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A LATE GLACIAL AND EARLY HOLOCENE PROFILE FROM JASŁO AND A RECAPITULATION OF THE STUDIES ON THE VEGETATIONAL HISTORY OF THE JASŁO-SANOK DEPRESSION IN THE LAST 13 000 YEARS

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ABSTRACT. This work is a continuation of the studies started earlier by the author in the Jasło-Sanok Depression in which the palynology and the macrofossils were analysed. The first part of this paper gives a discussion of the changes in the vegetation on the basis of the profile from Jasło and the reconstruction of the vegetational history from the Oldest Dryas to the Boreal.

A recapitulation of the studies on the vegetational history of the Jasło-Sanok Depression in the last 13 000 years based on four examined profiles (Jasło, Roztoki a and b, Tarnowiec) is the essential part of the paper. The correspondence analysis shows the relationship between particular samples of the four profiles covering a period from the Older Dryas to the Boreal. Despite some inevitable local differences between the profiles they show a resemblance and, what follows, it has been pointed out statistically that the features characterizing the profiles of the Jasło-Sanok Depression are common to the four diagrams analysed.

The following characteristic features can be listed for the profiles analysed: The Late Glacial supported the survival of some trees present in a park-woodland landscape. The diagrams are conspicuous by very high percentages of birch trees. The region of the Jasło-Sanok Depression may have been a refugium of spruce. The rapid spread of alder in the Jasło-Sanok Depression, appears to be responsible for the remarkable shortening of the part of the profile corresponding to the Atlantic and even the hiatuses in the deposits. The particularly favourite climatic and edaphic conditions caused an early and intense – in comparison with other regions of the Carpathians – penetration of the area by man.

KEY WORDS: pollen analysis, Jasło-Sanok Depression (Polish Carpathians), vegetational history, Late-Glacial, Holocene, numerical analyses

INTRODUCTION

This paper is a continuation of the previous publications concerning the Late Glacial and Holocene vegetation of the Jasło-Sanok Depression. They were based on two profiles from Roztoki and one from Tarnowiec near Jasło, included as reference sites for the region Jasło-Sanok Depression and east forelands in the International Geological Programme IGCP No 158 B – Fig. 1 (Ralska-Jasiewiczowa 1986, Harmata 1987, 1989, 1992, Wójcik 1987). Information about the study area and methods applied here will be found in those works.

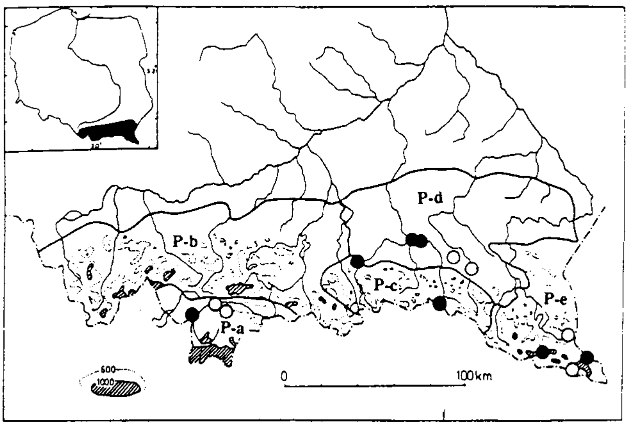

Fig. 1. The subdivision of the Polish Carpathians into palaeoecological type region (Ralska-Jasiewiczowa 1986). P-a – Tatra Mts., P-b – Western Beskidy Mts., P-c – Low Beskidy Mts., P-d – Jasło-Sanok Depression and eastern forelands, P-e – Bieszczady Mts. (● IGCP 158 reference sites, ○ additional sites)

The site at Jasło (Fig. 2) was discovered by A. Wójcik during his work on the geological mapping of the area. His research, including the digging of a small exploratory shaft and the ^{14}C dating of samples, was financed by the Carpathian Division of the Polish Geological

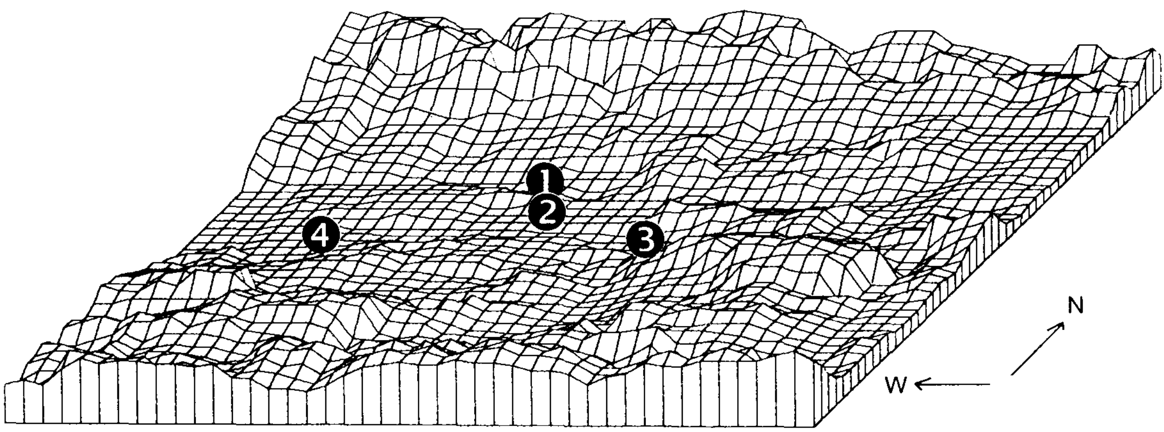

Fig. 2. The morphology of the investigation area (side of square – 13 km; altitude: 220–370 m a.s.l.) 1 – Roztoki a, 2 – Roztoki b, 3 – Tarnowiec, 4 – Jasło

Institute. The site is located in the Jasiołka River valley in the eastern part of the town (Jasło-Sobniów).

A LATE GLACIAL AND EARLY HOLOCENE PROFILE FROM JASŁO

DESCRIPTION OF THE PROFILE

0.00–0.40 m	soil
0.40–1.90 m	silty clay, yellow-grey
1.90–2.25 m	clay, grey
2.25–2.30 m	clay, brown
2.30–2.40 m	peat, brown
2.40–3.07 m	peat strongly compressed, brown
3.07–3.25 m	chalk, white
3.25–4.08 (5.00) m	clay, dark-grey with shells of molluscus and ostracods at the top.

^{14}C dating was performed for only two samples from the profile under study. Nevertheless, using the interpolation method we can date a considerable part of the diagram by comparing it with the profiles from Roztoki and Tarnowiec. The pollen diagram has been devided into 8 local pollen assemblage zones (Fig. 3).

DESCRIPTION OF LOCAL POLLEN ZONES

Zone 1 *Pinus cembra – Helianthemum* PAZ (3.60–4.00 m)

The deepest part of the profile is characterized by a very low frequency of sporomorphs and a considerable degree of their deterioration and degradation. The percentages of undetermined pollen grains range from 9 to 13% and – in the sample from a depth of 3.90 m – reache 19%. *Pinus cembra* and *Pinus* are dominant and the *Betula* curve rises to 5% in this zone. The curves of *Alnus, Ulmus* and *Corylus*, remarkable in this and the next zones, represent the contamination of the material, whereas part of the pollen grains which make up the curve of spruce in this part of the diagram is not necessarily rebedded. Shrubs are represented by high proportions of *Betula nana*-t., *Salix* and *Juniperus*, the latter reaching 4.5% in the older part of zone. *Hippophaë, Populus, Ephedra fragilis*-t. and *E. distachya* pollen is also present. High NAP values (30–42%) are typical of this zone. Pollen grains of *Plantago lanceolata, Hypericum, Saxifraga oppositifolia, Rumex, Pleurospermum austriacum, Anthemis*-t., *Dianthus* and *Gypsophila muralis* were also found here. Gramineae, Cyperaceae and *Artemisia* have the highest percentage values among the herbaceous plants. The curves of Chenopodiaceae, Umbelliferae, Ranunculaceae, Cichorioideae, *Thalictrum* and *Calluna* are also significant and so is, above all, continuous the curve of *Helianthemum* only in this part of the diagram, (max. nearly 2%). *Lycopodium annotinum* and *Sphagnum* have conspicuous curves in this zone. Spores of *Selaginella selaginoides* occur in two samples only. As regards the aquatic plants, *Alisma plantago aquatica*-t., *Potamogeton, Sparganium, Myriophyllum, Typha angustifolia, Ranunculus flammula*-t. and the algae *Pediastrum* and *Botryococcus* were found.

Zone 2 *Betula* PAZ (3.40–3.60 m)

A distinct rise in the *Betula* curve is characteristic of this zone. It is accompanied by a decrease in the percentages of nearly all herbs with the exception of Gramineae, Cruciferae and *Thalictrum*. The curves of the sporophytes and aquatics do not change significantly in comparison with the previous zone except for the disappearance of Filicales monoletae. There is an increase in the percentages of the algae *Botryococcus* and *Pediastrum boryanum*.

Zone 3 *Salix – Juniperus* PAZ (3.15–3.40 m)

The distinguished zone containing a very small amount of sporomorphs is characterized by a marked increase in the pollen values of *Betula* and *Juniperus*, whereas the proportion of *Pinus cembra* becomes smaller. Although the NAP sum falls in this zone because of a decrease in the Gramineae and Chenopodiaceae pollen values, many taxa grow in percentage (*Artemisia*, Umbelliferae, Ranunculaceae, Cichorioideae, Rubiaceae, Rosaceae) or appear for the first time (*Sanguisorba officinalis, Plantago major/media, Dryas octopetala*). Single microspores of *Selaginella selaginoides* were also identified from this zone. The aquatic plants are represented by *Sparganium, Potamogeton, Alisma plantago-aquatica*-t., *Typha angustifolia, Ranunculus flammula*-t. and *Rumex maritimus*-t. The curves of algae (*Botryococcus* and *Pediastrum boryanum*) are the highest in this zone.

Zone 4 *Betula – Larix* PAZ (2.85–3.15 m)

The sample from the middle of this zone was dated 11 890 ± 90 BP. The sum of tree pollen is higher and reaches 80% this is due to very high proportion of *Betula*, which attains maximum pollen values at the decline of the previous zone and to a distinct increase in *Larix*. There is a fall in the curves of *Juniperus* and *Salix* and the proportions of *Hippophaë*, with still very high percentages of *Betula nana* (approaching 10%). Distinctly lowered are the curves of Cyperaceae and *Artemisia* and the proportions of a majority of herbs in the spectra are lower (*Helianthemum*, Umbelliferae, Ranunculaceae, Cichorioideae, Rubiaceae, Asteroideae and Cruciferae). *Filipendula, Urtica, Geum* and Filicales monoletae play a greater role than in the previous zone. Despite the change of the deposit the aquatic plants are represented just as in the previous zone, only the alga *Tetraedron minimum* appears and forms a continuous curve.

Zone 5 *Pinus* PAZ (2.62–2.85 m)

Pinus dominates absolutely in this zone. The remaining components of AP (*Betula nana, Salix, Juniperus, Pinus cembra, Larix* and *Betula*) occur in decreased proportions. The NAP sum reaches maximum values in this zone, but the picture is disturbed by a local pollination of grasses. In the sample from a depth of 2.85 m there are 3 800 pollen grains of Gramineae to 730 grains of AP. In the neighbouring samples the numbers of pollen grains of Gramineae are lower but even there they produce the highest peak throughout the diagram. *Filipendula*, Umbelliferae, Cruciferae, *Potentilla, Geum* and Filicales monoletae also attain their peaks in this zone. The aquatics are represented by *Sparganium, Potamogeton, Alisma plantago-aquatica*-t. and the alga *Botryococcus*.

Zone 6 *Betula nana – Artemisia* PAZ (2.37–2.62 m)

The curves of *Betula nana, Salix, Juniperus, Betula* and *Picea* distinctly rise in this zone. The growth of NAP to 40% is due to the high percentages of Cyperaceae, *Artemisia* and Chenopodiaceae. The appreciable occurrence of *Potamogeton, Alisma plantago-aquatica* – t. and the algae *Botryococcus, Pediastrum* and *Tetraedron* is noted among the aquatic plants.

Zone 7 *Corylus – Ulmus – Picea* PAZ (2.12–2.37 m)

Within this zone the top of the peat was dated at 8120 ± 90 BP. In this zone the pollen values of *Corylus, Ulmus* and *Picea* play an important role, whereas *Pinus cembra* and *Betula* occur in distinctly smaller proportions and the curves of *Betula nana, Salix* and *Juniperus* come to an end. Single pollen grains of *Quercus, Acer, Fraxinus* and *Sambucus* were identified. The NAP sum lowers and the percentages of Cyperaceae, *Artemisia* and Chenopodiaceae decrease. At the beginning of this zone *Filipendula* attains its peak and so do the Cruciferae somewhat later, while the pollen values of Filicales monoletae reach 10%. The aquatics are represented by *Sparganium, Typha angustifolia* and the alga *Botryococcus*.

Zone 8 *Alnus – Tilia – Quercus* PAZ (2.00–2.12 m)

This zone is characterized by a rise of the AP curve to 95%. Rapid increases in the proportions of *Corylus, Alnus, Tilia* and *Quercus* contribute to that rise. The pollen values of *Picea* remain somewhat higher than in the preceding zone. The curves of *Pinus, Betula* and *Ulmus* descend, those of Chenopodiaceae, Rosaceae, Cichorioideae and Cruciferae discontinue and the percentages of Gramineae, Cyperaceae, *Artemisia* and Umbelliferae decrease considerably in the spectra of this zone. As far as the herbaceous plants are concerned, only Filicales monoletae and *Filipendula* increase their percentage occurrence.

MACROFOSSIL ASSEMBLAGE ZONES

Zone 1 *Chara contraria, Potamogeton filiformis* MAZ (3.00–3.70 m)

In this zone the deposit changes from clay through chalk into peat. The zone is little diversified in respect of macrofossils. Nevertheless, the number of the oospores of *Chara contraria* ranges from 300 to 820 in the samples from 3.30–3.70 m. *Potamogeton filiformis* is fairly abundant (up to 11 fruitlets); moreover, *Schoenoplectus tabernaemontani, Hippuris vulgaris* and *Carex rostrata* and shoot of the moss *Calliergon trifarium* were identified.

Zone 2 *Chara contraria, Drepanocladus aduncus* var. *kneifii* MAZ (2.72–3.00 m)

Besides *Drepanocladus aduncus* var. *kneifii*, also *Calliergon trifarium, Scorpidium turgescens* and *Drepanocladus revolvens* were determined from this zone, but the two taxa of *Drepanocladus* are in their occurrence restricted only to this zone. The oospores of *Chara* are still abundant and so is *Potamogeton filiformis* in the lower part of the zone. A seed of *Najas maritima*, a fragment of *Equisetum* and – in the sample from a depth of 2.95 m – 17 caryopses of *Phragmites* were identified.

Zone 3 *Scorpidium turgescens, Carex rostrata* MAZ (2.37–2.72 m)

Scorpidium turgescens (max. 94 shoots in a sample) and also *Carex rostrata* were determined mainly from this zone. From the top part of this zone 149 oospores of *Chara contraria* were obtained and 6 nutlets of each, *Betula nana* and *B. pubescens*, fruits of *Eupatorium cannabinum*, numerous caryopses of *Phragmites communis* (41), *Cladium mariscus*, one fruit of *Comarum palustre* and *Schoenoplectus tabernaemontani* and 2 fragmentary fruitlets of *Potamogeton filiformis* were determined.

Zone 4 *Cladium mariscus* MAZ (2.22–2.37 m)

In addition to *Cladium mariscus*, a shoot of *Scorpidium turgescens*, indeterminable needles, and nutlets of *Carex* were found in this zone. In the sample neighbouring upon the preceding zone there were some nutlets and fruit scales of *Betula nana* and *B. verrucosa* fruits of *Carex rostrata* and fairly numerous shoots of the moss *Calliergon trifarium*.

CHANGES IN THE PLANT COVER OF THE JASŁO REGION IN LATE GLACIAL AND EARLY HOLOCENE

Zone 1 *Pinus cembra – Helianthemum*

The oldest zone of the Jasło 4 profile has been acknowledged, in all probability, to represent the Oldest Dryas. Two phases can be distinguished within this period: an older phase with a high curve of *Juniperus* and a peak of *Helianthemum* and a younger one with a gently ascending curve of *Betula*. Park landscape probably prevailed in the Jasło region in the Oldest Dryas. The AP sum ranges from 53 to 70% in this period; it is high enough to rule out the existence of the vegetation of woodless areas (Ruffaldi 1994). In spite of the relatively high NAP curve, with a great proportion of heliophytes and the high curves of *Betula nana*, *Salix* and above-mentioned *Juniperus*, it should be supposed that *Pinus cembra* and single trees of *Larix*, *Betula* and *Pinus* grew in the closest surroundings of Jasło. It may well be, too, that the *Picea* pollen from that period does not come from contamination but from the spruce trees growing in the vicinity of the site. In the profile from Tarnowiec (Harmata 1987) the occurrence of spruce in situ is suggested by the presence of its seeds in the Older Dryas. Both in the profile from Jasło and in that from nearby Tarnowiec the pollen curves of *Picea* are very low in the Older Dryas and Alleröd. According to Hicks (1994), the representation of spruce is low in pollen spectra owing to its low pollen production. It seems probable that part of the pollen grains constituting the basis for plotting the *Picea* curve for the Oldest Dryas derived from contamination and part may corroborate the presence of these trees in situ. In the vicinity of the study site there probably occurred some aspens, as evidenced by the pollen grains of *Populus*, and *Hippophaë rhamnoides* (single pollen grains of this species).

Zone 2 *Betula*

This zone, characterized by a rise in the *Betula* curve, was referred to the Bölling. More favourable conditions for the development of trees are evidenced also by a reduced proportion of herbaceous plants in the pollen spectra, especially that of the heliophytes (*Artemisia*, Chenopodiaceae, *Helianthemum* and *Filipendula*). A rapid growth in the curves of algae must have been associated with the formation of a water body. The following Chlorophyceae were identified from that period: benthic *Botryococcus braunii* and two littoral subspecies of *Pediastrum boryanum: P. boryanum* var. *boryanum* and *P. boryanum* var. *longicornae* (Jankovská 1980, Komarek & Fott 1983). In most samples from the Jasło profile, in which *Pediastrum boryanum* occurs, both subspecies appear simultaneously except for the samples from the younger part of the Oldest Dryas, from which only *Pediastrum boryanum* var. *longicornae* was determined.

Zone 3 *Salix – Juniperus*

This zone referred to the Older Dryas. The cooling of the climate caused an increase in the area of shrub tundra but around the Jasło site a park-woodland landscape probably was occupied, with clusters of tree birch, larche, sea buckthorn and juniper. The curves of *Artemisia, Helianthemum, Thalictrum, Anthemis*-t., *Plantago major/media*-t., *Geum, Campanula, Dryas octopetala* and, from the sample adjacent to the top of the zone, *Armeria* and *Heliosperma* indicate the existence of heliophilous communities. In depressions filled by water *Chara contraria* and *Potamogeton filiformis* grew in abundance and also algae developed.

Zone 4 *Betula – Larix*

The boundary between zones 3 and 4 is marked by a change in the deposit, clay being followed by chalk, which more or less in the middle of the zone is, in turn, replaced by peat. The bottom of the peat is dated at 11 890 ± 90 BP. On the basis of the pollen spectra the zone is attributed to the older phase of the Alleröd. There were no significant changes in the composition of trees but the wooded area increased distinctly at the cost of open areas. *Betula, Larix* and *Pinus cembra* were the taxa that spread most. In the places where the cover of trees was thin, undergrowth of *Juniperus* developed and the unshaded habitats became occupied by thickets of *Hippophaë* and *Ephedra fragilis*-t. *Betula nana* grew around the lake and, when it had been overgrown, on the peat-bog.

Zone 5 *Pinus*

This pollen zone covers the younger phase of the Alleröd, and is dominated by *Pinus*. Pine encroached on the study area and spread in part of the habitats previously occupied by *Betula nana, Salix, Juniperus, Pinus cembra* and *Betula*. However, birch was still present in the study area, beside the pollen curve of *Betula* its presence in situ was confirmed by a nutlet of *Betula pubescens* found in the top sample from this zone. The macrofossil analysis showed the presence of all the moss taxa identified from the profile at Jasło and oospores of *Chara contraria*. Spores of *Sphagnum* were also encountered in the pollen profile.

Zone 6 *Betula nana – Artemisia*

The pollen spectra of this zone indicate that the forest withdrew again and the park landscape became prevalent. This zone was referred to the Younger Dryas. The groups of trees consisted of *Pinus, P. cembra, Betula* and *Larix*. The shrubs of *Betula nana, Salix, Juniperus* as well as *Ephedra fragilis* and *Hippophaë* grew among the group of trees. The presence of *Betula nana* on the peat-bog is evidenced by its nutlets found in the top sample of this zone. A relatively large area was occupied by heliophilous communities composed of *Artemisia,* Chenopodiaceae, *Helianthemum, Thalictrum, Hypericum, Potentilla*-t., *Dianthus, Sanguisorba officinalis, Symphytum, Polygonum aviculare* and Cyperaceae. There were sedges on the peat-bog (nutlets of *Carex rostrata* and *Carex* sp.).

Zone 7 *Corylus – Ulmus – Picea*

In this zone the peat deposit was covered by clay. Although the top of the peat was dated at 8120 ± 90 BP, on the basis of the curves of sporomorphs the zone may be treated as corresponding with the Preboreal. The improving climate favoured the appearance of trees and shrubs with greater thermal requirements (*Alnus, Ulmus, Corylus* and *Sambucus*) and the spread of *Picea,* which perhaps had occurred in the Jasło-Sanok Depression since the Oldest Dryas. *Pinus, P. cembra, Larix, Betula, B. nana* still played a significant role. There is a rise in the curve of *Filipendula* at the beginning of the Preboreal. It was probably *Filipendula ulmaria*, the species indicating a more humid climate. The pollen of *Typha angustifolia* and the abundant occurrence of *Cladium mariscus* fruits might suggest the warming of the climate. In the Preboreal the remainders of hieliophilous (steppe-like) communities survived in the Jasło region, as evidenced by the presence of *Artemisia*, Chenopodiaceae, *Thalictrum*, *Anthemis*-t. and *Geum*.

Zone 8 *Alnus – Tilia –Quercus*

This zone may be treated as corresponding with the Boreal chronozone. It was marked by a significant increase of the AP pollen curve. A rapid increase in the *Alnus* pollen curve is indicative of a wide expansion of this tree into damp habitats so common in the Jasło-Sanok Depression region, as a result a forest with spruce and alder developed. On the surrounding flat hills around depressions the hazel communities prevailed in this zone. Oaks and limes with elms, whose pollen appears in fairly high quantities at that time may have been a component of the communities on rather moist soils, rich in nutrients. In the profile from Jasło the beginning of the Boreal chronozone is synchronous with the complete withdrawal of *Betula nana, Salix* and *Juniperus*. The NAP sum hardly exceeds 5%.

A HISTORY OF THE LOCAL PLANT COMMUNITIES FROM THE OLDEST DRYAS TO THE PREBOREAL RECONSTRUCTED ON THE BASIS OF THE PROFILE AT JASŁO

The profile at Jasło reflects the plant succession starting from the Oldest Dryas. However, the bottom part of the profile does not contain any determinable macrofossils with the exception of a small number of *Chara contraria* oospores found in two samples referred to the Oldest Dryas. At the study site a water body existed in this time, which is evidenced by the presence of algae, pollen grains of *Potamogeton, Sparganium*, *Alisma plantago-aquatica, Myriophyllum* and *Ranunculus flammula*-t., and single grains of *Typha angustifolia*, determined from palynological samples. In connection with the warmer and more humid climate in the Bölling, more favourable conditions were created for the development of *Chara* and *Potamogeton filiformis*. A community of this type persisted until the mid-Alleröd. A fruit of *Hippuris* and a seed of *Najas maritima* were also identified from that period. Nevertheless, even somewhat earlier, in the middle of the older phase of the Alleröd, when the lake chalk deposit changed to peat, the communities composed of the mosses *Drepanocladus aduncus*, *D. revolvens*, *Calliergon trifarium* and *Scorpidium turgescens* appeared. Except for *Drepanocladus aduncus*, which species is characterized by a wide biotopic scale (Szafran 1961), the remaining three taxa are the calciphilous, boreal mosses (Karczmarz 1989, 1992). Although the deposit changed into peat, the small lakes must still have existed, which is indicated by high curves of algae (*Botryococcus, Pediastrum* and *Tetraedron*). The edge of the water body was overgrown by *Phragmites*. *Carex rostrata* grew on the peat-bog, as can be seen from the top sample of the Alleröd and in the period of the Younger Dryas. In this area there were probably some pools, with which the fruits of *Potamogeton* (also the peak of the pollen of *Potamogeton*), *Lycopus europaeus, Comarum palustre, Eupatorium cannabium*, *Phragmites communis*, *Schoenoplectus tabernaemontani* and *Cladium mariscus* may also be associated. These last, warmth requiring species were found at the beginning of the Preboreal (Borówko-Dłużakowa & Janczyk-Kopikowa 1989). *Cladium mariscus* was placed by Szafer (1959) among the Ancylus relicts referred to a warm and humid climate. *Betula nana* nutlets were found in a sample from the decline of the Younger Dryas. The pollen curve of dwarf birch is fairly high throughout the Late Glacial section of the diagram, the presence of nutlets in situ therefore confirms its occurrence on the peat-bog or in the nearest surroundings of the lake. Neither should there be any doubt about the occurrence of tree birches in the nearest region of the site, seeing that their curve is very high throughout the Late Glacial. In the course of an analysis of the macrofossils one nutlet of *Betula verrucosa/pubescens* was identified from the top sample of the Alleröd, 6 nutlets of *Betula pubescens* from the bottom of the Preboreal and 4 nutlets and a fruit scale of *Betula verrucosa* from the next, higher sample. In the older part of the Preboreal the development of a peat-bog was stopped by the accumulation of silt clay and later alluvial clay.

A RECAPITULATION OF THE STUDIES ON THE VEGETATIONAL HISTORY OF THE JASŁO-SANOK DEPRESSION IN THE LAST 13 000 YEARS

An attempt was made to reconstruct the Late Glacial and Holocene vegetation of the

Jasło-Sanok Depession on the basis of the pollen analysis of 4 profiles from Roztoki a, Roztoki b, Tarnowiec and Jasło. The location of these sites is shown on the map in Fig. 2. The complete diagrams from the Roztoki sites and from Tarnowiec were published in an earlier work (Harmata 1987). In the present paper the percentage diagram from Jasło is accompanied only by the plots of concentration curves for the selected taxa taken from the Roztoki a, Roztoki b, Tarnowiec and Jasło diagrams (Figs 4–7). The profile from Jasło records the vegetational history from the Oldest Dryas to the Boreal, the other profiles illustrate the plant succession from the Older Dryas to the Boreal at Roztoki a, to the Atlantic at Roztoki b and to the sub-Atlantic at Tarnowiec. All the four diagrams therefore make up a picture of history embracing the whole Late Glacial and Holocene without the last nearly 1000 years (the history of vegetation at Tarnowiec ends at the early Middle Ages). The profiles from the Jasło-Sanok Depression studied before, that is, those from Besko (Koperowa 1970) and Kępa (Gerlach et al. 1972), serve for comparison.

Oldest Dryas

This period is represented by mineral deposits only in the profile from Jasło. It is characterized by the occurrence of redeposited pollen grains of thermophilous trees (*Alnus, Ulmus, Tilia, Carpinus* and *Corylus*, and – in the bottom sample – a Tertiary form of Arecipites from the family Butomaceae), discussed widely in numerous papers devoted to the Late Glacial (Mamakowa 1962, Wasylikowa 1964, Ralska-Jasiewiczowa 1966, Koperowa 1970). The high mineral material content, the low concentration of pollen resulting from it, the presence of redeposited sporomorphs and the spectrum with a high proportion of herbs and pioneer species point to the occurrence of open, unstable soil surfaces with a discontinuous cover of low vegetation (Kolstrup & Buchardt 1982). In the Oldest Dryas the sum of pollen of thermophilous trees, redeposited here, reaches a maximum value of 5.7%. The problem of interpretation of the pollen grains of *Picea*, which neither in the Oldest Dryas nor in the Bölling exceed 3%, remains open. In keeping with its ecological properties, this taxon belongs to the plants capable of withstanding low temperature and is hygrophilous as regards both air humidity and soil moisture (Borówko-Dłużakowa & Janczyk-Kopikowa 1989). Fossil remains of common spruce are known from European floras starting from the boundary between the Pliocene and Pleistocene onwards. In the Pliocene common spruce repeatedly went out beyond the area of its present distribution. Such a wide distribution area of spruce in Europe occurred for the last time in the main interstadial of the Vistulian glaciation, in the Brörup.

In order to understand the Late Glacial vegetational history of the Jasło-Sanok Depression we need go back to investigations concerning older periods. The oldest site at Dąbrówka near Jasło has only been studied in a preliminary way. In this profile Mamakowa (Mamakowa & Wójcik 1987, Mamakowa 1989) distinguished the sequence of the pollen zones from the late-glacial of the Middle Polish Glaciations s.l. to optimum of the Eemian Interglacial. The late-glacial section of the Middle Polish Glaciation has 32% NAP and 2.5% *Betula nana* pollen but its characteristic feature is the extremely high amount of *Selaginella selaginoides* microspores.

Up to now Carpathian pollen floras correlated with the Interstadial Brörup were different from analogous floras from Central Poland (Mamakowa 1994). Pollen diagrams from Brzeziny (Birkenmajer & Środoń 1960) and Wadowice (Sobolewska et al. 1964) represented a succesion of vegetation, with the climatic optimum characterized by high participations of *Picea* and *Alnus*.

The interstadial flora attributed to Hengelo from Brzeźnica on the Wisłoka River (Mamakowa & Starkel 1974) gives evidence that in the studied region with a park – type landscape were present clusters of *Pinus cembra* and *Larix*. Their presence in situ is confirmed by macroscopic remains. The upper part of the profile from Brzeźnica, linked by Mamakowa (1994) with the cold oscillation between the Interstadials Hengelo and Denekamp is characterized by an increase of the amount of *Betula nana* pollen and NAP, among which Gramineae and *Artemisia* are dominant. A similar pollen sequence is represented by the yet unpublished diagram from the locality Jasło-Bryły (Mamakowa & Wójcik 1987, Mamakowa 1994). Several ^{14}C dates from about 33 up to more than 45 ka BP (45 000 years), and Tl dates allow to conclude that this sequence comprises a much longer period of time (prob-

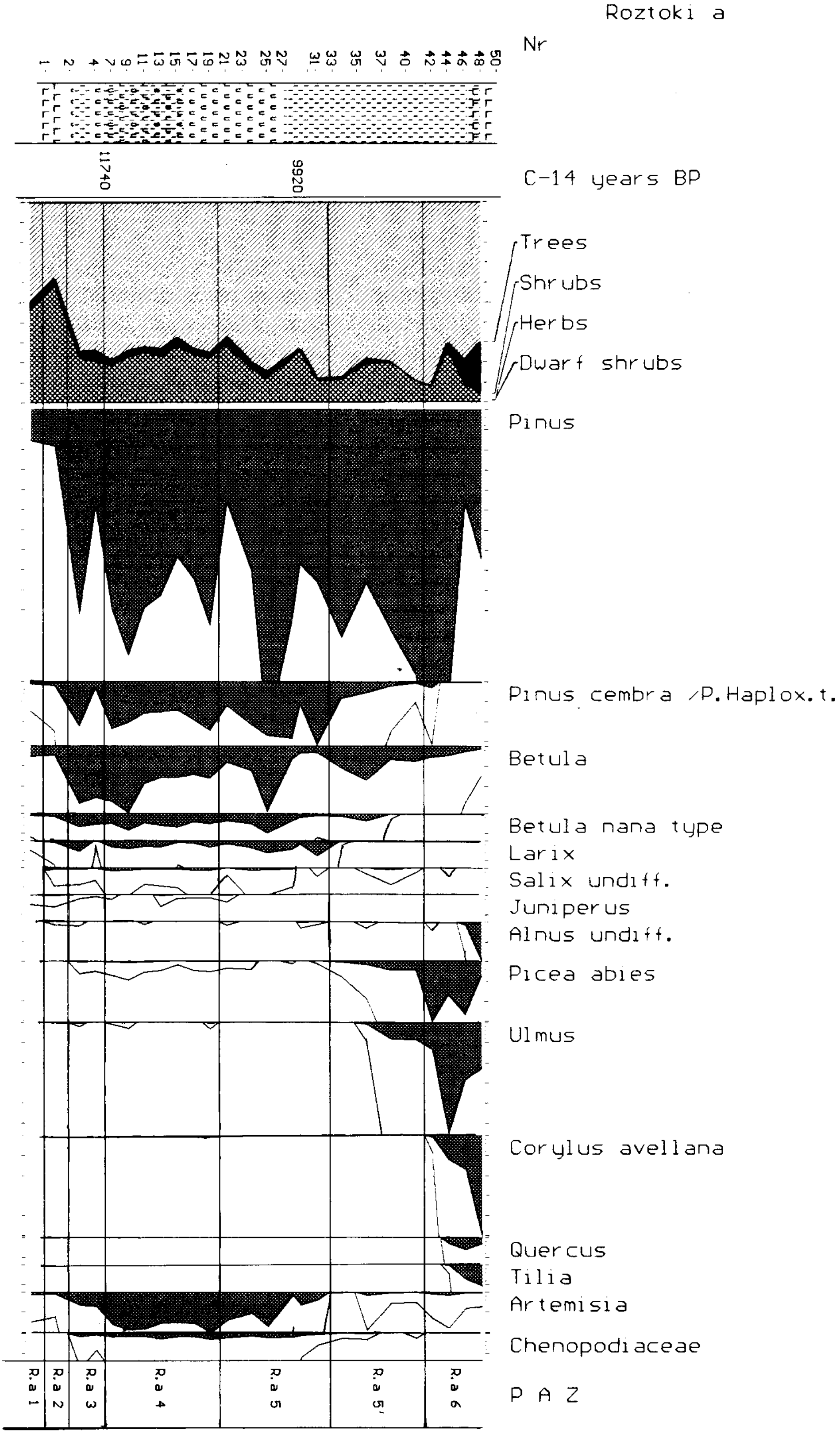

Fig. 4. Pollen concentration diagram from Roztoki a. Lithology see Fig. 3

ably from the beginning of the Pleniglacial up to the beginning of the Interstadial Denekamp – Mamakowa 1994). The character of the vegetation was similar to that of Brzeźnica.

From several localities in South Poland are known pollen diagrams which present an oscillation having a character of a cool interstadial that on the bases of ^{14}C data is treated as synchronous with the Interstadial Denekamp. It is characterized by high participation of *Pinus*, the presence of *P. cembra*, *Larix* and sporadic occurrence of pollen of other trees.

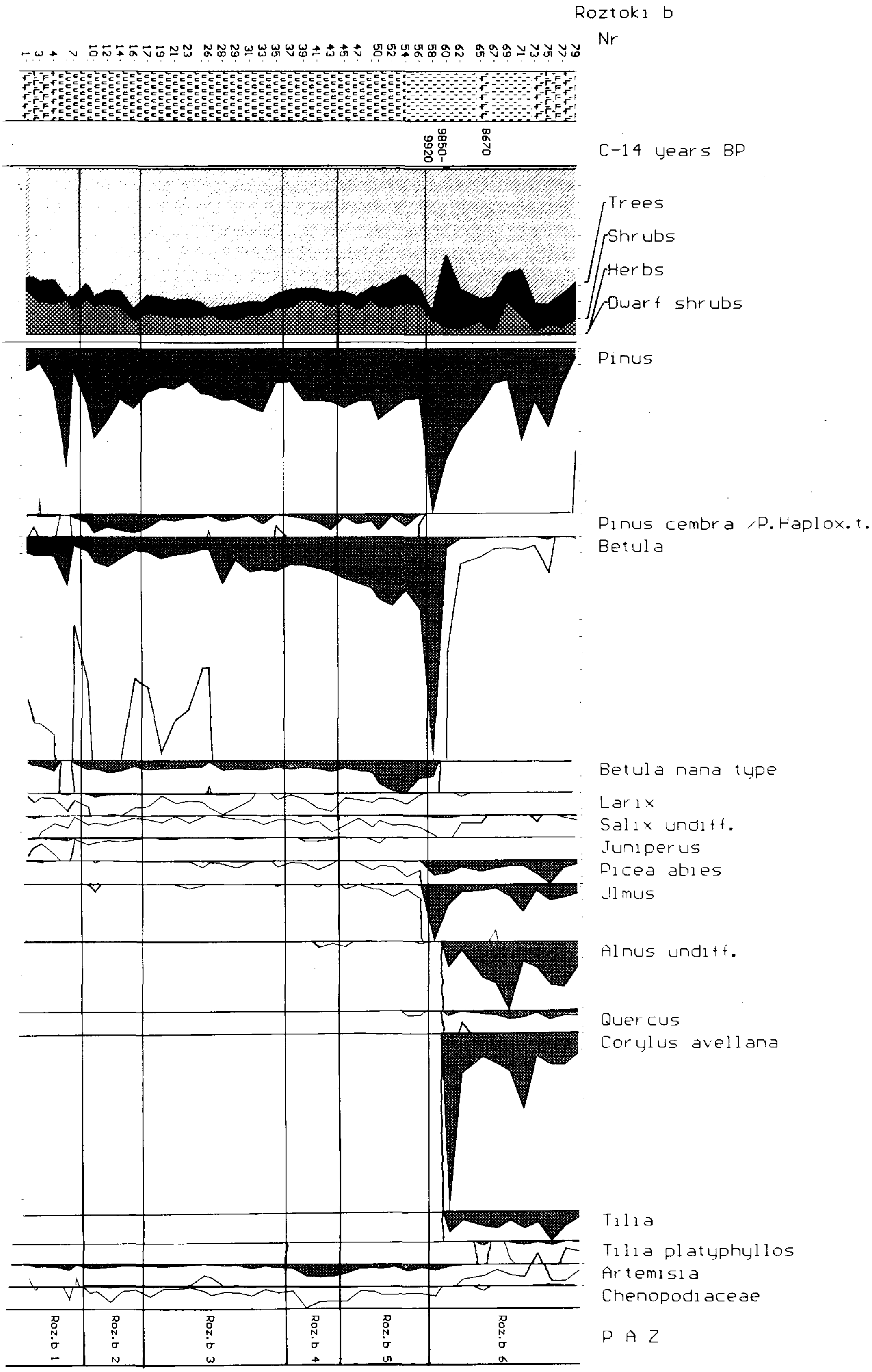

Fig. 5. Pollen concentration diagram from Roztoki b. Lithology see Fig. 3

With the younger Pleni-Vistulian (ca 29–13 ka BP) is linked the flora from Podgrodzie a dated 22 450 BP representing a forest tundra with *Pinus cembra* and *Larix* (Mamakowa & Starkel 1977) and from Smerek dated about 17 000 BP (Ralska-Jasiewiczowa 1980) if the ^{14}C dates in those profiles are not rejuvenate. At the time of that interstadial oscillation from Smerek *Pinus* and *Pinus cembra* are dominant in the pollen spectra, while *Larix,*

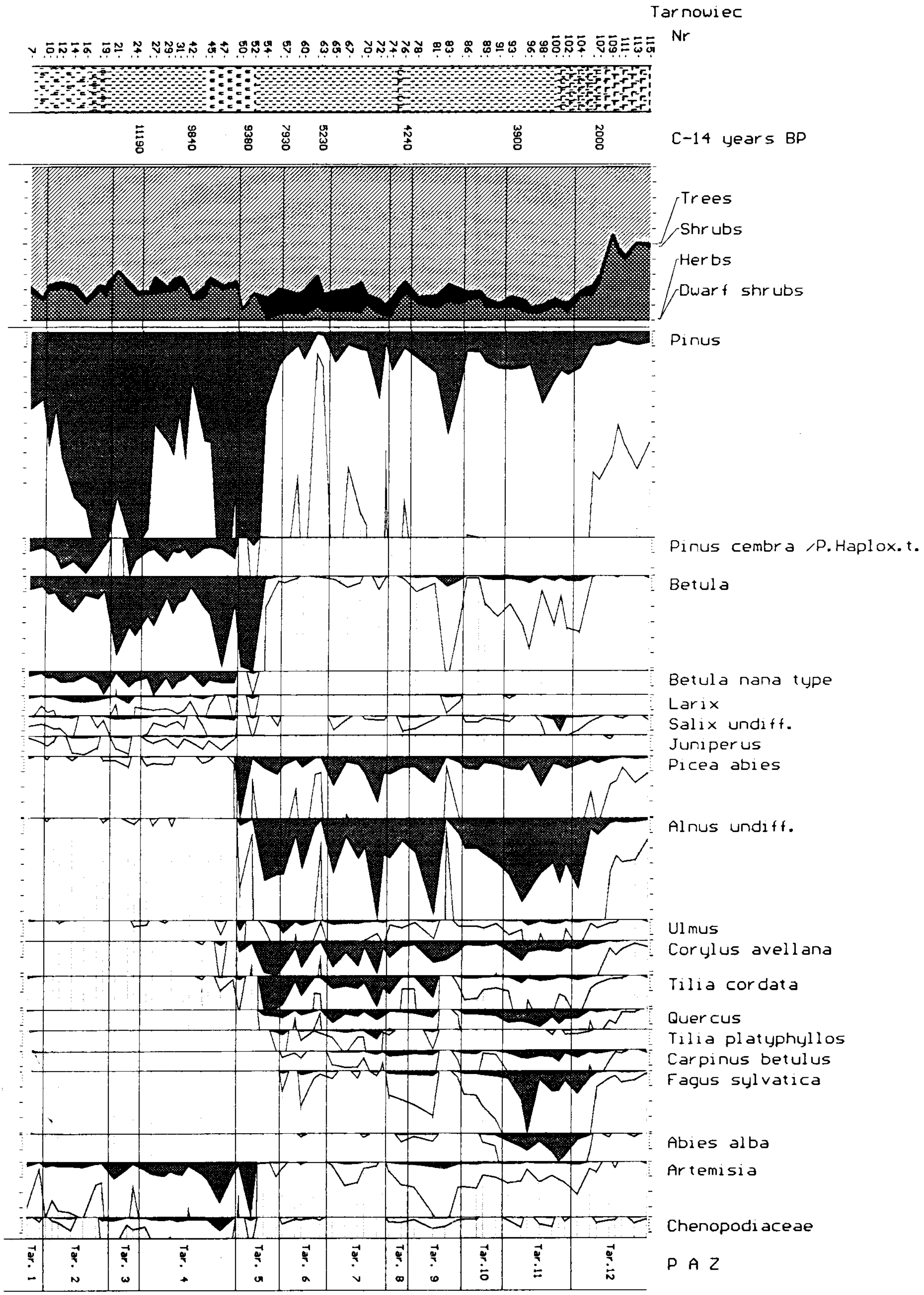

Fig. 6. Pollen concentration diagram from Tarnowiec. Lithology see Fig. 3

Betula, *Salix* and *Picea* pollen occur in high percentages. According to Mamakowa (1994) the palaeobotanical data of the periglacial zone demonstrate that boreal trees *Pinus cembra, Pinus, Larix, Betula* and probably also *Picea* may have survived the whole Pleni-Vistulian in the lower situations of the Carpathians and their forelands. And so the high percentage curve of *Picea* in the diagram from Jasło, in its part representing the Oldest

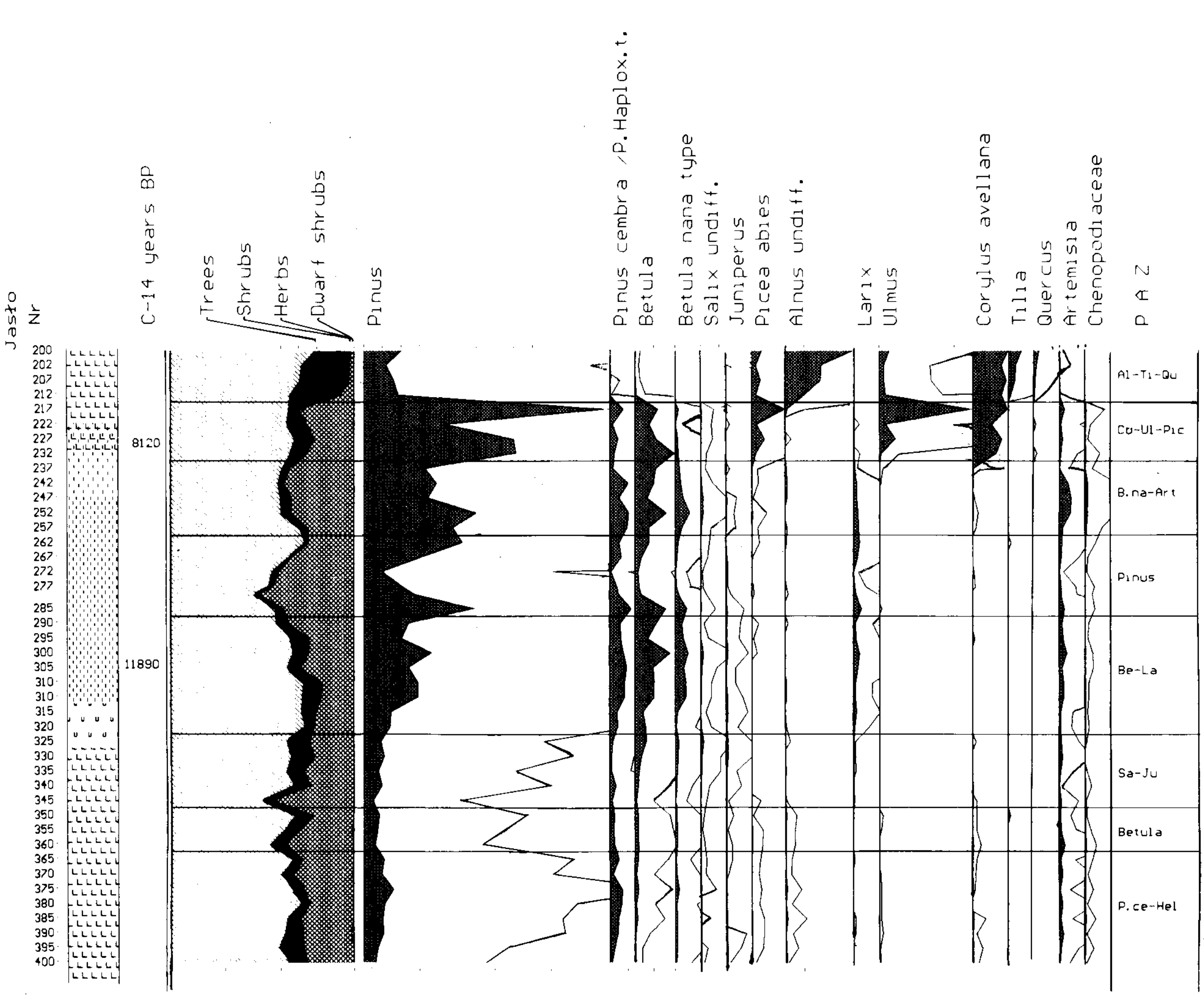

Fig. 7. Pollen concentration diagram from Jasło. Lithology see Fig. 3

Dryas and Bölling, might indicate the presence of this taxon in the Jasło-Sanok Depression, even though part of the pollen had come from contaminations. Almost from the beginning of this centuries the matter of the distribution on spruce in Europe, its ranges, disjunctions, morphological types of cones, and variability of pollen grains have constituted the subject of discussion carried out by many scientists (Szafer 1921, 1931, Wierdak 1927, Dyakowska 1964, Środoń 1967, 1990, Birks 1978, Ralska-Jasiewiczowa 1983, Krippel 1986, Schmidt-Vogt 1987, Rybníčková & Rybníček 1988). The pollen diagrams from Jasło and especially the analysis of macrofossils from the profile at Tarnowiec irrefutably deny the historical basis of the intra-Carpathian disjunction of spruce and so do the other works concerning the Jasło-Sanok Depression and Low Beskids (Więckowski & Szczepanek 1963, Koperowa 1970, Gerlach et al. 1972, Gil et al. 1974, Szczepanek 1987, Harmata 1987). The situation of its hitherto existing refuge areas in the time of the last glaciation should be subjected to a revision.

Similar though not so clear is the problem of the occurrence of *Alnus* in the Late Glacial parts of the diagrams from the Jasło-Sanok Depression. In the Carpathian pollen spectra of the Brörup Interstadial (Birkenmajer & Środoń 1960, Środoń 1968, Sobolewska et al. 1964) the presence of alder was found. In the Oldest Dryas and Bölling alder, similarly to spruce, has a fairly high percentage curve (up to 3%), which in the Older Dryas falls to 0.7% and in the Alleröd and Younger Dryas is discontinuous until the Boreal, when it begins rapidly to play a great role in all the profiles from the Jasło-Sanok Depression. Despite its occurrence in small proportions and the lack of a continuous curve an analysis of macrofossils showed the presence of wood of *Alnus* in the Younger Dryas part of the profile from Besko (Koperowa 1970) and in the Preboreal of the profile from Tarnowiec (Harmata 1987). Środoń (1965) gives some examples of a divergence between the low percentage of alder pollen and the simultaneous occurrence of macrofossils of genus in the deposits. In the profile from Besko the curve of *Alnus* reaches 5% in the Alleröd. The high percentages of *Alnus* pollen in the Oldest Dryas and Bölling sections of the diagram from Jasło are accompanied by mineral deposits and other contaminations, which do not raise doubt as to their being redeposited, although they occur in relatively lower percentages (*Corylus, Ulmus, Carpinus* and *Tilia*). It may well be therefore that part of the pollen grains which make up the percentage curve of *Alnus* are of autochthonous origin and that the alder was in a position to survive in the study area and to have its habitats throughout the Late Glacial. The remaining trees (*Pinus cembra, Pinus, Larix* and *Betula*) do not give rise to so much controversy regarding their contribution to the loose park landscape prevalent in the Oldest Dryas and in the following younger periods of the Late Glacial. The concentration diagram of selected taxa (Fig. 4) points to their considerably lower proportion than that shown by the percentage diagram. That is so because of the low concentration of pollen throughout the mineral part of the profile from Jasło, from its bottom upwards to the Younger Dryas inclusive. Although there are no datings for this part of the diagram, yet it can be stated, naturally very roughly, on the basis of the duration of particular periods given by Paus (1992) (he adopts the chronozones proposed by Mangerud et al. 1974 and modified by Welten 1982) and the thickness of their deposits, that in the Late Glacial section of the profile from Jasło the deposits accumulated more or less uniformly and, as has already been mentioned, being silty was responsible for this low concentration.

According to palaeobotanical investigations the climate of the pleniglacial of this part of the Carpathians may have been considerably milder than in north-western Europe, or in central Poland. Important for the differences in the plant composition and so for the type of the climate was probably among other things the distance from the border of glaciation, that is, the location of the sites further to the south. At that time vegetation in the Jasło-Sanok Depression enjoyed more favourable conditions, because it lay a long way away from the range of glaciers covering the highest parts of the Carpathians. On comparing the maps showing the maximum ranges of continental glaciations in Poland or in Europe (Mojski 1993, Lindner 1992), we may suppose that this part of the Carpathians lay outside their boundary. The sites discussed in this paper, situated in the Jasło-Sanok Depression, were protected from the north by the Ciężkowickie and Dynowskie ranges of the Carpathian Foot-hills. Both the sporomorphs suggesting a subarctic climate, such as *Selaginella, Hippophaë* and the continental climate indicator *Ephedra* and the pollen grains of the plants having greater thermal requirements, namely, *Filipendula, Populus*, *Betula, Myriophyllum* sp. and *Typha angustifolia* were identified from the Oldest Dryas section of the profile from Jasło. *Calluna* is also present in this part of the diagram. Kolstrup (1980) thinks that sporomorphs of *Calluna* and *Selaginella* evidence the mean July temperature higher than 7^0C, whereas Paus (1988 after Kolstrup 1979) claims that the appearance of *Filipendula* indicates that the mean July temperature was not lower than 8–9^0C. In his opinion (Paus 1992), the presence of the *Betula pubescens* shows that the mean July temperature was not lower than 10^0C and the occurrence of *Hippophaë* proves that it was not below 12^0C (Paus 1989 a, b). These minimum thermal requirements vary somewhat with particular geobotanical macroregions. For central Poland in the Bölling Wasylikowa (1964) gives the mean July temperature of at least 12^0C for *Betula pendula* and the very probably presence of *B. pendula* proves, in her opinion, a still higher temperature. It should be kept in mind that in a case of climatic conditions favourable to birches, *B. pendula* more readily tolerates water deficiency than does *B. pubescens* (Kornaś & Medwecka-Kornaś 1986). From among the plants having still greater climatic requirements, found in the profile from Jasło, *Typha angustifolia* and *Myriophyllum* (unfortunately not identified to species level) should be mentioned here.

A comparison of the Oldest Dryas part of the diagrams from the Jasło-Sanok Depression with the corresponding sections from other regions allows the statement that both in southern Great Poland (Tobolski 1966) and in Central Poland (Wasylikowa 1964) the culmination of *Hippophaë* characteristic of this period and the very high NAP percentages do not find a corroboration in the diagram from Jasło. Considerably closer, not only in the sense of distance and geographical situation, are the diagrams from Wolbrom (Latałowa & Nalepka 1987) and from the western part of the Sandomierz Basin (Nalepka unpubl.). Their spectra show that in the Oldest Dryas tundra communities with single tree specimens prevailed in southern Poland. Individual tree birches, *Pinus cembra*, and possibly *Pinus* could have grown at Wolbrom, whereas in the Sandomierz Basin in addition to the also singly growing *Larix, Pinus cembra*, and *Populus* the presence of single birches is confirmed by nutlets of *Betula* sect. *albae* determined from the Grobla profile (Nalepka unpubl.).

Bölling

This period of a short-lived warming is represented only in the profile from Jasło. The Jasło-Sanok Depression region was gradually occupied by tree birches. The areas of open communities with *Artemisia* had diminished. To what has been given before in the description of the zones it can only be added that the raised water level, indicated by an increase in the curves of algae and the appearance of oospores of the thermophilous *Chara contraria* and fruits of *Potamogeton filiformis*, points at a more humid climate.

Older Dryas

This period is recorded in 4 diagrams: from Jasło, Roztoki a and b, and Tarnowiec. All of them have very low pollen frequencies because of mineral deposits. In the Older Dryas the area of the Jasło-Sanok Depression presented a park landscape. The communities of dwarf shrub-tundra, with a high proportion of heliophilous plants, were common; the occurrence of trees was, however, irrefutably proved by macrofossils: nutlets of *Betula* and seeds of *Pinus* and *Picea* were identified from the Tarnowiec profile. The percentage curve of *Picea* does not exeed 0.5% in the pollen spectra in this period. The feature that both the percentage diagrams and the concentration diagrams from the Jasło-Sanok Depression and from the Wolbrom region (Silesio-Cracovian Upland – Latałowa & Nalepka 1987) have in common are the high curves of *Juniperus*. They evidence a cold continental climate in these regions, not very distant from each other. The diagrams from the Jasło area are characterized by very high curves of *Betula* in that period. The rising percentages of heliophillous plants indicate that the landscape was more open than in the Bölling. It may therefore be supposed that certain amount of in pollen grains of birch was due to long-distance transport and so they came from the warmer south. Studies on present-day pollen rains permits conclusion (Hjelmroos 1991) on the range of possibilities of long-distance transport of *Betula* pollen. In discussing the differentiation of climate conditions in the Low Beskids and their forefield, Obrębska-Starklowa (1983) states that analysing the wind conditions of the area under study, we are struck of prevailing winds with a meridional component and so corresponding with the direction of the transversal lowering formed by the Low Beskids in the arch of this part of the Carpathians. The easy accessibility of the Low Beskids to the advection of air masses from the south accounts in many cases for the occurrence of the föhn-type gravity winds. Here they bear the local names: Dukla or Rymanów winds. Air flows in over the Carpathians, especially over the Low Beskids, from the south northwards. All that suggests that a considerable part of the percentage contribution of *Betula* pollen and other components of pollen spectra may possibly have come by way long-distance transport from Slovakia or even from Hungary. Dealing with contemporary long-distance transport, Hjelmroos and Franzen (1994) found that in each stratigraphic layer there was a huge possibility of contamination with pollen from distant sources. And so it would be expedient if the reconstruction of vegetation on the basis of indicator pollen grains could be supported by macrofossils (unfortunately this is often not possible).

Nutlets of *Betula pubescens* were determined from the Older Dryas part of the profile from Tarnowiec using the size-and-shape-line method described by Jentys-Szaferowa (Białobrzeska & Truchanowiczówna 1960). Within the range of 3 macrofossil diagrams (Tarnowiec, Roztoki a and Jasło) nearly 150 graphs of the size and shape line were plotted. It did not seem purposeful to include them in this publication. Determinations were given only in cases of the curves which did not raise any doubt at all. Most of the remaining graphs are hard to classify, probably because of huge variation in the generative organs of birches. Recent studies show that only in a small number of specimens the fruit scales and nutlets are typical in respect of shape and that is why it is advisable to be very cautious while determining fossil materials of birches (Staszkiewicz et al. 1991).

The sections of the diagrams referred to the Older Dryas do not lack aquatic plants with high thermal requirements. As climate indicators they were widely discussed by Szafer (1946, 1954), Iversen (1954), Wasylikowa (1964) and Tobolski (1966). The aquatic plants are better at reflecting the regional climate than the terrestrial plants; owing to their greater rate of migration they take less time to respond to a rise in tempetature; on the other hand, however, the water environment brings about weaker reactions to thermal fluctuations. Pollen grains of *Typha angustifolia* were indentified from the profiles at Roztoki a and Jasło, while *T. latifolia* was determined from the sample bordering upon the Alleröd at Tarnowiec. Striking is the occurrence of fruits of *Nymphaea alba* and *Heleocharis mamillata*, numbered among the species with high climatic requirements and included among the South-Scandinavian-Atlantic species by Samuelsson (1934), in the Older Dryas deposits of the profile. In Scandinavia *Nymphaea alba* grows south of the July isotherm of 15^{0}C (Borówko-Dłużakowa & Janczyk-Kopikowa 1989), whereas *Typha latifolia* identified from the sample bordering upon the Alleröd requires a mean July temperature of 14–15^{0}C, acc. to Wasylikowa (1964), and 13–14^{0}C, acc. to Paus (1992). Bałaga (1990) also determined *Typha latifolia* from the Older Dryas part of the profile from Lake Łukcze (Łęczna-Włodawa Lakeland).

The climate of the Older Dryas has given rise to many controversies, starting from the diagrams in which it is not distinguished at all because of the lack of distinct criteria, through those in which it is treated as a late phase of the Bölling, up to the profiles undoubtedly reflecting a distinct cooling of the climate. A series of examples can be presented in support of the above-mentioned variants. Let us dwell somewhat on a few of them. Basing himself on the presence of *Typha latifolia, Nymphaea alba* and *Nyphar luteum* in profile from Belgium, Verbruggen (1979) denies the cooling of the climate in the Older Dryas. Kolstrup (1982) infers from the decreasing values of *Betula pubescens* and from the rate of accumulation of the deposits that the climate became drier. Studies on the isotope ^{18}0 in the deposits of some Swiss and French lakes (Eicher & Siegenthaler 1976, Eicher et al. 1981) did not discover any essential changes in temperature in those times. Perhaps, in connection with a rise in continentalization the distinction of the Older Dryas in the Polish profiles does not present so much difficulty. In Wasylikowa's (1964) opinion, the climate in central Poland about 12 000 BP was dry, sub-arctic, and cooler than at the decline of the Oldest Dryas, with the mean July temperature fluctuating between 10 and 12^{0}C. It may be supposed, with a high degree of probability, that in the Older Dryas it was warmer in the Jasło-Sanok Depression than in central Poland. That is proved, if not by anything else, by the above-mentioned aquatic plants, which indicate that the summer was warm.

Alleröd

This interstadial was distinguished in all the profiles of the Jasło-Sanok Depression, in mainly organogenic and partly mineral deposits with a considerably higher frequency than in the preceding periods. The samples from depths of 272 and 277 cm in the Jasło 4 profile constitute an exception, in which the frequencies illustrated by all the curves dropped rapidly without any perceptible changes in the layer of strongly compressed peat. The birch and pine phases often separated in the Alleröd are not very distinct in the diagrams from the Jasło-Sanok Depression, which is due to the fact that here the curve of *Betula* is very high throughout the Late Glacial. The older, birch phase of the Alleröd is more distinct in the concentration diagrams (Figs 4–7). An analysis of the macrofossils made it possible to determine *Betula pubescens* and *B. humilis* from that period in the profiles from Roztoki a and Jasło and in addition, *B. carpatica* from Tarnowiec. This analysis confirmed also the presence of pine and spruce (seeds) and larch (needles) in situ. The pollen spectra show an increase in the area occupied by these trees and *Pinus cembra*.

The older phase of the Alleröd is characterized by a much greater proportion of plants with higher thermic requirements than in its younger phase. Sporomorphs or fruits of at least two of the following taxa were determined from the older phase of the Alleröd in all the profiles studied from the Jasło-Sanok Depression: *Thelypteris palustris, Nymphaea alba, Typha latifolia, T. angustifolia, Myriophyllum spicatum* and *Schoenoplectus tabernaemontani*. Five taxa were identified from the Tarnowiec profile, whereas in the younger phase of the Alleröd fruits of *Schoenoplectus tabernaemontani* were identified only from one sample. What has been said above on the reflecting of the regional climate by the aquatic plants would find a confirmation here. The accumulation of indicator plants is connected with that of aquatic plants (with the exception of *Ranunculus flammula*-t.). However, the presence or lack of the remains of aquatic plants in the deposits originating from the river valleys may only partly indicate the sort of climate, because it depends to a great extent upon the appearance and disappearance of suitable habitats caused by the action of sometimes accidental factors. In the profile from Tarnowiec in the younger phase of the Alleröd the lacustrine deposit was replaced by peat; at Jasło this change occurred earlier (in the middle of the older phase of the Alleröd), but in the profiles from Roztoki the younger phase of the Alleröd is comprised in gyttja. Similarly in the western part of the Sandomierz Basin (Nalepka unpubl.) the proportion of sporomorphs and macrofossils of aquatic plants decreases in the pine phase, although gyttja is present in the profile till the end of the Alleröd. This might suggest that after the rapid warming that occurred at the beginning of the Alleröd and brought about an expansion of tree birch in vast areas, the climate began to become gradually cooler as early as the beginning of the younger phase of the Alleröd to go on cooling till the Younger Dryas. Taking into account the laws of the natural succession of plant communities, it seems that the replacing of the dominant birch by the dominance of pine might also be a symptom of that cooling, which, on the other hand, might be confirmed by the rise in the curve of *Betula nana* and the presence of *Juniperus* at Tarnowiec and Roztoki a. The drying of the climate occurring in the Alleröd eventually led to the overgrowing of the water bodies. Ralska-Jasiewiczowa (1980), however, claims that in the Bieszczady the older, birch phase of the Alleröd had a more severe climate than the younger, pine phase.

The reconstruction of the changes in the palaeoclimate based on a study of the isotopes of oxygen (Stuvier 1970) employed by Kolstrup and Burchardt (1982) for lacustrine deposits from Denmark showed that the older part of the Alleröd had the highest mean annual temperature, which subsequently became progressively lower. Likewise, the studies of the fossil Coleoptera in north-eastern England show that the maximum temperature occurred at the beginning of the Alleröd and were followed by a gradual cooling. These findings prompt us to consider whether the pine phase of the Alleröd should not be included in the Younger Dryas. According to Bohncke (1992), the ground freezing processes in north-western Europe intensified in it in connection with the continentalization of the climate.

Younger Dryas

The park lanscape was restored in the Jasło-Sanok Depression. The wooded area shrank here in favour of herbaceous vegetation, the curves of *Artemisia* and Chenopodiaceae being the most characteristic of the sections representing this period in all the diagrams. The pollen diagrams reveal that the composition of woody plants did not undergo a change in comparison with the Alleröd. An analysis of macrofossils constitutes a particularly valuable source of information about this type of Late Glacial communities developed as a result of rapid climatic changes (Birks 1992). And so we may state that in the Younger Dryas spruces, pines, larches and birches grew in the study area (apart from *Betula humilis, B. pubescens* was identified from Jasło and Roztoki a and *B. carpatica* from Tarnowiec).

Out of the palynologically studied sites in the Jasło-Sanok Depression, the profile at Roztoki b shows the thickest continuous layer of lacustrine gyttja. And so the samples for measuring the isotope .of oxygen, $^{18}0$, were taken from that layer (Różański et al. 1988). They are presented in Fig. 8. The plotted curve of $^{18}0$ would suggest that in this diagram the lower boundary of the Alleröd should be shifted downwards to the beginning of the measuring of $^{18}0$. This means a lowering by one sample, convening with the changes in the spectrum. One may even wonder why this boundary was not placed there at once, if the values of *Betula nana*-t, *Hippophaë* and *Juniperus* fall and those of *Filipendula* and

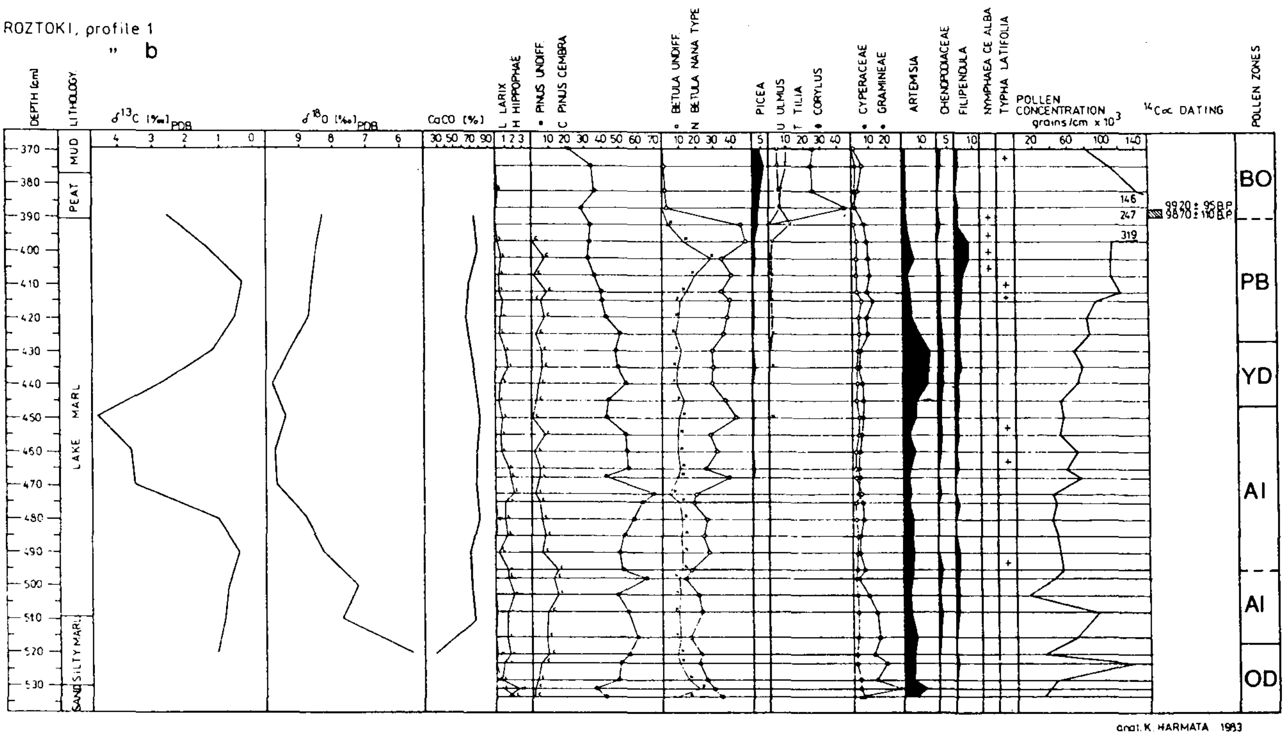

Fig. 8. Isotope and pollen diagram from Roztoki b fossil lake

Thalictrum rose. The fall of temperature in the Alleröd was considerable, 4^{0}C for Roztoki b. This is an argument for the inclusion of the younger phase of the Alleröd in the Younger Dryas. On the basis of the Netherlandish pollen diagrams and Coleoptera Bohncke (1992) pointed out a distinct fall in the mean July temperature about 10 850 BP (from 18^0 and 15^0 to 11^0 and 10^{0}C). In consequence, the mean annual temperature calculated by him dropped roughly to between –2^0 and –5^{0}C. Somewhat later, about 10 500 BP, the summer temperature rose. It may well be that the rise of the curve at Roztoki b occurring more or less in the middle of the Younger Dryas is correlated with that rise in the curve of temperature (about 10 500 BP). Analyses of the laminated deposits of Lake Gościąż near Włocławek (Ralska-Jasiewiczowa & Geel van 1993, Kuc et al. 1993) show that the record of the final 300–500 years of the Younger Dryas indicates a milder and warmer climate than in the main, older part, whereas the last century before the threshold of the Holocene shows as if a short rapid attack of the cold. According to the ascertainments updated by the correction of chronology, the duration of the Younger Dryas, calculated on the basis of the laminated deposits from Gościąż, was 1140 ± 40 yrs (Goslar 1993 b). The very transition to the Holocene, characterized by a rapid warming, covers a period of hardly 30–80 years. This warming is accompanied, apart from the changes in the nature of lamination and in the chemical composition of the deposits, by a distinctly evidenced lowering of the water-level in the lake (Ralska-Jasiewiczowa 1992 a, Wicik 1993). The calendar age of the Younger Dryas/Preboreal boundary was determined by many authors, who used various methods. Having applied the dendrochronological method on the combined oak and pine scales, Becker et al. (1991) assumed the age of the Younger Dryas/Preboreal boundary to be 10 970 cal. yrs BP. In his most recent statements Becker et al. (1991) has changed the age of this boundary to 11 045 cal. yrs BP (Becker oral comm., after Goslar 1993 a, b).

On the basis of the change in the rate of the ice-sheet retreat in Sweden, from rapid to slow, interpreted as the worsening of the climate between the Alleröd and the Younger Dryas, Strömberg (1994) determines the Younger Dryas/Preboreal date, suggesting that it may be somewhat older than 11 600 BP. As a result of the cooling of the climate in the Younger Dryas there was a slight accretion of the ice-sheet – about 10 m during 700 yrs, followed by its retreat at a rate of 50–75 m/yrs for the first 200 yrs. After these 900 yrs the rate increased to 100–200 m/yrs (or more), being characteristic of the next 1500 yrs of deglaciation in Sweden. Strömberg (1994) thinks that the change in the rate of the ice-sheet retreat from 50–75 m/yrs may reflect the improvement of the climate at the Younger Dryas/Preboreal transition. On the basis of the laminae this transition is dated about 10 740 BP with an error from +100 to –250 yrs. As a result of the most recent studies of the correlation between the cores of laminated deposits from Lake Gościąż and the radiocarbon dating made by the accelerator method, the age of the Younger Dryas/Preboreal transition was found to be 11 250 ± 50 cal. yrs BP, corresponding to the ^{14}C date 10 050 BP (Ralska-Jasiewiczowa oral comm.). The boundary was placed in the middle of the about 80-years-long period of a rapid increase in $^{18}0$.

These data agree with the results of the calibration measurements of the coral *Acropora palmata* published by Bard et al. (1990) and indicating that the difference existing between the radiocarbon age and the calibration age increases with the growing age of the samples from the Late Glacial. In that period the age determined by radiocarbon dating was considerably lower than the calendar age (Saarnisto 1988, Lotter 1991, Goslar 1993 b).

Preboreal – chronozone

The transition to the Holocene, for the most part expressed in the lacustrine deposits by a distinct stratigraphic boundary, which came into being owing to the transformation of the deposit caused by the warming of the climate and the lowering of the water-level and leading to the overgrowing of the water bodies, is also marked in the profiles studied from the Jasło-Sanok Depression. While analising the geological positions of this best-seen boundary, marked by the drastic change of the light, carbonate lacustrine deposits with a malacofauna to dark phytogenic deposits of peat, this boundary was found to run more or less synchronously in the diagrams from Besko (Koperowa 1970), Kępa (Gerlach et al. 1972, Gerlach 1990), Tarnowiec, Roztoki and Jasło (Wójcik 1987, Harmata 1987). The divergencies in the dates of peat samples: 9530 BP (Besko), 9380 BP (Tarnowiec), 9920 BP (Roztoki a) and 9880 BP (Roztoki b) can be accounted for by the fact that the sample from Tarnowiec was taken not from the bottom of the peat but somewhat higher. Moreover, it should be assumed that the shallowing of the water bodies and the overgrowing of their marginal parts preceded those of the central part, whereas in cases of small shallow water bodies the whole underwent a transformation into swamps or peat-bogs. On the basis of accurate borings in the Jasło Basin, Wójcik (1987) found that the deposits of lacustrine chalk in the region of Roztoki are far less spread than assumed by Klimaszewski (1948) and the location of the top of chalk at various depths suggests that the lake may have undergone a remarkable shallowing or even flowing of and part of the deposits was probably eroded. That may have been due to the deeper cut of the bed of the River Jasiołka and the lowering of ground watertable. It should be added that the abovementioned change of the deposits in the profiles from the Jasło Basin occurred in various stages of the Preboreal marked out on the basis of the pollen zones. At Roztoki a it takes place relatively most early, in the initial phase of the Preboreal, at Tarnowiec after the middle of this period and at Roztoki b almost towards its end. On the other hand, in the profile from Jasło the peat is replaced by clay in the older part of the Preboreal.

The behaviour of the curves in the pollen diagrams from Roztoki b and Tarnowiec unambiguously indicates a hiatuses in sedimentation. The Preboreal is most fully represented in the profile from Roztoki a. In the older phase of this period *Pinus, P. cembra, Betula,* and *Picea* prevailed in the forest communities. Their presence in situ is corroborated by seeds of spruce, needles of larch, nutlets (*Betula pubescens* and *B. humilis*) and wood pieces of birches, seeds and wood pieces of pine. Moreover, several wood pieces of *Alnus* were determined from 2 samples of this period from the profile at Tarnowiec. That is therefore a confirmation of the earlier presence of this tree in situ than is suggested by the isopollen maps (Ralska-Jasiewiczowa 1983). As has already been mentioned on the occasion of the discussion of the profile from Jasło, it may well be that alder survived in this area all through the Late Glacial. In the younger phase of the Preboreal forest spread in the Jasło-Sanok Depression and in it *Picea* and *Ulmus* began to play an increasingly important role. In response to their expansion *Pinus cembra* and *Larix* withdrew to higher parts of the Carpathians. Remnants of the Late Glacial shrub communities (*Betula nana*, *Juniperus*) were declining gradually. The curve of *Corylus* appeared in the diagrams from Jasło and Tarnowiec. The high curve of *Filipendula* cf. *ulmaria*, the species characteristic of this period in many regions of Central Europe and indicating the more humid climate, is present in all the diagrams for the profiles from the Jasło Basin. In the diagrams from Jasło, Tarnowiec and Roztoki a its curve is high, especially in the older phase of the Preboreal; it may indicate the development of meadow-type communities in openings in moist forest (Ralska-Jasiewiczowa 1980, Bałaga 1990). At the beginning of the Holocene the climate, characterized by fairly high but fluctuating temperatures and its considerable continentality, remained in the state of unbalance with unstable, developing vegetation, the composition of which underwent continual changes under the influence of some new migrating species and changing conditions of competition (Ralska-Jasiewiczowa 1992 a). A short cold swing perceptible in the middle part of the Preboreal in some diagrams (Latałowa 1982, Pawlikowski et al. 1982) is not recorded in the profiles from the Jasło-Sanok Depression. Its contradicted by the pollen curve of *Nymphaea alba* in the diagram from Roztoki b and numerous fruitlets of *Cladium mariscus* in the profile from Jasło. A fall in the curve of *Filipendula* in the younger phase of the Preboreal may evidence the overgrowing of open moist habitats by birch (Bałaga 1990), which increased its proportion in the profiles from the Jasło-Sanok Depression.

Boreal – chronozone

In the Boreal spruce and alder occupied low-lying places in the Jasło-Sanok Depression while elm-dominated forest expanded on the slopes of the elevations. Hazel thickets turned up in parts not covered by close forest.

From about 9000 BP boreal forests with dominant spruce, whose range extended further to the east than it does at present, occurred in Europe (Huntley 1988). A greater part of southern and western Europe was covered by mixed deciduous forests varying in composition.

Elms were the first to appear in the territory of Poland (10 000–9000 BP) and they were followed by hazel. In the Polish Lowland the most dynamic changes in the development of vegetation fell in between 9000 and 8000 (7500) BP. They resulted in the transformation of the communities of open pine-birch forest with luxuriant understorey and still loose competitive relations into close, shady, multi-species, deciduous or mixed woodlands. These communities developed under the conditions of increasing competition, tending to reach the state of balance with the biotope and climate, which differed considerably from the present climate, among other things, in greater insolation and different relations of rainfall and temperatures (Ralska-Jasiewiczowa 1992 a).

In the Vistulian in the unglaciated areas in southern Poland the expansion of broad-leaved species occurred somewhat earlier (from about 9500 to 9000 BP) than in the regions lying within the range of glaciation (Ralska-Jasiewiczowa 1992 a). These migrations were initiated by elm and hazel, which together with spruce and pine and later with other deciduous trees (ash, oak and lime) led to the formation of multispecies, mixed forests. In various regions their formation depended, among others, upon the ground configuration and edaphic conditions. Most of the thermophilous trees reached the territory of southern Poland from the south or southwest. In the Carpathians the expansion of *Ulmus* proceeded from the east westwards. In the Bieszczady Mts this tree appeared about 9300 BP (Ralska-Jasiewiczowa 1980) and arrived in the western Carpathians about 8800 BP (Obidowicz 1990). *Corylus* and *Tilia* came in through the lowering between the Eastern and Western Carpathians soon after 9000 BP and next they spread both to the east and to the west (Ralska-Jasiewiczowa et al. 1987). The composition of the plant communities which came to be about 8000 BP lasted in a comparatively stable form for the next about 3000 yrs.

In the profiles from the Jasło-Sanok Depression the different order of appearance of the thermophilous trees could be caused by various edaphic conditions or a hiatus in deposition. Consequently, in the diagram from the Jasło profile the curves of *Corylus* and *Ulmus* begin before those of *Tilia* and *Quercus*, at Roztoki a the curve of *Ulmus* appears considerably earlier than do the remaining deciduous species, whereas at Roztoki b and Tarnowiec the curves of the above-mentioned species rise rapidly almost simultaneously, but that may be so because of the hiatus in sedimentation.

The rapid spread of alder in Jasło-Sanok Depression was undoubtedly due to the appearance of suitable habitats arising as a result of the long-lasting influence of the mild climate, characterized by great annual fluctuations in humidity. The communities originating in these habitats, probably resembled modern alder woods (sets of the alliance Alnion glutinosae) developing on low peat-bogs and swampy soils; these are influenced by the high water table, rising, at least in some seasons of the year, to above the ground surface and flooding the local depressions (Medwecka-Kornaś 1972). Out of the species that make the forest complex of such communities, the following ones were determined: *Alnus glutinosa* (nutlets), *Fraxinus excelsior* (pollen), *Betula pubescens* (nutlets), *Picea abies* (pollen), *Viburnum opulus* (pollen), *Salix* sp. (wood, pollen), *Sambucus* cf. *nigra* (pollen), Filicales monoletae (conspicuous curve of spores) and perhaps *Humulus* (identified pollen of H*umulus-Cannabis*-t.). Cyperaceae (pollen), *Lycopus europaeus* (fruits), *Lemna* sp. (fruits), *Mentha aquatica* (fruits), *Alisma plantago-aquatica* (fruits) and perhaps *Typha latifolia* (pollen) may have grown in the water pools among tree clusters.

Atlantic - chronozone

At the Boreal/Atlantic boundary the organic accumulation in the valley of the River Jasiołka was interrupted by the ingression of clays and burying of the peat-bog with Holocene muds (Wójcik 1987). The dating of the buried peat about 10 cm below its top in the profile at Roztoki b, where the first distinct traces of mineral fraction were found, gave the date 8670 ± 50 BP, which refers the beginning of floods to the Boreal/Atlantic boundary. The peat-bog was not buried until the Atlantic, which can be connected with the increase in the frequency of floods recorded between 8700 and 8000 BP caused by the more humid climate. This humid period may correspond to the Venediger phase of the Alpine glacier invasion and, at the same time, it began the climatic optimum of the Holocene (Starkel 1977, Starkel & Gębica 1992).

A mid-Holocene hiatus in deposits appears in many European pollen diagrams; it was fairly broadly discussed by Königsson (1968) and Rybníček and Rybníčková (1987). It is not always possible to state univocally whether here we are concerned with a hiatus in deposits or a fall in the rate of sedimentation. Some of the diagrams from Poland are characterized by much reduced profile section corresponding to the Atlantic (Latałowa 1982, Szczepanek 1982). A comparison of the two diagrams from Roztoki (a and b) shows that the changes of vegetation recorded in the profile from Roztoki a from the beginning of the Holocene to the Boreal are more complete in the profile from Roztoki b. The pollen spectra from the hollows without outflow at Jasło and Tarnowiec appear similar; they show some hiatuses in the deposits assigned to the Boreal, which are particularly distinctly expressed in the concentration diagrams (Figs 4–7). These hiatuses are not linked to a distinct change in the deposit.

In the Tarnowiec profile, in which organic sedimentation was not interrupted as it was in the profiles from Roztoki a, b or Jasło, the Atlantic is characterized by a strong shortening like that at Besko, studied by Koperowa (1970). It might be expected that the humid and mild climate of the Atlantic would favour quick increase in deposits; however, the associations which occupied the lowest parts of the Jasło-Sanok Depression, resembling swampy alder woods described above, show a low rate of peat accumulation. Alder wood and other constituents of the peat undergo a quick decomposition and compression (Obidowicz oral comm.). Working on the peat-bogs of Polesie, Kulczyński (1940) wrote: "Forest associations on peatbogs, including that of alder woods, show a very small aptitude for peat-formation. Forest appears on a peat-bog in connection with the inhibition of its growth as a natural consequence of the stoppage or considerable retardation of the increase of the peat in thickness". The encroachment of forest on to the peat-bog leads to the lowering of the water-table owing, among other things, to evapo transpiration. In the periods when the surface of the peat-bog was above the water level, its upper part underwent weathering (Rybníček & Rybníčková 1987). If we keep in mind that this process was recurrent, it seems quite clear that the deposits in the Atlantic (when the pollen curve and macrofossils of *Alnus* evidence its local occurrence) are of so small thickness.

The lower river terraces in the Jasło-Sanok Depression were occupied by alder-ash and elm carrs. The Foothills and Beskids were covered by moist mixed forests with both lime species (a conspicuous, continuous curve of *Tilia platyphyllos* and *T. cordata* in the diagram from the Tarnowiec profile), oak, maple, pine and hazel. It is assumed that a remarkable climatic stability – equalized thermal air currents and humidity – is characteristic of the Atlantic. The mean annual temperature was 2.5^{0}C higher than it is at the present time (Starkel 1968).

In many pollen diagrams from central Europe changes caused by human activity in the plant cover appeared in the Atlantic. It is not always possible to distinguish explicitly the effects of man's activity from natural transformations. Controversies about the causes of the decrease in the elm values are still being held. The present-day opinions on this question have been summarized by Groenman – van Waateringe (1983), Göransson (1991), Andersen and Rasmussen (1993) and Peglar and Birks (1993). It appears that this decrease in the elm values might have been caused by several factors but undoubtedly human activity was one of them. This is indicated by the fact that in pollen diagrams there occur several decreases in elm curves which can be correlated with periods of land occupation (Hjelmroos – Ericsson 1981, Tobolski 1991, Ralska-Jasiewiczowa & Geel van 1992, Latałowa 1992, Miotk-Szpiganowicz 1992).

A closer study was given to the traces of man's activity in the diagram from Tarnowiec (Harmata in print). It is not the aim of the present paper to repeat those results, however, the history of vegetation cannot possibly be discussed without mentioning anthropogenic indicators. The earliest ones, roughly estimated in connection with the strong compression of deposits, come from before 6500–6000 BP. In spite of the presence of people (suggested by the determined pollen of *Plantago major*, *Carduus*-t., Ranunculaceae, Cichorioideae, Rubiaceae and the rise in the curves of Chenopodiaceae and Gramineae) the deforested area was probably still small which is indicated by still high percentage of AP (95%). Neverthless experimental studies of Groenman – van Waateringe (1993) showed that the high values of AP in the spectrum, seemingly reflecting close woodlands with scanty brushwood, unsuitable for grazing, in fact derived from intensively grazed woods or pastures neighbouring upon woods. On the other hand, despite the generally accepted opinions, the rise in the curve of *Plantago major / media* better documents an increase in grazing than does the analogous rise in the curve of *Plantago lanceolata* (Richard & Gery 1993). Although at Tarnowiec there are only single grains of *Plantago major* pollen, a species characteristic of heavily trodden places, yet they may point to the presence of settlement phase in this region. The next phase of colonization can be placed about 5200 BP. Archaeological studies confirmed such early – in comparison with the remaining Carpathian regions – human activities in the Jasło-Sanok Depression (Valde-Nowak 1988).

Subboreal – chronozone

An increase in the peat accumulation after 5000 BP in all the Carpathian regions investigated may evidence a rise in humidity. In Tarnowiec profile the Subboreal period is represented by organic deposits showing the increasing rate of sedimentation. In the older phase (to 4250 BP) the deposit does not differ visually from that occurring in the Atlantic. Judging from the pollen spectra and the results of macrofossil analyses, the vegetation growing on the peat-bog had not changed significantly. According to Kulczyński (1940), decisive of the peat formation is the plant association together with existing circumstances, the most important of which are hydrological processes. The alder peat swamp which at Tarnowiec might have been responsible for that very small thickness of deposits from the Atlantic, probably persisted as long as the seasonal water inundation ensured the sufficient supply of nutrients. In case of the lowering of water level the peat-bog becomes converted directly into a transitional forest bog. Then an admixture of pine and birch appears in the stand (Kulczyński 1940). At the beginning of the Subboreal in the diagram from Tarnowiec *Salix* appears after an interval and the curves of *Betula* and *Picea* ascend. *Alnus* still plays an important role on the bog, which is evidenced, apart from the pollen curve as high as before, by macrofossils. In the younger phase of the Subboreal birch gradually supplanted alder on the bog; the deposit changes its colour from black to brown, the sedimentation rate increases, as evidenced by the ^{14}C dates. About 4240 BP the peat accumulation is interrupted by a clay interbedding, which could be referred to the increase in floods and a larger delivery of clayey components from the slopes, probably caused by man's activity in the Neolithic.

Archaeological data indicate that in the Neolithic short, successive infiltrations of pastoral-agricultural populations took place in the Jasło-Sanok Depression. Their traces can be seen in the diagram from Tarnowiec (Harmata 1987, in print). Those tribes cleared and cultivated new areas every now and again to abandon them when the soil had become depleted. A natural succession, started with the settling of pioneer trees, followed, and so between the episodes of forest felling and soil cultivation there were fairly long intervals, during which the forest regenerated (Fig. 9). The short-lasting felling periods took 100–200 years.

The colonization of the Jasło Basin on a fairly large scale occurred about 4200–3800 BP (Corded Ware Culture). In the corresponding section of the diagram there is a great concentration of the indicators of man's activity. Pollen curves of *Ulmus*, *Quercus* and *Tilia cordata* fall and, somewhat later the curves of *Betula*, *Salix* and *Sambucus* – the pioneer species – and also of *Carpinus* and *Fagus* rise. A similar colonization took place all over Europe, which was possible owing to the existence of many large deforested areas arising in consequence of the clearing of the forest communities with lime and oak. The appearance of fir in the Jasło-Sanok Depression is recorded in the diagram from Tarnowiec somewhat below the sample dated 3930 ± 60 BP, and so later than in the Low Beskids (Szczepanek 1987) and earlier than in the Bieszczady (Ralska-Jasiewiczowa 1980, 1992 b). The rise in the proportion of *Abies* in natural forest communities was induced, apart from the climatic factors (increased humidity), by the disturbance of the balance in forest biocenoses caused by man's activity. The finding of a spore of the liverwort *Anthoceros* may be added to the more widely presented traces of man's activity at that time (Harmata in print). It was identified from a sample from about 4000 BP; it occurs on clayey soils deficient in calcium carbonate, indicating the development of agriculture, and appears in stubble fields after harvest (Geel van et al. 1981).

The essential transformation of vegetation in the Polish Carpathians happened between about 4900 and 3600 BP. At that time a fall occurred in the curves of *Ulmus* and *Corylus* in all the diagram analysed except for the curve of *Corylus* in Podhale (Obidowicz 1990). It was immediately followed by the expansion of *Carpinus* and *Fagus* proceeding from the east, while *Abies* spread from the west (Ralska-Jasiewiczowa et al. 1987). The formation of the recent altitudinal belts in the Polish Carpathians took place between 4300 and 3300 BP, in the Bieszczady Mts about 4300 BP, although the drop in the value of *Tilia* and the expansion of *Abies* happened here later, in Podhale 3600 BP and in the Low Beskids about 3300 BP (Ralska-Jasiewiczowa et al. 1992). In the Jasło-Sanok Depression the forest communities resembling the contemporary ones became established about 4000 BP (now the area is occupied mainly by anthropogenic communities). At that time owing to the climate, but not without man's intervention, the communities with *Fagus* and *Carpinus*, and somewhat later with *Abies*, took up the areas of the former thermophilous forest.

Subatlantic – chronozone

Since the decline of Subboreal the amount of mineral fraction in the peat in the profile from Tarnowiec had been increasing, which may be connected with frequent floods and the increased delivery of clay from the slopes to the resevoir. About 2000 BP the development of the swamp-peat was interrupted and the swamp-peat had been buried with clays forming together with organic matter a layer 0.25 m thick (Wójcik 1987). That was probably caused by the development of settlements in this region and the deforestation of the area. The summary curve of herbaceous plants reached nearly 55%. Pollen analysis was successfully carried on till levels deposited at ca 1500–1000 BP (with a low frequency in the last section of the profile from Tarnowiec). The devastation of forest communities, lasting from the beginning of the Subatlantic affected also the communities with alder, which had played a very important role in the Jasło Basin. It caused a spread of swamp communities (high curve of Cyperaceae, nutlets of *Carex rostrata*, fruits of *Ranunculus repens*, *Lycopus europaeus*, *Comarum palustre* and *Valeriana*) and wet meadows with *Lychnis flos-cuculi* (pollen grains, fruits). The effects of

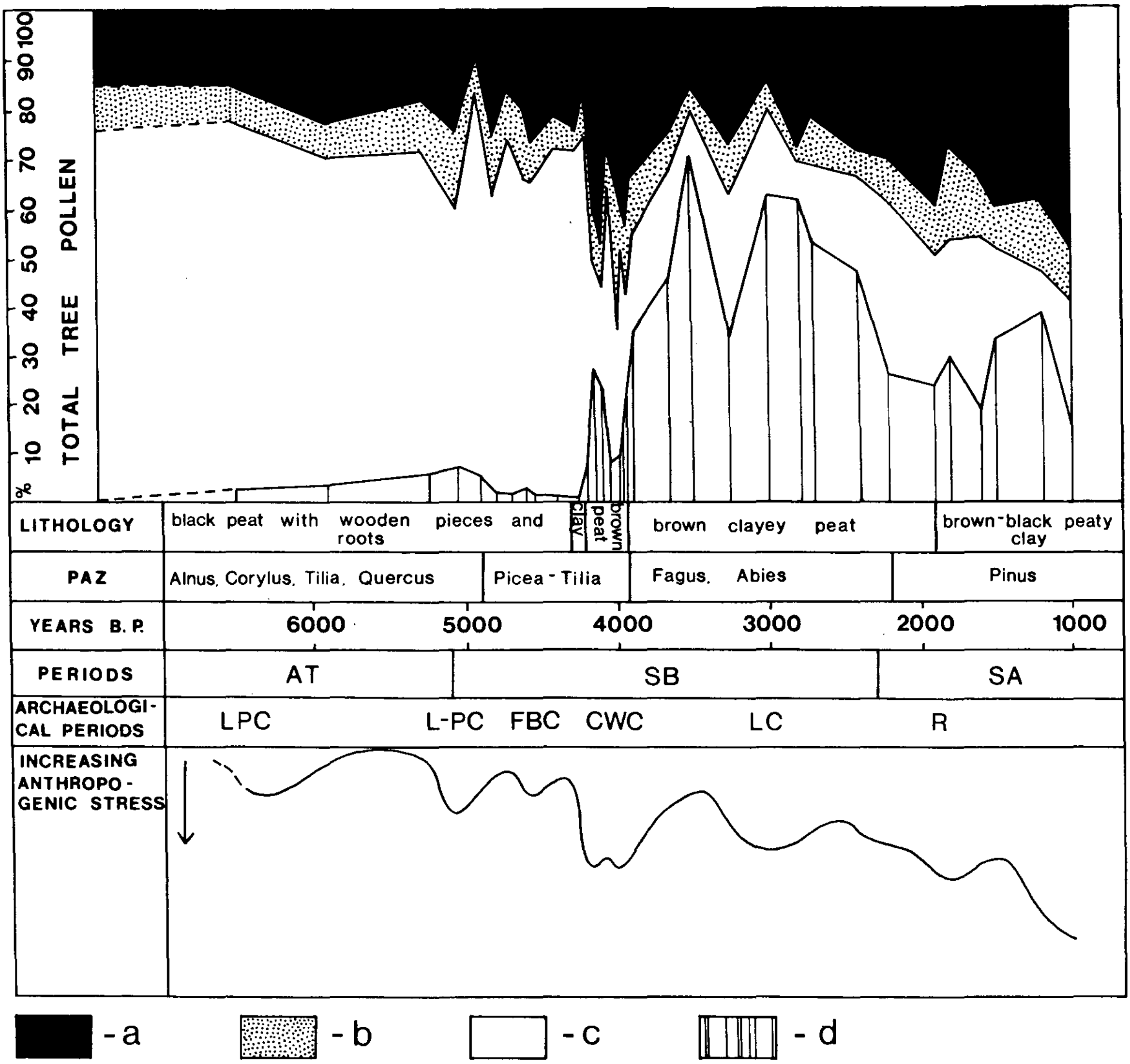

Fig. 9. Survey of the increasing anthropogenic stress. Cumulative tree pollen diagram, calculation sum recalculated (Andersen 1970, 1973) a – fen wood Σ *Alnus*: 4, *Salix*; b – early succesional Σ *Corylus*: 4, *Betula*: 4, *Sambucus*; c – late succesional Σ *Ulmus*: 2, *Tilia* × 2, *Quercus*: 4, *Fraxinus* × 2, *Acer* × 2; d – Σ *Fagus*, *Carpinus*: 3, *Abies*; LPC – Linear Pottery Culture, L-PC – Langyel – Polgar Cyrcle, FBC – Funnel Beaker Culture, CWC – Corded Ware Culture, LC – Lusatian Culture, R – Roman Period

human activity can therefore be seen them selves in pollen diagrams not only by the appearance of new species of synanthropic plants but also by the formation of habitats favouring the development of plants that had only scarcely occurred before. In the Pannonian regions (South Slovakia, South Moravia and Central Bohemia) pasturing favoured the dissemination of xerothermic plants and their communities. In moist habitats man‘s activity contributed to the formation of new anthropogenic communities, e.g. wet meadows or even fishponds (Rybníček & Rybníčková 1992). In the drier areas of the Jasło-Sanok Depression cereals were grown on a fairly large scale by then (*Secale cereale* and *Hordeum*-t).

NUMERICAL ANALYSES OF THE RESULTS OF PALYNOLOGICAL STUDIES OF THE JASŁO BASIN DEPOSITS

The pollen zones distinguished by the traditional method on the basis of the percentage diagrams from Roztoki a, b, Tarnowiec and Jasło (Fig. 3 and diagrams in Harmata 1987), were juxtaposed with the numerical divisions carried out later, which were expected to point to the local pollen zones objectively distinguished. That is the aim of the three procedures put together in the ZONATION programme (Birks & Gordon 1985), whereas the correspondence analysis (CA) also applied, makes it possible to draw more general conclusions. The numerical methods indicate certain divisions as more probable than the others. All the computer analyses were carried out by Dr A. Walanus, the author of the POLPAL programme (Walanus in print), aimed to zonate the pollen diagrams for the IGCP 158 B Project. The brief description of the procedures employed and their interpretation follow a paper by Mahonienko and Walanus (1991).

CONSLINK

This procedure is based on the numerical measure of similarity between samples. The chord distance measure applied, based on all the taxa included in the analysis, adds to the importance of the taxa with a small concentration. The action of the procedure consists in the successive linking of neighbouring samples or groups of samples linked together before. Groups of samples are coupled on the principle of a single link; two samples most resembling each other from the two groups are taken into account. Only neighbourring zones may be linked (this is a constraint of the method). After l-1 steps, where l is the number of the samples from a profile, all the samples are linked and therefore there is no division. The simplest method to obtain pollen zones or groups of similar samples consists in the discarding of the combinations nearest to the trunk.

SPLITSQ and SPLITINF

As far as the above-discussed procedure depends on the combination of samples into groups until one group covering the whole profile has been obtained, the function of SPLIT-s consists in successive dividing the profile into smaller sections. Division might be continued till the number of zones equals the number of samples; it is, however, stopped after the execution of one-quarter of divisions.

The profile has certain mean relative contents of particular taxa and also a certain dispersion connected with the deviations from the mean. The SPLITSQ and SPLITINF procedures differ in the method of the calculation of dispersion. The results of analyses from the foregoing three procedures comprised in the ZONATION programme, should be complementary. If there are boundaries indicated by all the three procedures (in a significant manner), they are in all probability valid boundaries. Nevertheless, not each actual boundary must be corroborated by each of the procedure.

Correspondence analysis (CA)

In this analysis we receive several main components (new taxa created by the summing up of correlated taxa) of decreasing significance. Its fundamental characteristic is the fact that taxa and samples appear in the final result in the same scale, they are directly comparable with each other. The CA result is most frequently given as an X-Y graph in which the first component is represented on the horizontal axis (X) and the second on the vertical axis (Y). The broken line of the graph represents the profile and the taxa are marked with separate dots. The palaeoecological significance lies in the positions of samples in relation to each other, taxa in relation to each other and samples in relation to taxa.

Results of the ZONATION programme

The column "Numerical analysis" presenting the effects of the application of the three numerical procedures for the percentage diagram and for the concentration curves was placed between the graph of local pollen zones and that of chronozones in all the diagrams (Harmata 1987). The boundaries between pollen zones determined in a traditional, intuitive manner most frequently coincide with the boundaries based on the CONSLINK procedure. In the diagram from Jasło this conformity is almost entire. The Late Glacial parts of the diagrams from Roztoki a, b and Tarnowiec are characterized by a great "affinity" of particular sequential blocks, which is evidenced by the numerical measures of similarity of the combined dendrogram units (blocks are combined on low levels). A comparison of the results of SPLITSQ and SPLITINF operations with the traditional boundaries appeared much lower similarity, especially in the Late Glacial parts of the diagrams (they are given only for the diagrams from Roztoki a, b and Tarnowiec – Harmata 1987).

RESULTS OF CORRESPONDENCE ANALYSIS

The correspondence analysis (Figs 10 and 11) shows the relationships between particular samples of the 4 profiles covering a period from the Older Dryas to the Boreal the oldest samples from Jasło and the upper part of the

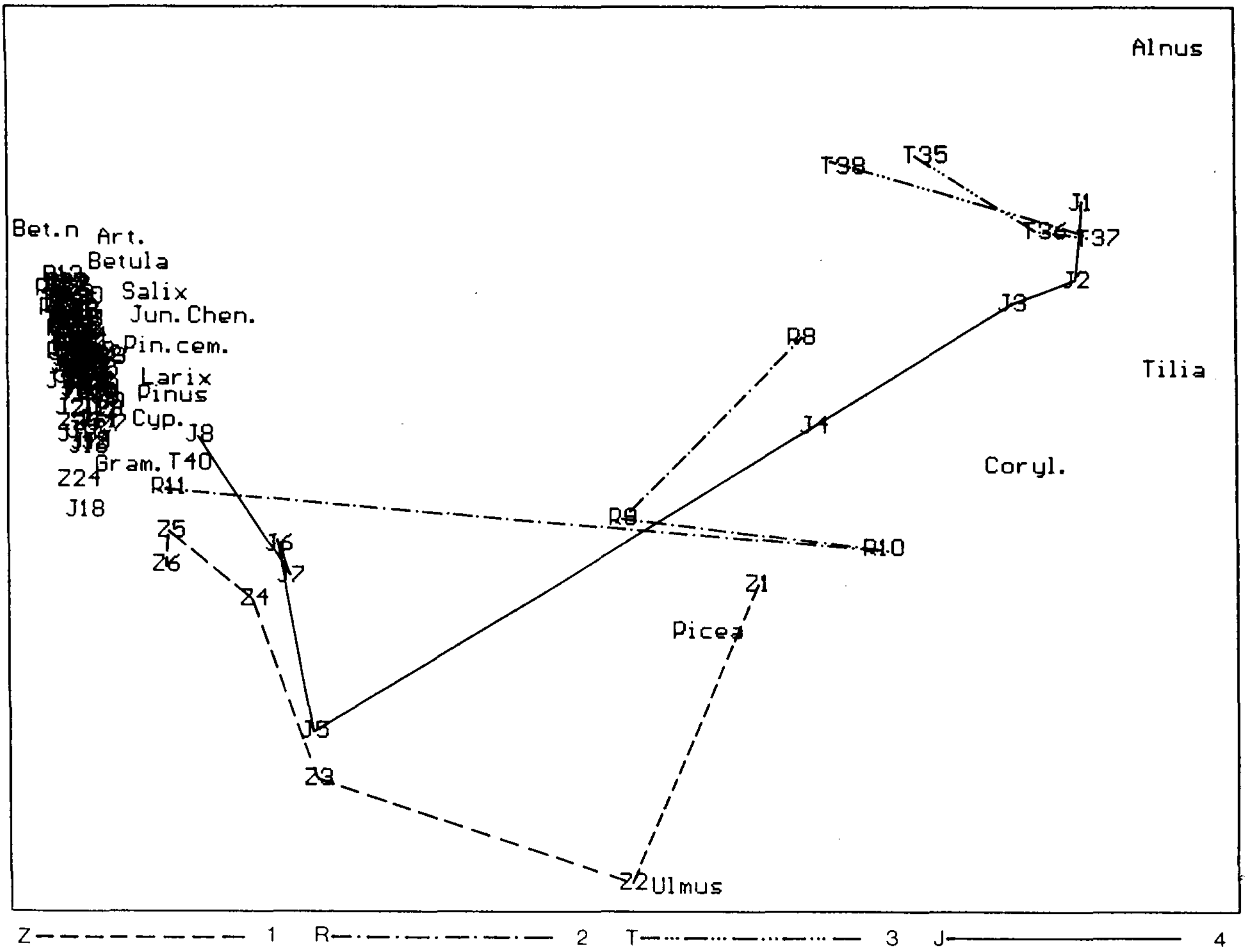

Fig. 10. Correspondence analysis. 1 – Roztoki a, 2 – Roztoki b, 3 – Tarnowiec, 4 – Jasło

profile from Tarnowiec excluded. Fig. 10 shows that the J1-J8 samples from Jasło, Z1-Z6 from Roztoki a, R8-R11 from Roztoki b and T35-T40 from Tarnowiec are distinctly isolated. All those samples represent the pollen zones corresponding to the decline of the Preboreal and to the Boreal. Hence it may be inferred that the course of succession at the beginning of the Holocene was so different from the Late Glacial vegetation that these samples are quite incongruous with the remaining ones. That is so because of the taxa holding the extreme positions oriented in this part of the graph of correspondence analysis. These are the furthest isolated: *Alnus* and *Tilia,* later *Corylus, Picea* and *Ulmus*. The opposite position in Fig. 10 is held by a mass of illegible overlapping Late Glacial samples with the following taxa characteristic of this period in the Jasło-Sanok Depression: *Betula, B. nana, Pinus, P. cembra, Larix, Juniperus, Salix, Artemisia,* Chenopodiaceae, Cyperaceae and Gramineae. It is this very part of the graph that was again subjected to a correspondence analysis, now with the exception of the distinctly isolated right side of Fig. 10, Fig. 11 illustrates the results of that operation. It can be seen from it that the profiles from Jasło and Roztoki b show a certain consistent distinctness. The profiles from Roztoki a and Tarnowiec more resemble each other except for the decidedly isolated bottom samples from Roztoki a, which correspond to the pollen zone included in the Older Dryas. However, it may be stated in general that the Late Glacial and early Holocene parts of the 4 diagrams have similar compositions of sporomorphs and despite some inevitable local differences between the profiles they show a resemblance. It has been pointed out statistically that the features characterizing the profiles of the Jasło-Sanok Depression are common to all the diagrams analysed.

Moreover, the correspondence analysis shows relationships (correlations and anti-correlations) between the taxa, permitting

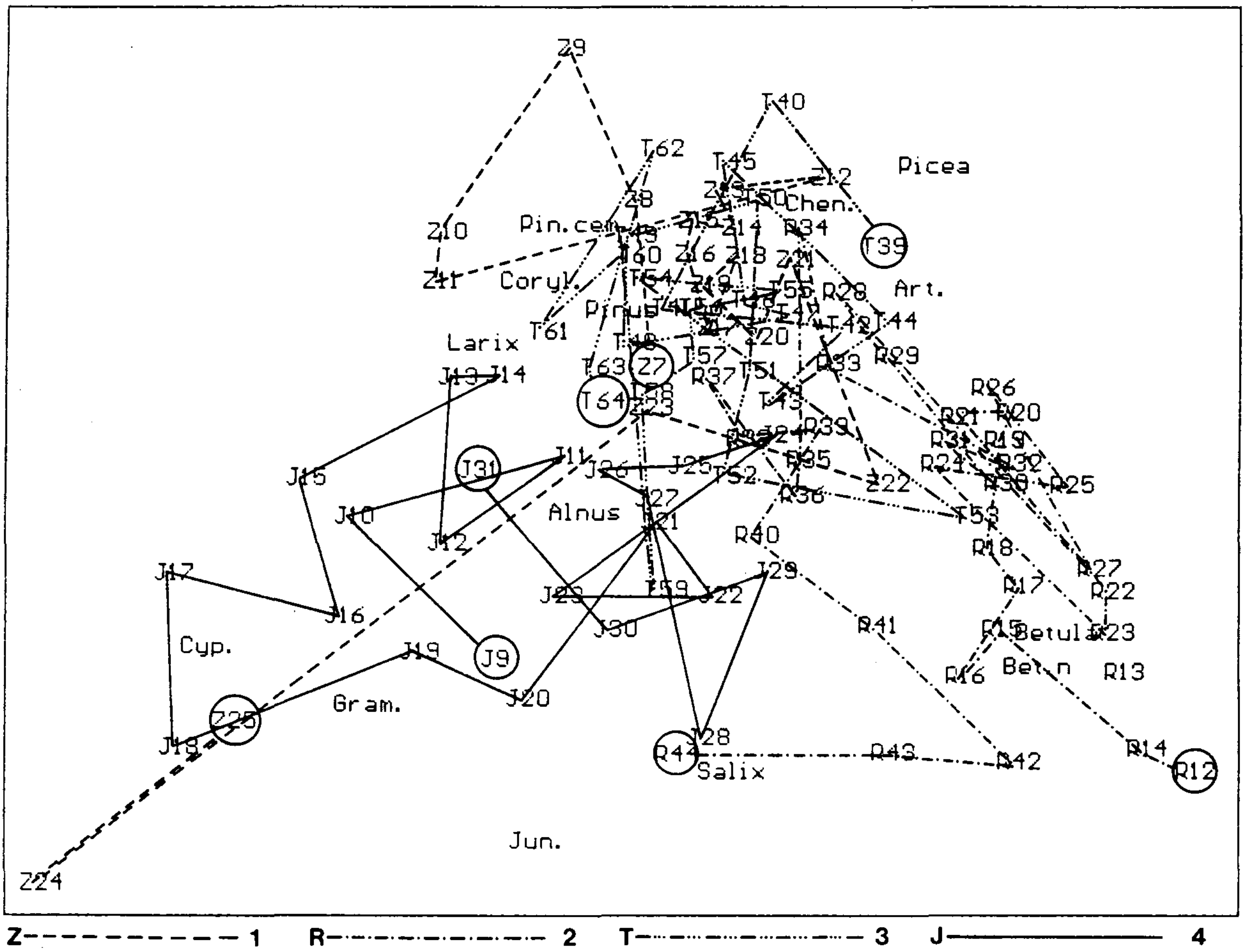

Fig. 11. Correspondence analysis. 1 – Roztoki a, 2 – Roztoki b, 3 – Tarnowiec, 4 – Jasło

their arrangement into "communities". The taxa which make up the Late Glacial communities are distinctly isolated from those contributing to the formation of communities at the beginning of the Holocene. Numerical technique may help palynologists to answer the crucial question whether the plant communities in the past were similar to the present ones (Janssen & Birks 1994).

SUMMARY

An attempt was made to reconstruct vegetational history from the Oldest Dryas to the Subatlantic on the basis of 4 profiles from the Jasło-Sanok Depression. The results of analyses of 2 profiles from Roztoki a, b and one from Tarnowiec were published separately (Harmata 1987, 1989). The present paper gives a discussion the changes in the vegetation based on the profile from Jasło. The succession of local and regional vegetation, changes in the climate and changes of water level in the studied basins were investigated using the palynological and plant macrofossil analyses. The correlation of the anthropogenic changes of vegetation reconstructed on the basis of palaeobotanical studies with the development of settlement of the area described by archaeologists is presented in another paper (Harmata in print). The application of numerical methods aimed at the presentation of the distinction of the local pollen zones. The correspondence analysis aimed at the statistical demonstration that the features characterizing the profiles of the Jasło-Sanok Depression are common to all the diagrams under study.

The following characteristic features can be listed for the profiles analysed:

1. Owing to the wide depression of the area and the higher humidity of the climate in the Jasło-Sanok Depression the conditions prevailing in the Late Glacial supported the survival of some coniferous trees forming loose forest

communities. The low sum of NAP and shrub pollen indicates that tundra did not dominate here.

2. The palynological and macrofossil analyses evidence that the region under discussion could be a refugium of spruce, enabling it to survive here, possible even from the Pliocene. The region is situated rather far from the ranges of glaciations, and in front of the Dukla Pass, on the way warm air masses coming from the south.

3. The Late Glacial parts of the diagrams are conspicuous by very high pecentages of tree birch, whereas the Holocene spectra are characterized by the low percentage curves of birch. If the first ones were induced by the above-mentioned mild climatic conditions and perhaps by long-distance transport, then the low proportion of birch from the Boreal chronozone parts of the diagrams would evidence the limited possibilities for heliophilous species in such dense deciduous forests as appeared from this period. Only during to the anthropogenic phases of deforestation, birch could become more distinct in the pollen spectra for some time. Furthermore, if one resorted to the analyses of recent pollen rain from particular years compared with the climatic data (Hicks 1994), they would show that the pollination of the early flowering birch can be inhibited by the recurring waves of frost. This may result in the low proportion of *Betula* pollen in recent pollen spectra, in spite of the presence of birch trees around the sampling area. These explanations are however at variance with the high percentage values of birch pollen in the Late Glacial and it is hard to assume that these values were derived chiefly from long-distance transport.

4. The rapid spread of alder in Jasło-Sanok Depression, as it appears, determined by the occurrence of favourable habitats, appeared to be responsible for the remarkable shortening of the part of the profile corresponding to the Atlantic and even for the hiatuses in its deposits.

5. The particularly favourite climatic and edaphic conditions caused an early and intense – in comparison with the other regions of the Carpathians – penetration of the area by man. The stages of man‘s economic activity, distinguished in the Tarnowiec pollen diagram on the basis of the pollen indicators and studies on the middle and late Holocene changes in the forest composition correspond, with the settlement phases found in the Jasło-Sanok Depression by archaeologists.

6. The similarity of the Late Glacial and early Holocene parts of the diagrams from Roztoki a, b, Jasło and Tarnowiec and the synchronization of their pollen zones can indicate that the profiles record not only the local changes of vegetation but also the regional ones.

7. Finally, the significance of the analysis of macrofossils should be emphasized. Thanks to it, among others, the presence of spruce in situ in the Late Glacial was confirmed despite its low proportion in the pollen spectra. Significant is also at the beginning of the Holocene the presence of nutlets of *Cladium mariscus*, the indicator plant for its climatic requirements. Characteristic pollen grains of this plant were not observed in the pollen diagram.

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