



# UPPER HOLOCENE DEVELOPMENT OF VEGETATION AND RADIOCARBON DATING IN THE VICINITY OF THE CERHOVKA BROOK (BOHEMIAN-MORAVIAN UPLANDS, CZECH REPUBLIC)

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**Abstract:** The paper reports the results of a palynological study of a newly exposed section in the peat sediments of Bezděkov site and its correlation with the previous palaeobotanical studies. The main goal was to elucidate the stratigraphic position and paleogeographic development of fossil peat bog and its environment in the Protected Landscape Area Žďárské vrchy and Železné hory in the Bohemian-Moravian Uplands. The development of peatbog vegetation, as shown by the pollen analysis and radiocarbon dating, took place in the Holocene. Pollen analyses provide evidence for occurrences of wetland assemblages with huge representation of alder wood in all the part of succession, followed by willow near the Cerhovka Brook. *Alnus* and *Abies* were the dominant trees during all the time. The deciduous forests consist of elm (*Ulmus*), oak (*Quercus*), lime tree (*Tilia*), maple (*Acer*) and hazel (*Corylus*). The mosaic picture of woodland and wetland, which covered this landscape during the Upper Holocene, contrasts with the present day monotonous open lowland. Sediments of the peat bog provide information on the origin and vegetation evolution of this area.

**Keywords:** palaeoecology, radiocarbon dating, Holocene, Bohemian-Moravian Uplands, Czech Republic.

## 1. INTRODUCTION

Pollen analysis of peat bog complexes in the Českomoravská vrchovina (Bohemian-Moravian Uplands) provides a possibility of monitoring the development of vegetation during the Late Glacial and the Holocene period after recession of the last glaciation about 15,000 years ago. A review of the oldest palynological studies on this territory (Firbas 1927, Rudolph 1927, Salaschek 1935, Puchmajerová 1943, Knebllová-Vodičková 1961, 1966, 1970) allows to conclude that pollen analyses were

being carried out almost since their introduction into geological research. Later palaeobotanical research was carried out for the southern part of the region by Rybníček (Rybníček and Rybníčková 1961, 1968, Rybníčková 1974, Rybníčková and Rybníček 1980) and Peichlová (1977). Palaeobotanical research in the Světelsko area was carried out by Jankovská (1971, 1990).

The current paper presents the results of research performed in the northern part of the Protected Landscape Area of Žďárské vrchy Hills and Železné hory Mts (Fig. 1). The most integral palaeoecological results were obtained from the deepest part of Velké Dářko peat bog

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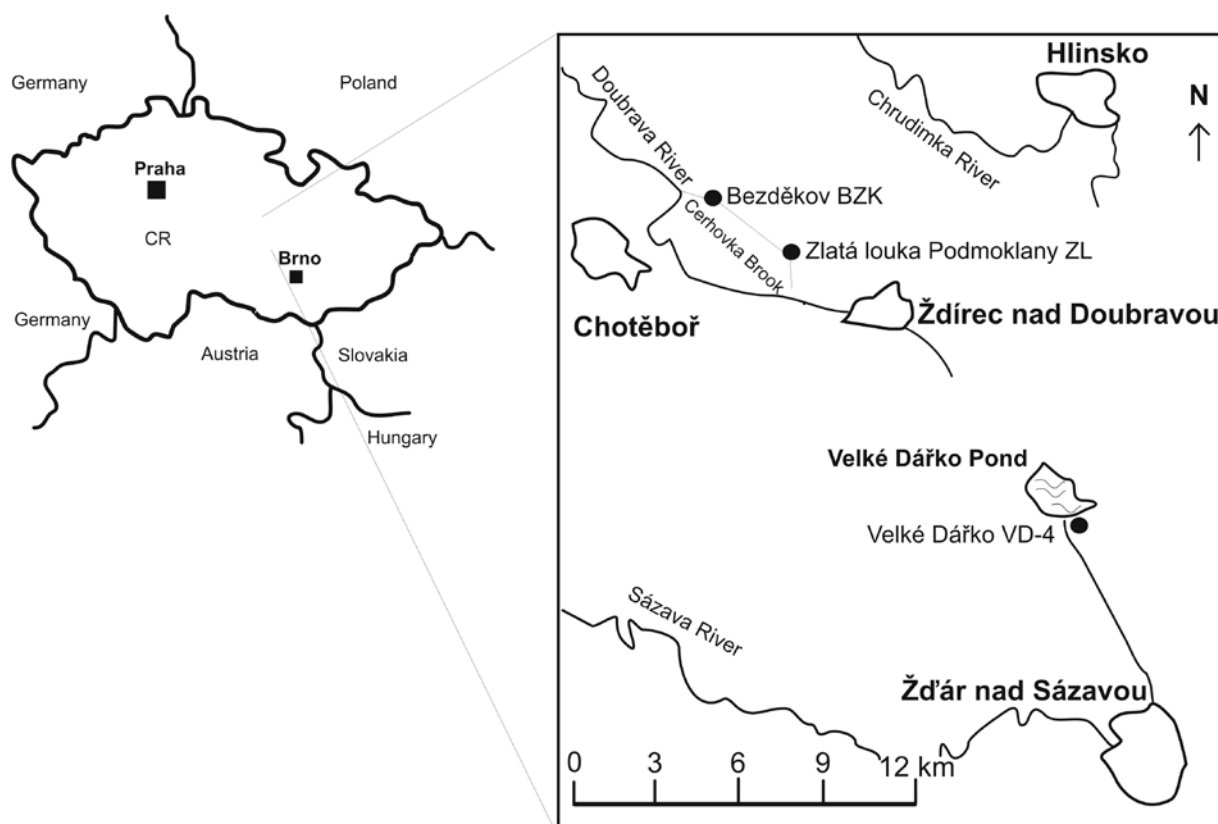


Fig. 1. Map of the area surrounding Bezděkov (BZK), Velké Dářko (VD-D4), Zlatá louka (ZL). BZK, VD-D4, ZL – localities (locations of profiles).

(8.25 to 8.6 m, Krucemburk sheet of geological map, scale 1:25 000), transitional peat bog Zlatá louka meadow by Podmoklany (2.00 m, Chotěboř sheet of geological map, scale 1:25 000) and fens in the alluvial plain of the brook Cerhovka (locality Bezděkov, Chotěboř sheet, Figs. 2 and 3).

The geological mapping of Quaternary sediments of the Protected Landscape Area of Žďárské vrchy Hills and Železné hory Mts and palynological research in the chosen localities provide important data on the Quaternary development of this territory. The results of pollen analyses extend the knowledge on the territory development and its state from the standpoint of environmental quality, dynamics of forest development and other vegetation cover. They also indirectly draw attention to water management importance of this area.

In the past a number of peat bogs were devastated by exploitation, for example, one of the most unique peat bog complexes of Zalíbené was entirely extracted (Knebllová-Vodičková 1961, 1966, 1970). Smaller wetlands were often affected by local exploitation or had to undergo technical works. In the past, peat was mainly used locally in gardening, for balneological purposes and probably for heating.

The Železné hory Mts were declared Protected Landscape Area only in 1991, but their height, area and importance cannot be compared with the Žďárské vrchy

Hills. The geological basement originated in the Pre-Palaeozoic (quartzites, granites), the Mesozoic (sandy marls, marlstones), while the younger part of the territory has been developing until the present time. In the southern part, the mountains border with Cretaceous sediments of the so-called Long ridge. Inside the mountains, the landscape is divided by many valleys, river plains, rocky gorges and hills, forests and human settlements. The good state of preservation of the natural environment ranks it among unique objects in the Czech Republic.

For the reconstructions of the palaeogeographical and palaeoecological development of the territory the peat bogs are most important, situated roughly between towns of Hlinsko – Svatka – Nové Město na Moravě – Žďár nad Sázavou – Ždírec nad Doubravou. Altogether, there are about 135 wetlands which are classified as raised bogs, transitional peat bogs and fens. Besides the above listed wetlands, there are also peat bogs originated secondarily, for example, in places of discharged ponds, obviously as remnants of former fish farming. The largest complex of unique wetland biotopes is indisputably the Ranské mokřady (wetlands); they are a spring area of rivers Doubrava and Sázava. The Žďárské vrchy Hills and their surroundings are a principal spring area of rivers Chrudimka, Svatka, Svitava and Oslava.

The geographical and geological situation of the Žďárské vrchy Hills and the presence of peat bogs deter-



Fig. 2. The present state of the Bezděkov site.



Fig. 3. The location of the Cerhovka Brook and the present state (see Fig. 2).

mine their important location for water management (Břizová 2006a, 2006b). One of the main factors influencing the hydrological regime is a state of forest vegetation in the areas of upper streams and small inflows of big rivers. Disturbance of forest ecosystems and consequent disturbance of peat bogs function is caused in the area by aggressive interventions, wood exploitation and drainage of peat bogs. Activities like those might have prominent consequences such as floods on big rivers as it appeared in years 1997 and 2002. The development of vegetation conditions of peat bogs is influenced, except climate, by a range of factors, like sea level and geographical position, as well as the type of geological background (Břizová 2009a, 2009b). Peat soils have been deposited for millennia on impermeable basement of the crystalline rocks or Cretaceous sediments. Runoff conditions from the territory have fluctuated slightly which is caused by natural retention possibilities of landscape elements such as peat bogs, meandering streams, ponds and water reservoirs.

## 2. METHODOLOGY

Samples for pollen analysis were collected by hand-drilled well or extracted directly from exposures. The laboratory preparation included one-day maceration in HF (Overbeck 1958) and acetolysis method described by Erdtman (1954). Maceration in HF enables to decompose inorganic particles (Faegri *et al.*, 1964, Overbeck 1958), while acetolysis allows decomposition of cellulose and surplus organic remains that prevent good observation and calculation of palynological objects (pollen grains, spores, non-pollen microfossils). As a medium for microscopic biological samples a mixture of glycerine-ethanol-distilled water was used. 1-5 preparations of glass were

observed under the microscope, depending on sporomorph concentrations in a given sample.

Data obtained by microscopic analysis were evaluated in order to construct a pollen diagram, considering a sum of found pollen grains of wood species (AP) and herbaceous (NAP) to be 100% (AP+NAP=100%). The counted absolute values of pollen grains of different types of wood and herbs species were normalised to this sum to obtain relative values which were the basis for construction of pollen diagrams in the program POLPAL (Walanus and Nalepka 1999, Nalepka and Walanus 2003). Relative dating of pollen spectrum was carried out according to its composition. For the reconstruction of vegetation development the classification according to Firbas (1949, 1952) and Walanus and Nalepka (2010) was used. Taxonomic classification of found pollen grains and spores is according to Kubát *et al.*, (2002) and Beug (2004).

Radiocarbon dating was carried out in the Gliwice Radiocarbon Laboratory at the Silesian University of Technology, Poland. Radiocarbon concentration determinations for the samples was performed with use of the radiometric technique as described by Pazdur *et al.*, (2003). Before measurements, samples were pre-treated using an acid-alkali-acid washing sequence in order to remove any carbonates, humic and fulvic acids and bacterial CO<sub>2</sub>. The obtained results, i.e. conventional radiocarbon ages were calibrated in order to attain information about the calendar ages of samples. Calibration was undertaken using the IntCal09 calibration data (Reimer *et al.*, 2009) and accompanied by age-depth modelling with the use of Bacon software, performed for 1-cm-thick slices (Blaauw and Christen, 2011). The results of measurements are provided in Table 1, and the age-depth model is presented in Fig. 4.

**Table 1.** The results of radiocarbon dating of samples from Bezděkov BZK profile.

Sample name, depth	Lab. no.	Age <sup>14</sup> C (BP)	Calibrated age range 95.4% cal BP	95.4%
Bezděkov 5 0.10-0.15 m	Gd-15789	1210±60	1280-980	95.4%
Bezděkov 4 0.30-0.35 m	Gd-15788	1040±80	1180-780	95.4%
Bezděkov 3 0.65-0.70 m	Gd-15798	1900±70	2010-1680 1670-1620	92.6% 2.8%
Bezděkov 2 0.95-1.00 m	Gd-12740	1955±55	2050-1730	95.4%
Bezděkov 1 1.05-1.10 m	Gd-15787	2460±80	2730-2350	95.4%

### 3. RESULTS

#### Lithology

The sediment for the present study was collected from Bezděkov near Chotěboř, placed 420 m above the sea level (Fig. 1). It is a fen located on the plain of small river Cerhovka Brook. The depth of analysed sediments ranged from 0 to 1.10 m (Fig. 5).

Following lithological units have been distinguished:

- 0-0.10 m flood loam, brown;
- 0.10-0.33 m peat, dark brown;
- 0.33-1.05 m clayey, grey-brown;
- 1.05-1.10 m sand with trunks at the bottom.

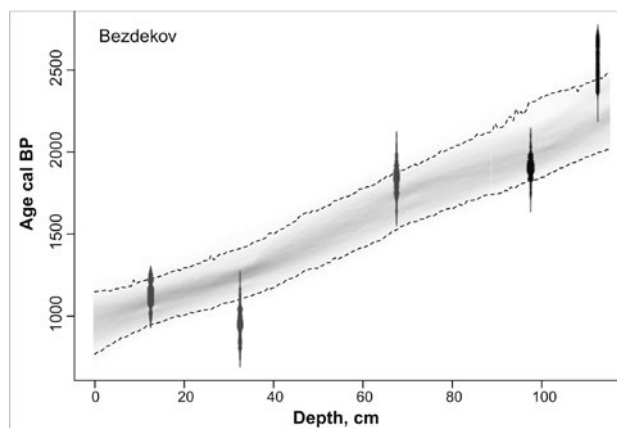
#### Dating

The obtained age-depth model for investigated profile provides Maximum *A posteriori* Probability (MAP) estimates, which are modes of the posterior probability distribution of calendar age for a given depth, as well as maximum and minimum ages (see Fig. 4). The relatively high intervals of modelled ages have to be kept in mind, i.e. the average age interval for the probability of 95.4% is ca. 360 yrs.

#### Pollen analysis and non-pollen microfossils

The collected Bezděkov profile records ca. 1500 years of the vegetation development. Sedimentation of the Bezděkov fen profile started under more favourable conditions of the Older Subatlantic (2550 cal BP, see Tables 1, 2 and Appendix), when the Cerhovka floodplain was raised. A younger Holocene section (Upper Holocene) can be clearly distinguished on the pollen diagram (Figs. 6 and 8). Four Local Pollen Assemblage Zones (L PAZ: BZK1a, b, c-2) were distinguished in the pollen diagram made from a 1.10 m thick sediment profile from the Bezděkov fen:

- BZK-1a-IX: *Cyperaceae* – *Pinus* – *Picea* (Older Subatlantic);
- BZK-1b-IX: *Alnus* – *Abies* – *Picea* – *Fagus* – *Anthropophyta* (Older Subatlantic);



**Fig. 4.** Age-depth model for Bezděkov core based on radiocarbon dating, obtained with the use of Bacon software (Blaauw and Christen, 2011). The probability distributions of calendar age obtained for single samples are dark grey. Grey-shaded area represents the ranges of the model, while the darker grey colour is used for the higher probability.



**Fig. 5.** The situation (location) of the Bezděkov profile (see Lithology).

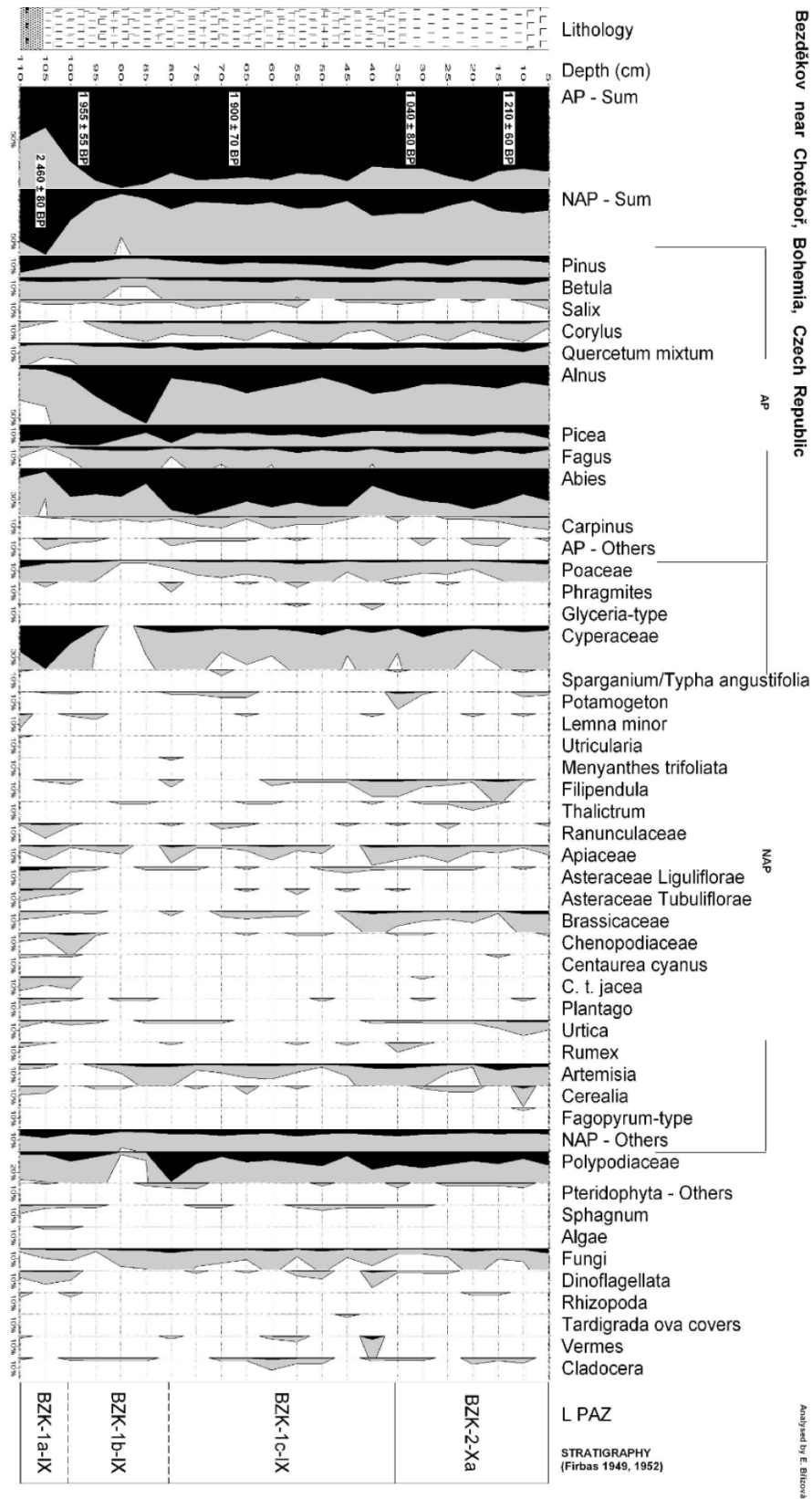


Fig. 6. Pollen diagram Bezděkov (BZK, 420 m a.s.l.) by Chotěboř, Bohemia, Czech Republic. Lithology: see Stratigraphical and lithological development of newly elaborated locality. Analysed by E. Břizová.

**Table 2.** Stratigraphic table of Holocene periods used in text follows (according to Břízová in Dreslerová *et al.*, 2004, Mangerud *et al.*, 1974, Walanus and Nalepka 2010).

Holocene	Modified stratigraphy by Břízová (Dreslerová <i>et al.</i> , 2004), <sup>14</sup> C BP	Modified stratigraphy by Břízová (Dreslerová <i>et al.</i> , 2004), cal. BP	Stratigraphy by Mangerud <i>et al.</i> , 1974, <sup>14</sup> C BP	Modified stratigraphy by Mangerud (Walanus and Nalepka 2010), cal. BP
Subatlantic IX, X	2800-recent	2900-recent	2500-recent	2550-recent
Subboreal VIII	5100/4500-2800	5800/5150-2900	5000-2500	5750-2550
Atlantic VI, VII	7700-5100/4500	8500-5800/5150	8000-5000	8950-5750
Boreal V	9100-7700	10250-8500	9000-8000	10150-8950
Preboreal IV	10250-9100	12000-10250	10000-9000	11450-10150

c) BZK-1c-IX: *Abies* – *Alnus* – *Picea* – Polypodiaceae – Vermes (Older Subatlantic);

d) BZK-2-Xa: *Abies* – *Alnus* – Anthropophyta (Older phase of the Younger Subatlantic).

The present results indicate that the Older Subatlantic (IX) phase is extensively developed on the locality of Bezděkov by Chotěboř (Figs. 6 and 8), with fir (*Abies*) as dominant specie (Fig. 7.1). Alder and floodplain forest was growing in the plain of the Cerhovka brook. The period is characterised by huge invasion of fir and development of beech-fir forests with addition of spruce and decline of *Quercetum mixtum* (QM, Fig. 7). Today's vegetation was formed in this time. In some areas the first traces of scarce settlement occur.

More permanent settlement occurs only in the following period of Younger Subatlantic (Xa, ca. 800 cal BP - present, Břízová in Dreslerová *et al.*, 2004). The original natural forests were very often cut down, burned out or changed to arable land and settlements. Forests were later artificially planted; the original woody species were replaced by quickly growing pine (*Pinus*) and spruce (*Picea*) with addition of birch (*Betula*). Human activity is represented in the diagrams by synanthropic plants and corn (Asteraceae, Brassicaceae, *Artemisia*, Cerealia, *Fagopyrum*). The development of this vegetation differs between individual localities.

The consequence of agricultural activities was the clearance of alder-dominated woodland. During the several millennium history of vegetation development, the woody species such as fir (*Abies*), small-leaved linden (*Tilia cordata*) and large-leaved linden (*T. platyphyllos*), beech (*Fagus*) have lost dominant importance. The spruce (*Picea*) has started to appear more vigorously, as it can be seen today on the majority of the area, which has probably been amplified by artificial planting that began mainly in the first half of the 19<sup>th</sup> century. In 15<sup>th</sup> and 16<sup>th</sup> centuries ponds were built in the area, e.g. the Velké Dářko, which have been functioning up to now. For centuries the agriculture affected remaining forests which were used for pasture of beef cattle and sheep. Significant amounts of wood were consumed by ironworks and glassworks that used mainly beech (*Fagus*), which resulted in its considerable decline. Traces of mineral deposit

extraction of silver, ironstones, coloured metals and peat can also be found.

Wetland plants such as species from families Cyperaceae and Ranunculaceae, *Phragmites*, *Thalictrum*, *Filipendula*, *Glyceria*-type, *Sparganium*/*Typha angustifolia*, *Menyanthes trifoliata*, the spores *Sphagnum*, Polypodiaceae and *Polypodium vulgare* indicate on the presence of swampy areas. The free water level was indicated by *Utricularia*, *Potamogeton*, *Lemna minor*, by algae (*Botryococcus*, *Pediastrum*) and by Cladocera (Fig. 7).

#### 4. DISCUSSION

Pollen analyses and radiocarbon dating verified sediment age from the Older Subatlantic (IX) up to the older phase of Younger Subatlantic (Xa). Wetland has been created in the plain of Cerhovka brook and according to the research results, its age ranges cover only the Upper Holocene around 2500-3000 years (Břízová 2008a, 2008b). From the stratigraphical standpoint, sedimentary filling on the locality of Bohutín in the plain of small river Litavka has also the same character of development (Břízová 2008a). Significant occurrence of fir (*Abies*) in the period of the Older Subatlantic and the Older phase of Younger Subatlantic (Bezděkov) was confirmed also at palynological research of the Bohemian Paradise Geopark on the locality of Mřičná – Zimrov (end of Subboreal, Older Subatlantic and Older phase of Younger Subatlantic, Semily sheet of geological map, scale 1:25 000, Břízová, 2010). Therefore, the dominance of fir revealed at around 400-500 m above sea level was proven for the period, when man did not intervene so much in development of forest ecosystems in piedmont and mountainous areas.

Palaeoecological development of the Bohemian-Moravian Uplands territory can be compared with development of the border mountains of the Czech Republic (e.g. Mentlík *et al.*, 2010). The specific local conditions are prominently different from the conditions for the area of southern Moravia, where several palaeolakes were discovered and examined, e.g. Vacenovice (Břízová 2006c), Čejčské Lake (Břízová 2009c), Pohansko (Doláková *et al.*, 2010).



**Fig. 7.** Palynomorphs from the Bezděkov (BZK) profile AP: 1 – *Abies*, depth 0.05 m; 2 – *Picea*, depth 0.05 m; 3 – *Pinus*, depth 0.05 m; 4-7 – *Alnus*, depth 0.35 m, 0.05 m, 0.15 m, 0.20 m; 8, 9 – *Acer*, depth 0.10 m, 0.30 m; 10, 11 – *Carpinus*, depth 0.05 m; 12 – *Quercus*, depth 0.80 m; 13 – *Fraxinus*, depth 0.10 m. NAP: 14 – *Thalictrum*, depth 0.20 m; 15 – *Urtica*, depth 0.20 m; 16 – *Cerealia T. Secale*, depth 0.65 m; 17 – *Lemna cf. minor*, depth 0.10 m; 18, 19 – *Asteraceae Liguliflorae*, depth 0.30 m, 0.25 m; 20 – *Astraceae Tubuliflorae*, depth 1.10 m; 21 – *Carduus/Cirsium*, depth 0.80 m; 22 – *Fagopyrum*, depth 0.10 m; 23 – *Centaurea cyanus*, depth 0.15 m; 24 – *Poaceae*, depth 0.05 m; 25 – *Chenopodiaceae*, depth 0.35 m; 26, 27 – *Apiaceae*, depth 0.05 m; 28, 29 – *Brassicaceae*, depth 0.05 m; 30 – *Cyperaceae*, depth 0.05 m; 31 – *Sparganium/Typha angustifolia*, depth 0.10 m. Spores: 32 – *Polypodiaceae*, depth 0.05 m; 33 – *Polypodium vulgare*, depth 0.15 m. Other microfossils: 34 – *Cladocera*, depth 0.10 m. Scale 30  $\mu\text{m}$  (1, 2), 10  $\mu\text{m}$  (3-34). Photo E. Břizová.

Pollen analyses carried out so far for the area of Bohemian-Moravian Uplands revealed satisfactory state of the current forest ecosystems (Břízová 2006a, 2006b, 2006c, 2009a, 2009b) against, for example, the Krušné hory Mts (Jankovská *et al.*, 2007, Vile *et al.*, 1995) and other territories (Jankovská 2006, 2007, Novák *et al.*, 2008).

The Older Subatlantic (IX, ca. 2900-800 cal BP, Břízová in Dreslerová *et al.*, 2004) was identified in all pollen diagrams of the Bohemian-Moravian Uplands at Velké Dářko and Zlatá louka (Břízová 2006b), except Zálíbené site, where the upper part of sediment was removed before sampling for pollen analysis (Kneblová-Vodičková 1961, 1966, 1970).

The herb taxa are again represented by anthropogenic indicators and by cereals (*Cerealia* T. *Secale*, T. *Triticum*). Mainly the types of family Polypodiaceae and the destroyers of organic matter such as Ascomycetes were found among the spores together with lesser amounts of *Arcella*, *Hyalosphenia subflava* (Rhizopoda).

More varied weed types and anthropogenic indicators such as *Centaurea cyanus*, as well as plants typical for medieval settlements, for example *Fagopyrum*, occurred on a larger scale. Intestinal parasites of humans and pigs such as *Ascaris* cf. *lumbricoides*, *Trichuris* cf. *trichiura* (BZK-1c-IX) were also recorded in this period, similarly to the medieval Prague, Budeč and in other medieval towns (Břízová 1997, 1998, Břízová and Bartošková 1994).

## 5. CONCLUSIONS

Pollen and non-pollen microfossils have been successfully used in this study for the precise reconstruction of local palaeoenvironments demonstrating new possibilities for the interpretation of palynological assemblages. It is especially important for the understanding of regional and local environmental trends in swampy regions of the Protected Landscape Areas Žďárské vrchy Hills and Železné hory Mts. Such reconstructions are important in the vicinity of the Bohemian-Moravian Uplands. Moreover, they provide a basis for the prediction of the future changes there, which is especially important for the floodplain areas of Bohemia, where anthropogenic influence has strongly increased during recent decades.

Pollen analysis has been carried out on a 1.10 m thick sediment profile from the locality Bezděkov (420 m a.s.l.) near Chotěboř (Figs. 1, 2 and 3) in the Protected Landscape Area Železné hory Mts (Czech Republic). Analyses of 22 samples characterise the development of the wetland biotope and the surrounding landscape during the time interval from 2550 to 800 cal BP. The pollen diagram shows a transition between the Upper Holocene biostratigraphic units at a depth of 0.33 m (ca. 1180-780 cal BP, see Table 1). *Alnus* and *Abies* were the dominant trees during all the time.

The Cerhovka Brook was an important factor in the development of the vegetation cover in the vicinity of wetland in the Upper Holocene. Palynological study of the organic sediments of the Cerhovka revealed the complexity of the vegetation history of this small floodplain. Instability of the mostly inorganic sediments has been proved by the redeposition of Cretaceous sporomorphs and by Dinoflagellata presence (see pollen diagram in the Fig. 6). The brook banks were covered by alder-dominated woodland with local formations of native grassland with herb-dominated photophilous vegetation and wetland vegetation.

Human impact on the natural ecosystem has been recorded since the beginning of the second half of the Older Subatlantic (ca. 1800 cal BP). It was first marked by pasture then by crop cultivation towards the end of the period.

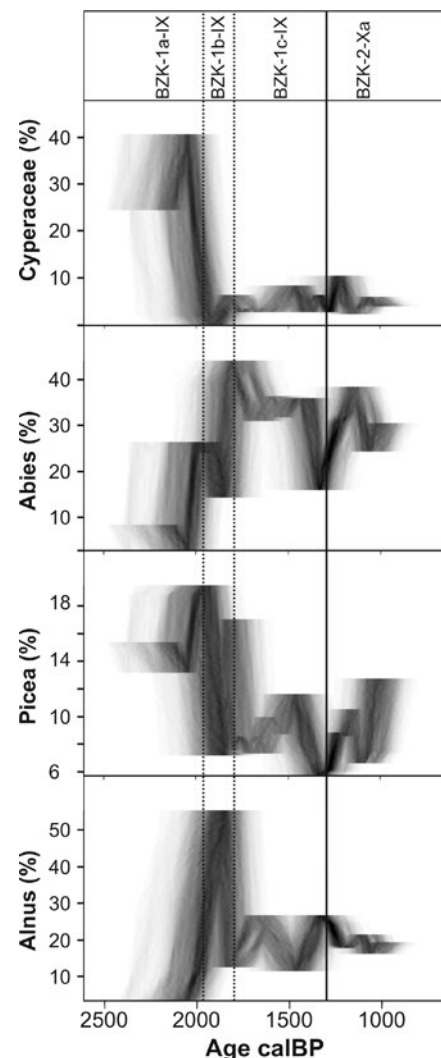


Fig. 8. Changes of the relative abundance of selected representative pollen taxa on the absolute age scale. Grey-shaded area represents the uncertainty of the age-depth model (see Fig. 4). Plots prepared with use of Bacon software (Blaauw and Christen, 2011).



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## APPENDIX

The table with real amount of pollen grains and spores in individual samples from the locality of Bezděkov BZK is available in electronic version of this article at <http://dx.doi.org/10.2478/s13386-012-0016-2> as Supplementary Material.

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