Silva Gabreta	vol. 18 (2)	p. 61–78	Vimperk, 2012

Reconstruction of vegetation and human impact from the sediments of the Rybárenská Slať mire (Bohemian Forest, Czech Republic)

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Abstract
Pollen analysis has been carried out on a 0.38 m thick sediment profile from the Rybárenská Slať mire. The mire is situated in the central part of the Bohemian Forest westerly of the Modrava village at the elevation from 1011 to 1037 m a.s.l. Upper sediments of the mire were biostratigraphically evaluated. Its upper part was palynologically evaluated some time ago for comparison with other methods determining humolite age and conditions of its origin. Based on the results of pollen analysis, the profile of the Rybárenská Slať mire (RS, RYBS) proved to represent the younger phase of the Younger Subatlantic (Xc) and was more exactly dated by the ^{210}Pb method into the range of 1847–1993 (the thickness of the dated sediment was 0.28 m). It seems that, in this part of the Bohemian Forest, the anthropogenic influence was much earlier and stronger; however, more natural forest still persisted. The forestation of the territory was much more pronounced here in the Bohemian Forest than in the Krušné Hory Mts. On the basis of vegetation development established by the pollen analysis the profile can be divided into 4 local pollen assemblage zones (L PAZ). In the whole profile, a woody component prevailed with bigger or smaller oscillations. Only spruce (*Picea*) has a considerable prevalence and partly also the pine (*Pinus*), in this case it probably concerns types of the peat-bog dwarf pine (*Pinus mugo*) or the marshland pine (*Pinus uncinata*). The extent, method and time of farming in the Bohemian Forest can be read out from the pollen diagram, as well as two waves of resettlement in 1939 and 1945, which were reflected in the vegetation composition. A higher degree of afforestation (*Picea*, *Fagus*, *Abies*, *Carpinus*) was characteristic for the Younger Subatlantic (older phase, Xa). During Younger Subatlantic (younger phase, Xb-c), pollen of synanthropic plants appeared.

Key words: palynology, Holocene, Rybárenská Slať mire, biostratigraphy, ^{210}Pb dating

Introduction

The Bohemian Forest (Šumava in Czech) belongs geologically to the oldest mountains in the Central Europe being formed of various igneous and metamorphic rocks (Babůrek 1996, 2001, Babůrek & Pošmourný 2001, Babůrek et al. 2006a,b). Quaternary organic sediments cover a big part of the mountains territory (Spitzer & Bufková 2008). Peat bogs and glacial lakes were formed after the recession of the Last Glacial period (Břízová et al. 2006, Břízová & Pazdur 2007, Jankovská 2006, Mentlík et al. 2010). Their sediments are the archives, in which traces of extinct life can be found in the form of pollen grains, spores, plant macroremains, animal remains, and other organic remains. The organic sediments of peat bogs are in the Bohemian Forest territory very vast both in terms of the area and the amount of humolite and are of considerable and very significant stratigraphic and palaeogegraphical importance. During the last years a big progress in their research has been made particularly due to the detailed palynological research of Svitavská-Svobodová on the peat bogs. A good example is Nová Hůrka (Hůrecká Slať mire, 860 m a.s.l., Svobodová 1995, Svobodová et al. 2001, 2002) – a typical well-preserved Bohemian Forest peat bog, which originated as a small oligotrophic lake that was subject to terrestrialization and since the Boreal existed as a peat bog. Other analyzed sediments belonged to the Rokytecká Slať mire (1120 m a.s.l., Svobodová et al. 2002, Svitavská-Svobodová 2007). Of other localities it is necessary to mention the mires of Velká Niva-Volary, Buková Slať, Spálené, Chalupská Slať, Rokytecká Slať, Mrtvý Luh, Malá Niva, Luzenská Slať (Soukupová et al. 2001, Svobodová at al. 2001) and others. The palynological research was carried out also on the peat bog in the altitude of 1200 m (Brande 1995) on the southern slope of the Plechý Mt. (1379 m a.s.l.). Since 1996, the pollen monitoring of the current vegetation has been carried out in the Bohemian Forest area (Svitavská-Svobodová et al. 2007).

Revitalization projects aiming at restoration of vegetation cover and a function of peat bogs, which were destroyed by the former drainage, are in progress on a number of peat bogs (e.g., Modravská Slať mire at the village of Borová Lada, Spitzer & Bufková 2008).

Apart from the study of peat bogs, the research on the Bohemian Forest glacial lakes sediments, which are the only natural preserved lakes in the Czech Republic, has been still performed. Simultaneously the lakes, which have already been terrestrialized today, were found (e.g., Stará Jímka lake at the Poledník Mt.). At first a great attention was paid to Černé Lake (Reissinger 1930, 1933, Břízová 1991a,b, 1993, 1995, 1996, Řeháková 1991) and informative also to Čertovo Lake (Veselý et al. 1993, Veselý 1994, Břízová 1996). Besides Černé and Plešné lakes (Jankovská 2006, Břízová 2007a–d, 2010) are also significant localities of occurrence of rare plants (quillworts *Isoëtes lacustris* and *I. echinospora*). The lacustrine sediments of Černé, Čertovo, and Plešné lakes, which are of Quaternary age, reach a thickness of about 5–6 m. Their age ranges from the Late Glacial (I–III, Firbas 1949, 1952, Jankovská 2006, Mentlík et al. 2010) up to the Holocene. The lakes have existed since the recession of last glaciation. The current state of our all 5 Bohemian Forest lakes is determined by antropogenic air-borne contamination.

The important verification of this state was the study of geological, geomorphological, climatic and vegetation development of the Quaternary in the former lake, nowadays a raised bog of Stará Jímka (altitude of 1115 m a.s.l.), which has been intensively examined by pollen analyses, palaeoalgological analyses, and radiocarbon dating. Apart from these, the geomorphological study has been carried out (Mentlík 2002, 2003, 2004, Mentlík et al. 2010, Břízová 2004a,b, Břízová & Havlíček 2004, Břízová et al. 2006, Babůrek et al. 2006). These findings confirmed a hypothesis of glacial lake, which later was terrestrialized. Glaciation in this broader surroundings of Prášilské Lake probably ended 13 000–14 000 years ago, which is proved by AMS and conventional radiocarbon dating, and by pollen and palaeoalgological analysis of organic matter sampled from the limnic sediments just in the Stará Jímka lake. A presumed hypothesis of this lake origin has been discussed in the papers by Břízová & Mentlík (2005a,b), Mentlík & Břízová (2005), Mentlík et al. (2006, 2010).

The vegetation conditions found out by pollen analysis in the Prášilské Lake sediments are similar to the former elaborated peat bog profiles in the Bohemian Forest area (Hruška et al. 1999, Břízová 2000).

The study of diatom flora in Černé Lake was performed by Řeháková (1991), who aimed at the study of current trophic state of the lake as well as the state of its last development in order to explain possible anthropogenic impacts on its ecology, particularly recent acidification of its environment by atmospheric depositions. Later the diatom flora was studied in Čertovo Lake (Veselý et al. 1993).

As opposed to the palynological research, limnological research of water ecosystems has been carried out since the end of the 19th century; in the 1990s implementation was mostly in Černé Lake and later it moved to the other lakes. The palaeolimnological research on Čertovo Lake were carried out by Veselý et al. (1993) and Plešné Lake was studied by Jankovská (2006).

The thorough biostratigraphic research of peat and lake sediments is the basis for monitoring of the natural environment of the Bohemian Forest in the Quaternary period. Special attention was paid to the last 200 years of development of all ecosystems, which have been influenced by human interventions to the natural landscape development.

Study area

The detailed biostratigraphical research was concerned with the upper part of the Rybárenská Slať mire (Břízová 1998a,b, 2004a,b) carried out for the purpose of dating the upper part of the profile by the ^{210}Pb method. Thus a link of the historical literature review with the sediment research was enabled. The similar development of vegetation have already been found out here in the Bohemian Forest area in the Jezerní Slať mire (Vile et al. 1995, Břízová 1996, Novák et al. 2008), further in the Černé and Čertovo lakes (Břízová 1993, 1995, 1996, 2009, Veselý et al. 1993).

The slope raised bog of the Rybárenská Slať mire (Fig. 1), westerly of the village of Modrava, northward of the Cikánská Slať mire, is on the west, the north and the east marked off by the Roklanský Potok stream, on the south by the Slatinný Potok stream, which drains it off simultaneously. It probably consists of several parts (Dohnal et al. 1965), it is in the continuous forest complex in the altitude of 1011–1037 m with an area of 134 ha, a thickness of 2 665 000 m^3, a depth of up to 6.5 m, with an annual rainfall of 1100 mm, an average annual temperature of 3.7°C. The basement is formed by the crystalline rocks represented by granite and grey mica sand under peat. The whole complex is considerably rugged. Its development carried dispersedly on a few probably debris water springs. Obtained cores gradually flowed one into another and the unbroken complex most likely arose in the last phases of development. pH varies in the range of 3.55–6.35 (Dohnal et al. 1965, Fuksa 1968).

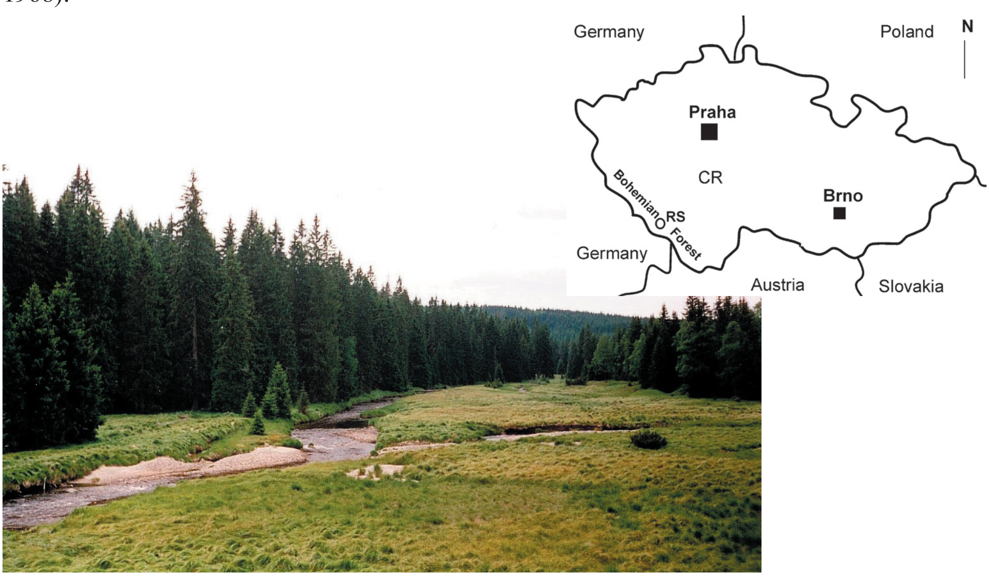

Fig. 1. The map and photo of location of the Rybárenská Slať mire (Bohemian Forest, Czech Republic).

Methods

Pollen analysis was the basic method to reconstruct the past vegetation development in the Upper Holocene. The vegetation is visually the most distinct component in a landscape, and its composition is the result of both abiotic and biotic factors. Based on vegetation composition deductions can be made concerning other factors (for example climate, pedology, geomorphology, and even the time of human colonisation of the studied region and the scope and quality of human activities).

Within the grant project, the upper part of the peat profile of the Rybárenská Slať mire, 0.38 m thick, was palynologically evaluated for comparison with other methods determining humolite age and conditions of its origin (Novák et al. 2008). Altogether 19 samples with sampling every 2 cm were analyzed palynologically.

Laboratory treatment: decomposition of inorganic component was carried out by maceration in HF for ca. 24 hours (Faegri & Iversen 1964). An organic part, mainly cellulose, was removed by Erdtman's acetolysis (Erdtman 1943, 1954). Obtained sporomorph were preserved in a mixture of ethylalcohol, glycerine and distilled water.

Microscopic treatment: calculation of individual objects was carried on the cover glass at the size of 22×22 mm; because of low frequency of pollen grains of woody plants, AP (an amount of AP above 500 was taken for the statistical evaluation), a number of preparations at individual samples was only 1–6, what was 59 altogether. Raw counts of palynomorphs (see Table 1, AP+NAP = 100 %, Fig. 2) after percent calculation were the basis for construction of a pollen diagram in the program POLPAL (Walanus & Nalepka 1999, 2010, Nalepka & Walanus 2003). Among pollen grains and spores, a number of plant tissues and microscopic animal remains were found out in the microscopic biological preparations.

Results and discussion

Four local pollen assemblage zones (RS-1-Xc to RS-4-Xc) were distinguished in the pollen diagram. The collected profile of the Rybárenská Slať mire sediment covers the last ca. 150–200 years of the vegetation development. The pollen diagram (Fig. 3) covers the youngest Holocene section.

On the basis of pollen analysis the profile of the Rybárenská Slať mire (RS, RYBS) was classified into the younger phase of the Younger Subatlantic Xc according to Firbas (1949, 1952) and simultaneously it was dated by the ^{210}Pb method to the range of 1847–1993 years (samples 14–1, respectively; thickness of the dated sediment of 0.28 m, Novák et al. 2008). The same methodology was used at the Jezerní Slať mire (Břízová 1996, Vile et al. 1995), and at the Černé and Čertovo lakes (Břízová 1995, 1996).

Fig. 2. Palynomorphs from the Rybárenská Slať mire (RS, RYBS). **AP:** 1 – *Pinus*, depth 0.02 m; 2 – *Picea*, depth 0.10 m; 3 – *Betula*, depth 0.08 m; 4 – *Acer*, depth 0.08 m; 5 – *Quercus*, depth 0.34 m; 6 – *Fagus*, depth 0.32 m; 7 – *Carpinus*, depth 0.22 m; 8 – *Fraxinus*, depth 0.24 m; 9 – *Sambucus nigra*, depth 0.14 m; 10 – *Alnus*, depth 0.22 m. **NAP:** 11 – *Urtica*, depth 0.30 m; 12 – Brassicaceae, depth 0.18 m; 13 – Cyperaceae, depth 0.08 m; 14 – *Plantago lanceolata*, depth 0.20 m; 15–17 – *Anemone*-type, depth 0.22 m; 18 – Brassicaceae t. *Barbarea*, depth 0.30 m; 19 – Poaceae, depth 0.18 m; 20 – Cerealia T. *Triticum*, depth 0.18 m; 21 – *Bistorta*, depth 0.36 m; 22 – Asteraceae Tubuliflorae, depth 0.18 m; 23 – *Carduus/Cirsium*, depth 0.38 m; 24 – Asteraceae Liguliflorae, depth 0.28 m; 25 – Chenopodiaceae, depth 0.10 m; 26 – *Artemisia*, depth 0.28 m. **Spores**. 27–28 – *Sphagnum*, depth 0.06 m, 0.22 m. 29 – **Tardigrada** – ova cover, depth 0.32 m. **Fungi**. 30 – Ascomycetes, depth 0.22 m. **Rhizopoda**. 31 – *Amphitrema flavum,* depth 0.30 m. **Fungi**. 32 – *Microthyrium microscopicum*, depth 0.04 m. Scale 20 μm (2, 32), 10 μm (1, 3–31). Photo by E. Břízová.

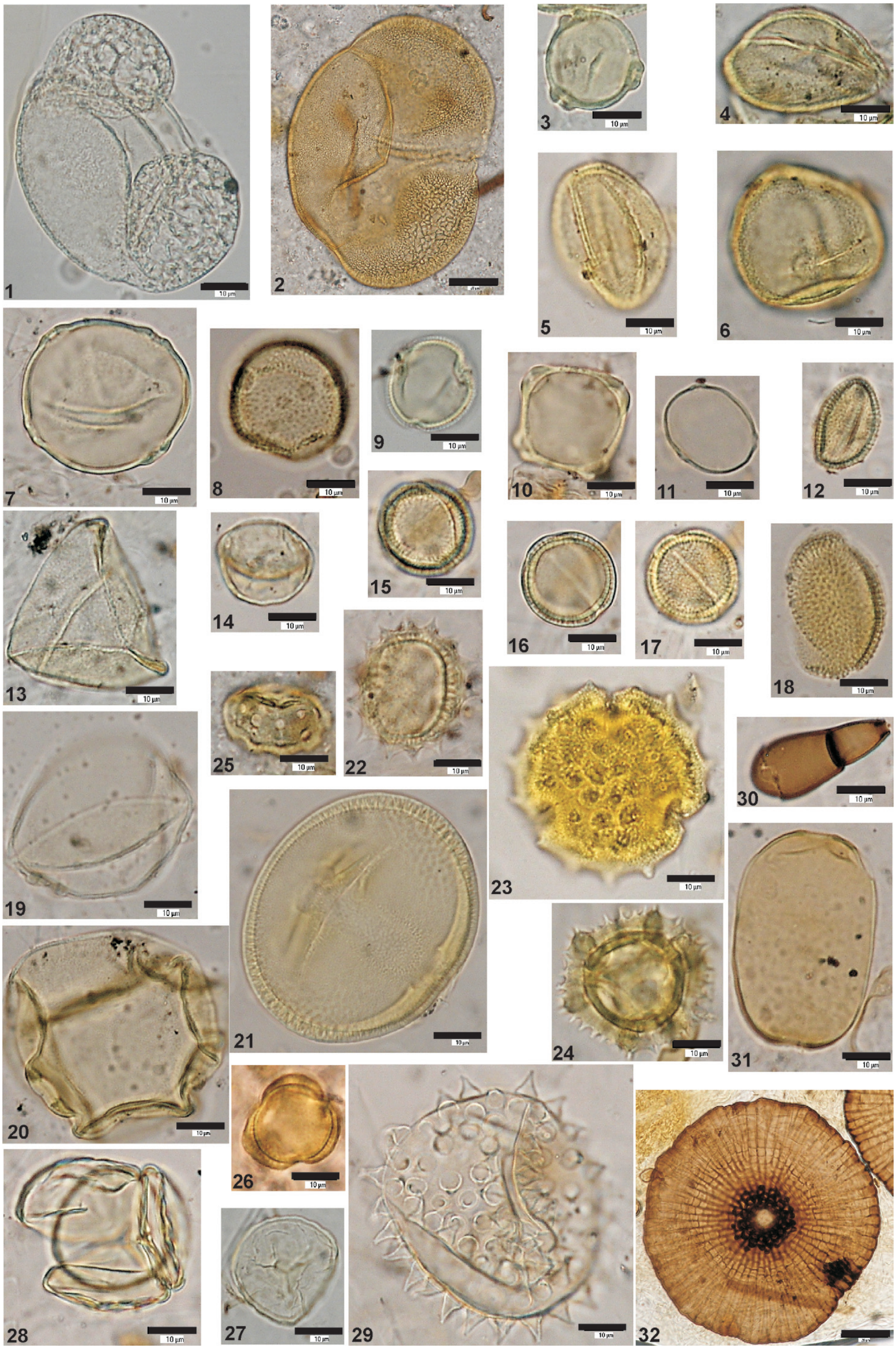
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Table 1. Raw counts of pollen grains and spores in individual samples from the locality of Rybárenská Slať mire (RS, RYBS).

Sample (depth, cm)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**
AP: trees and shrubs																			
Pinus	72	43	163	166	145	102	145	156	135	187	159	115	129	156	136	141	126	144	128
Betula	63	45	36	68	95	127	49	76	49	59	78	85	30	65	89	65	102	109	103
Juniperus	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	2	0	0	0
Salix	2	1	3	2	2	4	5	0	4	7	8	12	6	7	15	5	18	19	12
Corylus	7	4	3	7	9	8	8	5	0	0	0	0	0	0	0	0	0	0	0
Cornus sanguinea	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Ulmus	0	0	1	0	2	3	1	1	0	2	4	3	1	0	1	0	4	3	2
Quercus	6	5	3	11	5	6	5	11	3	16	5	11	3	1	10	15	17	11	8
Tilia sp.	0	0	0	0	0	1	0	1	0	0	0	0	3	1	0	1	0	1	3
Tilia platyphyllos	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Fraxinus	6	0	1	2	2	2	1	1	0	3	0	3	0	0	0	1	4	1	1
Acer	1	0	1	0	0	0	1	2	0	1	0	5	0	1	2	1	0	0	1
Alnus	48	16	18	26	30	23	15	20	4	15	15	27	13	17	40	17	21	31	25
Picea	303	351	274	235	222	228	279	241	311	265	243	229	326	229	154	210	162	161	194
Fagus	7	13	7	9	3	11	21	8	17	6	5	23	7	14	33	31	33	27	28
Abies	21	42	1	1	0	9	7	1	2	3	8	9	12	17	15	31	24	15	14
Carpinus	2	4	1	2	2	2	0	1	0	4	7	2	0	0	0	2	5	1	0
Frangula alnus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Populus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Juglans	0	0	0	1	0	0	0	0	0	0	1	1	0	1	0	0	1	0	0
Rhamnus-type	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Sorbus	2	1	0	0	0	0	0	0	0	0	1	5	0	1	3	1	1	1	0
Lonicera	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Rosa-type	0	0	0	1	0	0	4	0	1	0	2	3	0	0	0	0	2	0	0
Ligustrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	2	0
Viburnum	0	0	0	0	0	0	1	0	0	0	0	1	0	0	7	0	1	1	0
Castanea-type	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
NAP: herbs																			
Poaceae	46	33	72	44	62	106	146	142	112	210	128	147	7	65	165	106	176	200	123
Cyperaceae	66	25	115	434	313	130	290	950	181	350	231	359	62	270	890	801	347	203	108
Helianthemum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Sparganium/Typha a.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Potamogeton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Butomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Comarum	0	0	0	0	0	1	1	1	2	0	0	8	2	0	0	0	0	3	0
Bistorta	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1	1	3	0
Polygonum t. *aviculare*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

Table 1. Continued

Filipendula	0	0	1	0	2	1	0	0	2	2	1	0	2	3	0	2	1	0	3
Thalictrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Ranunculaceae	0	4	0	1	2	2	2	0	0	2	4	0	3	3	5	2	7	2	5
Anemone-type	0	0	0	0	0	1	1	0	0	0	1	1	0	0	2	0	1	1	1
Rosaceae	1	0	0	0	1	3	4	0	2	6	4	22	1	3	7	3	9	15	1
Sanguisorba officinalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
Caryophyllaceae	0	1	0	1	1	4	1	1	1	0	2	2	3	2	8	6	4	4	12
Apiaceae	0	0	3	1	3	3	1	5	3	1	0	3	1	8	2	5	2	3	2
Trifolium	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1
Vicia-type	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Asteraceae Liguliflorae	1	0	2	1	4	1	4	3	1	5	2	8	3	7	3	4	9	5	10
Asteraceae Tubuliflorae	2	1	0	1	0	0	2	1	1	0	2	3	6	8	5	5	7	4	6
Carduus/Cirsium	0	2	0	1	0	0	1	0	0	1	2	9	21	11	2	5	15	93	68
Achillea-type	0	1	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Rubiaceae	0	0	2	1	1	1	2	1	0	2	0	0	0	1	0	1	0	4	3
Campanula	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	1	1
Valeriana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Ericaceae	2	0	0	0	0	0	0	0	3	1	0	3	3	0	2	3	1	4	1
Calluna vulgaris	1	1	0	0	0	0	1	1	0	1	0	0	0	0	2	2	5	0	0
Epilobium	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0
Lythrum-type	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Brassicaceae	2	0	2	1	1	2	0	4	1	1	2	8	4	3	12	2	4	17	18
Cardamine-type	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Euphorbia-type	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	7	0	0
Chenopodiaceae	3	4	0	0	5	1	4	3	5	7	2	4	3	5	4	3	3	3	4
Centaurea sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Centaurea cyanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Centaurea t. *jacea*	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Echium	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Polygala-type	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Mentha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Plantago lanceolata	2	1	1	0	0	5	8	2	7	6	3	5	0	0	4	2	8	9	5
Plantago major-media	0	0	0	3	0	0	2	1	1	3	1	3	0	0	2	2	3	1	1
Urtica	0	0	0	0	0	0	0	0	1	1	0	3	0	0	3	4	3	0	0
Cannabis/Humulus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Rumex sp.	0	0	3	2	0	0	3	2	0	2	4	3	0	1	0	0	15	0	21
R. t. *alpinus*	0	0	0	0	0	1	1	0	0	1	0	1	0	0	20	0	0	7	0
R. t. *acetosella*	1	2	0	0	4	1	1	0	0	4	0	3	0	0	0	8	9	6	0
Artemisia	1	3	3	2	2	1	0	3	1	2	6	9	6	5	8	1	3	8	15

Table 1. Continued

Ambrosia-type	0	0	0	2	1	1	3	0	0	2	0	1	2	1	0	6	0	5	2
Agrostemma githago	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Cerealia sp.	2	10	1	4	2	7	1	6	9	9	11	9	1	8	21	11	36	14	25
Cerealia T. *Secale*	0	0	1	0	0	0	2	0	1	1	0	1	0	3	7	4	3	8	8
Cerealia T. *Triticum*	3	0	0	3	5	3	11	3	4	3	6	14	0	3	9	4	4	4	6
Varia	25	12	19	25	12	17	27	20	19	30	34	45	19	51	79	37	51	49	100
Sum AP	541	526	512	540	517	542	542	525	528	573	540	536	530	514	513	524	527	529	521
Sum NAP	158	100	225	528	529	292	519	1153	358	653	426	688	151	463	1293	1034	752	632	458
Sum AP+NAP=100%	699	626	737	1068	938	834	1061	1678	888	1226	966	1224	681	997	1806	1558	1279	1231	979
PTERIDOPHYTA																			
Lycopodium sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Lycopodium clavatum	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1
Equisetum	0	0	0	0	0	1	0	0	0	5	164	6	6	42	8	13	4	4	5
Botrychium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Polypodiaceae	8	1	1	0	7	2	0	3	0	7	4	38	19	50	28	19	13	27	15
Pteridium aquilinum	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
BRYOPHYTA																			
Sphagnum	71	200	282	356	369	107	13	140	550	925	405	46	54	97	40	222	30	91	72
ALGAE																			
Zygnema-type	0	0	2	2	0	0	0	0	0	0	1	0	0	0	0	7	0	0	2
FUNGI																			
Microthyrium microscopicum	6	27	25	9	11	14	10	11	17	17	17	6	0	0	2	1	0	1	0
RHIZOPODA																			
Hyalosphenia subflava	269	231	24	0	5	0	0	0	0	0	0	80	24	44	76	66	90	89	70
Amphitrema flavum	2	0	0	0	0	1	0	0	0	0	0	2	6	19	178	86	67	38	40
Nebella	24	13	8	1	2	2	2	1	4	4	5	24	3	4	11	26	13	7	1
Arcella	20	34	26	0	7	2	0	0	0	0	0	0	2	4	19	42	25	6	3
TARDIGRADA																			
Tardigrada ova covers	0	0	0	0	1	0	0	0	0	0	0	2	0	1	5	29	3	10	4
Tardigrada animal	28	57	22	0	11	0	0	0	0	0	0	8	5	4	10	38	17	25	33

The pollen diagram (Fig. 3) suggested that the forestation of the territory was much more pronounced here in the Bohemian Forest than in the Krušné Hory Mts., which were more negatively affected by anthropogenic devastation (Vile et al. 1995, Novák et al. 2008) than the Bohemian Forest.

Pollen diagram can be dividend into 4 L PAZ (Local pollen assemblage zones):

RS-1-Xc: Cyperaceae – Poaceae – *Carduus/Cirsium* – Antropophyta – (*Hyalosphaenia subflava – Amphitrema flavum*)

Depth 0.28–0.38 m.

The ^{210}Pb dates of the botton section are only informative (within ca. 1650–1817), because a scope of dating over 200 years is not conclusive. Dating is possible only in the range of the 19th to 21th centuries. A woody component (AP) ranges about 50%, which probably meant the previous forest overexploitation at the foundations of ironworks, glassworks and charcoal production. Later, probably due to forestation, the AP increases by 10–16% (to 65% on average). It is mainly caused by a proportion of spruce (*Picea*), substantially less pine (*Pinus*), birch (*Betula*), fir (*Abies*), beech (*Fagus*), hornbeam (*Carpinus*), and oak (*Quercus*). At the end of this zone particularly a proportion of woody species of the natural forest decreases (fir *Abies*, beech *Fagus*, hornbeam *Carpinus*, oak *Quercus*, linden *Tilia*). Due to the nearby settlement a shrubby layer was probably very abundant (mainly privet *Ligustrum*, snowball *Viburnum*, *Rosa*-type) and also whitebeam (*Sorbus*). Herb layer was rich in species and in an amount. Grasses (Poaceae) and family Cyperaceae (sedge family) were mostly represented. Pastures are indicated in the pollen diagram by nettle (*Urtica*), sorel (*Rumex*) and juniper (*Juniperus*). Cultivation of cereals is expressed by pollen curves of Cerealia sp., C. T. *Triticum*, C. T. *Secale* and their weed corncockle (*Agrostemma githago*), and bluebottle (*Centaurea cyanus*), accompanied by other anthropogenic indicators: Apiaceae, Asteraceae Liguliflorae, A. Tubuliflorae, Brassicaceae, *Carduus*/*Cirsium* (common thistle), Chenopodiaceae, *Plantago lanceolata* (ribwort plantain), *P. major*-*media* (plantain bigger-medium), *Artemisia* (wormwood), *Polygonum* t. *aviculare*, *Trifolium*-type (clover type), etc. *Carduus*/*Cirsium* was in this phase a very abundant plant (see Fig. 3). Wetland herbal types are accompanied by a curve of spores *Equisetum* (horsetail) and Polypodiaceae. *Sphagnum* spores (peat moss) are represented however their values are the lowest in this zone. Other micro--remains are present in considerable quantitites. These are: Rhizopoda *Hyalosphenia subflava*, *Amphitrema flavum*, *Nebella*, *Arcella,* and Tardigrada.

RS-2-Xc: *Picea* – Cyperaceae – *Pinus* – (*Equisetum*)

Years 1847–1942, depth 0.22–0.28 m.

The proportion of arboreal pollen (AP) increases. It is a consequence of spruce monoculture plantation, somewhere possibly also pine. Other woody plants occurred in smaller amount. *Rosa*-type is well represented within types of a shrubby layer. In the second half whitebeam (*Sorbus*) is still present. Man settlement was accompanied also by planted walnut (*Juglans*). Herbal vegetation was not so rich and abundant as in the previous part of the profile. This zone probably reflects an end of the land cultivation, which is connected with the resettlement of the border area in the years of 1939 and 1945. Several plants producing spores were still present, e.g., local wetland types such as horsetail (*Equisetum*), Polypodiaceae, peat moss (*Sphagnum*). Some animal micro-remains of Rhizopoda (namely *Hyalosphenia subflava*, *Amphitrema flavum*, *Arcella),* as well as Tardigrada occur more rarely in the diagram.

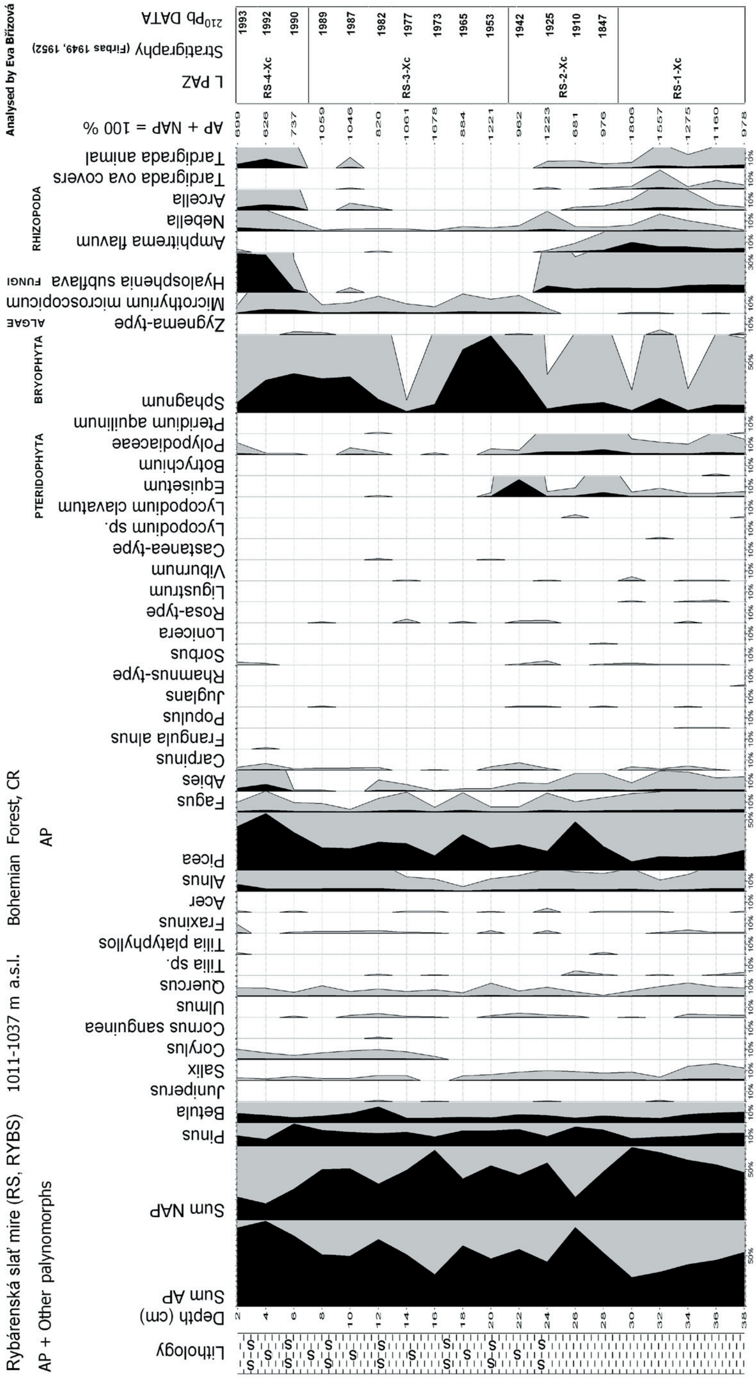
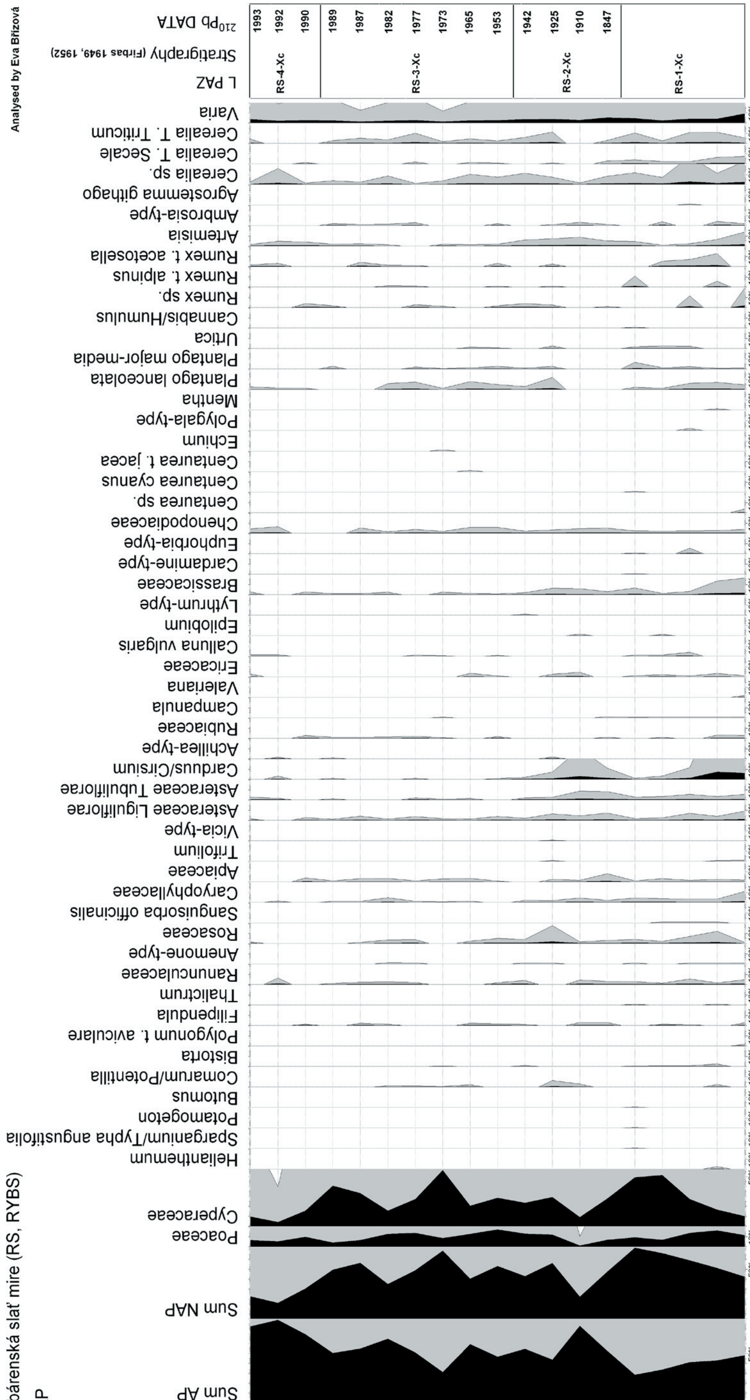


Fig. 3. Pollen diagram Rybárenská Slať mire (RS, RYBS, 1011–1037 m a.s.l.), Bohemian Forest, Czech Republic. Analysed by E. Břízová.



Rybárenská slať mire (RS, RYBS)
NAP
Analysed by Eva Břízová
Depth (cm)
Sum AP
Sum NAP
Poaceae
Cyperaceae
Helianthemum
Sparganium/Typha angustifolia
Potamogeton
Butomus
Comarum/Potentilla
Bistorta
Polygonum t. aviculare
Filipendula
Thalictrum
Ranunculaceae
Anemone-type
Rosaceae
Sanguisorba officinalis
Caryophyllaceae
Apiaceae
Trifolium
Vicia-type
Asteraceae Liguliflorae
Asteraceae Tubuliflorae
Carduus/Cirsium
Achillea-type
Rubiaceae
Campanula
Valeriana
Ericaceae
Calluna vulgaris
Epilobium
Lythrum-type
Brassicaceae
Cardamine-type
Euphorbia-type
Chenopodiaceae
Centaurea sp.
Centaurea cyanus
Centaurea t. jacea
Echium
Polygala-type
Mentha
Plantago lanceolata
Plantago major-media
Urtica
Cannabis/Humulus
Rumex sp.
Rumex t. alpinus
Rumex t. acetosella
Artemisia
Ambrosia-type
Agrostemma githago
Cerealia sp.
Cerealia T. Secale
Cerealia T. Triticum
Varia
L PAZ
Stratigraphy (Firbas 1949, 1952)
210Pb DATA
RS-4-Xc
RS-3-Xc
RS-2-Xc
RS-1-Xc
1993
1992
1990
1989
1987
1982
1977
1973
1965
1953
1942
1925
1910
1847

RS-3-Xc: *Picea – Betula – Pinus* – Cyperaceae – (*Sphagnum*)

Years 1953–1989, depth 0.06–0.22 m.

This zone is marked by falls and subsequent rises of a woody component (average rise in 10%), which is caused mainly by spruce (*Picea*) and partially by pine (*Pinus*). After depopulation of the border area, human activity in the landscape declined. Settlement comeback can be seen again in the eighties of the 20th century. Except the above-mentioned trees, a woody layer was becoming less varied as well as herb and shrubby layers. Wetland types (e.g., Cyperaceae) and types of meadow communities still persisted. Some types of anthropogenic indicators appear and some cereals. At the beginning and at the end of the zone a curve of peat moss (*Sphagnum*) grew up markedly, which can be connected with changes of the water regime directly in the locality. There was an unbroken occurrence of fungi micro-remains (Fungi) *Microthyrium microscopicum*, and of Rhizopoda *Amphitrema flavum*. Other fauna representatives occur only sporadically.

RS-4-Xc: *Picea – Abies – Alnus* – (*Hyalosphenia subflava – Nebella – Arcella* – Tardigrada animal)

Years 1990–1993, depth 0.00–0.06 m.

A woody component behaves similarly as in the previous zone, however, a significant rise in AP is recorded (80%), which is by the increase in spruce (*Picea*) and fir (*Abies* up to 7%). The highest value of fir found in this zone testifies to a considerable recovery of *Abies*. Some other trees disappear with exception of whitebeam (*Sorbus*) as well as some taxa of a shrubby layer. Bushes probably disappeared as a consequence of settlement comeback to the Bohemian Forest area, when people tried to farm again in approachable places. Variety and amount of the herb layer considerably decreased. It was probably the reaction to the previous limitation of human activity in the whole area of the Bohemian Forest, when self-sowing overgrowing of pastures and fields with trees and bushes occurred. In this zone a considerable increase of animal micro-remains, mostly *Hyalosphenia subflava*, *Nebella*, *Arcella*, and Tardigrada, appeared. On the contrary, an amount of peat moss spores declines (*Sphagnum*), a curve of Polypodiaceae and *Microthyrium microscopicum* remains continuous. This state is typical for the upper horizons of peat bogs.

Interpretation of the paleobotanical results

In the whole profile, the arboreal component prevails, showing bigger or smaller oscillations. From the very deep past, extensive forests have been observed in the Bohemian Forest area; the fact is reflected in its Czech name (Šantrůčková et al. 2010). At the turn of the era the forest expansion from Rhine over Danube up to Elbe was recorded in chronicles.

The historical sources (Nožička 1957, Šantrůčková et al. 2010) stress that in the first half of the 18th century new settlements were founded at the place of former glassworks. Besides the timber was floated from the Bohemian Forest to the town of Český Krumlov (1832 – bad forestry in the Český Krumlov area). There are, for example, references about the year of 1790, when in the places of floating the spruce-fir-beech forests were quickly disappearing, which is reflected in the lower part of the pollen diagram in the zone RS-1-Xc. In 1778, the area of Prášily was affected by the huge windstorm. Similarly, the area of Tachov was affected in 1830 and the forests in the area of Vimperk in 1833, 1834, and 1839. Moreover, in 1839 bark beetle appeared. Lower values of spruce pollen grains are recorded also in the pollen diagram (from 0.32–0.38 m), then there is a strong increase of spruce from about 0.30 m to 0.24 m. In 1843, abundant clear-felled areas occurred in many places in the Bohemian Forest. Therefore, in the following year a decree to expand cultivation of broadleaved trees by maple (*Acer*), ash tree (*Fraxinus*), beech (*Fagus*), and oak (*Quercus*) was issued. This state becomes particularly evident in the pollen diagram at oak and linden pollen values. Taking into account that pollen production of other broadleaved trees (ash, maple) is very small and without dating method almost irrecordable. In 1836, cultivation of beech (*Fagus*) was forced out by spruce monocultures (see pollen diagram with the first biggest spruce maximum in the thickness of 0–0.38 m), at the beginning of the 19th century also larch (*Larix*) was cultivated there. Because of the small pollen production larch was not recorded in the diagram. Similarly in the 1790s, larch (*Larix*), oak (*Quercus*) and beech (*Fagus*) were cultivated. In 1833, pine monocultures were spread in surroundings of the town of Týn Nad Vltavou. The pollen diagram records the rise in pollen grains also after this time.

The extent, way and time of farming in the Bohemian Forest can be read out from the pollen spectra. For example, two waves of resettlement (in 1939 and 1945) were reflected in the vegetation composition. In general, the natural environment has been considerably less negatively disturbed than in the Krušné Hory Mts. (Vile et al. 1995). By the years of 1925–1942, the substantial agricultural impacts are apparent (particularly pollen grains of herbage and a shrubby layer indicate these activities). After the years of 1942–1990, these matters are gradually restrained and partially vanish.

The peat bog fauna is also relatively abundant. Rhizopoda, the protozoan whose body is protected by a firm shell, are well represented. They mostly feed on algae, bacteria and tiny parts of dead bodies. Shells are preserved in peat moss so that the individual species can be determined (Hausmann & Hülsmann 1996, Jankovská 2006, Bartošová et al. 2011).

Both the Allerød and the Younger Dryas have been recognized in six pollen diagrams from the Bayerischer Wald (Stalling 1987). The Younger Dryas has been described from the Bohemian Forest in the pollen diagram from the Boubín virgin forest (Boubínský Prales, Kral 1979).

According to the results of pollen analyses and radiocarbon dating, the origin of peat bogs has been most frequently suggested at the beginning of the Holocene (Pre-Boreal–Younger Subatlantic, Firbas 1949, 1952). However, more intensive and recent palynological studies within the geological mapping of the Czech National Parks and Protected Landscape Areas (Břízová 1991a,b, 1993, 1995, 1996, 2004a, 2004b, Mentlík 2002, 2003, 2004, Břízová & Havlíček 2004, Břízová et al. 2006, Břízová & Mentlík 2005a, 2005b, Mentlík et al. 2005, 2006, 2010) have dated back the origin and age of peat bogs to the Late Glacial (15 000/13 000–10 250 yr BP). The same conclusion was formulated for example on the Rokytecká Slať mire (Svobodová et al. 2002), where the vegetation history begins in the Late Glacial (III, Firbas 1949, 1952) as a steppe tundra. It continues through the Holocene development via the climatic optimum of the Holocene Atlantic (VI, VII) that is represented by spruce-beech forests with indicators of warm and humid climate. The forests were developing also in the Sub-Boreal (VIII) and the Older Atlantic (IX), when fir appeared in smaller amount. In the Younger Subatlantic (X) human influence is recorded in forest composition, particularly in the 13th century AD as a result of the German colonization. In the last 300 years, pine and spruce expanded in the forests, originally with prevailing beech, fir and spruce. In some cases, these are probably pine plantation (Břízová 1996). A type of humolite is also changing with vegetation alteration in a certain period; its age is continuously exemplified together with the pollen analysis and radiocarbon dating.

The pattern of vegetation development presented in the present study resembles the ones elaborated in the profiles from Prášilské Lake (upper ca. 0.50 m). It was found out by ^{210}Pb dating and pollen analysis (Hruška et al. 1999) that, at the beginning of the 19th century, an amount of pollen grains of woody species of the natural forest, namely beech (*Fagus*), fir

(*Abies*), and hornbeam (*Carpinus*), decreased, wheres spruce (*Picea*) and pine (*Pinus*) increased as a consequence of plantation of these woody species as contemporary monocultures. This fact is as well verifiable by the historical sources. The territory shows stable forestation (about 80% of AP component in the pollen spectrum). The pollen values of the herbal component were very low (about 20%), however, the plant communities were very variable in species. Their composition was influenced by human activity mostly in the upper parts of the profile. Human factor was likewise confirmed as in the sediments arising from the Krušné Hory Mts. that the results were compared with.

Unlike to the Krušné Hory Mts. (Oceán peat bog – Břízová 1997, Novák et al. 2008), it seems that, in this part of the Bohemian Forest, the anthropogenic influence was much earlier and stronger but, in spite of it, preservation of natural forest was possible and to a certain extent in harmony with the laws of nature. The similar development of vegetation was found out also in the Jezerní Slať mire (Břízová 1996, Vile et al. 1995), Černé and Čertovo Lakes (Břízová 1995, 1996, Veselý et al. 1993). Forestation of the territory is also much more visible here than in the Krušné Hory Mts. The natural environment is considerably less negatively disturbed than in the Krušné Hory Mts. Up to 1925–1942, considerable agricultural influences are evident (proofs: mainly pollen herbal grains and a shrubby layer). After 1942–1990, these matters are gradually restrained and partially vanish.

Conclusions

The complex of the Rybárenská Slať mire is situated in the transition zone between the montane-mixed beech forests and coniferous montane taiga. Peat thickness reaches 6.5 m. Above the grey clay, the profile is formed by gyttja, overlain by *Carex* peat with *Sphagnum* remains and brown mosses (Hypnaceae). The most of the upper part of the profile is built by *Carex*-*Eriophorum vaginatum* peat (Svobodová et al. 2002).

(i) On the basis of palynology, the analyzed profile of the Rybárenská Slať mire (RS, RYBS) was classified into the younger phase of the Younger Subatlantic Xc (according to Firbas 1949, 1952, modified stratigraphy by Břízová & Juřičková 2011, Břízová et al. 2012). It was dated by the ^{210}Pb method (Novák 1998, Novák et al. 2008) into the range of 1847–1993 years (1847, 1910, 1925, 1942, 1953, 1965, 1973, 1977, 1982, 1987, 1989, 1990, 1992, 1993; thickness of the dated sediment 0.28 m).

(ii) On the basis of vegetation development found out by pollen analysis, the profile can be divided into 4 local pollen assemblage zones (L PAZ): RS-1-Xc: basis of profile (?1650–?1817 undated), thickness 0.28–0.38 m, RS-2-Xc: 1847–1942, thickness 0.22–0.28 m, RS-3-Xc: 1953–1989, thickness 0.06–0.22 m, RS-4-Xc: 1990–1993, thickness 0–0.06 m.

(iii) The natural forest development in the Bohemian Forest area depends on the structure of woody composition from the viewpoint of its migration, expansion and altitude.

(iv) In the whole profile a woody component ranges with bigger or smaller oscillations, but a variety of forest communities is small, only spruce (*Picea*) considerably prevails and partially pine (*Pinus*), in this case it is probably peat types: dwarf pine (*Pinus mugo*) or marshland pine (*Pinus uncinata*).

(v) Taking into account the contemporary state of vegetation the spruce (*Picea*) expansion in the Bohemian Forest has been dated on the basis of pollen analyses since the Boreal, becoming a dominant woody plant since the older phase of the climatic optimum (Atlantic). Then it is steadily declining to the reintroduction in the younger phase of the Younger Subatlantic, which can be partially seen in the pollen diagram (Fig. 3) and it is also exemplified by the historical sources (e.g., Nožička 1957).

(vi) The beech (*Fagus*) expansion took place with delay, starting here on the Rybárenská

Slať mire in the Younger Atlantic and dominating at the beginning of Sub-Boreal in company with fir.

(vii) Fir (*Abies*) expanded later in the Sub-Boreal, when they form fir forest or fir-beech forest mostly in the lower parts of the Bohemian Forest.

(viii) Hornbeam (*Carpinus*) always occurred rather sporadically.

(ix) On the basis of anthropogenic indicators and pollen grains of cereals, a growth of a settlement, which to a certain extent appears in all pollen diagrams, was anticipated. Human influence was becoming slowly visible at the end of the early Middle Ages (5th–12th centuries), when the forest structure began to be affected by wood exploitation and cattle grazing. People started to penetrate step by step into forests of the Bohemian Forest along the trading paths. They built their settlements at the water sources and at the edge of deep forests. Later in the Middle Age (12th–15th centuries), there is a launch of precious metals mining and glassworks development. In the 16th century, it is iron ore exploitation and processing. Yet at the turn of the 18th–19th century, there was the maximum settlement in the Bohemian Forest, but later glassworks and ore mining was on decline. Development of the Bohemian Forest region caused by glassworks, metallurgy, development of agriculture, shepherding, and stockbreeding resulted in woodcutting and later in plantation of spruce monocultures. This situation is precisely recorded in the pollen diagram (Fig. 3, zone RS-1 and beginning of RS-2). The pollen spectrum reflects the rate, way and time of farming and power of human influence in the Bohemian Forest.

Acknowledgments

Within the grant project of M. Novák (GA ČR No. 205/96/0370, CGS research programme), the upper part of the Rybárenská Slať mire, 0.38 m thick, was palynologically evaluated some time ago for comparison with other methods determining humolite age and conditions of its origin. The author continued in dealing with this problems during the geological mapping of the Šumava National Park on a scale of 1 : 25 000 within the research aims of the Ministry of Environment: 0002579801 and Global Climatic Changes.

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Received: 6 September 2011
Accepted: 24 July 2012