase of AP
Gd-6955	85–95	1490(100	peat, beginning of organogenic accumulation

However, the accumulation rate of peat determined here was considerably lower than values recorded for raised bogs (Żurek 1986).

Because of the small thickness of the Kosobudy profile and the fact that just two radiocarbon datings could be made, only an approximate accumulation rate of peat could be determined here – it was about 0.60 mm/year.

DESCRIPTION OF THE LOCAL POLLEN ZONES

The diagrams have been divided into biostratigraphic units which correspond to pollen assemblage zones PAZ (Birks & Berglund 1979, West 1970). Thirteen local pollen zones are characterized in Tables 4, 5 and 6.

CHANGES OF VEGETATION

The pollen assemblage zones distinguished (Figs 2, 3 and 4) suggest that the vegetational succession in the neighbourhoods of the examined sites followed somewhat different lines, as a result of the varying habitat conditions: soil, relief and water supply. This aspect will be discussed in this chapter. The pollen assemblage zones will be referred to chronozones *sensu* Mangerud et al. (1974).

Pinus-Betula PAZ

This zone, corresponding to the late phase of the Alleröd, was described from two of the examined sites (Tarnawatka and Krasnobród) and it is characterized by the development of pine-birch forest with an admixture of *Larix, Picea* and *Populus*. The forest was open, with stands of heliophilous communities composed of *Artemisia,* Chenopodiaceae, *Thalictrum, Potentilla,* Rubiaceae and with shrubs of *HippophaD* and *Juniperus*. Wet habitats near lakes were occupied by willow scrub with dwarf birch (*Betula nana* type). Communities with *Nymphaea alba, Potamogeton* and *Pediastrum* developed in lakes. The diatom analysis of some samples from the base of the Tarnawatka profile (Table 7) revealed a diatom assemblage typical of a small, shallow lake or a lake littoral zone. *Typha latifolia* and *Sparganium* occurred at the lake margins, while in places with a lower water table communities of sedges and tall herbs developed with *Filipendula, Thalictrum* and Apiaceae. The occurrence of *Nymphaea alba* and *Typha latifolia* indicated mean July temperatures not lower than 15°C. The beginning of lacustrine sedimentation in the Krasnobród profile was dated at 11780±180 BP.

Artemisia-Chenopodiaceae PAZ

This zone corresponds to the Younger Dryas and was found in two sites (Tarnawatka and Krasnobród). The Younger Dryas cooling caused thinning of the forest. *Pinus* and *Betula* occurred as groups of trees in a park landscape. Steppe-like herb communities, with *Artemisia* and Chenopodiaceae playing an important part, developed in sandy, sunny sites. Moderately wet sites were still occupied by tall herb and sedge communities, and by willow thickets with shrub birch. In the lake thermophilous species like *Typha latifolia* and *Nympheaea alba* retreated, and towards the end of the zone numerous pondweeds (*Potamogeton*) appeared in the Krasnobród lake.

Pinus-Betula-Ulmus PAZ

This zone, distinguished in the diagrams of Tarnawatka and Krasnobród, corresponds to the Preboreal chronozone. Warming up at the beginning of the Holocene initiated the rapid development of birch-pine forest, changing later into more dense pine-birch forest with an admixture of elm and spruce. Elm was the first thermophilous tree to appear in this area. It was already evident at the beginning of the Holocene and was becoming a more and more important component of forest (Mamakowa

Table 4. Tarnawatka, a description of the local pollen assemblage zones

Local PAZ	Name of PAZ	Depth (cm)	Description
T-1	*Pinus-Betula*	355.0–327.5	High values of *Pinus* (13.1–48.0%), *Betula* (25.6–52.0%) and *Salix* (11.4–1.1%); relatively high NAP, especially Cyperaceae (22.5–5.0%), Poaceae (3.6–5.8%), *Artemisia* (4.3–9.7%); *Saxifraga* and *HippophaD* pollen appear. T-1/T-2 limit: NAP increases, AP decreases.
T-2	*Artemisia*-Chenopodiaceae	327.5–287.5	High frequencies of *Artemisia* (9.0–14.5%), Chenopodiaceae (1.3–2.2%), Cyperaceae (2.6–12.1%) and Poaceae (5.9–7.6%); *Helianthemum* sp. and *Gypsophila fastigiata* sporadic; *Pinus* (35.6–49.9%), *Betula* (19.4–30.6%), and *Salix* (0.9–2.3%) remain high. T-2/T-3 limit: *Artemisia* decreases, *Ulmus* and *Betula* rise.
T-3	*Pinus-Betula-Ulmus*	287.5–272.5	*Betula* dominant (max. 67%); increase of *Ulmus* (0.8–4.7%) and *Corylus* (up to 1.4%), decrease of *Pinus*; *Alnus* and *Quercus* sporadic; *Artemisia*, Chenopodiaceae and Cyperaceae pollen decrease; *Myriophyllum spicatum* (2.6%), *M. verticillatum* (1.0%), *Typha latifolia* and *Nymphaea* alba present. T-3/T-4 limit: *Corylus, Quercus, Alnus* increase, *Betula* decreases.
T-4	*Corylus-Ulmus-Alnus*	272.5–237.5	*Corylus* dominant (8.9–28.2%); *Ulmus* (3.9–8.2%), *Quercus* (1.6–3.0%), *Alnus* (1.3–8.6%) and *Tilia* (0.4–1.4%) increase; *Salix* decreases; *Fraxinus* and *Humulus* pollen appear; *Typha latifolia* (up to 6.4%) and *Nymphaea alba* present. T-4/T-5 limit: *Corylus* decreases, *Quercus* increases.
T-5	*Alnus-Ulmus-Corylus*	237.5–212.5	*Alnus* (6.7%), *Pinus* (21.0–38.8%), *Quercus* (4.5–5.0%), *Fraxinus* (0.2–2.2%) and *Tilia* (0.4–3.0%) rise; *Corylus* (to 8.7%) and *Ulmus* (9.9–4.5%) decrease. T-5/T-6 limit: *Ulmus, Corylus* decrease, *Quercus* increases.
T-6	*Quercus-Alnus-Ulmus-Tilia*	212.5–177.5	*Quercus* (8.5–14.4 %) increases, *Pinus* ((33.1–12.5%) and *Corylus* (6.5–3.2%) decrease; *Ulmus* after decrease in the older part of the zone increases up to 6.5%; relatively high *Alnus* (5.9–10.8%), *Betula* (10.0–38.6%), *Fraxinus* (1.0–1.7%) and *Tilia*(0.3–2.8%). T-6/T-7 limit: *Ulmus, Quercus, Alnus* decrease.
T-7	*Quercus-Alnus-Tilia-Fraxinus*	177.5–142,5	High *Pinus* (25.4–44.7%), *Quercus* (6.5–16.3%), *Alnus* (3.6–7.3%) and *Fraxinus* (0.9–3.8%); *Picea* (1.6–2.6%) peaks; *Ulmus* (6.5–2.8%) and *Tilia* (to 0.7%) slowly decrease. T-7/T-8 limit: beginning of continuous *Carpinus* curve.
T-8	*Quercus-Carpinus*	142.5–122.5	*Carpinus* (up to 4.4%) and *Fagus* (up to 1.5%) appear; *Ulmus* (to 1.1%), *Tilia* (0.5–1.4%) and *Fraxinus* (0.2%) decrease; high values of *Quercus* (10.6–12.4%) and *Picea* (to 2.6%); *Viscum* appears. T-8/T-9 limit: final fall of *Ulmus* and *Tilia*, *Carpinus* increases.
T-9	*Carpinus*	122.5–107.5	*Carpinus* (max. 17.2%) dominant; *Fagus* (up to 3.2%) increases in the late phase of the zone; *Ulmus, Fraxinus* and *Tilia* up to 1.5%; relatively high *Pinus* (9.2–36.8%), *Quercus* (8.5–13.6%), and *Alnus* (5.6–9.5%). T-9/T-10 limit: fall of *Carpinus*.
T-10	*Carpinus-Quercus Fagus*	107.5–67.5	*Quercus* (9.6–22.6%) dominant; *Carpinus* declines to about 6%; *Pinus* (10.4–41.0%) strongly fluctuates; high *Alnus* (max.18.7%) in the older part of the zone; *Fagus* up to 2%; *Abies* sporadic; human indicators present in the older part of the zone. T-10/T-11 limit: beginning of continuous *Abies* curve.
T-11	*Carpinus-Pinus-Fagus-Abies*	67.5–35.0	*Carpinus* (2.7–8.4 %) and *Corylus* (to 2.1%) increase; *Pinus* decreases from 46.9% to 29.2%; relatively high *Quercus* and *Fagus* in the upper part of the zone; continuous curve of *Abies*. T-11/T-12 limit: fall of AP.
T-12	*Pinus-Fagus-Abies*-NAP	35.0–0.0	All deciduous trees decrease: *Alnus* (6.0–2.2%), *Carpinus* (to 3.2%), *Fagus* (to 2.7%), *Fraxinus* (to 0.5%) and *Quercus* (9.0–3.4%); NAP and anthropogenic indicators increase.

1962, Ralska-Jasiewiczowa 1983, Bałaga 1991). The representation of other thermophilous trees was small. Only hazel and oak pollen reaches frequencies above 1% indicating that they were beginning to encroach upon the Roztocze area. Willow thickets were probably becoming confined to river valleys, sharing habitats with tall herbs and sedges. Xerothermic communities typical for the Younger Dryas occupied considerably smaller areas. A com-

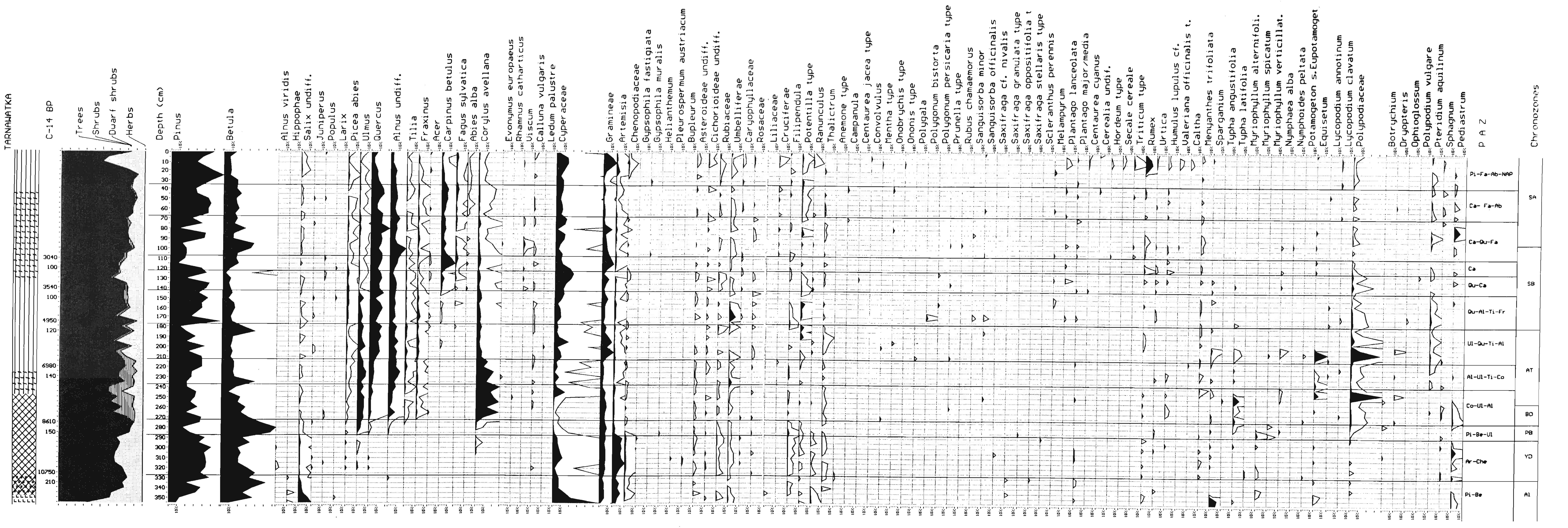

Fig. 2. Percentage pollen diagram from Tarnawatka

Fig. 3. Percentage pollen diagram from Krasnobród

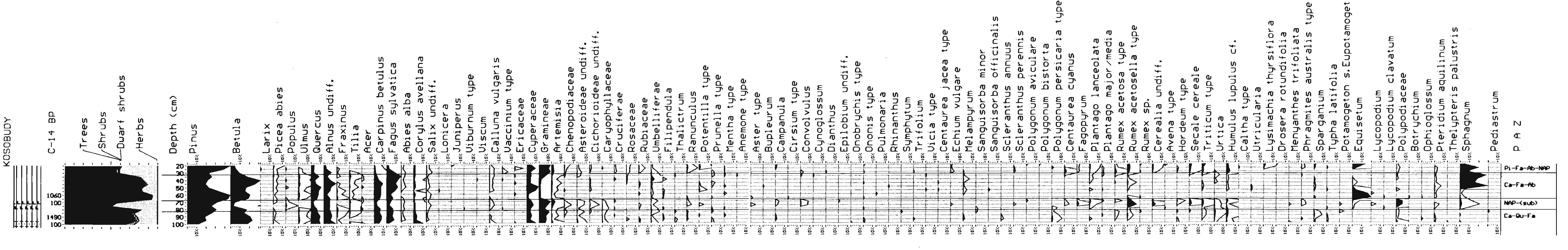

Fig. 4. Percentage pollen diagram from Kosobudy

Table 5. Krasnobród, a description of the local pollen assemblage zones

Local PAZ	Name of PAZ	Depth (cm)	Description of pollen spectra
K-1	*Pinus-Betula*	495.0–530.0	*Pinus* (22.3–45.9%) and *Betula* (16.4–43.3%) dominant; high values of Cyperaceae (1.4–21.7%), Poaceae (4.9–19.6%), *Artemisia* (2.1–6.3%) and Chenopodiaceae; *Salix*, *Juniperus* and *HippophaD* present. K-1/K-2 limit: NAP, *Artemisia* decrease.
K-2	*Artemisia*-Chenopodiaceae	495.0–455.0	High NAP, mainly *Artemisia* (7.4–13.7%), Chenopodiaceae (1.8–3.6%), Poaceae (4.6–7.0%), Cyperaceae (1.5–5.0%), *Thalictrum*, *Filipendula* and Apiaceae; relatively high *Pinus* (37.7–54.1%), *Betula* (21.8 -26.1%), and *Salix (*1.4–2.8%); *Potamogeton* up to 10.7% in the upper part of the zone. K-2/K-3 limit: *Artemisia,,* Chenopodiaceae decrease, beginning of *Ulmus* rise.
K-3	*Pinus-Betula-Ulmus*	455.0–375.0	*Pinus* (38.6–72.8 %) increases; *Betula* (48.9–13.6%) decreases; *Ulmus* rises to 6.7%; low (about 1%) values of *Quercus*, *Fraxinus* and *Corylus*; *Picea* and *Populus* present; *Artemisia*, Chenopodiaceae, *Thalictrum*, Apiaceae and Rubiaceae decrease; Polypodiaceae increases; *Sphagnum* appears. K-3/K-4 limit: *Corylus, Alnus, Tilia, Fraxinus* rise.
K-4	*Corylus-Ulmus-Tilia*	375.0–345.0	*Pinus* (57.8–40.9 %) and *Corylus* (7.8–10.0%) decrease; thermophilous species, such as *Tilia* (2.4–4.1%), *Fraxinus* (1.2–2.0%), *Quercus* (1.5–2.25), *Alnus* (0.8–1.6%) increase; *Ulmus* increases up to 7.2% after small decline in the older part of this zone; *Betula* reaches 14.1–18.3%; high percentage of Ericaceae. K-4/K-5 limit: rise of *Corylus.*
K-5	*Corylus-Ulmus-Alnus*	345.0–305.0	Corylus (21.2–27.5%) dominant; *Ulmus* (2.9–3.9%), *Alnus* (up to 8.5%), *Quercus* (2.6–3.9%) and *Fraxinus* (1.4–3.2%) slightly increase; *Tilia* (to 2.6%) and *Pinus* (39.6–28.6%) decrease; *Hedera* and *Viscum* appear. K-5/K-6 limit: fall of *Corylus*, rise of *Tilia.*
K-6	*Alnus-Ulmus-Corylus-Tilia*	305.0–265.0	*Corylus* (17.8–15.1%), *Pinus* (40.6–18.5%) and *Fraxinus* (to 0.7%) decrease; *Alnus* (1.7–14.5%), *Ulmus* (6.1–13.0%), *Quercus* (2.6–4.6%), *Betula* (13.9–20.4%) and *Tilia* (4.6–5.2%) increase; *Pteridium aquilium* appears; rise of *Sphagnum.* K-6/K-7 limit: rise of *Quercus, Fraxinus,* fall of *Corylus.*
K-7	*Alnus-Ulmus-Tilia-Quercus*	265.0–217.5	*Pinus* (29.6–12.0%) decreases; *Quercus* (6.2–9.6%), *Corylus* (12.9–21.3%) and *Alnus* (up to 15%) increase; *Ulmus* (10.0–12.0%), *Tilia* (2.8–6.2%), *Fraxinus* (3.1–5.4%) and *Betula* (12.2–19.2%) relatively high; *Acer* pollen appears. K-7/K-8 limit: fall of *Ulmus, Tilia, Fraxinus.*
K-8	*Quercus-Alnus -Tilia-Fraxinus*	217.5–152.5	*Quercus* (up to 17.9%), *Alnus* (8.9–15.9%), *Tilia* (2.9–6.8%) and *Fraxinus* (2.1–4.7%) dominant; *Alnus* (2% -14.2%) and *Corylus* (10.6–33.4%) show considerable fluctuations; relatively high *Pinus* (11.7–23.4%) and *Betula* (9.2–32.2%); *Picea* up to 1%. K-8/K-9 limit: final fall of *Ulmus, Tilia, Fraxinus,* beginning of continuous *Fagus* and *Carpinus* curves.
K-9	*Quercus-Carpinus*	152.5–132.5	*Ulmus* (0.5–1.7%), *Fraxinus*, *Tilia* and *Corylus* (3.5–9.1%) decline finally; *Quercus* (13.4–5.6%) and *Alnus* (12.3–8.35%) slightly decrease; *Pinus* (14.0–23.1%) and *Betula* (13.3–25.6%) increase; *Carpinus* (up to 7.1%) and *Fagus* (up to 1.4%) appear. K-9/K-10 limit: rise of *Carpinus.*
K-10	*Carpinus*	132.5–102.5	*Carpinus* (14.4–26.4%) peaks; high *Alnus* (10.7–12.8%) and *Quercus* (8.2–9.5%); low *Pinus* (8.6–14.7%); *Ulmus, Fraxinus, Tilia* and *Fagus* at about 2.5%; *Abies* and *Acer* sporadic; *Betula* (17.9–31.9%) and *Corylus* (4.5–12.4%) pollen reach maxima at the beginning of the zone; human indicators (*Plantago lanceolata, Triticum* type) increase in the middle part of the zone. K-10/K-11 limit: fall of *Carpinus* and *Alnus*; rise of *Pinus.*
K-11	*Carpinus-Pinus-Fagus*	102.5–52.5	*Pinus* (24.9–33.2%), *Fagus* (up to 4.9%), *Ulmus* (up to 4.1%) and *Fraxinus* (up to 1.6%) increase; *Carpinus* and *Alnus* (8.1–7.2%) decrease; high values of *Quercus*; *Tilia* (0.5–1.9%), *Corylus* (2.7–6.2%), *Betula* (16.4–28.2%) relatively low; *Abies* sporadic; human indicators present. K-11/K-12 limit: rise of *Carpinus.*
K-12	*Carpinus-Pinus -Fagus-Abies*	52.5–32.5	*Carpinus* (up to 20.0%) and *Fagus* (up to 12.9%) increase; values of NAP, mainly of anthropogenic indicators, decrease; low *Abies.* K-12/K-13 limit: fall of *Carpinus, Fagus,,* rise of *Pinus,,* NAP.
K-13	*Pinus-Fagus-Abies*-NAP	32.5–10.0	*Fagus* (up to 12.9%) dominant; *Carpinus* (to 5.4%), *Quercus* (to 3.8%), *Ulmus* (to 0.6%), *Tilia* (to 0.3%) and *Fraxinus* (to 0.1%) decrease; *Pinus* (up to 33.4%) rises in the upper part of the zone; low *Abies* (max. 0.5%); NAP reaches maximum; high human indicators.

Table 6. Kosobudy, a description of the local pollen assemblage zones

Local PAZ	Name of PAZ	Depth (cm)	Description of pollen spectra
Ks-1	*Carpinus-Quercus-Fagus*	100.0–82.5	Relatively high *Betula* (14.5–23.2), *Quercus* (7.1–9.8), *Alnus* (7.4–12.4), *Carpinus* (5.8–8.0%) and *Fagus* (2.7–8.2%); NAP with the highest values of Poaceae and Cyperaceae; human indicators scattered. Ks-1/Ks-1a limit: fall of AP, rise of NAP.
Ks-1a	NAP	82.5–67.5	*Quercus* (6.4–2.4%), *Carpinus* (6.8–2.9%), *Fagus* (6.8–2.9%), *Betula* (17.5–2.9%), *Pinus* (31.2–2.5%) decrease; human indicators increase: *Secale* (1.1–2.7%), *Triticum* (0.2–1.9%), *Rumex acetosella* (0.3–10.3%). Ks-1a/Ks-2 limit: rise of AP, fall of NAP.
Ks-2	*Carpinus-Fagus-Abies*	67.5–32.5	Relatively high *Carpinus*, *Fagus*, *Quercus*; low NAP, in it human indicators. Ks-2/Ks-3 limit: rise of NAP, fall of AP.
Ks-3	*Pinus-Abies-NAP*	32.5–20.0	High NAP, mainly Cyperaceae (4.5–9.8%), Poaceae (10.6–12.7%), *Artemisia* (1.8–2.6%), Cerealia (0.6–1.3%), *Plantago lanceolata* (0.8–1.3%),, *Rumex acetosella* (2.5–3.1%), *R. acetosa* (0.2–2.2%); low values of *Betula* (9.4–4.0%), *Alnus* (8.0–1.8%), *Carpinus* (1.6–0.8%), *Fagus* (8.6–1.8%), *Quercus* (2.9–3.3%); *Pinus* relatively high (22.7–46.2%).

parison of the diagrams from Krasnobród and Tarnawatka leads us to suppose that in Tarnawatka only the older birch phase is preserved. Most probably a hiatus in the gyttja deposits covering the younger phase of the zone occured here. At about 9430±100 BP the lake in Krasnobród became shallow and then overgrown to form a mire. This was caused by a climatic improvement, and especially by a change in the water supply caused by the cessation of feeding by groundwater. In a depression without outflow ombrophilous peat-bog began to form. In the extant Tarnawatka lake algae-detritus gyttja accumulated.

Corylus-Ulmus-Tilia PAZ

This zone is apparent only in the Krasnobród profile and corresponds to the Boreal chronozone. It is characterized by the beginning of the development of hazel communities, and by the slow, continuous increase in the proportion of thermophilous trees in forest. The first maximum value of lime (4.1%) is found here. From the interpolation of radiocarbon datings in the Krasnobród profile, it appears that the rise of the hazel curve started around 8630 BP, while in Tarnawatka the maximum of this curve is dated at 8610±150 BP. Thus, one can suppose that the succession of vegetation in the examined sites proceeded somewhat differently according to habitat conditions. The more diversified relief in the neighbourhood of Krasnobród (Fig. 5) and the probable occurrence of warm Cretaceous bedrock, especially on hill slopes (Turski et al. 1993), were favourable for the earlier spread of hazel and lime – species typical for this zone.

Corylus-Ulmus-Alnus PAZ

This zone corresponds to the Boreal chronozone at Tarnawatka, and to the early phase of the Atlantic chronozone at Tarnawatka and Krasnobród. It is characterized by the maximum predominance of hazel communities. The proportion of deciduous trees in forest still increased, with elm, oak, ash and lime especially, becoming more important. They were instrumental in the formation of mixed forest on the higher parts of slopes and on summits. Lime was more prominent in the forest communities near Krasnobród as a consequence of the more favourable soil conditions. In the Tarnavatka neighbourhood alder spread rapidly at the beginning of this zone (about 8600 BP) because the wide Wieprz river valley gave good conditions for its development along with other species, such as ash and spruce. At Krasnobród the first maximum of alder occurred a little later (7400 BP), and the proportions of ash and poplar were substantial. This could be the result of the development of riverside elm-poplar carr on alluvial terraces, while the areas of permanently flooded habitats, which were more favourable for alder, were smaller. Pine forest was still developing on nutrient poor sandy soils. From about 7300 BP the lake

Table 7. Diatom spectra (in percentages) of bottom samples from the Tarnawatka profile (anal. B. Bogaczewicz-Adamczak)

Diatoms	Habitat	pH	360–365 cm	355–360 cm	350–355 cm	345–350 cm
Amphora ovalis Kütz.	Be	Alf	+	1.6	1.0	2.1
Amphora v. *libica* (Ehr) Cl.	Be	Alf			+	+
Amphora v. *pediculus* Kütz.	Be (EP)	Alf	+	0.4	+	2.8
Anomoenonis spaerophora (Kütz) Pfilz.	Be	Alf			+	
Coconeis placentula Ehr.	Ep	Alf	+		0.5	
Coconeis placentula v. euglypta (Ehr). Cl.	Ep	Alf	+	5.2		
Coconeis placentula v. lineata (Ehr). Cl.	Ep	Alf		1.2		
Cymatopleura solea (Breb.) W.Sm.	Be	Alf	+	1.6		
Cymbella affinis Kütz.	Ep	Alf			2.0	2.1
Cymbella cistula (Hemp) Grun.	Ep	Alf	5.4	+	6.5	9.1
Cymbella helvetica Kütz.	Ep	Alf			+	
Cymbella leptocerus (Ehr.) Grun.	Ep	Alf			+	
Cymbella obtusa Grun.		Ind			+	+
Cymbella parvula Krasske	Ep				+	
Cymbella sinuata Greg.	Ep	Ind				+
Cymbella ventricosa Kütz.	Ep	Ind				+
Denticula tenuis Kütz.	Ep	Alf			3.7	2.1
Epithemia argus Kütz.	Ep	Alf		0.8	4.5	7.0
Epithemia intermedia Trike	Ep	Alf	11.9	4.6	+	+
Epithemia sorex Kütz	Ep	Alf	+	+	1.0	1.0
Epithemia turgida (Ehr.) Kütz	Ep	Alf	20.0	18.6	19.0	21.0
Epithemia zebra (Ehr.) Kütz.	Ep	Alf	38.7	28.8	37.5	37.1
Fragilaria brevistriata Grun.	Ep-Pl	Alf		+	+	
Fragilaria lapponica Grun.	Ep-Pl	Alf		+	+	+
Fragilaria pinnata Ehr.	Ep-Pl	Alf		+		
Gomphonema acuminatum (Kütz.) Rabh.	Ep	Alf		+	+	
Gomphonema acuminatum v.coronatum Ehr	Ep	Alf		+	+	
Gomphonema constrictum Ehr.	Ep	Alf		0.4		+
Gomphonema intricatum Kütz.	Ep	Alf		+	+	2.1
Gomphonema olivaceum (Lyngb.) Kütz.	Ep	Alf		+		
Melosira sp.				+		+
Navicula cuspidata Kütz.	Be	Alf				
Navicula dicephala (Ehr.) W. Sm.	Be	Alf		+	6.5	
Navicula oblongata Kütz.	Be	Alf	+	12.8	11.5	8.0
Navicula placentula (Ehr) Grun.	Be	Alf	8.0	+		+
Navicula radiosa Kütz.	Be	Ind		5.2		+
Navicula tuscula (Ehr) Grun.	Be	Alf	6.8	0.8	+	
Nitzcia amphibia Grun.	Be	Alf			6.5	5.2
Pinnularia borealis Ehr.	Ep		1.7		,	
Pinnularia viridis (Vitzsch.) Ehr.	Be	Ind		1.6	,	
Stauroneis sp.			+		,	
Rhopalodia gibba (Ehr.) O. Mill	Ep	Alf	2.4	13.2	+	
Synedra ulma (Nitzsch.) Ehr.	Ep	Alf	5.1	2.0	+	
Tabellaria fenestrata (Lyngb.) Kütz.	Ep-Pl	Ind		+	,	
Tabellaria flocculosa (Roth.) Kütz.	Ep-Pl	Ind		0.8		

at Tarnawatka was shallowing and fen was starting to develop.

Alnus-Ulmus-Tilia-Corylus PAZ

This zone corresponds to the middle part of the Atlantic chronozone in both of the profiles examined. During intraspecific competition, deciduous trees slowly established their proportions in forest. Elm, oak, lime and alder were still the most important. In the diagram from Krasnobród lime reached higher pollen

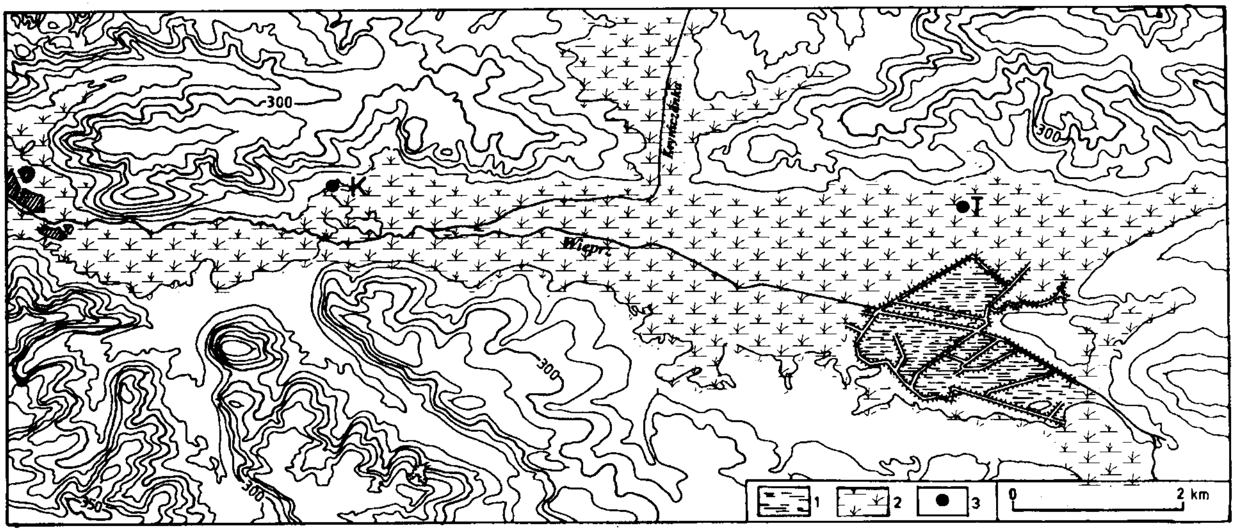

Fig. 5. Relief of the Krasnobród and Tarnawatka neighbourhoods. 1 – ponds, 2 – swamps, 3 – examined sites: K – Krasnobród, T – Tarnawatka

values. The expansion of deciduous forest limited the development of hazel communities. Hazel was forced out from its sites and shaded by higher trees, so its flowering was reduced. A maximum of *Pteridium aquilinum* spores and decreasing values of pine in both diagrams probably arose from the penetration of Mesolithic tribes and forest burning, most probably practised to make hunting easier.

Ulmus-Quercus-Tilia-Alnus PAZ

This zone, corresponding to the younger part of the Atlantic chronozone, was characterized by the predominance of deciduous trees. The varied habitats of the Middle Roztocze gave good conditions for the development of diverse forest communities. The lower and wetter areas, and river valleys, were occupied by alder woods, probably with an admixture of ash, elm and spruce. The higher parts of slopes and hill tops were covered by forest composed of oak, elm and lime with a minor contribution by other trees. Oak spread slowly, starting earlier and achieving a greater extent in the Tarnawatka neighbourhood than around Krasnobród. *Quercus petraea* could enter wet soils accessible to alder and ash, whereas *Quercus robur* dominated on drier sandy, poor soils. Pine still occupied dry, sandy habitats, growing also on dunes. Hazel communities, developed in an earlier period, persisted in the environs of Krasnobród, but in the Tarnawatka vicinity they became much reduced. The hazel curve in the Krasnobród diagram is similar to those from profiles at Imielty Ług and Obary in the Sandomierz Basin (Mamakowa 1962).

Quercus-Alnus-Tilia-Fraxinus PAZ

This zone marks the beginning of the Subboreal chronozone. After a decrease in the elm curve, more distinct in the diagram for Tarnawatka than in that for Krasnobród, this tree again reached high values almost equal to those from the Atlantic period, especially in the Krasnobród diagram. The ash and lime curves closely follow that of elm. Alder reached a significant dominance in flooded habitats. Climatic deterioration and increasing human impact resulted in the slow development of podsols, which caused successive changes in the plant cover of the Roztocze. In mixed deciduous forest the proportion of oak increased, especially near Krasnobród. At Tarnawatka pine reached higher values. Spruce occurred in forest occupying moderately wet habitats and was also most abundant near Tarnawatka. In the Krasnobród vicinity an extensive area was covered by deciduous forest, mixed coniferous forest, and by hazel communities situated probably at forest margins and on hill slopes.

Quercus-Carpinus PAZ

This zone corresponds to the middle part of the Subboreal chronozone and is similar in both described sites. By then the composition of forest had significantly changed with the proportions of elm, lime and ash greatly decreased. In deciduous forest new tree species had appeared, such as *Carpinus betulus* and *Fagus sylvatica,* but their frequencies were still rather small. Oak became a very important component of forest: together with pine it formed mixed forest in relatively fertile habitats. These communities were then dominant in the examined area. In wet places alder communities were still developing. Forest growth was disturbed by anthropogenic impact as is confirmed by the occurrence of human indicators in the pollen diagram.

Carpinus PAZ

This zone still belongs to the middle part of the Subboreal chronozone. Hornbeam reached its maximum in forest communities near the studied sites. The proportions of other components of mixed deciduous forest were still rather low. The development of forest communities followed a similar pattern in both of the sites examined with the frequency of pine considerably decreased. In the more fertile places it was probably replaced by the expansive hornbeam. Man also played a part in the changing of forest communities and traces of his economic activities were also found in this zone.

Carpinus-Quercus-Fagus PAZ

This zone marks the end of the Subboreal chronozone and the beginning of the Subatlantic period in Tarnawatka and Krasnobród. However, the succession of vegetation recorded in the two sites differed because of different habitat conditions. In the Tarnawatka neighbourhood, oak and pine were the most important components of forest, and the proportion of *Carpinus* distinctly decreased in comparison with the preceding zone. However, in the Krasnobród profile hornbeam was still dominant, though its curve shows some decline. A new component, fir, appeared more and more frequently in the forest communities.

Carpinus-Fagus-Abies PAZ

This zone, corresponding to the Subatlantic chronozone, is distinguished in all three of the examined sites. The *Carpinus* curve increases again, indicating the spread of hornbeam in the forest communities. The increasing frequencies of *Fagus* pollen in the Krasnobród and Kosobudy profiles show that this tree was abundant in neighbouring woods. Near Tarnawatka the proportion of beech in forest was lower. In all diagrams the value of *Abies* pollen does not exceed 1%, but most probably the pollen representation does not reflect the true proportion of this tree in the forests (Jedliński 1922, Brzyski 1959, Izdebski 1962a, b, 1963b). The occurrence of anthropogenic indicators pointing to disturbances in the plant cover, is distinctly visible, especially in the Kosobudy diagram (NAP subzone).

Pinus-Fagus-Abies NAP PAZ

The distinctly smaller quantity of deciduous trees in forest recorded in this zone resulted from disturbances of the vegetation caused by the economic activities of man. It is revealed, among other things, by the dominance of pine most prominently shown in the Tarnawatka and Kosobudy diagrams. In the Krasnobród neighbourhood high proportions of beech, oak and hornbeam in forest, and in wet habitats of alder, were still preserved. The high values of NAP, together with indicators of arable and pastoral farming in all three diagrams, indicate a considerable deforestation of the studied areas.

INFLUENCE OF PREHISTORIC MAN ON CHANGES IN THE FOREST COVER

In the older phases of the Atlantic period the Mesolithic nomadic tribes living in the Roztocze region were engaged in hunting and gathering and they had little impact on the natural environment. However, the changes in structure and composition of forest caused by Mesolithic man are more and more frequently discussed (e.g. Simmons & Innes 1987, Görasson 1988, Latałowa 1992, Ralska-Jasiewiczowa & van Geel 1992). The increased numbers of *Pteridium aquilinum* spores, and the decrease of *Pinus* pollen at 290–270 cm in the Krasnobród profile, and at 215–205 cm in the Tarnawatka diagram, probably reflect disturbances in the pine forest. In the regeneration of forest after burning, the developing herbaceous plants were very important. A great role was played by *Pteridium aquilinum, Calluna* *vulgaris* and *Melampyrum* – plants invading habitats after fires. At that time in the Krasnobród neighbourhood, birch and hazel would occupy clearings. Small fluctuations in the elm curve are recorded, and the frequency of ash decreases (Krasnobród diagram). These disturbances, probably of an anthropogenic nature, were probably caused by the spread of Late Mesolithic tribes. Traces of settlement by Mesolithic man were found in the Krasnobród vicinity (archival materials of the Department of Archaeology, Maria Curie-Skłodowska University).

The next maximum of *Pteridium aquilinum* at Krasnobród (240–215 cm) and at Tarnawatka (190–180 cm), together with the decline of the *Pinus* curve, the decrease of elm, the small fluctuations of other deciduous trees, the occurrence of *Plantago major/media, Rumex acetosa, R. acetosella, Melampyrum* and *Urtica,* and the maximum of *Artemisia* and meadow herbs (especially in the Tarnawatka diagram) should be attributed to the activities of Neolithic tribes who brought new techniques of stock raising and soil cultivation. The changes described above, starting at the end of the Atlantic period, can be taken as evidence of the settlement or penetration of Early Neolithic tribes – of the Linear Pottery, Volhynia-Lublin White-Painted Pottery and Funnel-Beaker Cultures. The decrease in the elm curve was formerly interpreted as an effect of the very intensive pollarding of trees for feeding to cattle in closed pens (Troels-Smith 1960). Recently, it has also been attributed to elm disease (Peglar 1993a, Peglar 1993b). The increased proportions of nitrophilous species (*Artemisia, Urtica, Plantago major*) probably reflect the occurrence of settlements. Cereal pollen was not found. The occurrence of *Plantago lanceolata* pollen in the Tarnawatka diagram and the high incidence of meadow species provide evidence of pastoral farming.

A succeeding phase of settlement in Krasnobród (175–160 cm) is shown by typical indicators of man's activity – *Plantago lanceolata* and the first pollen grains of Cerealia (*Triticum* type). These were found at a depth of about 170 cm corresponding to 4200–4100 BP, so they could be connected with the Globular Amphora Culture or, more probably, the Corded Ware Culture (4400–4000/3900 BP), as more traces of the latter than the former have been recorded in the Roztocze (Bargieł 1991). In Tarnawatka this phase is distinguished by a greater proportion of meadow plants. After suffering a decline, elm, lime, ash and hazel again reached relatively high values in some of the overlying spectra. Their values decrease above a depth of 150 cm in the Krasnobród, and 145 cm in the Tarnawatka diagrams.

The increased values of *Artemisia,* Poaceae, *Melampyrum* and *Pteridium aquilinum*, and the occurrence of *Plantago lanceolata* and *P. major/media* correspond to spectra from depths of 145–120 cm (3500–3100 BP) in Krasnobród and 130–115 cm (3400–3200 BP) in Tarnawatka. In Krasnobród grains of *Triticum* type pollen occur at depths of 145, 135, 125 and 120 cm. Pollen of cereals was not found in Tarnawatka. This phase probably coincided with the cultures of the middle Bronze Age, of which the most important was the Trzciniec Culture.

The settlement phase was interrupted by a short period of forest regeneration, especially by the invasion of new tree species, the very expansive hornbeam, and less invasive beech.

In the next overlying spectra (Krasnobród – 115–70 cm; Tarnawatka – 115–75 cm), the hornbeam values decrease, especially in the Tarnawatka profile (17.2–6%). In Krasnobród, after a short minimum, they rise again, even reaching 20%. The occurrence of cereals (*Triticum, Secale, Hordeum*), and *Plantago lanceolata*, and the increased values of *Artemisia,* Chenopodiaceae and *Rumex,* should be linked with the settlement and management of the Lusatian Culture population. The small numbers of synanthropic indicators allow us to suppose that in the younger Bronze Age – in the Hallstatt and La Tčne periods – the Roztocze were sparsely populated.

More visible traces of deforestation are shown by the decline of the *Pinus, Ulmus, Quercus* and *Fraxinus* curves and to a considerable extent also of *Carpinus*, and by a greater abundance of anthropogenic indicators. They are recorded in the Krasnobród profile (50–35 cm) and correspond to the Roman period. In the Tarnawatka diagram a small decline of hornbeam together with a slight increase in the *Artemisia* curve, and the occurrence of *Plantago lanceolata, P. major/media* occur during this period. In the archival archaeological materials collected from the examined area, only one site was recorded which showed evidence of Roman influence.

During the Migration Period a temporary regeneration of forest occurred. It saw the return of deciduous trees, mainly hornbeam, oak, beech and alder, and pine forest to some extent. It was probably the result of a reduction in farming which is recorded in the pollen spectra by decreasing frequencies of anthropogenic indicators.

Increased frequencies of Cerealia, *Rumex, Plantago lanceolata,* Chenopodiaceae, *Pteridium aquilinum* and *Artemisia* are recorded in the top parts of the profiles. They represent settlement in the early Middle Ages dated to 900 BP. This phase is distinctly shown in Kosobudy by the increased amount of mineral material and the abundance of anthropogenic indicators. The successive intensification of the economic activities of man resulted in higher frequencies of NAP, anthropogenic indicators and pine, and in considerably lower proportions of deciduous trees – elm, oak, ash and hornbeam. These were found from depths of 30–10 cm in Krasnobród, 30–0.0 cm in Tarnawatka and 30–15 cm in Kosobudy. Settlements from the Middle Ages are the most frequently recorded in archaeological materials from this area.

CONCLUSIONS

During the Alleröd the occurrence of shallow lakes at the Krasnobród and Tarnawatka sites in the Wieprz river valley is confirmed by diatom analyses. The beginning of lacustrine sedimentation in Krasnobród was dated at 11 780±150 BP. This lake existed until about 9450 BP and was later overgrown by an ombrophilous bog. At Tarnawatka carbonate deposits accumulated at first, and the radiocarbon dating (10 750±150 BP) defines only the start of non-carbonate sedimentation. The lake here existed longer (till about 7300 BP), and then a fen developed.

In the Kosobudy profile the examined deposits represent a peat accumulation during the Subatlantic period. They contain an episode of an intensive supply of mineral matter probably connected with man's activity during the period of Roman influence.

In the Alleröd the Middle Roztocze were covered by open pine-birch forest with an admixture of *Picea*, *Larix* and *Populus*. A high proportion of xerothermic communities was recorded. The occurrence of *Nymphea alba* and *Typha latifolia* suggests mean July temperatures not lower than 15°C prevailed.

The cooling of the Younger Dryas was marked by the spread of steppe-like herbaceous communities and by the thinning of forest. Landscape of a park type with groups of trees (*Pinus* and *Betula*) was dominant.

During the Preboreal period an expansion of pine-birch forest with elm took place. Elm was the first thermophilous tree invading this area at the beginning of the Holocene. Low pollen proportions of other thermophilous trees (only hazel and oak over 1%) indicate that they were to be found increasingly near the Roztocze area.

In the Boreal period the succession of the forest communities differed somewhat among the examined sites. The more diversified relief in the Krasnobród neighbourhood and the probable occurrence of warm Cretaceous bedrock, especially on hill slopes, were favourable for the earlier spread of hazel and lime. In the Tarnawatka vicinity alder played a more important part.

During the Atlantic period deciduous mixed forest with elm, oak, lime and ash were dominant. Lime and hazel reached relatively high proportions near Krasnobród, while oak and alder were prominent near Tarnawatka. In both profiles traces of man's activity in this period can be seen.

In the Subboreal period new tree species, *Carpinus betulus* and *Fagus sylvatica,* appeared in forest. The essential transformation of forest communities in the Roztocze started about 3700–3600 BP. The proportions of elm, ash and lime considerably decreased. Hornbeam became more and more important, especially in the Krasnobród neighbourhood while near Tarnawatka spruce was a significant forest component. Anthropogenic indicators show that the forest development was being disturbed by man.

During the Subatlantic period the vegetational succession was significantly affected by habitat conditions and the activity of man. In the Tarnawatka vicinity oak and pine were the principal components of forest. In the Krasnobród and Kosobudy neighbourhood hornbeam and beech were more prominent. The frequencies of fir pollen were low in all diagrams but it seems that these underestimate the true incidence of this tree in the forest (see Moe 1970, Birks 1983, Środoń 1967, Bałaga 1991).

Anthropogenic impact on the vegetation of the Roztocze is recorded from the Atlantic period; first probably in connection with the migration of the Mesolithic tribes, later with activities of the Neolithic people. The most important, as far as environmental changes in the Roztocze were concerned, were the economic activities of tribes of the Neolithic Funnel-Beaker Culture, followed by those of the Bronze Age Trzciniec Culture. The Lusatian Culture at the end of the Bronze Age, in the Hallstatt and La Tène periods, had a weaker influence on the environment. An increase of anthropogenic indicators, and a considerable decrease in *Carpinus* shows up clearly in the diagrams, especially so at Krasnobród in the sections corresponding to the period of Roman influence. This could be evidence of the heightened influence of man at that time. However, up till now archaeological investigations in the Middle Roztocze have not proved any intensive economic activity of man before the early Middle Ages.

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