Acta Palaeobot. 41(2): 341–353, 2001

# Late Holocene vegetation history in the Dukla Pass region (Low Beskidy, Carpathians) based on pollen and macrofossil analyses

KAZIMIERZ SZCZEPANEK

Department of Palaeobotany, Institute of Botany, Jagiellonian University, Lubicz 46, 31-512 Kraków, Poland

Received 23 March 2001; accepted for publication 22 August 2001

ABSTRACT. Organic deposits from the Dukla Pass region were studied by means of pollen and macrofossil analyses. The deposits under investigation derived from the landslide depression (495 m a.s.l.) on the north-western slope of Mt Cergowa (716 m a.s.l.) near Dukla (Low Beskidy, Carpathians). The radiocarbon age of the deposits (11 samples) is expressed as $^{14}C$ conventional years BP. The results of pollen and macrofossil analyses and datings with $^{14}C$ made it possible to reconstruct changes in the local and regional vegetation from about 4820±70 $^{14}C$ conv. years BP to the present time. Six local zones in each pollen and macrofossil diagram have been distinguished which illustrate primarily the formation of a mixed deciduous forest community with dominant hornbeam in the foothill zone, and a higher montane forest zone with dominant beech and fir. From the very beginning of sediment deposition the vegetation changes were accompanied by an increase in human activity of different cultures from the middle Neolithic.

KEY WORDS: pollen, macrofossils, vegetation changes, Holocene, Polish Carpathians

## INTRODUCTION

Interest in the history of the Holocene vegetation of the Low Beskidy region is associated with geobotanical problems in the area and the role of this mountain range (the lowest part of the Carpathian arch between the West and East Carpathians, Fig. 1) in determining the distribution of late Glacial vegetation and different primaeval human cultures in the area (Żaki 1955, 1966, Tacik et al. 1957, Pawłowski 1972, Święs 1982, Ralska-Jasiewiczowa 1983, Machnik 1989, 1992).

The results of pollen and macrofossil analyses refer to organic deposits derived from the landslide depression (495 m a.s.l.) below the main ridge of Mt Cergowa (49°32′ N; 21°42′ E) situated in the Dukla Mts, the lowest central part of the Low Beskidy (Fig. 2). The Dukla Mts fall away towards the north creating steep slopes overlooking the much lower central part of the Jasło-Sanok Depression which runs from the east to the west (Klimaszewski 1935, 1946, Starkel 1972a, b).

Earlier, in a joint publication (Więckowski & Szczepanek 1963) on assimilatory pigments

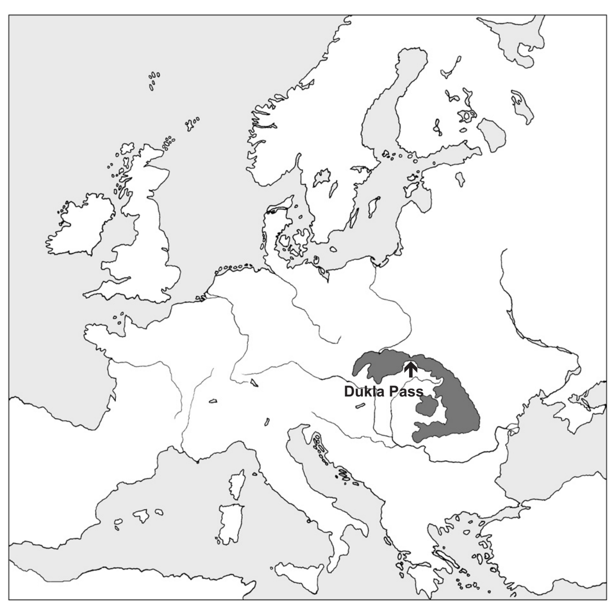


**Fig. 1**. The position of the Dukla Pass in the Carpathian Mts

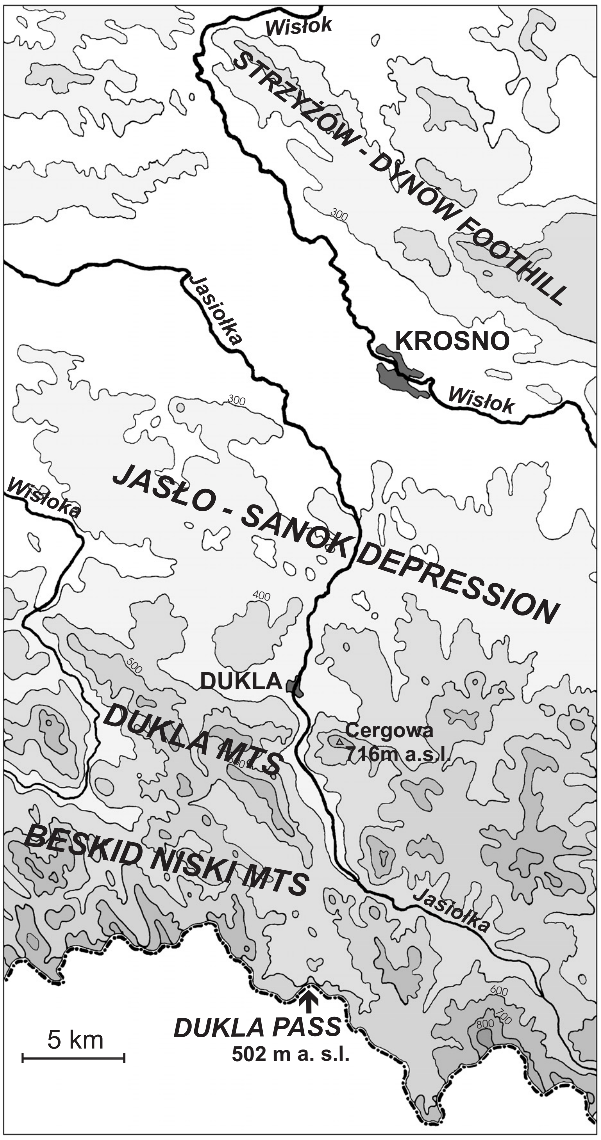


**Fig. 2**. The geomorphology of the Dukla Pass region

from subfossil fir needles taken from these sediments, a preliminary pollen diagram based on 23 samples and a list of macrofossils based on 12 sections of the core were presented. These data made it possible to determine an approximate age of these needles. There it was indicated that more detailed investigations would ensue and these finally got under way in 1994.

Anthropogenic vegetation changes in the Dukla Pass region and in the area north of it are presented in a separate publication (Szczepanek 2001).

## MATERIAL AND METHODS

In 1994 sediment samples were collected by means of a 10 cm diameter Instorf borer from the stand on the mire, 0.5 ha in area, where the organic sediment was deepest. For pollen analysis 121 samples, each of volume 1 $cm^3$ were taken at intervals of 5 cm. For macrofossil analysis, 110 samples from the same core were taken in sections each 5 cm long. The samples for pollen analysis were prepared according to the modified Erdtman's acetolysis method (Erdtman 1943) with addition of standard indicator tablets containing *Lycopodium*. Samples containing mineral material (clay) were pretreated with hot hydrofluoric acid. At least 500 pollen grains of trees and shrubs and all the accompanying herb pollen and spores of Filicales and *Sphagnum* were identified and counted. Samples for macrofossil examination, of ca. 200 $cm^3$ in volume, were soaked and boiled in a solution of KOH and then washed through a sieve of 0.5 mm diameter mesh. Identifiable macrofossils were sorted at $\times$ 5 magnification. From among the numerous fragments of wood small samples, randomly chosen from different zones, were taken for identification.

The pollen and macrofossil diagrams were plotted using the computer program POLPAL for Windows (Walanus & Nalepka 1996, 1999). The diagrams were divided into zones using the PC, Conslink methods (Birks 1986) and by visual inspection. All these methods gave the same results. Interpolated dates are marked by an asterisk (*).

11 samples of organic sediment from the chosen levels were $^{14}C$ dated (six by the Carbon Chronometry Laboratory, Silesian Technical University at Gliwice – Gd and five by the Radiocarbon Laboratory at Kiev – Ki). The results are shown in Table 1. The radiocarbon dates are expressed as $^{14}C$ conventional years BP and $^{14}C$ calendar years BC/AD (Kadrow 2001, Pazdur 2001, Szczepanek 2001).

## DESCRIPTION OF LITHOLOGY

Description of sediment according to Troels-Smith (1955). Depth in cm.

0–89 *Sphagnum*-*Polytrichum* peat, light brown, compact, slightly decomposed; traces of wood fragments
nig 1+, elas 3, sicc 3, strf 0, lim.sup. 0, $Tb^1$ 3.5, $Dl^1$ 0.5

89–100 *Carex*-*Polytrichum* peat, brown, very heavily water saturated, slightly decomposed; wood fragments
nig 2, elas 3, sicc 3+, strf 0, lim.sup. 0, $Tb^1$ 3.5, Dl 0.5

100–120 *Sphagnum*-*Eriophorum* peat, light brown, very slightly decomposed; spongy; wood fragments; compacting on exposure to air
nig 1+, elas 3, sicc 1, strf 0, lim.sup. 1, $Tb^1$ (*Sphag.*) 3.5, Dl 0.5

120–189 wood peat, brown, very slightly decomposed, compacted, formed by very numerous fragments of twigs, wood,

**Table 1**. Results of radiocarbon datings

| Depth (cm) | Nos of Radioc. Labor. | $^{14}$C conv. years BP | $^{14}$C calib. years BC/AD |
|---|---|---|---|
| 165 | Gd – 10857 | 520±80 | 1400 AD |
| 160–165 | Ki – 7051 | 650±90 | 1400 AD |
| 235–240 | Ki – 7052 | 1240±80 | 900 AD |
| 275 | Gd – 11430 | 1430±70 | 620 AD |
| 330 | Gd – 10432 | 2570±90 | 670 BC |
| 380 | Gd – 10864 | 3380±80 | 1630 BC |
| 410–415 | Ki – 7053 | 3690±80 | 2080 BC |
| 465 | Gd – 10859 | 4020±80 | 2460 BC |
| 530 | Gd – 11433 | 4080±90 | 2820 BC |
| 540–545 | Ki – 7055 | 4505±70 | 3200 BC |
| 545–550 | Ki – 7054 | 4820±70 | 3600 BC |

bark and fine rootlets (possibly of trees). Traces of present rootlets at the top of this section are likely. Fragments of slightly larger wood and slightly darker sediment towards the bottom
nig 2 (on top) to 2+ (towards the bottom), elas 2, sicc 2, strf 0, lim.sup. 0, $Dl^1$ 3.5, Sh 0.5

189–200 wood peat, light brown, slightly decomposed, compacted, very numerous fragments of twigs, wood, bark and fine rootlets, probably of trees
nig 1+, elas 2, sicc 2, strf 0, lim.sup. 0, $Dl^1$ 3.5, Sh 0.5

200–258 wood peat, brown, well-decomposed, small fragments of wood, numerous fragments of leaves and fir needles; the whole core compacted and of a homogeneous structure
nig 2, sicc 1, elas 1, strf 0, lim.sup. 0, $Dl^2$ 2.5, Sh 1.5

258–300 wood peat, brown, well-decomposed, compacted, small wood and bark fragments bound together with humus
nig 2, sicc 1, elas 1, strf 0, lim.sup. 0, $Dl^2$ 2, Sh 2

300–310 wood peat, brown, highly decomposed, compacted, slightly clayey and granular, small wood fragments bound together with humus and mineral matter
nig 2, sicc 1, elas 1, strf 0, lim.sup. 0, $Dl^3$ 0.5, Sh 2.5, As/Ag 1

310–360 wood peat, brown, well-decomposed, slightly granular and clayey; small wood fragments bound together with humus and very fine mineral matter
nig 2, sicc 1, elas 1, strf 0, lim.sup. 0, $Dl^2$ 1, Sh 2, As/Ag 1

360–385 wood peat, dark brown, compacted, well-decomposed, greasy; wood fragments bound together with humus
nig 3, sicc 2, elas 1, strf 0, lim.sup 0, $Dl^2$ 3, Sh 1

385–410 wood peat, dark brown, well-decomposed, compacted, greasy; wood and leaf fragments bound together with humus
nig 3, sicc 2, elas 1, strf 0, lim.sup. 0, $Dl^2$ 2, Sh 2

410–480 wood peat, dark brown, slightly decomposed; different wood fragments from a few cm in length (about 1 cm in diameter) to tiny pieces, small scattered bark and leaf fragments, the whole core bound together with humus
nig 3, sicc 2, elas 1+, strf 0, lim.sup.0, $Dl^1$ 3, Sh 1

480–525 *Sphagnum* peat, dark brown, well-decomposed, compacted; penetrated by compacted twig and leaflet fragments of mosses (*Polytrichum*?), small pieces of wood and single herb fragments (?); the whole core bound together with humus
nig 3, sicc 2, elas 2, strf 0, lim.sup. 0, $Tb^2$ 3, Sh 1, $Th^1$ + (?)

525–550 clay, brown, quite homogeneous, greasy; single wood fragments, rock fragments up to 2 cm in diameter. Clay gradually becoming lighter in colour downwards and wood fragments disappearing towards the bottom on top
nig 2+, sicc 1, elas 0, strf 0, lim.sup. ?, Dl +, Sh +, As/Ag 4, Gg + at the bottom: nig 1+, sicc 1, elas 0, strf 0, lim.sup. ?, Sh +, As/Ag 4, Gg +

## POLLEN ANALYSIS

In the pollen diagram six local pollen assemblage zones (L PAZ) and six subzones (pa subz) are distinguished (Fig. 3). In Table 2 mean percentages of selected taxa are presented in the distinguished zones and subzones.

### C-1, *Tilia-Picea-Pinus* L PAZ

Samples Nos 121–117 = 550–530 cm; ca. 4820±70 $^{14}C$ conv. years BP – ca. 4080±90 $^{14}C$ conv. years BP.

Tree pollen is dominant, especially of *Tilia* (max. 21.5%, mean 20.40%), *Pinus* (max. 20.5%, mean 19.20%), *Picea* (max. 17%, mean 13.90%) and *Corylus* (max. 13%, mean 11.40%). *Carpinus* and *Fagus* form continuous curves of low values, and *Abies* occurs sporadically. Herb pollen (NAP) does not exceed 10%. Low curves of *Urtica*, *Pteridium* and Filicales increase. Single pollen grains of anthropogenic indicators such as *Plantago lanceolata* and *Secale* are present. The upper boundary of the zone is marked by a fall of the curves of *Tilia*, *Pinus*, *Picea*, *Urtica*, *Pteridium* and Filicales.

### C-2, *Carpinus-Tilia-Ulmus* L PAZ

Samples Nos 116–87 = 525–390 cm; ca. 4080±90 $^{14}C$ conv. years BP – ca. 3480* $^{14}C$ conv. years BP.

The most characteristic feature of the zone is a rapid increase in *Carpinus* (max. 38%, mean 24.61%) and high values of *Tilia*, *Ulmus*, *Fraxinus*, *Quercus* and *Corylus*. The *Fagus* curve rises and *Abies* occurs more often. From the layer dated 4020±80 $^{14}C$ conv. years BP, i.e. from sample No 103, the curves of almost all trees start to fluctuate more frequently. The proportion of NAP increases because of high values of *Filipendula* (*ulmaria*?) – a plant favouring a high ground water level. Anthropogenic indicators such as *Artemisia*, Chenopodiaceae and *Plantago lanceolata* show a rise in frequency. The upper boundary of the zone is marked by a clear decline of the *Carpinus*, *Fraxinus* and *Corylus* curves, an increase in the *Fagus* curve, the beginning of a continuous *Abies* curve and a gradual distinct rise in Filicales. In this pollen zone four subzones are distinguished.

#### C-2a, *Carpinus-Corylus-Fraxinus* L PAZ subz

Samples Nos 116–104 = 525–475 cm; ca. 4080±90 $^{14}C$ conv. years BP – ca. 4020±80 $^{14}C$ conv. years BP.

This subzone is characterized by a high proportion of *Carpinus* (max. 38%, mean 30.38%), followed by *Corylus* (max. 21%, mean 14.71%), *Fraxinus* (max. 13.5%, mean 9.21%) and *Tilia* (max. 13.5%, mean 5%). The upper boundary of the subzone is marked by a drop in the *Carpinus* and *Fraxinus* curves, and an increase in *Fagus*, *Pinus*, *Betula*, *Filipendula* and Filicales.

#### C-2b, *Fagus-Alnus-Pinus* L PAZ subz

Samples Nos 103–100 = 470–455 cm; ca. 4020±80 $^{14}C$ conv. years BP – ca. 3888* $^{14}C$ conv. years BP.

The characteristic feature of the subzone is a decrease in the *Carpinus* curve (min. 7.4%) synchronous with an increase in *Fagus* (mean 12.75%), *Abies* (mean 5.7%), *Alnus* (mean 8.75%), *Pinus* (mean 7.02%), *Betula* (mean 4.15%) and *Quercus* (mean 5.52%). The *Filipendula*, Filicales and NAP curves also rise. The upper boundary of the subzone is marked by an increase in *Carpinus* (to former values) and a fall of *Fagus*, *Abies*, *Alnus*, *Pinus*, *Quercus* and Filicales.

#### C-2c, *Carpinus-Ulmus-Corylus-(Filipendula)* L PAZ subz

Samples Nos 99–91 = 450–410 cm; ca. 3888* $^{14}C$ conv. years BP – ca. 3602* $^{14}C$ conv. years BP.

The high value of *Carpinus* at the lower boundary of the subzone shows the general

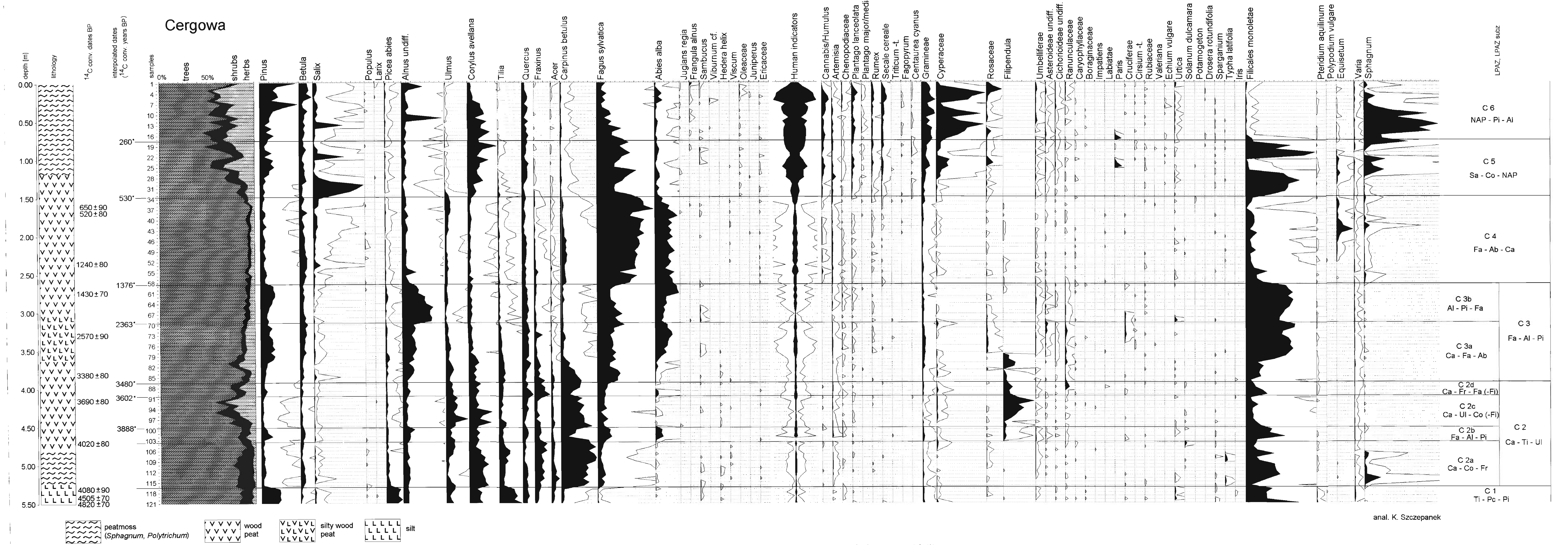


**Fig. 3**. Percentage pollen diagram. Interpolated dates are marked by an asterisk (*)

**Table 2**. Mean percentage pollen values of selected taxa in the zones and subzones of a pollen diagram from Cergowa

| Taxon/ Zone, subzone: | C1 | C2 | C2a | C2b | C2c | C2d | C3 | C3a | C3b | C4 | C5 | C6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Abies* | 0.14 | 1.15 | 0.15 | 5.7 | 0.3 | 1.75 | 10.45 | 8.3 | 13.79 | 15.82 | 3.02 | 1.96 |
| *Acer* | 2.78 | 3.0 | 4.04 | 2.0 | 2.34 | 2.1 | 0.89 | 1.18 | 0.45 | 0.35 | 0.1 | 0.13 |
| *Alnus* | 5.72 | 5.83 | 5.80 | 8.75 | 4.42 | 6.20 | 16.89 | 11.25 | 25.60 | 5.21 | 3.34 | 7.05 |
| *Betula* | 1.28 | 2.8 | 3.18 | 4.15 | 1.84 | 2.37 | 4.61 | 4.68 | 4.49 | 5.46 | 8.21 | 4.96 |
| *Carpinus* | 2.56 | 24.61 | 30.38 | 17.10 | 23.50 | 15.87 | 5.52 | 7.37 | 2.66 | 4.54 | 1.11 | 0.89 |
| *Fagus* | 0.54 | 7.56 | 5.44 | 12.75 | 7.46 | 9.50 | 18.44 | 18.44 | 18.45 | 43.16 | 26.32 | 8.02 |
| *Fraxinus* | 4.06 | 7.69 | 9.21 | 6.20 | 4.36 | 11.70 | 3.42 | 4.41 | 1.89 | 1.35 | 0.18 | 0.03 |
| *Picea* | 13.90 | 1.96 | 2.53 | 2.17 | 1.36 | 1.22 | 1.54 | 1.74 | 1.22 | 0.56 | 0.71 | 0.51 |
| *Pinus* | 19.20 | 3.69 | 3.26 | 7.02 | 2.43 | 4.62 | 10.18 | 10.63 | 11.22 | 4.45 | 7.21 | 13.40 |
| *Quercus* | 5.66 | 5.06 | 4.15 | 5.52 | 4.84 | 8.05 | 6.32 | 6.62 | 5.86 | 3.97 | 4.58 | 3.6 |
| *Salix* | 1.12 | 0.49 | 0.60 | 0.62 | 0.31 | 0.45 | 0.66 | 0.77 | 0.50 | 2.83 | 13.93 | 3.33 |
| *Tilia* | 20.40 | 6.30 | 8.05 | 4.90 | 4.87 | 5.20 | 3.62 | 4.93 | 1.59 | 1.24 | 0.74 | 0.08 |
| *Ulmus* | 6.32 | 7.45 | 5.10 | 6.02 | 11.62 | 7.15 | 3.63 | 4.49 | 2.30 | 3.43 | 0.53 | 0.18 |
| *Corylus* | 11.40 | 12.86 | 14.71 | 9.50 | 13.04 | 9.77 | 4.95 | 5.60 | 3.95 | 2.83 | 12.57 | 8.40 |
| Gramineae | 1.50 | 1.49 | 0.71 | 1.72 | 0.57 | 1.42 | 2.11 | 2.34 | 1.75 | 1.52 | 5.0 | 6.62 |
| Cyperaceae | 0.64 | 0.58 | 0.35 | 0.47 | 0.81 | 0.90 | 0.37 | 0.54 | 0.1 | 0.3 | 5.03 | 26.65 |
| *Filipendula* | 0.04 | 5.46 | 0.007 | 2.12 | 14.04 | 7.25 | 1.65 | 2.68 | 0.07 | 0.14 | 0 | 0 |
| *Artemisia* | 0.14 | 0.54 | 0.48 | 0.72 | 0.43 | 0.77 | 0.61 | 0.74 | 0.4 | 0.98 | 1.47 | 0.66 |
| Chenopodiaceae | 0.26 | 0.12 | 0.04 | 0.27 | 0.11 | 0.22 | 0.23 | 0.20 | 0.29 | 0.12 | 0.22 | 0.44 |
| *Plantago* | 0.1 | 0.09 | 0.04 | 0.02 | 0.12 | 0.12 | 0.16 | 0.15 | 0.18 | 0.22 | 1.46 | 2.07 |
| *Rumex* | 0 | 0.02 | 0.03 | 0 | 0.02 | 0 | 0.09 | 0.09 | 0.10 | 0.15 | 0.93 | 1.18 |
| *Secale* | 0.08 | 0.01 | 0.01 | 0 | 0 | 0.02 | 0.007 | 0.005 | 0.009 | 0.08 | 1.22 | 1.95 |
| *Centaurea cyanus* | 0 | 0.003 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0.004 | 0.19 | 0.07 |
| *Cannabis/Humulus* | 0 | 0.04 | 0.03 | 0.12 | 0.03 | 0.02 | 0 | 0 | 0 | 0.36 | 1.64 | 2.28 |

tendency to decline although its mean value in the subzone is high (23.50%) and close to the mean value for the zone (mean C-2 = 24.61%). The values of *Ulmus* (mean 11.62%) and *Corylus* (mean 13.04%) increase and those of *Pinus*, *Betula*, *Alnus* and *Fagus* decline slightly. The subzone is characterized by high values of *Filipendula* (max. 32.5%) and a significant fall of Filicales. The upper boundary of the subzone is marked by the next decrease in *Carpinus*, a clear rise of *Fraxinus* and *Quercus* and an increase in Filicales.

### C-2d, *Carpinus-Fraxinus-Fagus-(Filipendula)* L PAZ subz

Samples Nos 90–87 = 405–390 cm; ca. 3602* $^{14}$C conv. years BP – ca. 3480* $^{14}$C conv. years BP.

The *Carpinus* curve (mean 15.87%) again rises to a maximum (21%) and the *Fagus* curve slowly increases. The high *Fraxinus* values (max. 17%, mean 11.70%) at the lower boundary of the subzone gradually decline (to 7.3%) towards its upper boundary. The *Pinus*, *Alnus*, *Quercus* and Filicales curves show a slight increase and then fall. In this subzone, Ranunculaceae, Umbelliferae (=Apiaceae), Compositae (=Asteraceae), *Artemisia*, Chenopodiaceae, *Plantago lanceolata*, *Rumex* and *Pteridium aquilinum* occur more often and their values increase somewhat more regularly. The upper boundary of the subzone is marked by the beginning of a fall in the curves of *Carpinus*, *Fraxinus* and *Corylus*, and by a distinct rise in the *Fagus* curve. There is a somewhat lesser increase in *Tilia* and the continuous *Abies* curve begins.

### C-3, *Fagus-Alnus-Pinus* L PAZ

Samples Nos 86–59 = 385–270 cm; ca. 3480* $^{14}$C conv. years BP – ca. 1376* $^{14}$C conv. years BP.

At the lower boundary of the zone the *Fagus* curve peaks (max. 24%) from where it declines coincidentally with a decrease in the

*Ulmus* curve and a rise in that of *Filipendula*. In the sample the *Carpinus* value falls considerably (to about 3%). The curves of *Pinus, Betula, Alnus, Abies*, Filicales, Ranunculaceae, Umbelliferae (=Apiaceae), Compositae (=Asteraceae), Rosaceae, Cruciferae (=Brassicaceae), Gramineae (=Poaceae) and anthropogenic indicators increase.

In the upper part of the zone *Alnus* dominates with *Pinus*, *Fagus*, *Abies* and *Quercus* (mean 6.32%) as co-dominants. *Tilia*, *Fraxinus*, *Acer*, *Ulmus* and *Corylus* values show a distinct tendency to decline to a minimum. The upper boundary of the zone is marked by an increase in *Fagus* and a decline in *Pinus* and *Alnus*.

The zone is divided into two subzones

### C-3a, *Carpinus-Fagus-Abies* L PAZ

Samples Nos 86–70 = 385–320 cm; ca. 3480* $^{14}$C conv. years BP – ca. 2363* $^{14}$C conv. years BP.

*Fagus* (mean 18.44%), *Alnus* (mean 11.25%) and *Pinus* (mean 10.63%) are dominants. In the lower part of the subzone the *Carpinus* curve is still high, although in the upper part its value decreases. From the middle part of the subzone the contribution of *Abies* (mean 8.3%) increases remarkably and that of *Betula* (mean 4.68%) somewhat less. In the younger part of the subzone the decrease in *Ulmus, Corylus, Tilia, Fraxinus* and *Acer* is accompanied by a substantial rise of Filicales and somewhat slighter ones of Gramineae (=Poaceae), Rosaceae, Umbelliferae (=Apiaceae), Compositae (=Asteraceae), Ranunculaceae, Cruciferae (=Brassicaceae) and anthropogenic indicators. In the older part *Filipendula* increases.

### C-3b, *Alnus-Pinus-Fagus* L PAZ

Samples Nos 69–59 = 315–270 cm; ca. 2363* $^{14}$C conv. years BP – ca. 1376* $^{14}$C conv. years BP.

*Alnus* definitely dominates (max. 29.5%, mean 25.60%). In the lower part of the subzone the high values of *Alnus* correspond to relatively high values of *Fagus*. In the upper part, a clear decline of the *Alnus* curve and slow decreases in the *Tilia*, *Carpinus*, *Fraxinus* and *Ulmus* curves are accompanied by increases in the *Pinus, Abies* and Filicales curves. The upper boundary of the zone and subzone is marked by an increase in the *Fagus* curve and a slight rise in the *Carpinus* curve. *Pinus* and *Alnus* sharply decline.

### C-4, *Fagus-Abies-Carpinus* L PAZ

Samples Nos 58–34 = 265–155 cm; ca. 1376* $^{14}$C conv. years BP – ca. 530* $^{14}$C conv. years BP.

*Fagus* (max. 61%, mean 43.16%) and *Abies* (max. 24%, mean 15.82%) prevail. At the lower boundary of the zone *Carpinus* (max. 7.2%, mean 4.54%) and *Betula* (mean 5.46%) increase. The *Ulmus* (max. 6%, mean 3.43%) and *Salix* (max. 7.5%, mean 2.83%) curves rise slightly. *Tilia* and *Fraxinus* show a distinct tendency to decrease towards the upper part of the zone. The herb curve (NAP) is of low value. Ranunculaceae, Umbelliferae, Compositae and Filicales, distinctly present in pollen zone C-3, occur less frequently in zone C-4. The contribution of anthropogenic indicators clearly increases. The upper boundary of the zone is marked by a decrease in the *Fagus*, *Abies* and *Ulmus* curves coinciding with an increase in *Corylus*, *Salix* and Filicales.

### C-5, *Salix-Corylus*-NAP L PAZ

Samples Nos 33–18 = 150–85 cm; ca. 530* $^{14}$C conv. years BP – ca. 260* $^{14}$C conv. years BP.

*Fagus* (max. 40%, mean 26.32%), *Salix* (max. 53%, mean 13.93%), *Corylus* (max. 30.5%, mean 12.57%) and *Pinus* (max. 13.5%, mean 7.26%) dominate. The NAP curve increases sharply from the lower towards the upper zone boundary. This increase is caused by high values of Gramineae (=Poaceae), Cyperaceae, anthropogenic indicators and ecologically undefined taxa (Umbelliferae = Apiaceae, Ranunculaceae, Compositae = Asteraceae, and others). The characteristic feature for this zone is the Filicales curve which forms two peaks (maxima 136% and 153%). The upper boundary of the zone is marked by rapid falls of *Fagus* and Filicales accompanied by an increase in Cyperaceae and a less pronounced increase in Gramineae (=Poaceae).

### C-6, NAP-*Pinus-Alnus* L PAZ

Samples Nos 17–1 = 80–0 cm from peat surface; 260* $^{14}$C conv. years BP – the present time.

Herb pollen (NAP) is dominant, and composed mostly of Cyperaceae (mean 26.65%) and Gramineae (=Poaceae). The proportion of anthropogenic indicators is high in the zone. Among trees, *Pinus* (mean 13.40%), *Corylus* (mean 8.40%), *Fagus* (mean 8.02%), *Alnus* (mean 7.05%), *Betula* (mean 4.96%), *Quercus* (mean 3.6%) and *Salix* (mean 3.33%) are the most abundant. Pollen values of other trees decline progressively or even disappear. Filicales spores occur in small numbers from the beginning of the zone.

## POLLEN CONCENTRATION ANALYSIS

The pollen concentration diagram of selected tree taxa (Fig. 4) largely repeats the fluctuactions of these tree curves in the percentage diagram (Fig. 3), particularly in the C-1, C-2 and C-3 pollen zones (excluding sample No 116 from a depth of 522.5–527.5 cm which occurs at the boundary between the silt and organic deposit in zone C-2 (subzone C-2 a, *Carpinus-Corylus-Fraxinus*)). In this sample pollen of all taxa except *Pinus* and *Abies* shows much higher concentrations. Such a pollen concentration increase present in only one sample suggests the possibility of pollen accumulation on the compacted silt surface when the sedimentation rate was very low.

The development of peat-bog and the rapid accumulation of bog-moss caused a decrease in pollen concentration in the succeeding samples of subzone C-2 a.

A second discrepancy between the percentage diagram (Fig. 3) and the pollen concentration diagram (Fig. 4) occurs in the upper part of pollen zone C-4, *Fagus-Abies-Carpinus* between the depths of 200 cm (sample No. 44) and 150 cm (samples Nos 34, 33). In this section of the pollen concentration diagram (Fig. 4) the curves of all the selected trees fall drastically with the most extreme decreases recorded in *Fagus* and *Abies*. In the percentage diagram the curve fluctuations are not so great and the curves of the two dominant taxa *Fagus* and *Abies* do not fall at all. The *Ulmus* pollen concentration increases slightly.

To explain these differences the macrofossil diagram must be considered (Fig. 5). At a depth of 200 cm the abundance of *Abies alba* needles, seeds and fruit scales and *Fagus* inflorescences ceases, being replaced higher up by fragments of the wood of *Juniperus communis*. Closer to the top of the zone C-4 (C-IV) fragments of the wood of a *Salix* sp. are recorded more frequently, while the contribution of anthropogenic indicator pollen increases synchronously. The fall in forest tree pollen concentration in the younger part of pollen zone C-4, *Fagus-Abies-Carpinus* could indicate the felling of forest in the immediate neighbourhood of the peat-bog. This would have caused a drop in pollen concentration in the deposit while the taxonomic and relative percentage composition of the forest in this region remained unchanged. This explanation of the concentration changes of tree pollen in the upper part of pollen zone C-4 seems to be supported by the *Filipendula* curve which suggests an increase in the peat-bog water table associated with forest felling around it.

In zones C-5, *Salix-Corylus*-NAP, and C-6, NAP-*Pinus-Alnus*, the pollen concentration and pollen percentage curves are highly consistent. The sudden changes of pollen percentages and concentrations of *Corylus*, *Pinus*, *Betula*, *Alnus* and *Fagus* were caused by changes in the water conditions in the peat-bog and by vegetation changes which resulted from the increasing influence of human activity on the plant cover in the region. These sudden changes seem to be associated in part with climatic fluctuations in the youngest section of the Holocene. All the above-mentioned changes are discussed in the next chapter.

## MACROFOSSIL ANALYSIS

The list of taxa identified from plant macrofossils contains 29 species from 27 genera, 8 taxa identified to genus level and 1 to family level only (Fig. 5). The taxa identified, and their distribution in the profile, complement and accurately define the taxonomic composition of the vegetation recorded in the distinguished pollen zones (Fig. 2). In the macrofossil diagram the depths of the distinguished zones correspond to those of the zones in the pollen diagram.

The macrofossil zones are distinguished by the names of those taxa characteristic or occurring most abundantly in them, their Roman numbers preceded with the symbol C (Cergo-

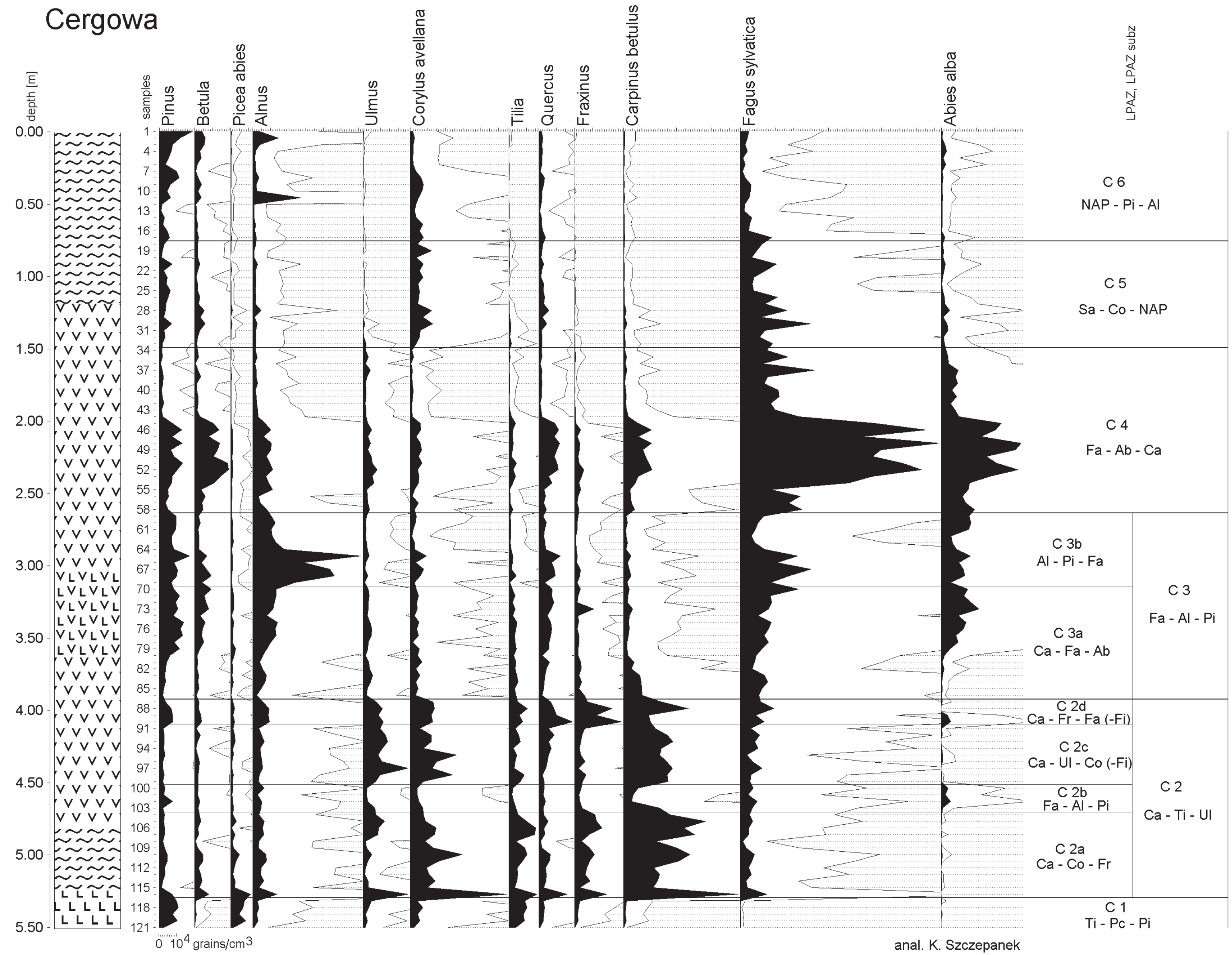


**Fig. 4**. Pollen concentration diagram

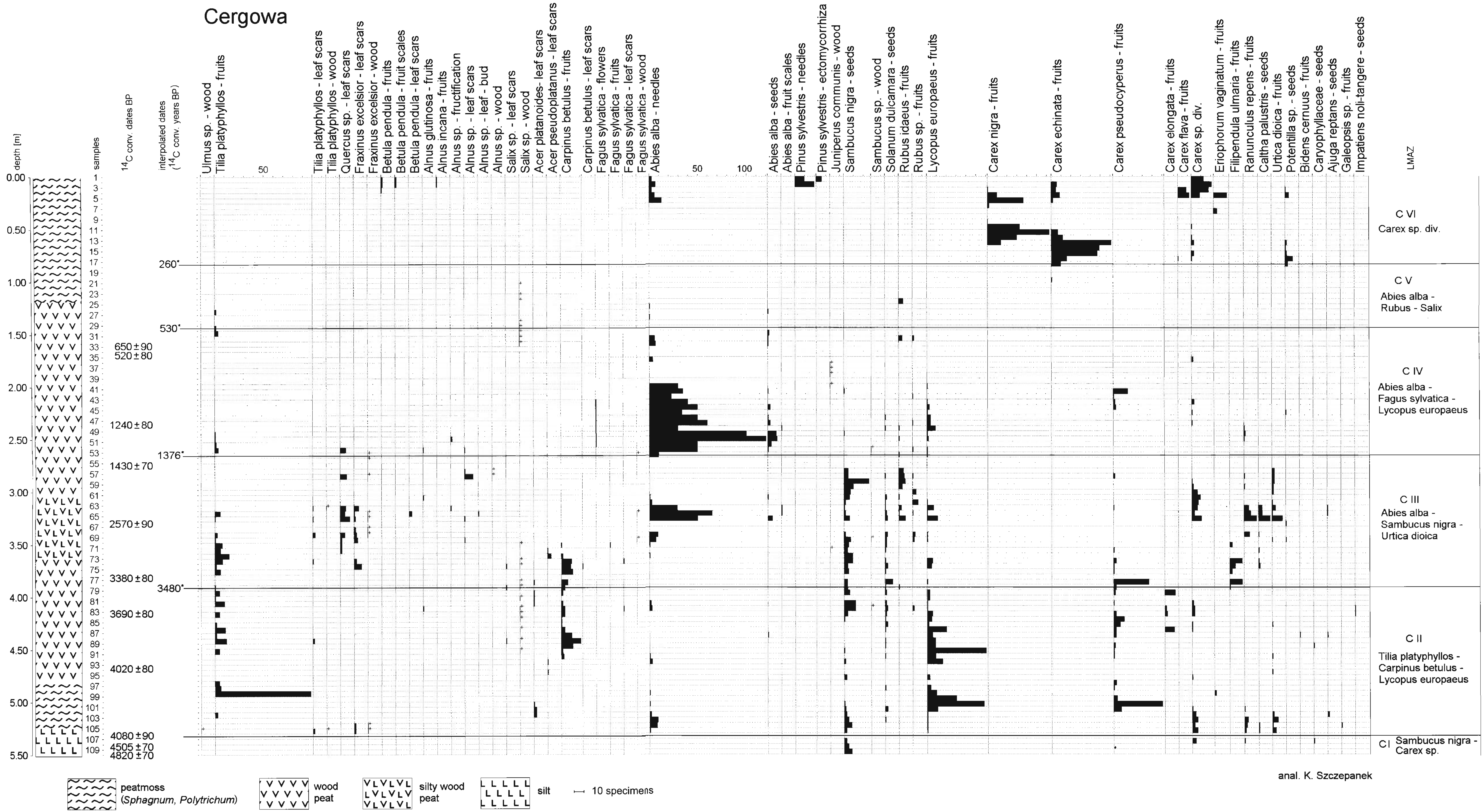


**Fig. 5**. Macrofossil diagram (number of macrofossils given in absolute values). Interpolated dates are marked by an asterisk (*)

wa). Six local macrofossil zones (L MAZ) are distinguished where M means macroscopic plant remains.

### C-I, *Sambucus nigra-Carex* sp. L MAZ

From 4820 ± 70 BP to 4080 ± 90 BP. Silt.

Seeds of *Sambucus nigra* and *Carex* sp. occur in insignificant numbers and only one seed of Caryophyllaceae is present.

Phase of compaction of landslide.

### C-II, *Tilia platyphyllos-Carpinus betulus-Lycopus europaeus* L MAZ

From 4080 ± 90 BP to 3480* BP. Bog-moss (*Sphagnum-Polytrichum*) and wood peat occur.

In the lower part of the zone the occurrence of *Sambucus nigra* and *Carex* sp. seeds continues. Somewhat infrequently, the needles of *Abies alba*, fruits of *Ranunculus repens* and *Urtica dioica* and seeds of *Caltha palustris* are observed. From the boundary between the bog-moss and wood peat, fruits of *Tilia platyphyllos*, *Lycopus europaeus* and *Carex pseudocyperus* occur abundantly in addition to the somewhat infrequent seeds of *Solanum dulcamara*. The characteristic feature of the zone is the presence of fruits of *Tilia platyphyllos*, *Carpinus betulus* and *Lycopus europaeus*. Sedimentation of organic deposits occurs from the very start of the zone.

### C-III, *Abies alba-Sambucus nigra-Urtica dioica* L MAZ

From about 3480* BP to about 1376* BP. Wood peat is slightly silty in the 360–300 cm section. In the lower part of the zone the occurrence of fruits of *Carpinus betulus* and *Tilia platyphyllos* continues. *Filipendula ulmaria* and *Carex pseudocyperus* fruits are quite numerous. Throughout the zone, seeds of *Sambucus nigra* and *Solanum dulcamara* occur regularly. In the upper part of the zone, starting from the top of the silty forest peat, leaf scars of a *Quercus* sp. and *Fraxinus excelsior* (also wood fragments), fruits of *Rubus* sp., *Ranunculus repens* and *Lycopus europaeus* and seeds of *Caltha palustris* and *Ajuga reptans* are quite abundant. Particularly frequent are *Abies alba* needles and *Urtica dioica* fruits, both of them characteristic for this zone.

The accumulation of organic deposits continues.

### C-IV, *Abies alba-Fagus sylvatica-Lycopus europaeus* L MAZ

From about 1376* BP to about 530* BP. Wood peat occurs. The zone is distinguished by the simultaneous and very abundant occurrence of *Abies alba* needles and seeds and by the less frequent occurrence of *Fagus sylvatica* inflorescences and *Lycopus europaeus* fruits. The presence of important but insignificantly represented species such as *Tilia platyphyllos*, *Ranunculus repens* and, somewhat higher in the zone, *Carex pseudocyperus* is recorded.

The accumulation of wood peat continues.

### C-V, *Abies alba-Rubus-Salix* L MAZ

From about 530* BP to about 260* BP. The deposit of wood peat changes into *Sphagnum-Polytrichum* peat. Macrofossils are very scanty in the zone. Insignificant numbers of *Tilia platyphyllos* and *Rubus idaeus* fruits and *Abies alba* needles appear coincidentally with quite numerous fragments of wood of *Salix* sp. The *Sphagnum-Polytrichum* peat is heavily saturated with water.

### C-VI, *Carex* sp. div. L MAZ

From about 260* BP to 1994 AD. *Sphagnum-Polytrichum* peat occurs. In the lower part of the zone *Carex echinata* and *C. nigra* fruits and *Potentilla* sp. seeds occur quite often. In the upper part, the abundant presence of fruits of *Carex nigra*, *C. echinata*, *C. flava*, *Carex* sp. div. and *Eriophorum vaginatum*, needles of *Abies alba* and *Pinus sylvestris*, fruits and fruit scales of *Betula pendula* and seeds of *Potentilla* sp. is recorded.

The accumulation of *Sphagnum-Polytrichum* peat continues.

The zone is characterized by the complete absence of aquatic plant macrofossils and the presence of those of plants favouring slightly shady or sunny habitats on wet soils ranging from poor (oligotrophic) trough eutrophic to extremely fertile and of slightly acid to acid reaction. These plants, i.e. *Ajuga reptans*, *Bidens cernua*, *Caltha palustris*, *Carex elongata*, *C. pseudocyperus*, *Eriophorum vaginatum*, *Filipendula ulmaria*, *Lycopus europaeus*, *Ranunculus repens*, *Solanum dulcamara*, and *Urtica dioica*, occur in the zones in which macrofossils of *Tilia platyphyllos*, *Carpinus betulus* and *Sambucus nigra* are also fairly to very abundant. From about 1376* BP when *Abies alba* and *Fagus sylvatica* macrofossils were most abundant, a clear impoverishment of the taxonomic composition of the plants represented by macrofossils took place. A reversal of this trend was observed after 260* BP.

## VEGETATION CHANGES

These are assessed from the results of pollen and macrofossil analyses of the lowest deposits obtained from the landslide depression situated on the slope of Mt Cergowa (716 m a.s.l.) as well as the results of radiocarbon datings ensuring that the studied organic deposits are of late Holocene age (Tab. 1, Fig. 3).

The local pollen zones and subzones reflect the vegetation changes, primarily, in the immediate surroundings of the peat. However, vegetation changes a little further afield are also undoubtedly reflected. Local changes were evidenced by macrofossils (Fig. 5). In the bottom local zone C-1, *Tilia-Picea-Pinus* which was dated at ca. 4820±70 $^{14}C$ conv. years BP – ca. 4080±90 $^{14}C$ conv. years BP, the contribution of tree pollen in the total pollen sum indicate complete forestation of this area. The percentage and taxonomic composition of the tree pollen show unequivocally that the forest communities in the Dukla Pass region at that time contained a significant proportion of *Tilia*, *Ulmus*, *Fraxinus*, *Acer* and *Quercus* – moderately thermophilous trees – with an abundance of *Corylus* in the brushwood. The low value of *Carpinus* and *Fagus*, and sporadic occurrence of *Abies* pollen prove the presence of these trees at the site or in the immediate vicinity of the peat-bog. The high contribution of *Pinus* and *Picea* pollen and the relatively high amounts of *Alnus* pollen may indicate that conditions in the landslide depression were favourable for these trees, for *Picea* in particular. Similar occurrences have been observed in nearby sites in the Low Beskidy, in Szymbark (Gil et al. 1974) and Regetovka in the Slovakian part of the Low Beskidy (Wacnik 1995).

The high contribution of *Picea* pollen in the period of ca. 5.0–4.0 ka BP was doubtless associated with the humid climate prevailing during this period. A similar occurrence has also been observed at other sites in the vast region of the Low Beskidy and areas to the north (Koperowa 1971, Szczepanek 1987, Harmata 1995). Single *Secale* and *Plantago lanceolata* pollen grains and somewhat higher values of *Urtica*, Chenopodiaceae and *Pteridium aquilinum* provide evidence of human settlements in the Middle Neolithic.

These forest communities underwent significant change from ca. 4080±90 $^{14}C$ conv. years BP to ca. 3480* $^{14}C$ conv. years BP during the period represented by pollen zone C-2, *Carpinus-Tilia-Ulmus*. The composition of mixed forest stands changed as a result of the spread and dominance of *Carpinus betulus*. A consequence was the creation of mixed deciduous forest stands composed of *Carpinus*, *Tilia*, *Quercus*, *Acer*, *Ulmus*, *Corylus* and, sometimes, also of *Fagus* and *Picea*. *Fagus sylvatica* also became a more important component of the forest at higher altitudes and on north facing slopes. The occurrence of *Abies alba* is evidenced by the greater frequency of its pollen grains (Fig. 3) and small numbers of needles (Fig. 5). The presence of *Picea* and *Pinus* was limited in forest compositions and most likely also in the immediate neighbourhood of the studied site. Changes in the forest taxonomic composition, especially the spread of *Carpinus*, took place mainly at lower altitudes. The presence of *Carpinus* near the peat-bog is proved by the occurrence of its fruits at depth of 455 cm below the peat-bog surface, i.e. from ca. 4020±80 $^{14}C$ conv. years BP.

It seems most likely that no deep water body was formed in the landslide depression and that there was just the one area with an increased ground water level. The evidence is the presence of macrofossils of species typical for wet and swampy habitats of moderately poor to extremely fertile acid soils (*Lycopus europaeus*, *Solanum dulcamara*, *Carex* sp. div., pieces of wood of *Salix cinerea* ?, *Filipendula ulmaria*; Fig. 5).

Four subzones distinguished in this zone illustrate how pollen percentage values, particularly forest tree pollen values, fluctuated. These fluctuations most probably resulted from human activity both in the wider region and in the immediate vicinity of the peat-bog.

The growth in agriculture caused a further slight increase in anthropogenic indicators (cf. Behre 1981) which was more marked than in the previous pollen zone. The responses of particular taxa to human activity could also have been modified by climate changes. In pollen zone C-3, *Fagus-Alnus-Pinus*, from ca. 3480*

$^{14}C$ conv. years BP to ca. 1376* $^{14}C$ conv. years BP, basic vegetation changes occurred both in the region and the neighbourhood of the peat-bog. Starting at the lower boundary of the zone, i.e. from ca. 3480* $^{14}C$ conv. years BP, *Carpinus, Tilia, Ulmus, Fraxinus, Acer,* and *Corylus* featured less and less in the composition of the mixed deciduous forest. It is most probable that the decline in the percentage values of these taxa was a result of forest felling, particularly at lower altitudes. Probably felling took place also in the pollen catchment area of the peat-bog.

The decline in the curves of taxa forming mixed deciduous forest coincides with an increase in the contribution of *Fagus*, and somewhat later on of *Abies* and Filicales. The rise of *Salix* and *Alnus* pollen values, and those of *Pinus* and *Betula* later on, could have been associated with their occurrence on the surface of the peat-bog. *Abies alba* needles present in the zone indicate the occurrence of this tree on the peat-bog itself or at its margins (Fig. 5). In pollen subzone C-3b, *Alnus-Pinus-Fagus*, alder was growing mostly on the peat-bog.

In the deposits, particularly in subzone C-3a, a significant admixture of mineral matter occurred. It would seem to have been the result of its flushing on to the peat-bog, especially during high precipitation and at times of forest felling. On the other hand it could have been the result of a lowering of the ground water level, desiccation of the area and the blowing of mineral matter on to the peat-bog surface which enabled trees to become established there.

The proportion of herb pollen, including anthropogenic indicators (*Artemisia*, Chenopodiaceae, *Plantago lanceolata*, *Rumex*), increased slightly but only in subzone C-3a, *Carpinus-Fagus-Abies*, i.e. ca. 3480* $^{14}C$ conv. years BP – ca. 2363* $^{14}C$ conv. years BP. This zone (C-3) could have been associated with the formation of meso- and eutrophic mixed forest, in which beech and fir (the latter at lower altitudes) prevailed. Mixed forest dominated at altitudes from about 600 to 1200 m a.s.l. in the Carpathians (Medwecka-Kornaś 1972), where it occupied the lower montane zone in a moderately cool climate. At lower altitudes, and in the West Carpathians, the constituents of mixed deciduous forest grew among the eutrophic species of beech forest.

Beech and fir-beech forest prevailed in the Dukla Pass region from ca. 1376* $^{14}C$ conv. years BP to ca. 530* $^{14}C$ conv. years BP, i.e. in pollen zone C-4, *Fagus-Abies-Carpinus*, but *Carpinus* and *Ulmus* also occurred in this forest. On the peat-bog, and at its margins, *Abies* and probably *Fagus* (Figs 3, 5), *Betula* and *Salix* appeared. These taxa doubtless did not form a dense plant cover as is proved by the presence of macrofossils of *Sambucus nigra*, *Lycopus europaeus*, *Solanum dulcamara*, *Ranunculus repens* and *Carex* (Fig. 5).

The pollen diagram illustrates in this zone the intensive development of beech-fir forest, the regeneration of mixed deciduous forest and, simultaneously, an increase in anthropogenic indicators (Fig. 3). However, forest communities still dominated in this area. Starting from 530* $^{14}C$ conv. years BP, i.e. from zone C-5, *Salix-Corylus*-NAP, or even earlier, the contribution of trees rapidly and continuously declined, particularly that of *Abies* and somewhat less of *Fagus*, which co-dominated in the forest of this region. The reduction took place, primarily, in the foothill zone and on north facing slopes of the lower montane zone.

On the one hand the extension of open areas could have favoured the spread of *Corylus* and *Betula* as pioneer taxa, but on the other it cannot be excluded that these open areas intensified long distance transport. The local situation on the peat-bog is reflected by fluctuations in *Salix* and Cyperaceae. Troughout this zone, but especially in its upper part, the deposit of wood peat changed into *Sphagnum-Eriophorum* and *Sphagnum-Polytrichum* peat heavily water saturated in the top part of the zone. This indicates an increasing ground water level which was undoubtedly associated with a damp climate and forest felling. The increase in the proportion of herb pollen was associated with a rapid increase in open areas which were mainly used as pasture. This is proved by the rise of anthropogenic indicators. The increase in cereal pollen (mostly *Secale cereale*) indicates an extension of corn growing. A new taxon of *Juglans* appeared, associated with the presence of man. The high contribution of Cyperaceae pollen is most probably associated with local vegetation on the peat-bog and its immediate surroundings.

The direction and rate of vegetation changes in the Dukla Pass region and adjoining areas were strongly and suddenly enhanced in the period represented by pollen zone C-5, *Salix-Corylus*-NAP, and continued into zone C-6, NAP-*Pinus-Alnus*, i.e. after ca. 260* $^{14}$C conv. years BP. The contribution of *Quercus* and *Betula* did not fluctuate much, but the proportion of *Fagus* rapidly decreased and *Salix*, *Pinus* and *Alnus* showed great fluctuations. Other trees occurred in small numbers.

Among herbs, an increase in the local vegetation on the peat-bog, mainly Cyperaceae and anthropogenic indicators, is significantly demonstrated. The pollen diagram (Fig. 3) distinctly shows intensive human pastoral and agricultural activity. This caused semi-natural and anthropogenic herb communities to become dominant in the vegetation of the Dukla Pass region in the Low Beskidy, and in the area to its north – the Carpathian Foothills and the Jasło-Sanok Depression.

## CONCLUSIONS

1. Sedimentation of organic deposits in the landslide depression started from ca. 4820±70 $^{14}$C conv. years BP.

2. In the pollen diagram six local pollen assemblage zones (L PAZ) and six subzones (pa subz) were distinguished which reflect essential vegetation changes in the Dukla Pass region, and in the area to the north of this region.

3. These sequence of vegetation changes reconstructed on the basis of pollen succession (Fig. 3) is confirmed and complemented by a pollen diagram of selected taxa (Fig. 4) and by macrofossils (Fig. 5)

4. On the basis of pollen analysis and definition of the age of deposits by radiocarbon datings, the periods of formation of the two main forest communities in the Low Beskidy can be recognized. Mixed deciduous forest (possibly related to the modern *Tilio-Carpinetum*) occurred from ca. 4080±90 $^{14}$C conv. years BP, and fir-beech forest ( possibly related to the modern *Fagetum carpaticum*) was present from ca. 4080±90 $^{14}$C conv. years BP to ca. 3480* $^{14}$C conv. years BP.

5. From the beginning of the laying down of organic deposit anthropogenic indicators of pastoral and agricultural human activity occurred. Their increase from ca. 530* $^{14}$C conv. years BP, particularly from ca. 260* $^{14}$C conv. years BP, prove that human activity in this area has been remarkably intensive in the last 600 years.


### ACKNOWLEDGEMENTS

The author is sincerely indebted to Professor Jan Machnik (Institute of Archaeology and Ethnology, Polish Academy of Sciences) for his sponsorship of radiocarbon datings performed by the Gliwice Radiocarbon Laboratory. The author extends his gratitude to Dr Jan Budziszewski (Institute of Archaeology and Ethnology, Polish Academy of Sciences) and to the Foundation for Friends of the Institute of Archaeology in Warsaw for sponsorship of radiocarbon datings carried out by the Kiev Radiocarbon Laboratory. The author is deeply grateful to Professor Kazimiera Mamakowa (W. Szafer Institute of Botany, Polish Academy of Sciences) for constructive comments on the manuscript. Thanks are due to Danuta Stępalska (Institute of Botany, Jagiellonian University) for translating the article into English, to Barbara Nowaczyńska (Institute of Botany, Jagiellonian University) for technical assistance, to Dr Dorota Nalepka (W. Szafer Institute of Botany, Polish Academy of Sciences) for her help in producing pollen diagrams, and to Zofia Tomczyńska (W. Szafer Institute of Botany, Polish Academy of Sciences) for the identification of wood fragments.

The author likes to extend his appreciation to Mr. Arthur Copping for linguistic verification of the English text.


## REFERENCES


BEHRE K.-E. 1981. The interpretation of anthropogenic indicators in pollen diagrams. Pollen and Spores, 23(1): 225–245.

BIRKS H.J.B. 1986. Numerical zonation, comparison and correlation of Quaternary pollen – stratigraphical data: 743–774. In: Berglund B.E. (ed.). Handbook of Holocene Palaeoecology and Palaeohydrology. John Wiley and Sons Ltd. Chichester, New York, Brisbane, Toronto, Singapore.

ERDTMAN G. 1943. An introduction to pollen analysis. Chronica Botanica, Waltham, Massachusetts.

GIL E., GILOT E., KOTARBA A., STARKEL L. & SZCZEPANEK K. 1974. An Early Holocene landslide in the Niski Beskid and its significance for palaeogeographical reconstructions. Studia Geomorh. Carpath.-Balcan., 8: 69–83.

HARMATA K. 1995. A Late Glacial and Early Holocene profile from Jasło and recapitulation of the studies on the vegetational history of the Jasło-Sanok Depression in the last 13000 years. Acta Palaeobot., 35(1): 15–45.

KADROW S. 2001. Radiocarbon dating calibration of a palynological profile from the Mount Cergowa site by means of the wiggle matching analysis: 187–190. In: Machnik J. (ed.). Prace Komisji Prehistorii Karpat, 2. Polska Akademia Umiejętności, Kraków.

KLIMASZEWSKI M. 1935. Z fizjografii Beskidu Niskiego (Physiography of the Beskid Niski). Wierchy, 13: 89–93. (in Polish).

KLIMASZEWSKI M. 1946. Podział morfologiczny południowej Polski (Morphological division of Southern Poland). Czasop. Geogr., 17(3–4): 133–182. (in Polish).

KOPEROWA W. 1971. Późnoglacjalna i holoceńska historia roślinności wschodniej części Dołów Jasielsko-Sanockich. (summary: Late-Glacial and Holocene history of the vegetation of the eastern part of the "Jasło-Sanok Doly" (Flysch Carpathians). Acta Palaeobot., [1970] 11: 1–42.

MACHNIK J. 1989. Wyniki najnowszych badań archeologicznych w Karpatach polskich oraz ich znaczenie dla innych dyscyplin naukowych (The results of the latest archaeological studies of the Polish Carpathians and their importance for other scientific disciplines). Rocznik Oddziału PAN, Kraków [1988]. (in Polish).

MACHNIK J. 1992. Aus den Forschungen über die Schnurkeramikkultur auf dem nördlichen Vorsfeld des Niederen Beskid. Acta Archaeol. Carpath., 31: 69–90.

MEDWECKA-KORNAŚ A. 1972. Przegląd ważniejszych zespołów roślinnych Polski. Zespoły leśne i zaroślowe (Review of important plant communities in Poland. Forest and thicket communities): 406–408. In: Szafer W. & Zarzycki K. (eds). Szata roślinna Polski, 1. PWN, Warszawa. (in Polish).

PAWŁOWSKI B. 1972. Szata roślinna gór polskich (Vegetation of the Polish mountains): 189–252. In: Szafer W. & Zarzycki K. (eds). Szata roślinna Polski, 2. PWN, Warszawa. (in Polish).

PAZDUR A. 2001. Radiocarbon age of the sediments from the Mount Cergowa site, Poland: 183–185. In: Machnik J. (ed.). Prace Komisji Prehistorii Karpat, 2. Polska Akademia Umiejętnosci, Kraków.

RALSKA-JASIEWICZOWA M. 1983. Isopollen maps for Poland: 0–11000 years BP. New Phytol., 94: 133–175.

STARKEL L. 1972a. Karpaty Zewnętrzne (The External Carpathians): 52–115. In: Klimaszewski M. (ed.). Geomorfologia Polski, 1. PWN, Warszawa. (in Polish).

STARKEL L. 1972b. Charakterystyka rzeźby polskich Karpat i jej znaczenie dla gospodarki ludzkiej (summary: An outline of the relief of the Polish Carpathians and its importance for human management). Problemy Zagospodarowania Ziem Górskich, 10: 75–150.

SZCZEPANEK K. 1987. Late-Glacial and Holocene pollen diagrams from Jasiel in the Low Beskid Mts. (The Carpathians). Acta Palaeobot., 27(1): 9–26.

SZCZEPANEK K. 2001. Anthropogenic vegetation changes in the region of the Dukla Pass, the Lower Beskid Mountains: 171–182. In: Machnik J. (ed.). Prace Komisji Prehistorii Karpat, 2. Polska Akademia Umiejętności, Kraków.

ŚWIĘS F. 1982. Charakterystyka geobotaniczna lasów Beskidu Niskiego. Analiza i synteza (summary: Geobotanical characterization of the Low Beskid forests. Analysis and synthesis). Rozprawy Wydziału Biologii i Nauk o Ziemi Uniwersytetu Marii Curie-Skłodowskiej w Lublinie. Rozpr. Habil., 23: 108.

TACIK T., ZAJĄCÓWNA M. & ZARZYCKI K. 1957. Z zagadnień geobotanicznych Beskidu Niskiego (Zusammenfassung: Geobotanisches aus dem Beskid Niski-Zuge im mittleren Teile der Karpathen). Acta Soc. Bot. Pol., 26(1): 17–43. (in Polish).

TROELS-SMITH J. 1955. Karakterisering af løse jordarter (Characterization of unconsolidated sediments). Geological Survey of Denmark. IV. Ser. 3(10): 1–73.

WACNIK A. 1995. The vegetational history of local flora and evidences of human activities recorded in the pollen diagram from site Regetovka, NE Slovakia. Acta Palaeobot., 35(2): 253–274.

WALANUS A. & NALEPKA D. 1996. Program POLPAL – Palynological Data Base. User's Guide (1994). W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

WALANUS A. & NALEPKA D. 1999. POLPAL. Program for counting pollen grains, diagrams plotting and numerical analysis. Acta Palaeobot., Suppl. 2: 659–661.

WIĘCKOWSKI S. & SZCZEPANEK K. 1963. Assimilatory pigments from subfossil fir needles (*Abies alba* Mill.). Acta Soc. Bot. Pol., 32(1): 101–111.

ŻAKI A. 1955. Początki osadnictwa w Karpatach polskich (The first settlement in the Polish Carpathians). Wierchy, 24: 99–116. (in Polish).

ŻAKI A. 1966. Starożytne i średniowieczne warownie karpackie (summary: Fortifications anciennes et médiévales dans les Carpates). Acta Archaeolog. Carpath., 8: 5–55.