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RECONSTRUCTION OF VEGETATION DEVELOPMENT ON THE FLOODPLAIN OF THE LITAVKA RIVER IN THE HOLOCENE (CENTRAL BOHEMIA, BRDY MTS.)

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Abstract. The Brdy Mountains are located in Central Bohemia and consist of resistant Cambrian quartz conglomerates, Ordovician quartzites and also Proterozoic chert-rocks in the south. Geological mapping based on palynological research show on sheet 22-122 Bohutín (1 : 25 000) sediments of bog soil in the locality of Bohutín (B), which are part of fluvial, predominantly loam-sandy sediments of Holocene age which filled up the valley floodplain on the terrace of the Litavka River. The aim of this work was to assess the probable composition of vegetation in the studied territory during the selected period. The finishing works in terrain were used for sampling and for laboratory analysis of samples the usual methods with HF and a modified method of acetolysis according to Erdtman (1943, 1954) were used. The sediments from the locality of Bohutín (B) are stratigraphically classified (according to Firbas 1949, 1952) as Older Subatlantic (IX, LPAZ: B1-IX – depth 0.43-0.50 m to B3-IX – depth 0.025-0.23 m) and the upper sample as Younger Subatlantic (Xa, LPAZ: B4-X – depth 0-0.025 m). Vegetation is represented mainly by fir-spruce and spruce-fir forests (*Picea*, *Abies*) mixed with alder (*Alnus*), pine (*Pinus*), birch (*Betula*) and climatically more demanding types: linden (*Tilia*), beech (*Fagus*), maple (*Acer*), hazel (*Corylus*), hornbeam (*Carpinus*), elm (*Ulmus*) and oak (*Quercus*). In the pollen spectrum the human impact also became evident by the presence of corn pollen grains and other weeds. The vegetation is greatly influenced by the close vicinity of the Brdy Mts.

■ palynology, floodplain, Litavka River, Bohutín, Central Bohemia, Brdy Mts., organic sediments, Holocene, Quaternary, Czech Republic

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Introduction

Geological mapping based on palynological research shows on sheet 22-122 Bohutín (scale of 1 : 25 000, Mašek et al. 1986) sediments of bog soil, which were on this occasion found by J. Straka on the terrace of the Litavka River in the municipality of Bohutín (Text-fig 1). The results gained by pollen analysis contributed to clarification of the palaeographic and stratigraphic development of the territory of Podbrdsko and the Brdy Mts. themselves. The aim of the present research was to assess the probable composition of vegetation in the territory studied during the selected period. Any results from this area are valuable mainly because in the Brdy Mts. it had not been possible to carry out similar research in the past.

The regional concept of the Brdy Mts. and the Podbrdsko area has been a matter of dispute in various literature depending on which criterion or division we are following at that very moment. As far as the whole natural territorial is concerned, its characteristics are a result of very distinctive natural agents. A great many authors have concluded that it is necessary to differentiate this territory into at least two parts: as a natural unit – the Brdy Mts. themselves and in addition a territory connected by certain social traditions – the broader territory of Podbrdsko (Štěpán 1988).

The broader area of the locality of Bohutín is geomorphologically classified as belonging to the Hercynian system – subsystem Hercynian Mountains – province: the Česká vysočina Highland I, where the Českomoravská subprovince belongs – area of Central Bohemian pahorkatina Upland and the Poberounská subprovince – area of the Brdská and Plzeňská pahorkatina Upland (Balatka et al. 1971, Czudek et al. 1972). The Brdy area core consists of the described territory of the whole of the Brdská vrchovina Highland with sub-deivisions of the Brdy Mts., the Hřebeny Mts. and the Příbramská vrchovina Highland.

Almost the whole territory of the geological map of Bohutín (22-122) is orographically a part of the Brdská vrchovina Highland, that is the Brdy Mts. themselves (N-W forested part) and the Příbramská pahorkatina Upland (Mašek et al. 1986). The Brdy Mts. are a system of uplands with the highest peak being Praha (860 m above sea level). It is the highest unbroken woody area in the Central Bohemian Mountain, which is also a hydrologically significant water reservoir in the territory between the Bohemian Forest (the Šumava Mts.) and the centre of Bohemia (Domin 1926). The Brdy Mts. are an important area of highlands between the West Bohemian and Central Bohemian pahorkatina Upland with a basement of predominantly Cambrian conglomerates and Ordovician quartzites; the S-W edge is formed by flinty shales. Rounded peaks and wide ridges of predominantly Barrandian direction divided by wide valleys are its characteristic relief. The forested surface of the

Brdy Mts. has an average height of 600-700 m a.s.l. It is distinctly marked off by steep slopes from its surroundings. It continues to the NE as the Hřebeny Mt., separated by the Litavka River.

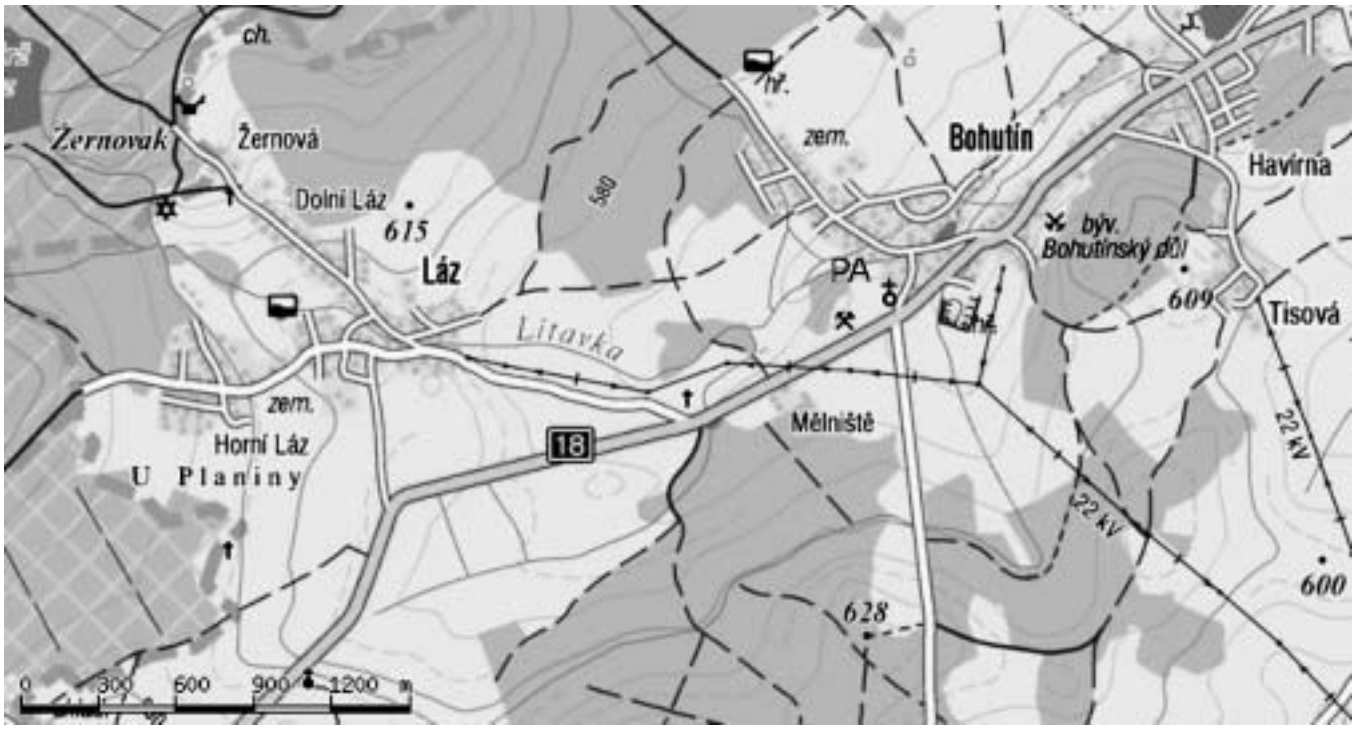
The broader area of Bohutín locality belongs climatically to the mildly warm districts with the exception of the territory of the Brdy Mts., which are in a transition between cold and mildly warm districts (Vesecký et al. 1961). The Brdy Mts. has a surplus of rainfall; the areas closest to the Central Povltaví area are in the rain shadow. The Brdy Mts. themselves are a local barrier against winds from N-W, because they are extending upright precisely in that direction. The total annual rainfall ranges from 594 to 657 mm on average (Štěpán 1988). The broader area belongs to the Berounka River Basin, the local river is the Litavka. Its valley gravels and slope sediments of the Brdy and Hřebeny Mts. are of hydrological importance (Mašek et al. 1986).

The locality of Bohutín lies in the territory between Rožmitál under Třemšín Hill and Příbram. The territory is built up of several regional geological units. The Barrandian Cambrian of the Příbramsko-Jince Basin, which is characterized by conglomerates, sandstones and greywacke of continental origin, is the most frequently represented. Its basement is formed by rocks of the Upper Proterozoic, which belong to the lower part of the Kralupy – Zbraslav group. Lithologically it consists of greywacke, siltstones, and shales, or perhaps volcanites. The Štěchovice group is also represented (again siltstones, shales with a small portion of greywacke). The valley between Bohutín and Příbram belonged to the Příbramský ore district and therefore it is strongly affected by mining. Since the 14th century, mining of silver and lead-zinc ore had been developing here, culminating in the 19th century. In the fifties of the last century there was a new boom of uranium ore mining, and to a lesser degree iron-manganese ore mining. In the area of the Bohutín locality several quartz veins occur in which a low content of gold were found. Before deep mining, gold panning had occured since the pre-Slavonic period to the 15th century (Vlašímský in Mašek et al. 1986).

Considering soil typology, soils of brown earth type prevail in this territory. It consists of lighter soils on granodiorites, heavier, loamier soils on Palaeozoic and Proterozoic layers. In the forested areas there are mainly podzol soils, in the valleys, floodplain soils.

Regarding the Quaternary sediments, there are vast overburdens of Quaternary slope deluvial debris and loams. With respect to the overlying rock, they are more widespread than other types of Quaternary sediments (deluvial-fluvial and fluvial sediments). Fluvial, predominantly sandy-loamy sediments filled up the valley floodplain of the Litavka River and all other small watercourses to a thickness of 1–2 m. The bases usually contain numerous boulders and blocks of a size up to 30 cm, upper parts are strongly sandy with a higher content of humus. Occasional outcrops S-W of Bohutín (recorde during regulation and melioration) exposed these sediments in the whole thickness including the upper part of the valley (Würm) terrace of the Litavka River. Only locally, there are lenses of light grey clay at a thickness of about 0.5–0.7 m on the terrace, higher is a layer of bog soil, locally up to 1 m thick with an abundant content of plant macro-remains. The bog soil turned out to be suitable for pollen analysis.

The Brdy Mts. covers phytogeographically the central highest almost entirely forested part of the Brdy Massif, which has the character of mountain vegetation and flora, where, with exceptions, representation of thermophilic species is lacking. In the natural forest communities, conifers are prevailing, mainly spruce (*Picea*) in climax vegetation (as mixed mountain forest with representation of spruce, beech *Fagus*, fir *Abies*, mapped as *Luzulo-Fagion*) in



Text-fig. 1 Map of the area surrounding Bohutín and the Litavka River. PA – locality. www.mapy.cz

mountainous positions and also in waterlogged to peaty communities. In places of deforestation, there are meadows and pastures.

The Brdy Mts. were originally overgrown by dense mixed forests, their remains are protected today in the reservations of Třemšín, Teslíny, Karlov, Terešovské hutě, etc. (Domin 1903, Veselý et al. 1954). Today, a big part of the territory is deforested or converted to cultivated spruce forests. In remains of fir-beech forests, sycamores (*Acer pseudoplatanus* L.), lindens (*Tilia*) and pines (*Pinus*) are plentifully represented (Veselý et al. 1954).

The locality of Bohutín belongs phytogeographically to the area of mesophyticum in the district of Podbrdsko and the sub-district of Příbramské Podbrdsko (Dostál 1960). The area of mesophyticum borders the oreophyticum of Brdy, therefore in this part particularly, forests projecting from the Brdy Mts. and some other ecosystems have a direct connection or relationship with the Brdy Mts. flora and vegetation.

Vegetation stages from supracolineous up to mountainous are represented here. The floral influence of the NW part of the Šumava Mts. is mediated and becomes evident only by the presence of some mountain plant species (e.g. *Soldanella montana* WILLD., *Circaea alpina* L., *Lonicera nigra* L., etc.). Thermophilic types can be found rather more in deforested parts. The Příbramské Podbrdsko area (where the locality belongs) consists of 2 different parts, from the forested Hřebeny including a canyon of the Litavka River and the less forested peneplain of the Milín part.

The current vegetation was studied and described by a number of botanists (Hlaváček et al. 1998, Hrouda and Skalický 1988, Sofron 1982, 1998). Spruce trees occur in the Brdy Mts. today (as *Piceo-Alnetum*, which accompanies watercourses in forests) also as relict vegetation first in flat parts usually as a mixture with fir (*Abies*), after termination of vegetation development in the sub-recent as fir-spruce trees up to firs. According to Svoboda (1943) spruce reached the greatest distribution in the surroundings of the present Padrťské ponds and between Chynín and Míšov. Nowadays the majority of the Brdy Mts. forests are covered by spruce mono-culture. Firs also grew on exposed peak positions on foothills of debris, because there was probably less rivalry with beech (*Fagus*). A spruce mixture was formed with fir in waterlogged places. Elsewhere another mixture was with alder (*Alnus*). Fir-spruce trees were more abundant than waterlogged spruce trees. As far as deciduous forests are concerned, characteristic species in the territory of the Brdy Mts. were mapped by Štěpán (1974, 1975), e.g. the alliance of *Tilio-Acerion* is scarce on nitrophilous debris in the Hřebeny and canyon of the Litavka River and on boulder debris in the Brdy Mts. (mainly an association of *Aceri-Carpinetum* and *Arunco-Aceretum*). Non-forest vegetation is represented by bog to peaty meadows and cultivated meadows.

On the peak parts of the Hřebeny and in a canyon of the Litavka River some types of plants living on rockeries and debris might have also continued. Along brooks, with exception of forest segments, a uniform species composition occurs. Nowadays, a big part of the territory of the Brdy Mts. is deforested or converted into the cultivated spruce forests. There are also remains of fir-beech forests, in places where beech (*Fagus*) prevails, there is corresponding undergrowth. In mountain forests *Soldanella montana* WILLD., which penetrated here from the Bohemian Forest (the Šumava Mts.), can be found. The once species rich meadow vegetation in the Brdy and Podbrdsko areas became mostly very impoverished or changed by intensive agriculture. The few untouched areas are in the vicinity of ponds or on forest meadows.

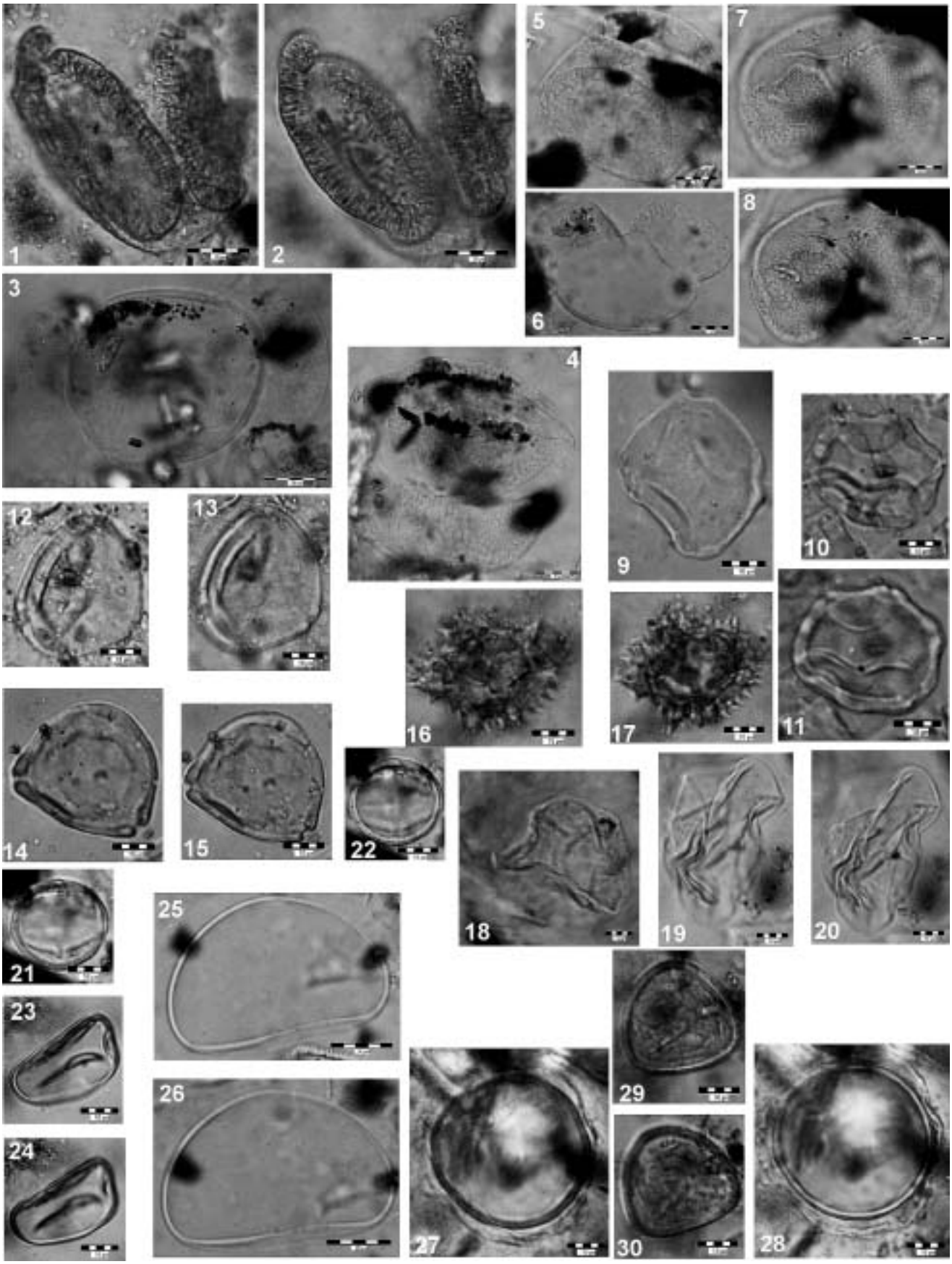
From the forestry point of view, limitation of natural areas of forest vegetation is controlled by the rock basement, terrain configuration and macroclimate. Work by Plíva and Průša (1969) was used for their classification. Forest areas in the study territory are approximately the Brdská vrchovina Highland with a) the Brdy Mts., b) the group of Radeč and the Středočeská pahorkatina Upland with a) the Central Bohemian Pluton b) the foothills of the Brdy Mts and the Hřebeny.

The development and characteristics of forests according to written documents was submitted in the work of Nožička (1957) and Tlapák (1988). In the nearest neighbourhood the spruce-fir or fir-spruce forests were documented at the turn of the 18th and 19th century; elsewhere birches (*Betula)* were planted out. In places pine (*Pinus*), less so larch (*Larix*), beech (*Fagus*) and aspen (*Populus tremula* L.) were scattered in forests.

Methodology

During the final work in this area, i.e. regulation and melioration excavations, samples were taken for pollen analysis. In the following years microscopic elaboration in the laboratory and final evaluation of results were carried out (Břízová 1990). Samples for pollen analysis were collected and placed in a metal box of dimensions 0.5 × 0.1 × × 0.1 m (Erdtman 1943, 1954). 11 samples from 0.01 m to 0.05 m were obtained from it in the laboratory. The laboratory procedure following one-day maceration in hydrofluoric acid HF (Overbeck 1958) involved a modified method of acetolysis as described by Erdtman (1943, 1954) . Maceration in HF serves to begin decomposition of inorganic substances (Overbeck 1958, Faegri et al. 1964), this method of acetolysis decomposes cellulose and surplus organic remains, which prevent clear observation and calculation of palynological objects. A mixture of glycerine – ethyl alcohol – distilled water was used as a medium for microscopy of biological slides. 1–5 slides were observed under the microscope according to concentration of sporomorphs in one sample.

Basic data gained by microscopic analysis were evaluated in order to draw a pollen diagram. In its construction, the sum of pollen grains of woody plants (AP) and herbage (NAP) was considered as 100% (AP+NAP=100%). On the basis of this sum, the absolute values of pollen grains of different types of woody species and herbage were calculated. The number of pollen grains of woody plants in 1 sample ranged from 30 to 500. Such relative values were the basis for construction of the diagram using the program POLPAL (Walanus and Nalepka 1999). Spores and remains of other represented groups were not included in the total sum, but only compared to it. The profile of Bohutín (B) had a thickness of 0.5 m, because of insufficient frequency of sporomorphs in the lower part of profile, the samples were evaluated as percentages. The real amount of pollen grains in individual samples is presented in Table 1, some palynomorphs are presented in the photo table (Text-fig. 2) and document the poor preservation of sporomorphs in these



Text-fig. 2 Photos of palynomorphs.
AP: 1.-2. *Picea* (B4-2, depth 0.35 m), 3.-4. *Abies* (B9, depth 0.10 m, B11-3, depth 0.01 m), 5.-8. *Pinus* (B8, depth 0.15 m, B9, depth 0.10 m), 9.-11. *Alnus* (B8, depth 0.15 m, B11, depth 0.01 m), NAP: 16.-17. Asteraceae Liguliflorae (B4-2, depth 0.35 m), 18.-20. Cyperaceae (B9, depth 0.10 m, B11-3, depth 0.01 m), 21.-22. *Artemisia* (B8, depth 0.15 m), Pteridophyta: 23.-26. Polypodiaceae (B4-2, depth 0.35 m, B8, depth 0.15 m), 27.-28. *Equisetum* (B7, depth 0.20 m), 29.-30. *Sphagnum* (B4-2, depth 0.35 m). Photo E. Břízová.

Table 1 Real amount of pollen grains and spores in individual samples from the locality of Bohutín.

depth (cm)	1	5	10	15	20	25	30	35	40	45	50
AP											
AP - Sum Trees and Shrubs	**609**	**171**	**700**	**643**	**510**	**689**	**570**	**724**	**95**	**11**	**10**
Pinus	196	59	203	203	333	174	103	465	47	3	3
Betula	64	3	39	75	33	104	30	52	5	1	2
Juniperus	1	2	4	6	0	2	0	2	0	0	0
Salix	18	0	1	10	0	0	0	0	0	0	1
Corylus	21	1	14	12	5	49	10	13	0	0	0
Ulmus	2	0	0	1	0	6	0	5	0	0	0
Quercus	1	1	0	3	0	0	3	0	0	0	0
Tilia	9	3	12	10	2	25	6	7	3	2	2
Acer	1	0	1	0	0	1	0	0	0	0	0
Alnus	169	8	118	146	17	201	104	53	16	2	0
Picea	79	55	210	139	84	84	137	80	15	2	1
Fagus	0	0	0	2	0	2	1	0	1	0	0
Abies	45	39	96	35	36	37	176	43	8	1	0
Carpinus	1	0	0	0	0	2	0	0	0	0	0
Larix	1	0	0	0	0	0	0	4	0	0	0
Lonicera	0	0	1	1	0	2	0	0	0	0	0
Hedera	1	0	1	0	0	0	0	0	0	0	0
Tsuga	0	0	0	0	0	0	0	1	0	0	0
Normapolles	0	0	0	0	0	0	0	0	0	0	1
AP + NAP = 100%	**861**	**181**	**879**	**883**	**555**	**859**	**631**	**797**	**118**	**28**	**32**
NAP											
Cyperaceae	62	1	57	81	14	37	7	29	2	5	3
Poaceae	28	0	13	14	2	15	3	2	1	0	0
Bistorta	0	0	3	0	0	0	0	0	0	0	0
Iris-type	0	0	0	0	2	0	0	0	0	0	0
Menyanthes trifoliata	0	0	0	1	0	0	0	0	0	0	0
Polygonum t. amphibium	0	2	0	1	2	0	0	0	0	0	0
Potamogeton	7	0	3	4	1	3	0	1	0	0	0
Scheuchzeria	0	0	1	0	0	0	0	0	0	0	0
Drosera	0	0	1	0	0	0	0	0	0	0	0
Sparganium/Typha angustifolia	8	0	0	5	1	9	4	1	0	0	0
Typha latifolia	1	0	2	6	1	1	0	0	0	0	0
Filipendula	7	0	6	3	0	4	2	2	2	1	0
Asteraceae Tubuliflorae	2	0	1	2	0	1	0	0	0	0	0
A. Liguliflorae	4	2	3	5	2	4	1	0	0	0	0
Brassicaceae	6	0	3	4	0	0	0	0	0	1	0
Campanula	2	0	6	3	0	1	0	4	0	2	0
Boraginaceae	0	0	0	0	0	1	0	0	0	0	0
Cannabis/Humulus	3	0	0	0	0	0	0	0	0	0	0
Cirsium-type	2	0	3	2	0	2	0	0	0	0	0
Convolvulus	1	0	0	0	0	0	0	0	0	0	0
Apiaceae	4	0	3	2	0	7	1	0	1	0	0
Ericaceae	0	0	0	0	0	0	0	0	0	0	1
Chenopodiaceae	2	0	1	1	0	1	1	0	1	0	0
Lamiaceae	1	0	0	0	0	0	0	0	0	0	0
Malvaceae	1	0	0	0	0	0	0	0	0	0	0
Polemonium	0	0	1	0	0	0	0	0	0	0	0
Ranunculaceae	1	0	1	3	0	2	0	1	0	0	0
Rosaceae	2	0	0	0	0	0	0	1	0	0	1
Rubiaceae	1	0	1	0	0	1	0	0	0	0	0
Saxifragaceae	1	0	1	2	1	9	0	5	0	1	3
Caryophyllaceae	1	0	1	3	2	1	0	0	1	0	0
Urtica	0	0	1	0	0	0	0	0	0	0	0
Rumex	5	0	3	1	0	0	0	0	0	0	3
Centaurea cyanus	1	0	0	0	0	0	0	0	0	0	0
Artemisia	3	0	4	6	1	1	3	0	1	0	4
Cerealia	15	0	2	3	0	0	0	0	0	0	0

varia	81	5	58	88	16	70	40	27	14	7	8
NAP - Sum Herbs	**252**	**10**	**179**	**240**	**45**	**170**	**62**	**73**	**23**	**17**	**8**
PTERIDOPHYTA											
Equisetum	12	1	4	6	2	0	0	0	0	0	0
Lycopodium annotinum	0	0	0	0	0	0	0	0	0	0	1
L. clavatum	5	3	6	4	4	1	5	6	0	0	0
Botrychium	0	0	0	1	0	0	0	1	1	0	0
Polypodiaceae	270	86	336	569	275	89	193	282	25	6	11
Polypodium vulgare	0	0	1	0	0	0	0	0	0	0	0
BRYOPHYTA											
Sphagnum	3	0	1	0	1	1	0	90	0	0	0
?spores	0	0	0	0	0	0	0	0	0	0	4
Sum Spores	**290**	**90**	**348**	**580**	**282**	**91**	**198**	**379**	**26**	**6**	**16**
ALGAE											
Pediastrum	5	0	0	0	0	0	0	0	0	0	0
FUNGI											
Tilletia sphagni	0	0	1	0	0	0	1	1	0	0	0
FLAGELLATA											
Dinoflagellata	0	0	0	0	0	0	0	1	0	0	0

sediments. The relative dating of the pollen spectrum was carried out based on its composition. During classification and reconstruction of the vegetation development, the division according to Firbas (1949, 1952) was used. The taxonomic classification of collected pollen grains and spores is according to the Key to flora of the Czech Republic (Kubát et al. 2002), New flora of ČSR (Dostál 1989) and other volumes of Flora of ČSR, ČR (1988-2004).

Phytocoenological evaluation of vegetation was carried out according to the classification by authors who worked in this territory; it is specified according to Flora of ČSR 1. (1988) and according to the list of Plant communities of the Czech Socialistic Republic and their threat (Barkman et al. 1988, Moravec et al. 1983).

Results

Description of profile of Bohutín (B)

During geological mapping of the sheet Bohutín (22-122, 1 : 25 000) J. Straka found (Mašek et al. 1986) locally developed areas of light grey clay and bog soil with plant material content on the terrace of the Litavka River. In the laboratory 11 samples were extracted (at 0.05 m intervals) taking into consideration boundaries of individual layers and designated B11-B1).

Characteristics of sediment:

0–0.01 m – sandy soil with humus admixture, slightly clayey, sample B11

0.05 m – grey-blue strongly sandy clay, sample B10

0.10-0.25 m – brown-grey sandy clay with plant remains and low admixture of peat, sample B9, sample B8 (0.15 m), sample B7 (0.20 m), sample B6 (0.25 m)

0.30–0.35 m – dark sandy clay with admixture of peat and plant remains, sample B5, sample B4 (0.35 m)

0.40 m – grey strongly sandy clay with admixture of peat, sample B3

0.45–0.50 m – grey-blue strongly sandy clay, sample B2, sample B1 (0.50 m)

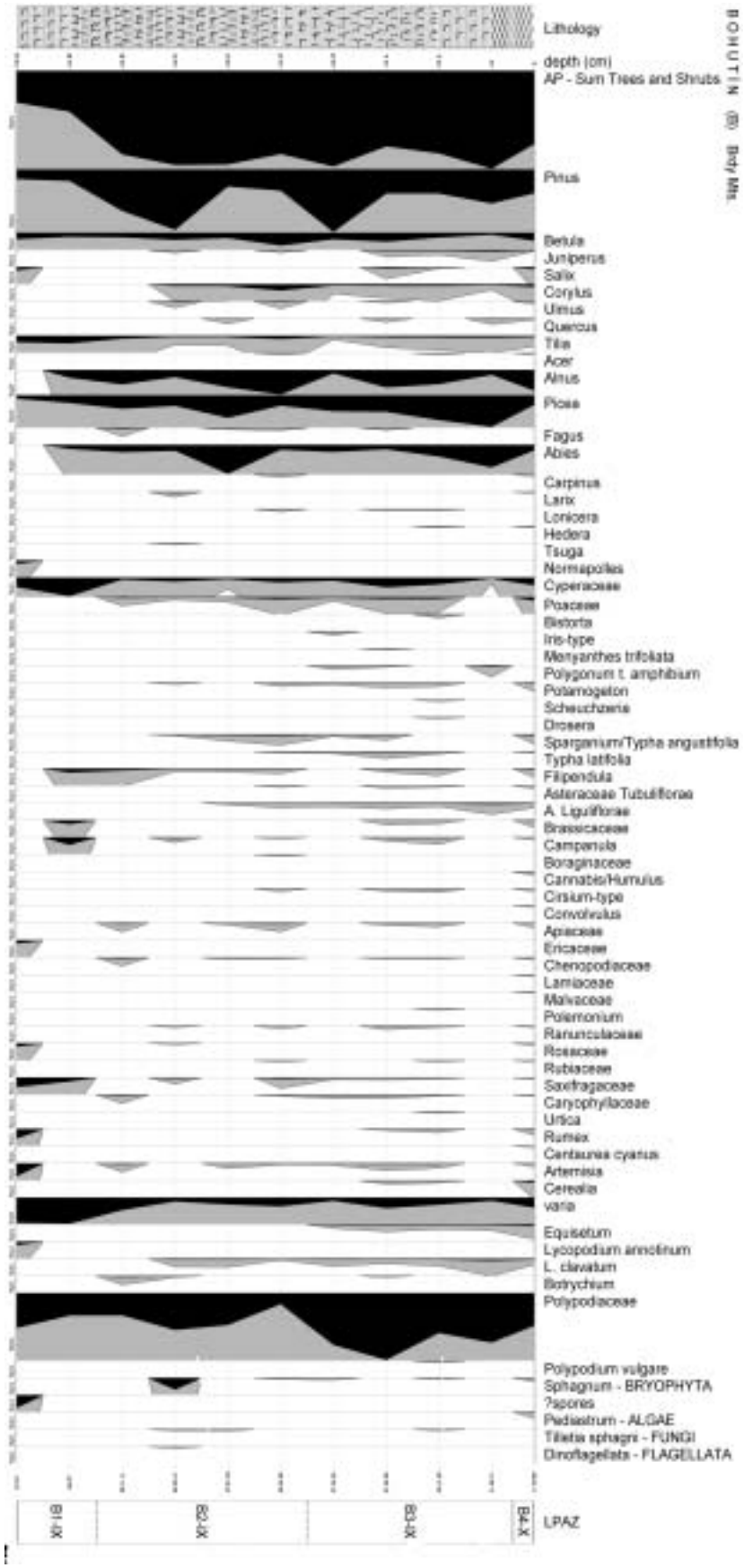
Palynologically assessed sediments were of organic origin with great differences in additional inorganic material. Frequency of pollen grains was not high, but taking into consideration character of the analysed sediment, it was sufficient for palynological evaluation, which is expressed in the pollen diagram (text-fig. 3).

Stratigraphic evaluation of the profile

The area of the Brdy Mts. belongs both botanical and palynologically to the least examined territory of the former Czechoslovakia. Therefore any data from this landscape are important for knowledge regarding the development of natural conditions there.

Research in this territory is mentioned in work from the beginning of the 20th century (Klečka 1926, Rudolph et Firbas 1922). A raised bog near the Tisý pond near Strašice was extrapolated by pollen analysis (Klečka 1926, Firbas 1927). Periods of the Holocene older than the profile of Bohutín are stratigraphically recorded here.

It is stated that since the Pre-boreal or the Boreal, the original woody plant of the Brdy Mts. had been the forest pine (*Pinus sylvestris* L.). Later appearing woody species edged it out to the extreme biotypes, where it has been preserved up to now in the form of relict pine woods (Sofron 1982). Spruce (*Picea*) occurred in the territory only in the Atlantic, in flat parts of the Brdy Mts. and has been preserved usually together with fir (*Abies*) up to now. It is possible that it was an original constituent of forests of the central Brdy Mts. Since the half of the 17th century it has not been naturally distributed, but was cultivated. A more frequent occurrence of fir (*Abies*) than in the Subatlantic has not been documented so far. It is only possible to suggest an earlier presence due to the occurrence in the Subboreal in the nearby Plzeňská pahorkatina Upland and in the Epiatlantic (end of Atlantic and part of Subboreal) in the Czech karst (Ložek 1973). Samek (1961, 1962) and Štěpán (1968, 1974) considered historical fir occurrence. In the 17th and 18th century it was a very abundant woody plant, in the 19th century it was still dominant in the forest vegetation in the hunting ground of Radošice. Only in the 20th century its occurrence decreased markedly. Fir trees grew also on exposed peak parts of the Brdy Mts., foothills of debris, etc., because there was a lesser rival force from beech (*Fagus*). Elsewhere it mixed with spruce trees, in another



Text-fig. 3 Pollen diagram from the locality of Bohutín.
0-0.01 m – sandy soil mixed with humus, slightly clayey, sample B11; 0.05 m – grey-blue strongly sandy clay, sample B10; 0.10-0.25 m – brown-grey sandy clay with plant remains and mixed with a small amount of peat, sample B9, sample B8 (0.15 m), sample B7 (0.20 m), sample B6 (0.25 m); 0.30-0.35 m – dark sandy clay mixed with peat and plant remains, sample B5, sample B4 (0.35 m); 0.40 m – grey strongly sandy clay mixed with peat, sample B3; 0.45-0.50 m – grey-blue strongly sandy clay, sample B2, sample B1 (0.50 m).

place it was replaced by alder (*Alnus*). Samek (1961) considered the beginning of artificial forestation of the Brdy Mts. (central) to be at the start of the 19th century. At that time larches – *Larix* were artificially planted out (Domin 1903, Nožička 1957). Nowadays, cultivated spruce monocultures cover the majority of Brdy forests. Hornbeam (*Carpinus*) spread during the Postglacial from the surroundings of Prague, especially during the Epiatlantic (Ložek 1973). Climatically more demanding forest communities were strongly connected to the lower parts of the Brdy Mts. and the Podbrdsko area.

As early as during prehistoric settlement and after forest development of the landscape (since the turn of the calendar up to Slavonic settlement) deforestation in the Middle Ages again changed the character of flora and vegetation. Forest vegetation remained preserved up to now in the Brdy Mts., on the Hřebeny, etc., even though the woody composition structure has changed to a large extent, which also influenced the herbage stage. The once species rich meadow vegetation in the Brdy and Podbrdsko areas became considerably impoverished or entirely changed by intensive agriculture.

The pollen diagram of Bohutín (B) and profile of Bohutín (B) is records the flora in the Upper (Youngest) Holocene at the boundary of the Older and Younger Subatlantic (IX 2800/2300 B.P.-500/650/700 A.D. and X 500/650/700-1200 A.D. – according to Firbas 1949, 1952). The local palynological zones (LPAZ: B1-IX – depth 0.43–0.50 m, B2-IX – depth 0.23–0.43 m, B3-IX – depth 0.025–0.23 m, B4-Xa – depth 0–0.025 m, see pollen diagram – LPAZ) express sedimentation of the sediment layers, which were influenced by the river, stratigraphically belonging to B1-IX, B2-IX, but B3-IX to the Older Subatlantic (IX) and B4-X to the older phase of the Younger Subatlantic (Xa).

Description of pollen zones (LPAZ)

B1-IX (depth 0.43-0.50 m): *Artemisia – Cyperaceae*

Organic sediments may have started deposition in small drainless depressions, marshland with wetland vegetation mainly with types of family of *Cyperaceae* origins. In the sediment palynomorphs redeposited from the older sediments (*Normapolles*, spores-varia, *Dinoflagellata*) were mixed in.

B2-IX (depth 0.23-0.43 m): *Pinus – Alnus – Picea – Abies – Corylus – QM – Sphagnum*

Deposition continued in mossy ground (spores of the genus of *Sphagnum*) and in alder woods. It is connected with the beginnings of forest invasion. In these sediments the pollen grains of woody plants, mainly pine (*Pinus*), spruce (*Picea*) and fir (*Abies*) were deposited in the floodplain of the Litavka River. The pollen spectrum is greatly influenced here by the nearby Brdy Mountains, where mainly fir, which fully replaced beech (*Fagus*) here, was abundantly widespread at that time. Sporadic findings of woody plants of *Quercetum mixtum* (e.g. elms *Ulmus*, lindens *Tilia*, oaks *Quercus*) document relatively varied forest vegetation in the neighbourhood of the river valley. The herbal constituent was varied, but did not create such a considerable portion of vegetation.

B3-IX (depth 0.025-0.23 m): *Pinus – Juniperus – Picea – Alnus – Abies – Polypodiaceae*

In this phase wetland was again developing, but another type than in the previous periods. After a mild decline of alder woods, willow vegetation (*Salix*) expanded into waterlogged places. Wetland vegetation is characterised in addition to *Cyperaceae,* by bogbean (*Menyanthes trifoliata*), sundew (*Drosera*) and *Scheuchzeria*. In the pollen spectrum, the beginnings of human impact on the surrounding landscape are recorded. Probable pasture is indicated by the occurrence of pollen grains of juniper (*Juniperus*) and stinging nettle (*Urtica*). Even corn (*Cerealia*) is appearing. On the peak parts of the Hřebeny and in the floodplain of the Litavka River some types of plants living on rockeries and debris might have continued (e.g. family *Saxifragaceae*). Abundant occurrence of spores of *Polypodiaceae* documents the presence of spruce woods and a more humid climate.

B4-Xa (depth 0-0.025 m): *Pinus – Cerealia –* anthropophytes *– Alnus – Picea*

It can be seen from the pollen diagram that the woody component was noticeably declining, spruce (*Picea*), pine (*Pinus*) and mainly fir (*Abies*) are diminishing. Forest areas were gradually replaced by meadows and fields. Agriculture is documented by an occurrence of corn (*Cerealia*) pollen grains), weeds (*Centaurea cyanus*) and other plants, which may accompany the human population (*Rumex*, *Apiaceae*, *Brassicaceae*, *Asteraceae*, *Artemisia*, *Poaceae*, etc.).

Development of the vegetation

According to the pollen grains and spores recorded, the vegetation in the surroundings of the locality can be characterized. Even though the profile of Bohutín lies in the area phytogeographically indicated as Podbrdsko, it is evident that it is considerably influenced by the nature of the nearby Brdy Mts.

The sediment probably represents the fading last phase of the Older Subatlantic (IX) and the consequent invasion of the Younger Subatlantic (Xa) seen only in the last sample B11. This is apparent from the appearance of larger amounts of plants, which complement the pollen spectrum as synantrop vegetation: e.g. types of families including: *Chenopodiaceae*, *Brassicaceae*, *Poaceae*, *Malvaceae*, *Lamiaceae*, genus *Artemisia*, *Rumex*, *Cannabis*/*Humulus*, *Centaurea cyanus*, *Convolvulus* and last but not least also corn (*Cerealia*).

The whole profile illustrates that it was a forested territory. Forests consisted mainly of coniferous trees, *Pinus*, *Picea* and *Abies*. There were fewer deciduous woods which included: *Betula*, *Corylus*, *Tilia*, *Quercus*, *Ulmus*, *Carpinus*, *Acer*, etc., a larger representation of *Alnus* accompanied by *Salix* is probably dictated by local conditions. Occurrence of sporomorphs of the type *Normapolles*, *Tsuga*,? undetermined spores and *Dinoflagellata* in the lower part of profile are proof of their redeposition from older sediments.

The climate of the Subatlantic in Central Europe is characterised by a drop of 1-2 degC in average annual temperatures and by mildly increasing amounts of rain in comparison with the Subboreal. Otherwise the climate was steady for the whole period, similarly as it is today (Firbas 1949, 1952, Krippel 1986).

In the Older Subatlantic (IX) in Central Europe, beech woods, into which hornbeam (*Carpinus*) had amply penetrated, prevailed. In Bohutín it was not like that (see pollen diagram text-fig.3), a stronger effect of substantially more

inclement climate due to the proximity of mountains appeared here.

In the Younger Subatlantic (X) also beech woods prevailed, this period is not entirely recorded in Bohutín; therefore it is not possible to reconstruct it precisely. In pollen diagrams of this age, pollen grains of cultivated plants (mainly *Poaceae* and *Cerealia* and different weeds) are already more represented here. The summary curve of pollen grains of woody plants in the pollen diagrams shows a considerable decline in the whole of Central Europe, and also here in the profile of Bohutín. Locally pollen grains of some coniferous trees (mainly *Pinus*, *Picea*, here also *Abies* – effect of the Brdy Mts.) prevailed in the pollen spectra, however some woody species may have been planted out in the neighbourhood (see Nožička 1957), similarly also larch (*Larix*) was introduced into the forest vegetation, but it does not reveal itself in the pollen diagrams so much (probably due to the lower pollen production and reduced ability for pollen preservation).

In the whole Subatlantic, the unfavourable impact of the human population on the environment occurs. Humans deforested vast forest areas for agricultural land; moreover the effect of gold, iron ore and uranium ore mining also became evident in this territory. Deforestation became apparent in the pollen diagram in the lower part of the profile; it could also be a consequence of just emerging wetland, in which all the pollen grains are not sufficiently preserved for reconstruction of vegetation. At the end of the Younger Subatlantic the human population started planting out also exotic woody plants into forests and agricultural cultivation of fields, meadows and pastures occured more.

Of woody plants, the highest representation in this locality was by grains of *Pinus* (pine) – in two maxima of 60 and 58.2%. The lowest values are 16.3%. In the period of the Older Subatlantic a greater number of grains were found than in the Younger Subatlantic. Relatively large values for pollen grains of this woody plant were again probably caused by proximity to the Brdy Mts. Directly after the peak for *Pinus* pollen grains, peaks for *Picea* and *Abies* followed (their proportional values were lower, nevertheless they prove that both these woody plants formed perhaps the dominant vegetation in forests of that period). Their pollen grains again probably originated from natural seeding from the nearby Brdy Mts.

Of deciduous trees, the highest representation was from pollen grains of the genus *Betula*, low values were recorded for other deciduous trees *QM* – sporadically pollen grains of the genus *Fagus* (beech), *Carpinus* (hornbeam), *Ulmus* (elm), *Quercus* (oak), *Acer* (maple), *Lonicera* (honeysuckle) and *Hedera* (ivy) were also found. A continuous curve was recorded for the genus *Tilia* (linden) and *Corylus* (hazel), it could have been already connected with human activity (plantation, impact on natural vegetation, etc.). Since the locality is nearby a watercourse, relatively large numbers of pollen grains from the genus *Alnus* (alder) were found and in the upper part of the profile, the genus *Salix* (willow) was represented. It may be connected with local conditions of the habitat. There were obviously a number of alder trees growing in damper places. Mostly in the upper part of the profile, pollen grains of a pioneer woody plant from the genus *Juniperus* (juniper) were found, its occurrence in nature may be connected with human activity (pasture together with stinging nettle *Urtica*, cutting down of forests, etc.) or as the first woody plant colonisation of unforested territories, as undergrowth, it occurs only to a small extent.

Regarding herbal plants, the greatest number of pollen grains obviously belonged to types of *Cyperaceae* and *Poaceae*. Considering other types, pollen grains of *Asteraceae*, *Caryophyllaceae*, *Saxifragaceae*, *Apiaceae* and *Filipendula* were represented the most frequently, less frequently were found for example, *Ranunculaceae*, *Campanula*, *Cirsium*-type, *Rosaceae*, *Boraginaceae*, *Rubiaceae*, *Lamiaceae*, *Malvaceae*, etc. In small amounts only, pollen grains of water or wetland herbal types: *Potamogeton*, *Sparganium*, *Typha latifolia*, *Filipendula*, *Bistorta*, *Scheuchzeria*, *Polygonum* t. *amphibium*, *Drosera*, *Iris*-type and *Menyanthes trifoliata* were found. From synantrop plants, pollen grains of *Centaurea cyanus*, *Cannabis*/*Humulus*, *Convolvulus* (in X), *Chenopodiaceae*, *Cerealia*, *Artemisia*, *Rumex* and *Brassicaceae* were represented. The number of types of plant increased mainly in the last sample B11 (X).

Of spores present, very abundant were *Polypodiaceae*, less abundant were *Lycopodium clavatum* and *Equisetum*, sporadically found were *Botrychium*, *Polypodium vulgare* and *Sphagnum*. Regarding algae and other remains I occasionally found *Pediastrum* and *Tilletia sphagni* and in the lower part of the profile *Dinoflagellata* (proof of redeposition from older sediments).

It can be seen from the total pollen diagram, Text-fig 3, (Sum of Trees and Shrubs) that in the whole profile, except the lower 5 cm, pollen grains of woody plants (AP) prevailed over herbage (NAP) in the period of the Older Subatlantic, in the Younger Subatlantic there was also a slow but noticeable drop in pollen grains of AP.

At the boundary of the older and younger part of the Subatlantic, a difference in the climate humidity between forested mountains and deforested lowlands came to the fore (Firbas 1949, 1952). In the first half of the Subatlantic, the forests in our territory were in their composition an ideal representative of the present groups of forest types (Zlatník 1959).

In river valleys or on waterlogged bog meadows, alder trees mixed with willows (*Salix*) grew with a corresponding undergrowth of wetland plants eg. *Cyperaceae*, also some *Poaceae*, *Sparganium*, *Typha latifolia*, *Bistorta*, *Potamogeton*, *Iris*-type and *Filipendula*, etc. In the younger period, the human population had greater and greater effect on the composition and expanse of this growth. Even though in the area of the Brdská vrchovina Highland and the Hřebeny, the influence of human activity was not so enormous, it became evident in the pollen spectrum from sample B11 at 0.01 m (X) by a richer representation of synantrop plants such as *Centaurea cyanus*, *Cannabis*/*Humulus*, *Convolvulus*, Chenopodiaceae, *Rumex*, *Artemisia* and Brassicaceae, also suitable types of *Poaceae* mainly used for corn (*Cerealia*) cultivation.

Although the typical forest vegetation for the period of the Subatlantic are beech trees, in this area they had been greatly replaced by coniferous trees (primarily spruce *Picea* and fir *Abies*), which almost wiped out beech (*Fagus*). They then formed mixed deciduous-coniferous forests. Spruce (*Picea*), fir (*Abies*) and pine (*Pinus*) obviously increased as

the principal woody plants. Pine might have also colonized peak parts of the Brdy Mts., various rock outcrops, etc. Maple (*Acer*) and relatively large numbers of linden (*Tilia*) mixed into forests on debris soils. Forest borders or undergrowth was created by hazel (*Corylus*) and juniper (*Juniperus*) – which might have also colonized newly arisen or declining pastures, plus honeysuckle (*Lonicera*) and ivy (*Hedera*). Height zonation of vegetation in the period of the Subatlantic corresponds with that in the present (Firbas 1949, 1952, Jankovská 1980, Krippel 1986).

A starting point for reconstruction of the original composition of forest vegetation is the pollen spectrum recorded in the sediment of the Older Subatlantic (IX). The climate of this period is very similar to the current conditions. Similarly the forest vegetation was not at that time influenced by the human population sufficiently to essentially change the composition. The biggest impact on the vegetation probably started at the turn of the 18th and 19th century, when some woody plants were introduced (Nožička 1957, Tlapák 1988).

During evaluation of the pollen spectrum of the Older Subatlantic, it had to be taken into account that the composition was affected by pollen litter from the territory of the Brdy Massif. As it has already been stated, the mountain massif of Brdy and Hřebeny were at that time continuously forested; fir-spruce or spruce-fir vegetation was the most widespread. In addition to the principal woody plants, pine (*Pinus*) also occurred. In waterlogged habitats, spruce vegetation mixed with alder prevailed. Moreover, the alder may have created vast alder forests around watercourses (with a mixture of herbal wetland vegetation). The presence of *Larix* (larch) pollen probably originates from the neighbourhood of the locality, because it is randomly distributed. Their introduction is documented in written sources much later (see Nožička 1957, Tlapák 1988). From the pollen diagram, the only striking change in the pollen spectrum can be registered in the area of herbal communities. In particular, a larger amount of cultivated plants appeared reflecting human impact on the environment. The summary curve for pollen grains of woody plants in the pollen diagram shows a decrease. Locally some coniferous trees, e.g. *Pinus*, *Picea*, and *Abies* prevailed in the spectra. They certainly extended into places where they would not get naturally, but were planted there later by humans.

Conclusion

The palynological analysis of bog soil sediments, which were a part of fluvial, predominantly loamy-sandy sediments of Holocene age, was presented in this work. These sediments filled up the valley floodplain on the terrace of the Litavka River in the locality of Bohutín (B), and were first recorded by J. Straka (see Břízová 1990, Mašek et al. 1986) during geological mapping of the sheet Bohutín (22-122, 1 : 25 000).

The natural conditions in the wider surroundings of the locality of Bohutín, demonstrate the complexity of classification of this area according to the various standpoints and different authors. Geomorphologic, orographic, forestry, phytogeographic and geological viewpoints were all used here. However, an important finding from all these standpoints is that the greatest impact on the locality is from the close vicinity of the Brdy Mts. that influences this territory in many respects.

The geological base is built up of rocks of the Lower Palaeozoic and Upper Proterozoic. Of the Quaternary sediments, the above described fluvial sediments with bog soil were promising with respect to palynological research. The territory between Bohutín and Příbram was affected by mining of silver, lead-zinc, less so iron (Fe-Mn) ores and gold panning (Vlašímský in Mašek et al. 1986). From an orographic standpoint, the broader surroundings of the locality belong to the Brdská vrchovina Highland, the Brdy Mts. themselves and the Příbramská pahorkatina Upland. From the climatic standpoint, the locality belongs to mildly warm regions; the Brdy Mts. themselves belong to the transition zone between cold and mildly warm regions (Vesecký et al. 1961). The locality itself lies in the rain shadow of the Brdy Mts.

From the phytogeographic standpoint, the locality belongs to the area of mesophyticum, to the district of Podbrdsko and sub-district of Příbramské Podbrdsko. This area borders the area of orephyticum of the Brdy Mts. themselves, which influences vegetation here (Dostál 1960). The Bohemian Forest (the Šumava Mts.) also have a similar impact on this region.

The pollen diagram and profile of Bohutín (B) records the flora of the Upper (the youngest) Holocene at the boundary of the Older and Younger Subatlantic (IX 2800/2300 B.P.-500/650/700 A.D. and X 500/650/700-1200 A.D. – according to Firbas 1949, 1952). The local palynological zones (LPAZ: B1-IX – depth 0.43-0.50 m: *Artemisia – Cyperaceae*, B2-IX – depth 0.23-0.43 m: *Pinus – Alnus – Picea – Abies – Corylus – QM – Sphagnum*, B3-IX –depth 0.025-0.23 m: *Pinus – Juniperus – Picea – Alnus – Abies – Polypodiaceae*, B4-Xa – depth 0-0.025 m: *Pinus – Cerealia* – anthropophytes – *Alnus – Picea*; see pollen diagram – LPAZ) express deposition of sediment layers, which were evidently influenced by river activity; B1-IX, B2-IX, B3-IX belong stratigraphically to the Older Subatlantic (IX) and B4-X to the older phase of the Younger Subatlantic (Xa). The finishing works in terrain were used; the usual methods with HF (Faegri et al. 1964, Overbeck 1958) and modified method for acetolysis according to Erdtman (1943, 1954) were used for laboratory elaboration. Research in this territory is mentioned in work from the beginning of the 20th century (Klečka 1926, Firbas 1927, Rudolph et Firbas 1922). On this basis, stratigraphic characteristics of the vegetation development were deduced.

The original species on the Brdy Mts., from the Preboreal or Boreal, was pine (*Pinus sylvestris* L.). Presumably also birch (*Betula*) was admixed to it. These woody plants were forced out by the later emerging woody plants in the later period to the extreme biotopes. Spruce (*Picea*) occurred on this territory only in the Atlantic and is indicated as an original component of forests of the central Brdy Mts. Fir (*Abies*) appeared probably in the Subatlantic. It has been preserved till the present together with spruce.

The locality of Bohutín (B) demonstrated that in the period of the Subatlantic mainly fir-spruce or spruce-fir forests occurred mixed with alder (*Alnus*), pine (*Pinus*), birch (*Betula*) and climatically more demanding types: lin-

den (*Tilia*), hazel (*Corylus*), hornbeam (*Carpinus*), elm (*Ulmus*), beech (*Fagus*), maple (*Acer*), oak (*Quercus*), etc. In the Older Subatlantic (IX) and probably during the course of the whole Holocene it remained a forested territory, in the Younger Subatlantic (X) forest decline might have taken place. In this area it is not so noticeable, because of the impact of the Brdy Mts. which continually revealed itself in the pollen spectrum. Cultivated plants (*Cerealia* – corn), various weeds and plants, which are connected with human impact, started appearing more markedly. These are, for example, *Centaurea cyanus*, *Chenopodiaceae*, *Cannabis*/*Humulus*, *Rumex*, *Artemisia*, Malvaceae, *Convolvulus*, *Poaceae*, etc., pollen analysis records only an invasion in this period, therefore I based my assumptions on written documents which were connected with this territory. The commencement of artificial forestation of the Brdy Mts., which started according to Nožička (1957) perhaps at the beginning of the 19th century, is not recorded here. It included spruce plantation, less so fir and larch. The climatically more demanding communities were probably connected to the lower parts of the Brdy Mts. and the Podbrdsko area.

The results of pollen analysis are not only important indicators of the development of plant cover, but they can be used in the resolving of some disputable geological and forestry questions concerning the studied territory.

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