ACTA PALAEOBOTANICA
XXII (1): 117—130, 1982

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DEVELOPMENT OF THE PEAT-BOG AT SŁOPIEC AND THE VEGETATIONAL HISTORY OF THE ŚWIĘTOKRZYSKIE (HOLY CROSS) MTS. IN THE LAST 10 000 YEARS

Preliminary results

Historia roślinności Gór Świętokrzyskich w ciągu ostatnich 10 000 lat na podstawie badań torfowiska w Słopcu

Doniesienie wstępne

ABSTRACT. The preliminary results of pollen analytical studies at Słopiec, in the southern part of the Świętokrzyskie (Holy Cross) Mts. are presented. A profile, 5·25 m long, was obtained from the peat-bog, and twelve samples were radiocarbon dated. The oldest sample gave the age of 10 280±210 BP.

On the basis of pollen analysis the regional history of vegetation and the main outlines of peat-bog development are reconstructed. The comparison of pollen analytical results obtained in 1961 and in 1979/80 showed their close similarity, concerning all phenomena of stratigraphical and successional significance. The radiocarbon datings revealed gaps or considerable changes in the rate of sediment accumulation in two time intervals.

THE NATURAL ENVIRONMENT OF THE REGION

The Świętokrzyskie (Holy Cross) Mts. are situated in the central part of the area between the Wisła and Pilica rivers. In the division of Poland into palaeoecological regions they were distinguished as a separate type region-4c (Ralska-Jasiewiczowa in Berglund 1979). These are old Caledonian and Variscite low mountains of a diversified geological structure and level changes of about 200–350 m. Parellel ridges running generally NW—SE are the main feature of the relief of the Świętokrzyskie Mts. The ridges are separated by longitudinal wide depressions and valleys modelled in less resistant rocks. They are also dissected by cross valleys, which gives the character of a grate to these mountains. The ranges and ridges form a zonal pattern. The Łysogóry Range is the highest (611 m a.s.l.); it is formed of Cambrian quartzites. The lower ranges and ridges (350–430 m) to the south and north are built of Cambrian and younger Palaeozoic rocks. The lowest external ranges and ridges (about 300–350 m) are built mainly of Mesozoic rocks.

The basic geomorphological relief of the Świętokrzyskie Mts. was formed in the Tertiary. The landscape formed during the last (Vistulian) glaciation persists up till today and is only slightly transformed by morphogenetic factors of the Holocene climate (Klatka 1965; Radłowska 1967; Gilewska 1972). The varied geological, lithological and morphological structure of the region corresponds with the diversity of the soil pattern. Strzemski (1967) distinguishes 7 lithological and pedological units in this area on the basis of the spatial distribution of rock types and of the character of soils conditioned by these rocks. Very acidic and acidic soils (about 51%) as well as slightly acidic ones (about 28%) are characteristic of the central part of the region, while less then 20% of soils show neutral and alkaline reaction.

The climate of the Świętokrzyskie Mts. differs from that of the surrounding areas, and resembles to some extent a mountain climate. The upper parts of hills are specially remarkable in this respect. These are areas of relatively low mean air temperatures, high totals of precipitation, a long period of snow cover persistance, and strong winds. In general, the climate of this region is characterized by the following data (Klimek 1959):

mean annual air temperatures (in °C)	5·7–7·6
mean January temperatures	1·9–4·9
mean July temperatures	16·2–18·4
relative humidity (%)	78–82
cloudiness	5·4–6·4
number of fine days	35–70
number of cloudy days	97–142
number of foggy days	21–56
number of days with wind above 10 m/sec.	12–21
number of days with snow cover	53–84
annual precipitation in mm	650–700

The occurrence of fir and fir-beech forests on the main ridges is a distinctive feature of the vegetation of that region. These forests represent a poor variant of Carpathian beechwood of lower situations (*Abietetum polonicum* and *Dentario glandulosae-Fagetum*). Mountain plants occur in both these associations. The slopes of lower ranges and the valleys floors are covered with more differentiated communities of deciduous, mixed and pine forests and with meadow communities. Thermophilous communities and xerothermic species are of a relatively great importance on calcareous grounds with a more diversified relief. The considerable participation of larch (*Larix polonica*) is a peculiarity of the Świętokrzyskie Mts. forests. This is an agricultural-sylvan area. Forests occupy about 30–40 % of that region.

Land cultivation encroaches now the ridges of the highest elevations. The oldest evidence of man's residence and activity in that region dates from before 50 000–60 000 years. Rich mineral resources, known and exploited long before, such as: flint, lead, copper, and iron ores encouraged the exploitation of that area. Population density exceeds now the mean value for the whole country what results from the urbanization and industrialization of the region.

DESCRIPTION OF THE REFERENCE AREA

The wide depression surrounded with quartzite ridges, situated between the southern mountain ranges of the Dymińskie (406 m a.s.l.) and the Cisowskie (427 m a.s.l.) Ranges is a distinct orographic unit. It is filled with Palaeozoic sandstones and shales and Quaternary sands. The Belnianka stream flows in the middle of this depression. Its valley floor is partly occupied by swamps and mires. The valleys along the mountain ranges are poorly drained and also covered with vast mires. The forests growing on barren sands, filling depressions between Cambrian outcrops, are almost pure pine stands. The forests on the mountain ridges and on their slopes are of a similar composition as the fir, fir-beech and mixed forests of the main ranges.

Mean annual temperatures oscillate between 6·0° and 6·5°C. Mean annual precipitation amounts to 650–700 mm.

In spite of rather poor soils, the area is cultivated largely. More extensive forest complexes persisted around the depression.

DESCRIPTION OF THE PEAT-BOG

The peat-bog studied is situated about 20 km SE of Kielce, in the north-east outskirts of the village Słopiec, east of the Borków — (Kielce) — Daleszyce highway. It occupies a small depression (possibly an old river bed) in the Belnianka stream valley, at an altitude of 248 m a.s.l. (Fig. 1). Its geographical latitude is 50°47′, longitude 20°47′. The depression is fairly regularly elliptic in shape, measuring about 362 by 275 m (Fig. 2). To the west, the highway separates the peat-bog from sandy hills, where numerous houses were built in the last few years. To the north, a low ridge of sand dunes overgrown with a thin pine wood passing into swampy meadows adjoins the peat-bog. To the east, the peat-bog borders on cultivated fields and riverside, moist, mowed meadows. To the south, the margin of the peat-bog reaches old farm buildings situated on the slope of a sandy hill.

The surface of the peat-bog is overgrown with a complex of natural plant communities. The forests to the south and east are successional stages of the *Alnetea* communities. *Eriophoro-Sphagnetum recurvi* in a variant with *Care* *rostrata*, forming a mosaic with the typical form of that association, predominates over a considerable part of the peat-bog surface. The central part is

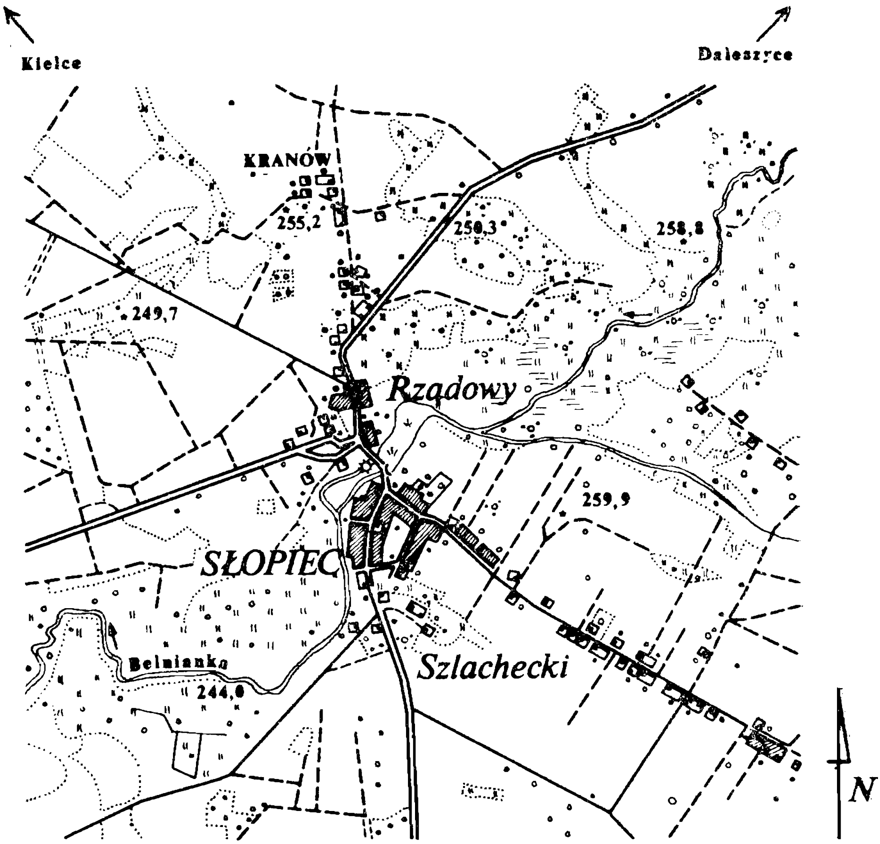

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Fig. 1. Map showing the location of Słopiec mire

occupied by patches of *Sphagnetum medii* forming characteristic hummocks (about 30–50 cm high), with small hollows in between. Dwarf specimens of *Pinus sylvestris, Frangula alnus, Alnus glutinosa, Juniperus communis* and shrub willows grow on these hummocks. The community *Caricetum lasiocarpae* develops very often in small valleys and pools filled with water during a considerable part of the year. Of the more interesting and rare vascular plants occur there: *Andromeda polifolia, Betula pubescens, Ledum palustre, Oxycoccus quadripetalus, Vaccinium uliginosum, Drosera rotundifolia, Menyanthes trifoliata, Triglochin palustre, Rhynchospora alba,* and the relict, boreal-arctic mosses: *Calliergon trifarium, Meesea triquetra, Scorpidium scorpioides, Cynclidium stygium* (Kuc 1964).

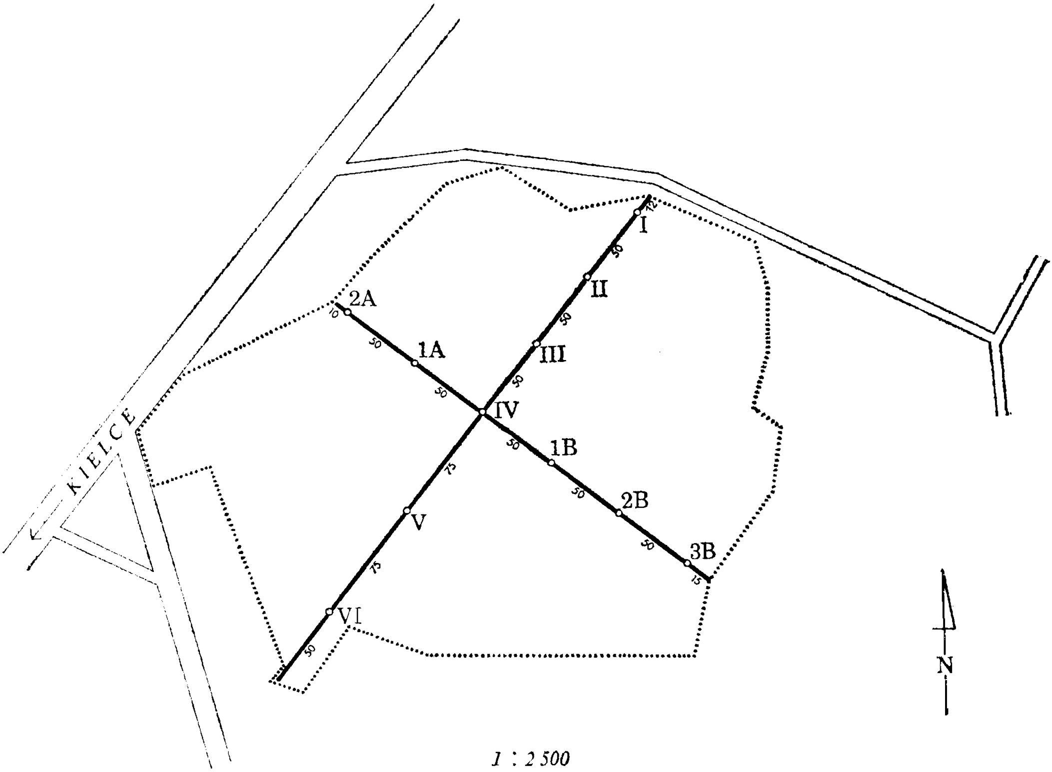

Fig. 2. Sketch map of Słopiec mire to show the position of borings

PALAEOECOLOGICAL STUDIES

Methods

On the surface of the peat-bog trial borings were carried out in two series at the right angles running more or less across the central part of the peat-bog (Figs. 2, 3, 4). At the distance of about 60 m from the northern border of the peat-bog (site II, Figs. 2, 3), a profile 5·15 m deep was taken using the Russian sampler "Instorf" and 104 samples for micro- and macroanalyses of plant remains were collected from it. The boring site is about 50 m southwards from the place, where the profile for studies published in 1961 was collected (Szczepanek 1961), nearer the central part of the peat-bog. The samples were taken at 5 cm intervals. At the first stage 68 samples were analysed, in which only 200 tree pollen grains and associated herb pollen and spores were counted, to compare the results with those from the year 1961 (Fig. 5). The basis for the calculation was the total sum of the tree, shrub and herb pollen (Σ P excluding the pollen of aquatic and swamp plants, and all spores). The percentage values for aquatic and swamp plants were calculated from Σ P+1 n. At the

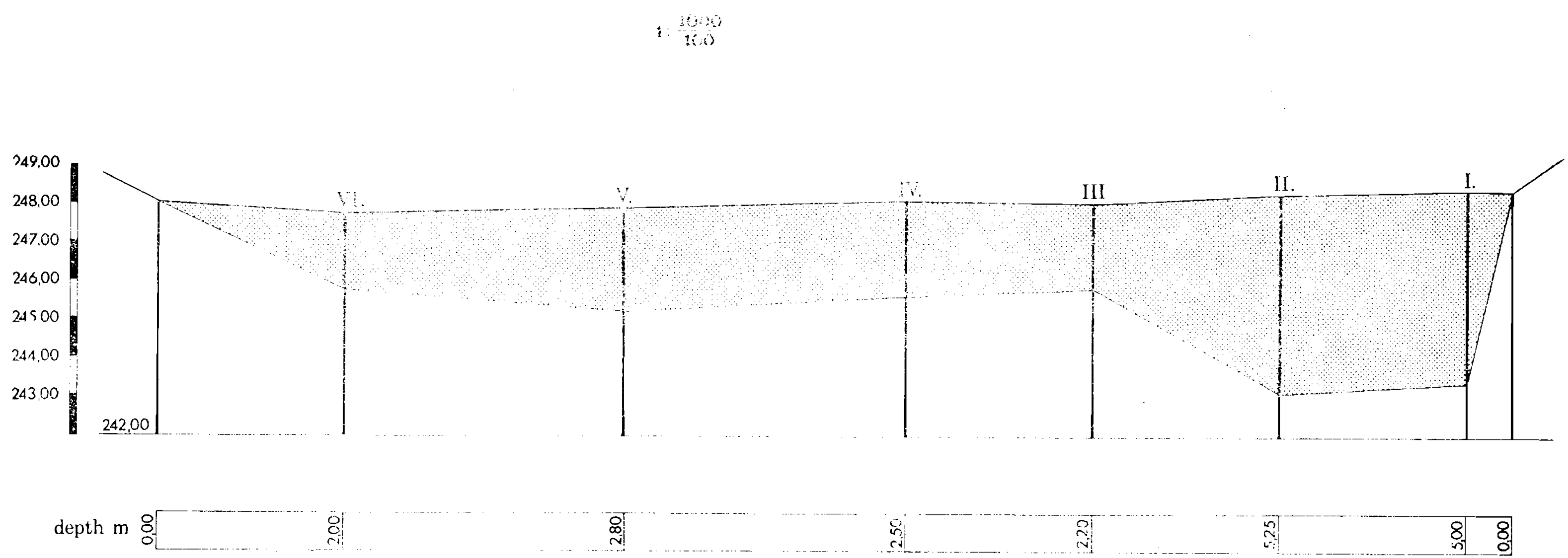

Fig. 3. Słopiec mire: NE—SW section

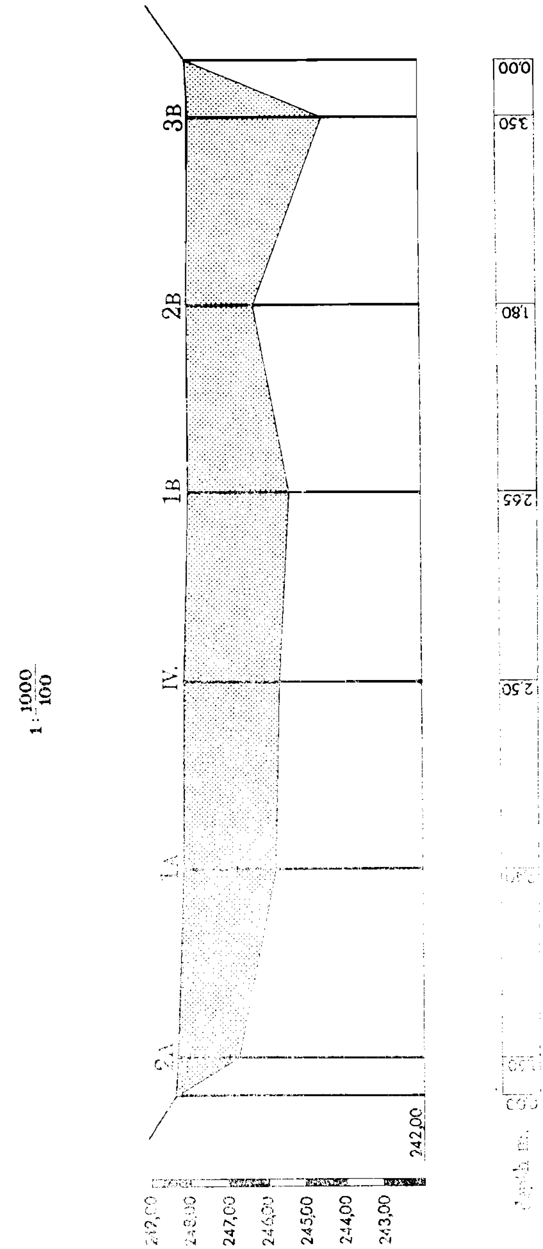

Fig. 4. Słopiec mire: NW—SE section

next stage 1 cm³ sediment samples were subject to Erdtman's acetolysis, adding 2 standart pellets of *Lycopodium* spores (Stockmarr 1971). The counting was continued till at least 500 grains of the tree and shrub pollen, and not less than 300 *Lycopodium* spores were counted. In this way, 20 samples were analysed (Fig. 6).

The pollen diagram from the year 1961 and the present results were the basis for selecting 12 samples for the radiocarbon dating. These measurements were performed in the Laboratory ^{14}C in Gliwice.

The following age determination for the profile Słopiec II (1979/80) were obtained (uncorrected years BP):

Gd — 768	Słopiec II/7	— 27·5– 32·5 cm —	<120
Gd — 774	Słopiec II/18	— 82·5– 87·5 cm —	370±65
Gd — 1157	Słopiec II/29	— 137·5–142·5 cm —	1090±95
Gd — 1241	Słopiec II/40	— 192·5–197·5 cm —	2710±55
Gd — 775	Słopiec II/45	— 217·5–222·5 cm —	3450±75
Gd — 1158	Słopiec II/49	— 237·5–242·5 cm —	3650±50
Gd — 776	Słopiec II/90	— 342·5–347·5 cm —	9090±100
Gd — 703	Słopiec II/80	— 392·5–397·5 cm —	9330±145
Gd — 700	Słopiec II/81	— 397·5–402·5 cm —	9620±120
Gd — 702	Słopiec II/85	— 417·5–422·5 cm —	10 080±160
Gd — 704	Słopiec II/104	— 512·5–515·0 cm —	10 280±210

These datings revealed considerable changes in the rate of sediment accumulation at 3650–9090 BP and 9000–10 000 BP, which requires additional datings and detailed analyses of sediment.

Up to now no other analyses have been done. The following are planned: plant macrofossils, pH, loss on ignition, content of Ca, Fe, Mg, C, N, peat analyses, present vegetation and flora of the locality studied.

Sediment description

The Troels-Smith (1955) system, in a simplified form, was applied to the lithology description. It is as follows (Figs. 5, 6)[1]:

0–85 cm *Sphagnum-Eriophorum-Ericaceae* peat, light brown, slightly silty; at 85 cm a distinct layer of *Ericaceae* shoots
Tb (Sph)^{2}2, Th^{2}2, Ag+, Tl+, Tl (Eric)^1 ++

85–125 cm *Sphagnum-Eriophorum* peat, light brown, with pieces of wood
Tb (Sph)^{2}2, Tb, (Erioph) 1, Th 1, Dl +++

125–360 cm Swamp peat, brown, slightly elastic, with pieces of wood, at 190–222 cm pieces of charcoal
Th^{3}4, Dl +, Anth +

360–450 cm Swamp peat, brown, elastic, numerous rhizoms and shoots of swamp plants, pieces of wood
Th^{3}3, Dl 1

450–512 cm Swamp peat, blackish-brown, very elastic, rhizomes (shoots) of swamp plants, numerous seeds of *Menyanthes*, single pieces of wood
Th^{2}4, Dl +, Ag +

[1] Figs. 5 and 6 under the cover.

512–515 cm Fine sand
Ga 4, Th +
515–525 cm Peat, dark brown, sandy
Th²3, Ga 1, Ag +

Division of pollen diagram into local pollen assemblage zones and their description

The distinction of local pollen assemblage zones was based on the proportional and characteristic participation of pollen and spore taxa in the spectra of the given section of pollen diagram (Figs. 5, 6). The division concerns the profile 1979/80.

Sł — 1, *Larix* — *Juniperus* — *Pinus* zone

Larix pollen occurs sporadically but it is characteristic of that zone. *Juniperus* pollen does not give a continuous curve in the whole zone either. *Pinus* and *Betula* are dominant pollen types. Within the herb pollen *Artemisia*, *Cyperaceae*, *Typha latifolia*, *Menyanthes* and *Rosaceae-Comarum* type have significant curves.

Sł — 2, *Populus-Polypodiaceae* zone

Pinus and *Betula* are still dominant pollen taxa. *Populus* pollen forms a low but continuous curve, nearly restricted to that zone. The high peak of *Polypodiaceae* curve (about 80%) is the second characteristic element. *Ulmus* pollen curve has also a low, but distinct peak.

Sł — 3, *Salix* — *Betula* zone

Betula pollen curve maintains constantly high but with a tendency to form peaks. *Salix* pollen reaches there its maximum values (17%).

Sł — 4, *Pinus* — *Ulmus* zone

Pinus pollen forms a distinct and regular maximum exceeding its values in other zones. *Ulmus* pollen, which appeared earlier, reaches its maximum, although not very high values.

Sł — 5, *Corylus* — *Alnus* zone

The zone begins with the continuous curves of *Alnus*, *Quercus*, *Fraxinus* and *Corylus* pollen, consistently rising throughout. *Pinus* pollen values decline constantly. The most prominent pollen taxa are *Alnus* and *Corylus* and of herb taxa also *Gramineae*, *Cyperaceae* and *Polypodiaceae*.

Sł — 6, *Corylus* — *Tilia* — *Picea* zone

Corylus, *Tilia* and *Picea* pollen curves have maxima, *Alnus* and *Quercus* pollen values rise. *Pinus* curve declines and *Carpinus* pollen appear for the first time. The most part of herb pollen curves show tendencies to decline, except for *Polypodiaceae* spores attaining continuously high values.

Sł — 7, *Alnus* — *Carpinus* zone

Alnus and *Carpinus* pollen curves increase continuously and reach their maximum values. The beginning of zone is indicated by the continuous curves of *Fagus* and *Abies* pollen (3650±50 years BP). The pollen curves of *Corylus*, *Ulmus* and *Tilia* show a pronounced tendency to fall.

Sł — 8, *Carpinus* — *Fagus* — *Abies* zone

Having reached its maximum in the zone Sł — 7, *Carpinus* pollen curve remains at high values. *Fagus* and *Abies* curves are rather consistent with a tendency to reach maximum values. *Pinus* pollen curve rises moderately. Most of other tree pollen curves decline. Culture indicators are sporadic but occur more regularly.

Sł — 9, *Pinus* — *Betula* — *Quercus* zone

The distinct peat of *Pinus* pollen and some rise of *Quercus* pollen curve are characteristic features of this zone. *Betula* also forms a distinct peak in the older part of zone. Almost all indicators of man activity form continuous curves. There occur simultaneous curves of the aquatic and swamp plants, with a high maximum of *Sparganium* (about 70%).

Sł — 10, *Cannabis* — *Fagus* — *Pinus* zone

The most characteristic features of this zone are: the maximum values of *Cannabis* pollen (4·7%), a slight rise of *Fagus* curve, and the increasing *Pinus* pollen curve. The peaks of *Gramineae*, *Cyperaceae* and *Artemisia* pollen, the gradual disappearance of pollen of aquatic plants, and to a lesser degree, of swamp plants (*Sparganium*) are also characteristic.

Sł — 11, *Rumex* — Cerealia zone

This zone is distinguished by the maximum pollen values of Cerealia and of man accompanying plants. The pollen curves of all trees decline or disappear in the diagram.

HISTORY OF THE CHANGES IN THE NATURAL ENVIRONMENT

History of regional changes

The pollen analytical studies of peat-bogs in the region of the Świętokrzyskie Mts. (Szczepanek 1961) have shown that the Słopiec peat-bog contains the fullest series of sediments and is representative of that region. The present studies show a considerable concordance of results with previous investigations, but age determinations indicate that there were breaks in the peat accumulation. A precise determination of the age of these breaks will no doubt influence the final interpretation of the pollen diagram.

The results obtained so far are the basis for reconstruction of the vegetational history of the Świętokrzyskie Mts. The ratio of the tree and shrub pollen to herb pollen proves that the pine-birch forests with some larch were dominant plant communities at least from 10 280±210 years BP (pollen zone Sł-1). The forest was not close at that time, there were vast open areas where light-demanding plants developed. They were represented by *Juniperus*, *Ephe-*

dra, Artemisia, Rumex, Gramineae and *Cyperaceae*. Forest communities seemed to show the tendency to expand over those treeless areas (the rise of *Betula* curve). The composition of those communities was enriched with new elements. This is indicated by the beginning of the *Ulmus* curve.

This stage of development of plant communities ended with the opening of forests (the pollen zone Sł-2, 10 080±160 years BP). Only the *Ulmus* curve shows a slight but distinct rise. *Populus* was here a light-demanding element. Herb communities gained good conditions for development there, especially *Artemisia* and *Gramineae*. The most abundantly represented were *Polypodiaceae*. Aquatic plants, and particularly swamp plants, expanded in water pools.

The next stage of vegetational development (the pollen zone Sł-3) was characterized by the expansion of forest communities. This is indicated by the rising pollen curves of *Pinus* and *Betula*. The birch species, as shown by the characteristic peak of *Betula* pollen, certainly played a pioneer role in colonizing various habitats. Various species of *Salix*, played a similar role on the habitats with a relatively high groundwater level. The formation of close forests and willow shrubs limited, to a high degree, the development of herbaceous plant communities.

The formation of pine forests, as dominating communities of a climax character on poorer habitats, and elm and mixed forests on more fertile soils was a new stage in the development of plant cover (pollen zone Sł-4).

During the pollen zone Sł-5 the plant communities showed successive changes, as new plants with higher habitat demands appeared. These were *Alnus*, *Quercus, Fraxinus* and *Corylus* and later *Tilia* and *Picea*. *Alnus* and *Corylus* dominated in the forest communities. *Pinus* was gradually replaced by deciduous trees. The forests were rather loose what is shown by high pollen values of *Gramineae, Cyperaceae, Polypodiaceae* and also of swamp plants (these are, besides *Cyperaceae* pollen representing mostly such type of vegetation, also *Lysimachia, Filipendula ulmaria* type, *Thalictrum* and *Rubiaceae*). This phase of vegetational development corresponds probably to the Atlantic period.

A new stage of changes in plant communities — pollen zone Sł-6 — was characterized by the dominance of deciduous trees. Besides alder and spruce — the latter showing pollen maximum of 7·6% — *Corylus, Quercus, Tilia* and *Fraxinus* were the most important forest components. *Carpinus* was a newcomer. Herbs were represented mainly by ferns (*Polypodiaceae* including *Pteridium*).

The next phase of forest succession (the pollen zone Sł-7) was a phase of mixed and deciduous forests with the dominance of *Alnus* and the participation of *Picea* and *Quercus*. These forests were relatively quickly transformed into the forests with a dominant role of *Carpinus* and decreasing participation of *Alnus* and *Picea*. The forests growing at higher altitudes were also subject to changes. There appeared new tree species, which up till now have been signalized by single pollen grains in the pollen spectra. These were *Fagus, Abies*, and *Acer*. The distinct decline of the *Ulmus* pollen curve, and subsequently of *Corylus, Tilia* and *Fraxinus* curves, was a characteristic feature of this phase of transformations of forest communities. The record of herbaceous vegetation shows an absolute minimum here. However, new elements appeared, i.e. the plants accompanying human activity (*Rumex, Plantago lanceolata*).

Fagus and *Abies*, which appeared at about 3650±50 years BP, became the dominant trees, particularly in the forests of higher situations (from about 2700±BP, the pollen zone Sł-8). In depressions and at lower altitudes *Carpinus* showed the greatest expansion. This tree replaced above all *Alnus* and *Picea*.

In this phase the forest development began to be distinctly influenced by human activity. This is expressed by the more and more regular appearance of pollen of cultivated and synanthropic plants. Tree stands were then formed mainly under the influence of anthropogenic factor, what is evidenced by the systematic rise of *Pinus* pollen curve, and most probably by the oscillations of the pollen curves of other trees (*Carpinus, Betula, Quercus*). Herbaceous plants react by the greater participation of *Gramineae* and also of *Cyperaceae*.

Since 1090±50 BP (the pollen zone Sł-9) human activity has essentially influenced the composition of forests of almost all types. *Carpinus, Fagus, Abies* and *Alnus* (decline of pollen curves) and *Pinus* (rise of pollen curve) reacted most distinctly. This phase in the pollen diagram is characterized by high participations of *Pinus*, *Betula* and *Quercus*. *Ulmus* and *Tilia* disappeared at the end of phase. The pollen curve of herbaceous plants rises. The clearances of forests and climatic changes are evidenced by the mass occurrence of aquatic and swamp plants in the basin under investigation. The change in the character of sediment proves the changes in its hydrological conditions. The pollen curves of cultivated and synanthropic plants became continuous at the end of that zone. Traces of ancient metallurgy in the Świętokrzyskie Mts. are dated at XI century (Łabęcki 1841), and the changes mentioned above were certainly connected with the intensification of economy.

The forests existing under an increasing pressure of human activity were subject to further transformation (the pollen zone Sł-10). Their area diminished. The composition of forests also changed as a result of selective timber exploitation. The forests growing in habitats unsuitable for cultivation, and the trees with a wide scale of ecological demands and great tendency to expansion have best chances for survival and preservation. All these conditions are to a high degree fulfiled by *Pinus*. The forests became looser and this is probably reflected by the relatively smooth pollen curve of *Quercus*. The habitats with a high groundwater level were the least disturbed and favoured the preservation of *Picea* and *Alnus*. The slight rise of the pollen curves of *Betula, Quercus, Alnus, Picea, Fagus* and *Corylus* may be interpreted as an expression of a short recession of settlement and agriculture.

This phase is characterized mainly by the increase of herbaceous plants in the pollen diagram. Besides *Gramineae* and *Cyperaceae*, cultivated and synanthropic plants predominate. Beside the cultivation of cereals, the cultivation of *Cannabis*, a plant of great significance for agriculture of this time, may be regarded as a characteristic feature of the phase.

The youngest stage of vegetational changes (the pollen zone Sł-11) is represented by the time shorter than 120 years. The picture shown in the pollen diagram is like that of the recent vegetational relationships in the nearest surroundings of the peat-bog and in the whole region. Pine forests, or mixed forests with pine, predominated. Other types of forest communities were heavily transformed by man and preserved in fragments only. The local herbaceous vegetation and cultivated fields were the main producers of pollen, recording the history of the transformations occurring in the plant cover. Cerealia and synanthropic plants were its most typical components.

The last two phases (the pollen zones Sł-10 and 11) covering the sediment section from a depth of 1 m up and the time of about 400 years (fig. 6) were studied in a more detailed way (see methods). The percentage pollen diagram was used to describe the history of the plant cover. The pollen concentration diagram may be interpreted as an expression of the rate of sediment accumulation. The distinct increase in the concentration of *Pinus* pollen, 120 years ago, was perhaps associated with the clearances of forests and cultivation of that tree.

History of the peat-bog

At the present stage of studies, a more detailed reconstruction of the history of the peat-bog investigated is impossible. In general, the reconstruction of changes of habitat conditions may be presented as follows:

In the meander, modelled by the Belnianka stream an oxbow lake was formed as result of the shifting of its central current and relatively quickly it was intruded by reedswamps (*Typha, Filipendula, Equisetum*). As the water pool became overgrown, shrubs and trees encroached the swamp. However, the high groundwater level was still maintained. It favoured the development of a mosaic of plant communities.

Distinct changes in the water regime in the swamp occurred as late as about 1090 years BP. The groundwater level was considerably raised. In the shallow lake, which was formed then, the communities of typical aquatics and of swamp plants developed. The trend of vegetational succession went towards the oligotrophic bog communities. The water pool became overgrown, and the recent mosaics of plant communities occupied the bog surface.

CONCLUSIONS

The comparison of the results of pollen analyses obtained in the years 1961 and 1979/80 has shown the similarity of the particular pollen curves, and similar stratigraphic position of the characteristic phenomena of successional significance. Twelve samples have been radiocarbon dated. The age of the bottom sample dates the beginning of the mire formation at 10 280±210 years BP.

The datings showed considerable changes in the rate of sediment accumulation within the time intervals of 9000–10 000 years BP and 3650–9090 years BP. These sections of the profile require more detailed studies and additional datings.

The results obtained at present do not change the interpretation of the plant history of that region, but they change essentially the chronology of the phases of vegetational development.

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Fig. 5. Percentage pollen diagram from Słopiec mire — a reference site for the region 4c — Świętokrzyskie Mts. (Holy Cross Mts.) in Poland. In the diagram: Percentage pollen values based on analyses made in 1961 (continuous line) and in 1978 (broken line) are compared. Calculation base is sum of trees, shrubs, dwarf shrubs and herb pollen. Exluded are pollen of aquatics and swamp plants and spores. Their percentage values are calculated from sum = $\Sigma P +$ taxon. Stratigraphic symbols follow Troels-Smith (1955).

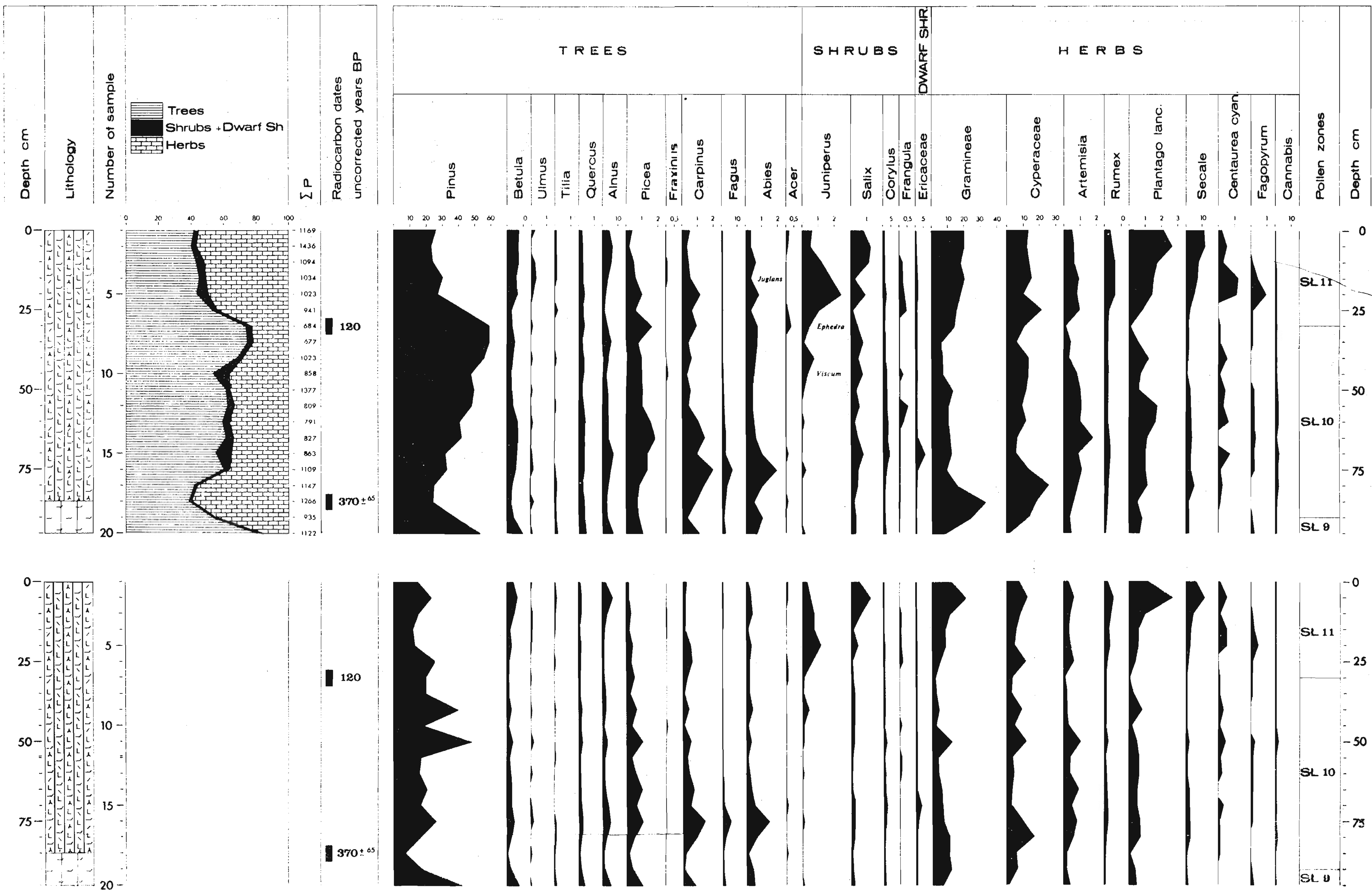

Fig. 6. Percentage pollen diagram (above) of the upper part of Słopiec profile, and pollen concentration diagram (beneath).