The origin and vegetation development of the Rejvíz pine bog and the history of the surrounding landscape during the Holocene

Vznik a vývoj vegetace blatkového vrchoviště Rejvíz a historie okolní krajiny během Holocénu

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The Rejvíz bog is an extensive mire complex in Central Europe, with up to 7 m deep sediments and two natural lakes. Recent vegetation is one of the best preserved examples of *Pinus uncinata* subsp. *uliginosa* (syn. *P. rotundata*) bog woodland in Central Europe. The origin and development of the mire and changes in the surrounding landscape vegetation are reconstructed using sediment stratigraphy, radiocarbon dating, pollen analysis and plant-macrofossils analysis, with particular emphasis on the processes that resulted in the origin of Rejvíz bog and on pine woodland dynamics. Based on identified species the water level changes were reconstructed. The sediment started to accumulate more than 9000 years ago at an open mixed-woodland spring with *Dichodontium palustre*. Later, poor fen vegetation with sedges and horsetails developed. Around 6170 cal. yr BC the fen became inundated for 2000 years and (semi)aquatic vegetation thrived. Next step in the succession followed a decline in water level which resulted in the development of drier oligothrophic vegetation with a high representation of pine and dwarf shrubs. After ca 1020 cal. yr BC the mire became the bog it is now. Three wooded stages appeared in both the minerotrophic and ombrotrophic developmental phases: before 6720 cal. yr BC, during ca 1960–1020 cal. yr BC and recently. The vegetation in the surrounding landscape developed without marked human interventions up till ca the last six or five centuries, when deforestation and later settlement took place. Comparison with published data from the Góry Bystrzyckie/Orlické hory Mts suggests that not only regional, but also local vegetation changed in a similar way across the middle-altitude eastern Sudetes, following oscillations in climate rather than local changes in mire water regime.

Keywords: Hrubý Jeseník Mts, eastern Sudetes, palaeoecology, peatland, pollen, plant macrofossils, sediment stratigraphy, spring

Introduction

Present habitats and biodiversity in the Hrubý Jeseník Mts, the second highest mountain complex in the Czech Republic, are well studied but little is known about the past vegetation and development of the landscape in this region. The region was palaeoecologically studied in the first half of the 20th century (Fahl 1926, Salaschek 1935, Fietz 1938, Firbas & Losert 1949). Later Opravil (1959) studied several small high-mountain bogs in the northwestern part of the Hrubý Jeseník Mts. Recently the eastern highest ridges have received more attention, resulting in a diploma thesis by Rypl (1980) and a later paper by Rybníček & Rybníčková (2004). Further palynological research of subalpine sites by Petr (in Treml et al. 2006, 2008) focused on the dynamics of the timberline during the Holocene.

In contrast, there is no modern study of the development of vegetation at sites at middle altitudes. Peat deposits in the Rejvíz bog (situated at 740–780 m a. s. l.) could be an important source of such information. Furthermore, its analysis may be crucial for understanding the origin and development of one of the most famous habitats in Central Europe: pine bogs with *Pinus uncinata subsp. uliginosa* (sensu Businský & Kirschner 2006, syn. *Pinus rotundata* Link). Pine bogs belong to the most endangered vegetation types in the Czech Republic and have attracted many phytosociological and ecological studies in the past and recently (e.g. Neuhäusl 1972, 1992, Rybníček et al. 1984, Bastl et al. 2008, Kučerová et al. 2008). Pine bogs, particularly in the Třeboňská pánev basin (Puchmajerová & Jankovská 1978, Jankovská 1980), Bohemian Forest (Svobodová et al. 2002) and Bohemian-Moravian Highlands (Salaschek 1935, Puchmajerová 1944, Břízová 2009) have been the subject of palaeoecological research. Nevertheless, generally there is only fragmentary knowledge about the origin and development of pine bogs.

The palaeoecology of the Rejvíz pine bog was studied at the beginning of the 20th century by Fahl (1926). He explored the peat deposit by means of 26 test cores and described the site as being formed by two more or less separated bogs, each with a small lake in the middle. In addition, the results of the pollen and macrofossil analysis indicated that the older eastern bog originated in the pine-hazel (i.e. Boreal) period and the younger western bog during the spruce (i.e. Atlantic) period. Another study was carried out by Salaschek (1935) as part of his comprehensive research of the Moravian and Silesian region. Although his pollen analysis was more thorough, the peat profile was not cored to the very bottom, except for one single sample. The greater age and depth of the Rejvíz sediment (Fahl 1926, Salaschek 1935) compared to that of the shallow and younger (sub)alpine bogs studied so far (Rybníček & Rybníčková 2004) promises a unique opportunity for detecting large scale changes in both the vegetation and landscape history during almost the entire Holocene.

Thorough understanding of the history of the local vegetation of the Rejvíz bog, one of the best preserved woody raised bog complexes in Central Europe, is also fundamentally important. There is currently no clear explanation of the origin of the Rejvíz bog. Fahl (1926) supposed that the western peat deposit originated at the foot of a wooded slope as a result of peat forming in swampy depressions. In the case of the older eastern deposit he assumes a similar process, but occurring in larger waterlogged depressions including at least one large water body whose remnant is Small Moss Lake (Fig. 1). Later, Dohnal et al. (1965) speculated about the existence of several springs under the peat sediment, but without any direct evidence.

The objective of this paper is to determine the origin of the Rejvíz bog and how the local vegetation changed using modern methods of plant macrofossil and pollen analysis. In addition, a mosaic of both the history of pine bogs in Central Europe and the development of the vegetation in the Hrubý Jeseník Mts at the landscape scale will be presented based on a comparison with published data.

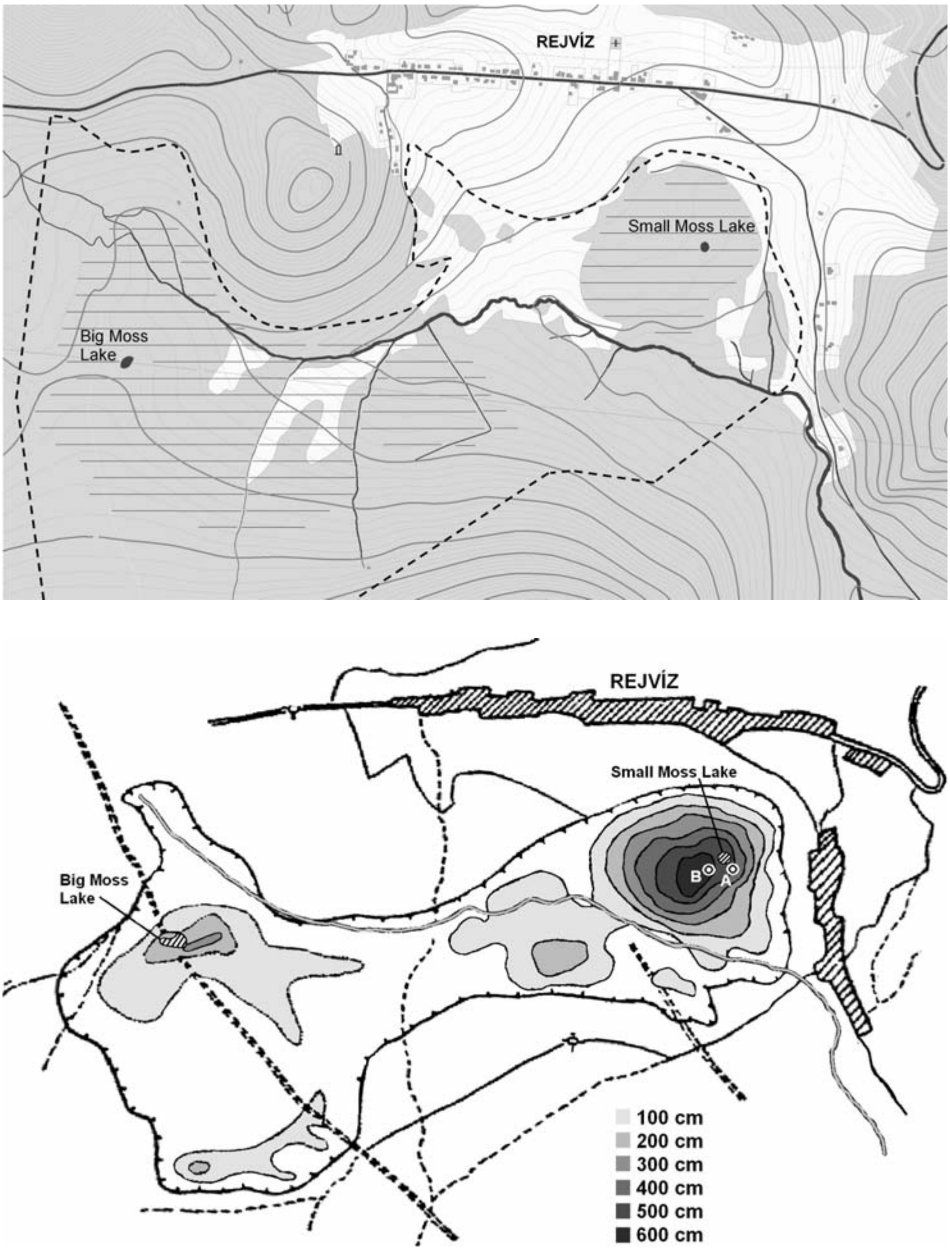

Fig. 1. – Site map of the Rejvíz bog (above) and its sediment thickness (below, redrawn from Kříž 1971). Dashed line shows nature reserve borders. Points indicate position on the bog where the first (A) and second (B) sections of sediment were obtained (the distance between points is 45 m).

Material and methods

Rejvíz site

The Rejvíz bog is situated in a shallow geomorphologic basin south of the village of Rejvíz and is a protected national nature reserve. It belongs to the Jeseníky Protected Landscape Area. The climate in the area is quite cold and wet (annual mean air temperature 5.3 °C, annual mean precipitation 1029 mm, Lednický 1971). The bedrock in the Rejvíz area is mostly metagranitoids, with locally younger Devonian rocks (hornblende schist, quartzite, phyllite and gneiss). The ground below the bog consists of deluvial impermeable deposits, which originated by weathering of the above mentioned rocks. Water from the western part of the basin flows into the Černá Opava river and that from the eastern part into the Vrchovištní potok brook (both are in the Odra river-basin). There are two small lakes in the peat bog (Fig. 1A). Big Moss Lake (BML in following text) is situated in the centre of the western part and has an open water surface (area of 1692 m^2) whereas Small Moss Lake (SML in the following text, 920 m^2) in the eastern part is mostly filled with submerged mosses and plants. The total area of peat is 195 ha and the volume about 2,480,000 m^3 (Kříž 1971).

The Rejvíz site presents a unique complex of various types of mire vegetation. Woody raised bog with *Pinus uncinata* subsp. *uliginosa* forms the main part of the nature reserve. Open raised bog and poor fen vegetation cover the margins in the south and east. Natural bog spruce woodland mixed with spruce plantation surrounds the site except in the north where wet meadows with willow shrubs occur. Apart from other remarkable and endangered plant species such as *Ledum palustre*, *Drosera rotundifolia*, *Carex appropinquata* and *Lysimachia thyrsiflora* (Šmarda 1948, Hradílek et al. 1999), the presence of *Scheuchzeria palustris* should be mentioned.

Sampling method and radiocarbon dating

A peat profile was obtained during the course of two field trips. In 2005 the peat was excavated to a depth of 220 cm (Fig. 1B, point A) and a section of the profile exposed was sampled and stored in metal boxes (10 × 10 × 50 cm). Profile section from 220 to 520 cm was obtained by coring using either a handle Intorf corer or handle soil sampler and stored in bisected PVC tubes. Because of the many branches and trunks in the peat profile it was not possible to reach the bottom of the profile.

In 2006 a second profile section was obtained from an adjacent area (Fig. 1B, point B, 45 m from point A) where it was possible to reach the bottom of the peat deposit. The lowest layer of organic sediment (610–643 cm) and the underlying soft mineral sediment (643–800 cm) were successfully cored using a special percussion drill. Unfortunately, it was not possible to obtain a core of the soft peat between 520 and 610 cm and link up with the previous sampling. Sediment was described according to Troels-Smith classification (Troels-Smith 1955) and the colour determined using Munsell soil color charts (Munsell Color Company 1954). Two samples of mineral substrate (648 cm and 653 cm) were analysed by means of X-ray diffraction in the Institute of Geology, AS CR.

Due to difficulties encountered in coring the woody sediment the statigraphy was partially contaminated. Repetitive coring in the same hole resulted in organic sediment from upper layers being inserted into the two layers of mineral material at a depth of 700–720 cm.

Conventional radiocarbon dating of the upper nine peat samples was done at the Gadam Centre in Gliwice, Poland. Acceleration mass spectrometry (AMS) dating of the pieces of wood was done at the Center for Isotope Research in Groningen, the Netherlands.

Macrofossil and pollen analysis

Standard macrofossil analysis (Berglund et al. 1986) was done only on samples from depths of 0–220 cm (sample of 100 ml) and 610–645 cm (samples of 60 or 30 ml), where there was sufficient material for this analysis. Samples were cut out from the peat monoliths stored in metal boxes or PVC tubes. Macrofossils were sieved from the samples using running water and sieves with mesh sizes of 1.0, 0.6 and 0.2 mm. Seed determination followed Beijerinck (1947) and wood and tissues were identified with help of Schweingruber (1978) and Mauquoy & van Geel (2007). The determinations of plant macro-remains were checked against specimens in the reference collection. Nomenclature for vascular plants follows Kubát et al. (2002) and bryophytes Kučera & Váňa (2003).

Pollen analysis was carried out using standard methods following Faegri & Iversen (1989). The samples were removed from the core every 10 cm and the peat samples subjected to acetolysis. The samples that contained some mineral material were pre-treated with cold concentrated hydrofluoric acid for 24 hours. At least 500 pollen grains from trees and all of those from herbaceous plants were counted per sample. Pollen was identified using a reference collection, Moore et al. (1991), Beug (2004) and Reille (1992, 1995, 1998). The nomenclature of pollen types follows Beug (2004). The determination of spores and non-pollen objects follows Moore et al. (1991) and van Geel et al. (1980–1981).

Data processing

Calibration of radiocarbon data was carried out with the Oxcal 4.1 program (Ramsey 2001) using an IntCal04 calibration curve (Reimer et al. 2004). The age-depth relationship model was constructed using the Depth-age program (Nalepka & Walanus 2003). The profile zone boundaries were determined using the same program, calibrated data (68.2% range of probability) and linear interpolation. Calibrated (BC = before Christ, AD = Anno Domini, after Christ) and uncalibrated years (BP = before present, i.e. before 1950) are used in this paper.

Pollen analysis results are presented in two pollen diagrams: the first is of the pollen taxa prevalent locally on the Rejvíz mire and the second of the taxa prevalent in the region. Taxa for which there is a local and regional source of pollen are depicted in both diagrams. Sporadically found pollen taxa are listed beneath the diagrams. Pollen diagrams created using the POLPAL program (Nalepka & Walanus 2003) are based on total sum of arboreal and non-arboreal pollen (AP + NAP = 100%). The percentages of spores and non-pollen palynomorphs are related to extended sum (AP + NAP + spores or non-pollen palynomorphs = 100%). Both parts of the cored profile are depicted together. List of genera or species included in individual pollen types is given in Appendix 1. Local pollen analytical zones (LPAZ) were delimited based on analyses of both macrofossils and pollen with the help of ConsLink (Constrained Linkage, implemented in POLPAL program), which is an agglomerative cluster analysis that clumps similar samples together. For the ConsLink analysis the general pollen fall-out dataset was used, including local pollen taxa, indicators of human activity and uncommon taxa. Holocene chronostratigraphical periods (chronozones) are delimited according to Mangerud et al. (1974).

Results

Sediment stratigraphy and radiocarbon dating

As the volume of the samples varied due to difficulties experienced in coring and use of different samplers the stratigraphy of the organic deposit at Rejvíz presented is a general one. For a thorough understanding of the processes and conditions that resulted in the accumulation of peat the deposit has to be systematically sampled at many points within the whole area. This is why the time of origin and development of the site is based mainly on the results of pollen and macrofossil analyses.

Most of the Rejvíz organic sediment consists of *Sphagnum* and/or herbaceous peat (Table 1), with several interlaid woody rich layers. Many small pieces of wood were found at the bottom of the peat profile (643–610 cm), plus thick layers of deposited wood at 520 cm and 200–240 cm. A few branches were found also at 300 cm and 90 cm. According to the X-ray diffraction analysis the soft grey coloured mineral material under the peat deposit consists of the weathered remains of the bedrock. Absence of layers of mineral sediments within the peat deposit indicates no allogenic over-flooding in the past.

Table 1. – Stratigraphy and description of the Rejvíz bog sediment. For details see Troels-Smith (1955).

	Physical properties						Components						
Depth [cm]	Limes (upper boundary)	Nigrositas (darkness)	Stratificatio (stratification)	Sicitas (dryness)	Elasticitas (elasticity)	Colour	Tb (Sph) (*Sphagnum* peat)	Th (herbaceous peat)	Tl (wood peat)	Dg (granular detritus)	Argilla steatodes (clay)	Limus detrituosus (gyttja)	Ga (fine sand particles)
0–10		1^{2}	2	2	2	2,5Y 5/6	3^{2}		1				
10–25		3^{4}	1	2	1	10YR 3/3	3^{4}	1	$+^{+}$				
25–40		3	1	2	2	5YR 3/4	2^{3}	2^{3}	+				
40–210		3	+	1^{2}	2^{3}	5YR 3/4	2^{3}	2	+				
210–520		3	1^{2}	2	1	5YR 3/4	$+^{+}$	1	$+^{+}$	3			
520–610						missing sediment							
610–625	0	3^{4}	1	2	2		1^{2}	2^{1}	+	1			
625–640	2	4	1	2	2	5YR 2/1	$+^{+}$	$+^{+}$	3	1			
640–643	2	3	0	3	1	10YR 2/2			+	2	2	+	
643–655	1	2	0	3	1	2,5Y 4/2				$+^{+}$	4	$+^{+}$	+
655–700	0	1	0	3	0	5Y 4/1					4	$+^{+}$	+
700–717	2	4	1	2	2	5YR 2/1	1	$+^{+}$	1	2			
717–720	2	3	0	3	1	10YR 2/2				1	3	+	
720–800	0	1	0	3	0	5Y 4/1					4	$+^{+}$	+

Six C^{14} dates were used to construct an age-depth relationship model (Fig. 2). Three of the remaining C^{14} dates indicated ages younger than that of samples from above them (aberrant data). Possible reasons for this are roots penetrating into older organic layers (GrA-42524, possibly also Gd-30201), a stratigraphical hiatus due to mineralization (Gd-30201) or contamination by younger peat material pushed down during the coring process (probably Gd-16405). In the case of Gd-30201 the first explanation is preferred because of

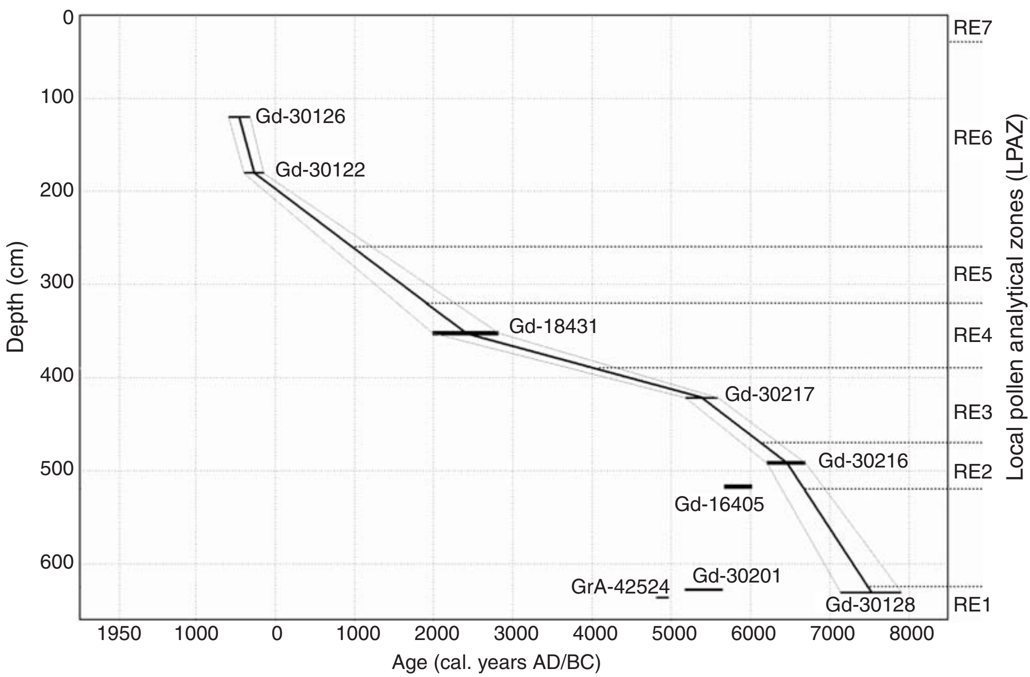

Fig. 2. – Age-depth relationship of the Rejvíz bog sediment based on six radiocarbon dates. Three aberrant dates are depicted but not used for the interpolation. Abbreviations: AD = Anno Domini (after Christ), BC = before Christ.

Table 2. – Radiocarbon dates of the Rejvíz bog core. Aberrant datings in brackets. Samples with laboratory number Gd were dated in the Gadam Centre (Gliwice, Poland), with GrA were dated in the Center for Isotope Research (Groningen, Netherlands). C – conventional dating method, A – acceleration mass spectrometry, AD = Anno Domini (after Christ), BC = before Christ, BP = before present (1950). Calibrated ages rounded to decades.

Laboratory number	Method	Material dated	Depth (cm)	Uncalibrated age ^{14}C BP	Calibrated age (calendar years)	
					range 68.2 %	range 95.4 %
Gd-30126	C	peat	120–121	1660±95	260–530 AD	140–580 AD
Gd-30122	C	peat	180–181	1800±90	90–340 AD	22–420 AD
Gd-18431	C	peat	350–355	3930±290	2870–2040 BC	3330–1690 BC
Gd-30217	C	peat	421–423	6500±200	5640–5230 BC	5810–5000 BC
Gd-30216	C	peat	490–494	7670±190	6750–6260 BC	7060–6110 BC
(Gd-16405	C	peat	515–520	7040±190	6080–5730 BC	6350–5570 BC)
(Gd-30201	C	peat	628–630	6520±240	5700–5220 BC	5970–4950 BC)
Gd-30198	C	peat	630–632	8530±270	7960–7190 BC	8300–6830 BC
(GrA-42524	A	wood	637	6060±40	5020–4860 BC	5200–4840 BC)

the differences in the pollen spectra of the sample collected at 630 cm and chronologically similar samples collected at around 420 cm. The most important C^{14} date is that for the sample from 630–632 cm, which is dated 7960–7190 cal. yr BC with 68.2% probability (Table 2). This indicates the Rejvíz bog organic deposit started to accumulate nine thousands years ago or even earlier.

Table 3. – Table of macroscopic plant remains. Countable macrofossils (seeds, needles etc.) are presented in absolute numbers and uncountable fossil material in terms of volume. Abbreviations: bs = bud scale, caps = capsule, fel = feloderm, need = needle (whole/fragment), nod = nodus, scle = sclerotium, spin = spindle, stws = stem with spindles, tiss = tissue. Volume: * = 0–5%, ** = 5–25%, *** = 25–100%.

Sediment (cm)	from	642	640	635	630	625	620	615	610	211	209	197	189	179	169	159	147	139	129	119	109	97	89	79	69	59	47	39	29	19	9	0
	to	644	642	640	635	630	625	620	615	220	211	199	191	181	171	161	149	141	131	121	111	99	91	81	71	61	47	41	31	21	11	4
Volume	ml	30	30	60	60	60	60	60	60	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Vaccinium vitis-idaea	leaf	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
Vaccinium vitis-idaea	seed	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.
Vaccinium myrtillus	leaf	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Vaccinium uliginosum	leaf	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Vaccinium sp.	leaf	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.
Polytrichum commune	stem	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	**
Carex canescens	seed	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	18	17
Betula sp.	seed	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1
Betula sp.	bs	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	3	1
Pinus uncinata subsp. *uliginosa*	need	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0/64	20	17/21
Pohlia nutans	stem	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
Sphagnum russowii/rubellum	leaf	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	.	**
Sambucus sp.	seed	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
Oxycoccus palustris	leaf	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	15	.	.	.	.	.	.	.	1
Sphagnum sp.	caps.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	6	4	5
Abies alba	seed	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Picea abies	need.	.	.	.	.	.	.	.	0/1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2/6	4	4/13
Potentilla erecta	seed	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex echinata	seed	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex nigra	seed	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Sediment (cm)	from	642	640	635	630	625	620	615	610	211	209	197	189	179	169	159	147	139	129	119	109	97	89	79	69	59	47	39	29	19	9	0
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Volume	ml	30	30	60	60	60	60	60	60	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Carex panicea	seed	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Scirpus sylvaticus	seed	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex rostrata	seed	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Poaceae	nod.	.	.	.	1	.	.	.	2	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex sp.	tiss	.	.	.	*	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	*	.
Rubus sp.	seed	.	.	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Betula/Alnus	wood	.	.	*	*	.	*	*	.		*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.
Dichodontium palustre	stem	.	.	2	1	.	29	4	27	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sphagnum fallax/cuspidatum	leaf	.	*	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	*	*	**
Picea/Larix	wood	*	*	.	.	*	**	*	.	**		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Coenococcum geophilum	scle	9	13	15	43	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pinus sp.	seed	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1
Pinus sp.	root	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	*	.	.	.	.	.	.
Pinus sp.	need	.	.	.	.	.	.	.	0/1	.	.	0/2*	.	.	0/1	.	.	.	.	.	0/2	0/8	.	.	0/1	.	.	0/3	.	.	.	.
Pinus sp.	wood	.	.	*	*	.	.	.	.	*		.	.	.	.	.	.	.	.	.	.	.	**	.	.	.	.	.	.	.	*	*
Pinus sp.	fel	*		**	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	**	**	.	.	.	**	*	.	.	*	.
Eriophorum vaginatum	root	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	*	*	*	*	*	*	*
Eriophorum vaginatum	stws	.	.	.	.	.	.	.	.	.	14	4	26	1	.	2	12	8	.	.	.	7	11	20	.	16	.	.	19	.	.	.
Eriophorum vaginatum	seed	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eriophorum vaginatum	tiss	.	*	.	*	.	*	.	**	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	*	.	*	*	***	.	*	**
Eriophorum vaginatum	spin	3	7	.	.	.	.	.	.	.	.	.	.	1	29	.	.	.	26	11	.	4	.	41	.	9	.	.	17	.	.	.
Sphagnum magellanicum	leaf	*	*	*	*	.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**	*	*	*	*

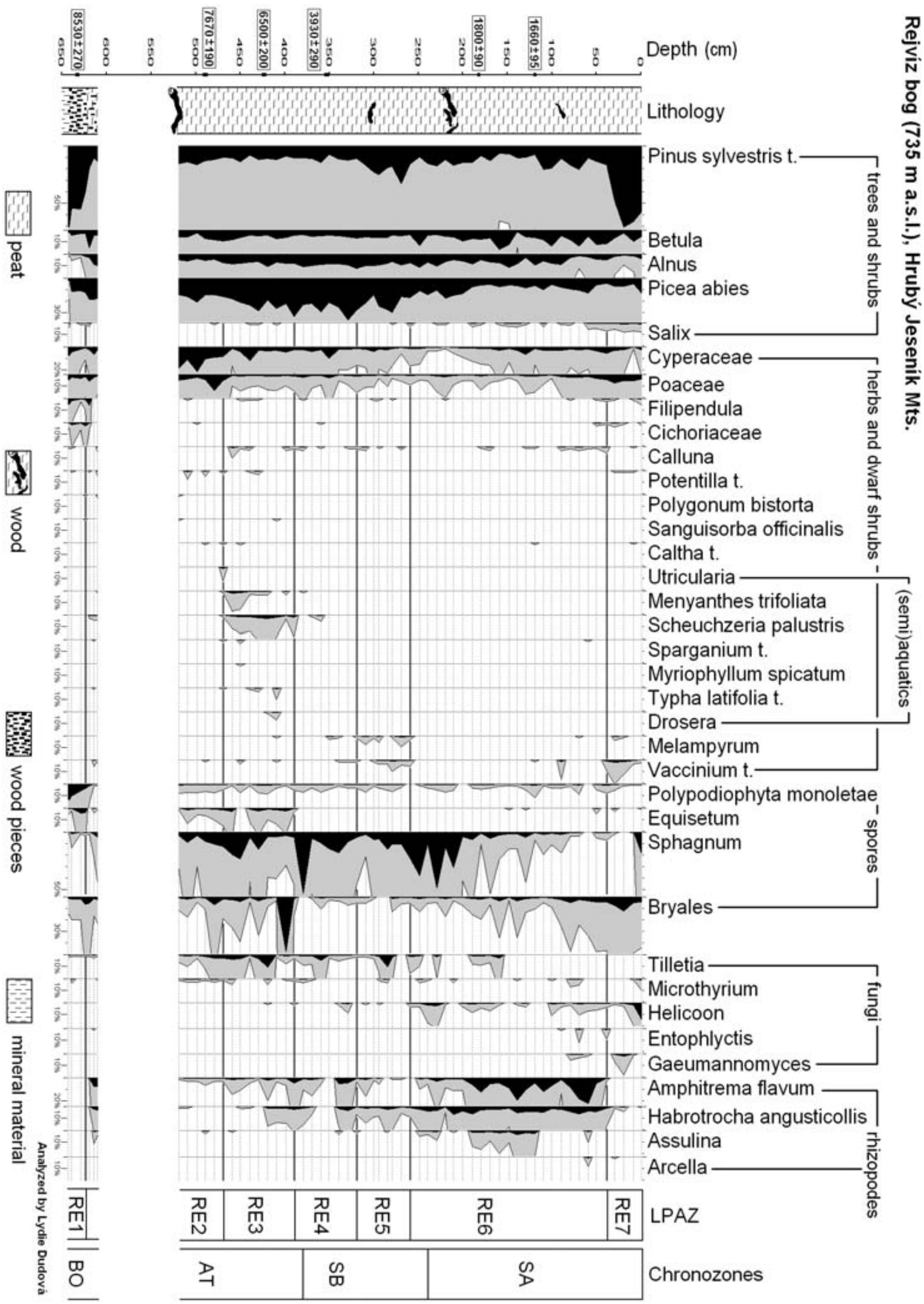

Fig. 3. – Local pollen diagram. Abbreviations: LPAZ = local pollen analytical zones, BO = Boreal, AT = Atlantic, SB = Subboreal, SA = Subatlantic.

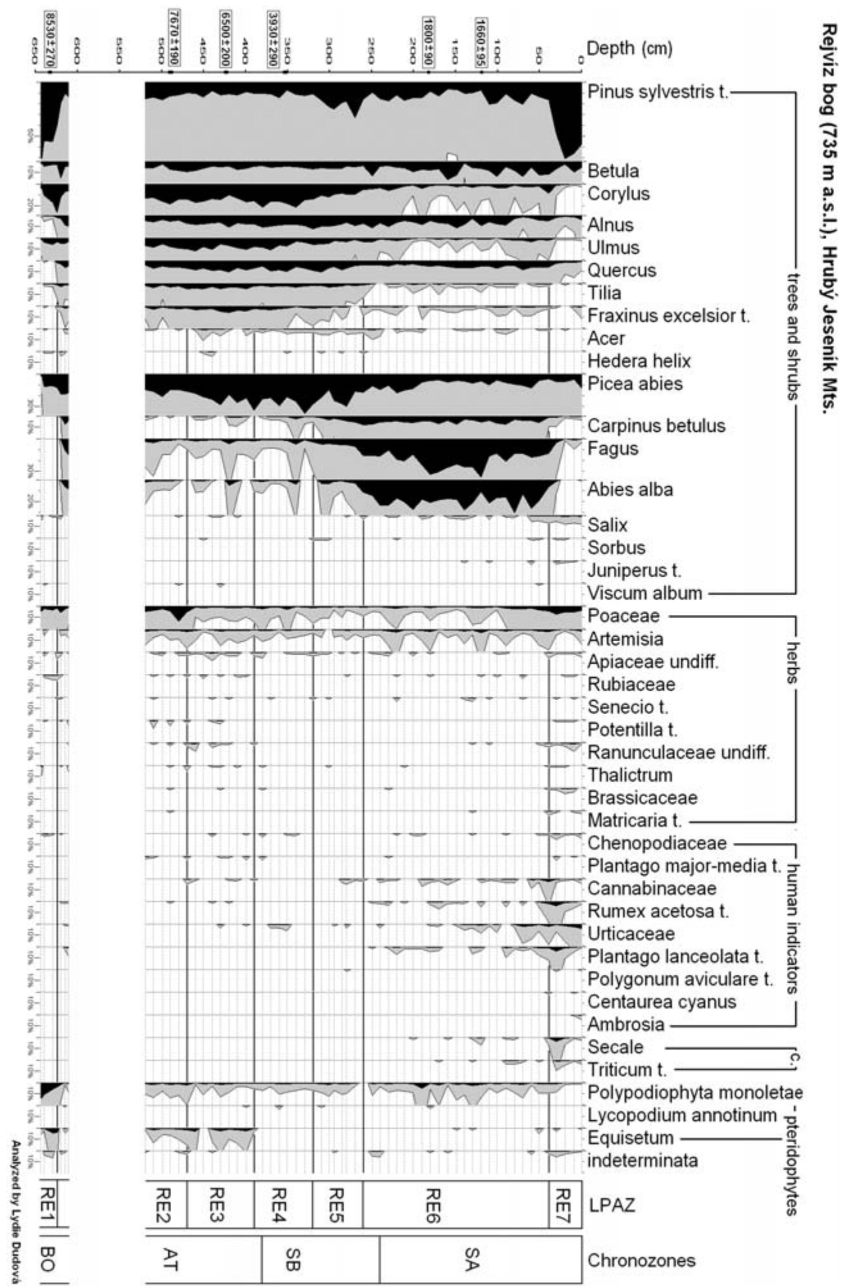

Fig. 4. – Regional pollen diagram. Abbreviations: c. = cereals, LPAZ = local pollen analytical zone, BO = Boreal, AT = Atlantic, SB = Subboreal, SA = Subatlantic. Scarce pollen or spore types (depth in cm/absolute number of finds): trees and shrubs: *Sambucus nigra* type 0/1, 9/2, 643/3; *Juglans* 0/1, 30/1; *Populus* 9/1; *Prunus* 285/1, 510/1; *Frangula alnus* 430/1, *Rubus* 70/1; *Loranthus europaeus* 180/1. Herbs: *Primula clusiana* type 0/1; *Lotus* type 20/1, 130/1; *Scrophularia* type 20/1; *Fagopyrum* 20/1; *Lysimachia vulgaris* type 30/1; *Trifolium repens* type 30/1; *Rhinanthus* type 110/1, *Trientalis europaea* 110/1; *Geum* type 120/1, *Centaurea scabiosa* 180/1; *Valeriana dioica* type 301/1; *Centaurea jacea* type 351/1, 399/1; *Viola odorata* type 370/1; *Stellaria holostea* 399/1, *Succisa* type 440/1; *Campanulaceae* 460/1, 643/1; *Alchemilla* 480/1; *Leucojum* type 490/1; *Viola tricolor* type 490/1; *Cirsium* 510/1, 640/1.

Macrofossil and pollen analyses

Results of the macrofossil analysis presented in Table 3 show that most of the material consists of hardly determinable tissues of herbaceous plants. Seeds were found only in the youngest and the oldest sediments. The majority of identified remains are of *Eriophorum vaginatum* sheaths and *Sphagnum magellanicum* leaves. In two zones humification of the organic matter is more advanced than in the other zones indicating the conditions were drier at that time: the upper zone is located at a depth of 30–50 cm and lower zone starts at 190 cm. In the rest of the sediment *Sphagnum* leaves are not decomposed. However, as little material is available for depths between 220 and 610 cm it was not possible to determine the species.

The results of the pollen analysis presented in the pollen diagrams show local (Fig. 3) and regional (Fig. 4) changes in vegetation. Seven local pollen analytical zones (LPAZ) identified using Conslink (Fig. 5) reflect the main changes in pollen spectra. The results of the pollen and macrofossil analyses are summarized in Table 4 together with the local and regional types of vegetation and assumed changes in water level.

The results of the pollen analysis confirm the above mentioned contamination of lower layers. Synchronous peaks of *Abies*, *Fagus* and *Carpinus* pollen (at 340 and 420 cm) and its presence at 611–620 cm is certainly a consequence of contamination due to the coring method. The part of the deposit from 611 to 620 cm is therefore not included in the RE1 zone. Consequently, the original location of the important plant macro-remains found in this profile is uncertain.

Discussion

Origin of the Rejvíz bog

Fahl (1926) indicated that this bog consisted of two distinct deposits of different ages. It is likely that not only the time of origin but also the primary cause and process of peat accumulation differed in the two deposits. Generally, three processes result in peat formation (Rydin & Jeglum 2006): (i) infilling of a water body, starting usually with peat development extending from the margins to the centre (often termed terrestrialization) with aquatic sediment at the base of the profile; (ii) paludification, the development of peat over previously drier mineral ground, often initially forested and therefore with a woody rich layer at the base; and (iii) primary peat formation, on wet mineral soils, often at spring outflows. In this sense, Fahl (1926) concluded that all three processes are likely to have occurred at the Rejvíz bog: primary peat formation in swampy depressions, later paludification of upland sites and infilling of former larger water body in the case of SML. However, our results support only paludification and primary peat formation, but not terrestrialization. There is neither aquatic sediment nor pollen of aquatic plants at the base of the profiles analysed. Of course, it is possible that the bottom of the hypothetical former lake was not sampled during the coring. If the former lake was so small that its bottom was not sampled by our corer it would have been terrestrialized and filled with peat a long time ago and covered by pine woodland today. In the case of the large former lake (whose remnant is likely to be SML) any aquatic sediment would have certainly been in the core. Thus, why does SML still exist? Presently, SML does not have open water, because the

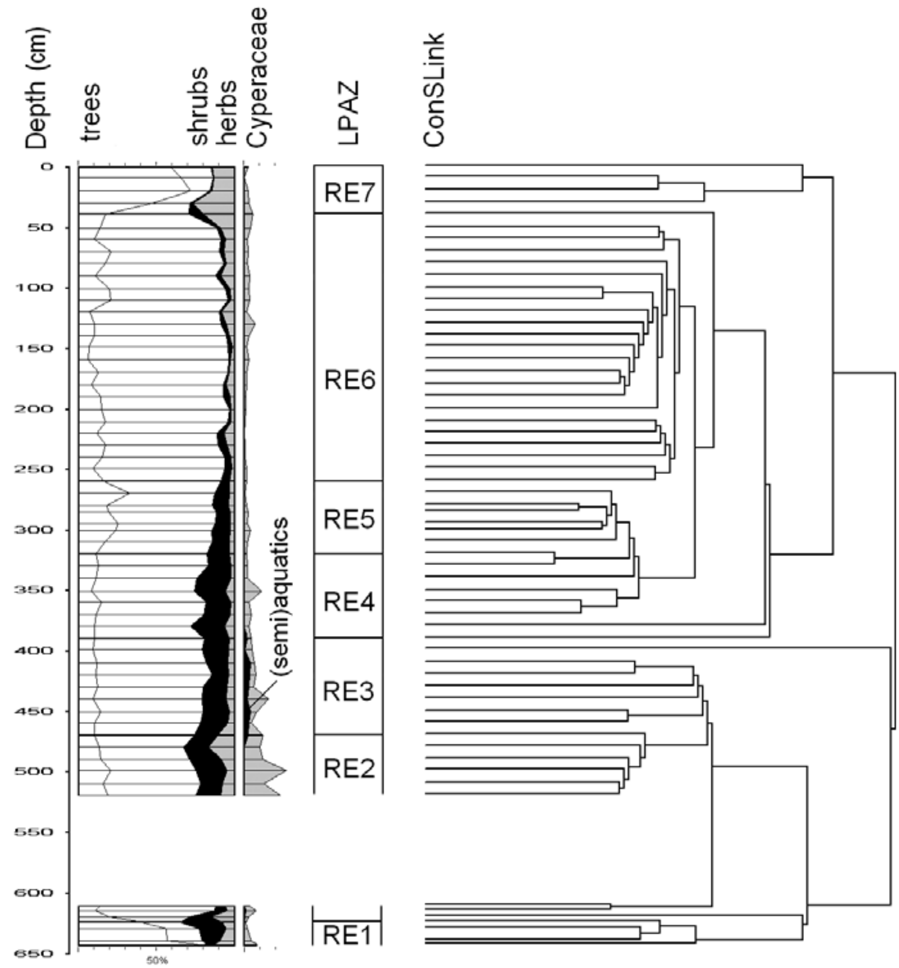

Fig. 5. – Cumulative diagram of defined groups of pollen taxa and results of Conslink analysis. Pollen taxa included in defined groups: trees: *Pinus sylvestris* t., *Betula*, *Alnus*, *Picea abies*, *Ulmus*, *Quercus*, *Tilia*, *Fraxinus excelsior* t., *Acer*, *Carpinus betulus*, *Fagus*, *Abies alba*, *Sorbus* t., *Juglans*, *Populus*; shrubs: *Corylus*, *Salix*, *Juniperus*, *Sambucus nigra* t., *Prunus, Frangula alnus*, *Rubus*, *Loranthus europaeus*, *Viscum album*, *Hedera helix*; herbaceous plants: all non-arboreal pollen taxa except *Cyperaceae* and local (semi)aquatics. Thin line in "trees" area depicts *Pinus sylvestris* t. pollen curve. Abbreviation: LPAZ = local pollen analytical zone.

surface is overgrown by submerged *Sphagnum* and *Eriophorum angustifolium*. It could indicate either that a former large lake has recently reached the stage of complete terrestrialization, or that the present vegetation represents a long term succesional stage blocked by a continuous water supply from a spring below the lake. The former hypothesis seems unlikely due to lack of aquatic sediments in all peat sections so far sampled at Rejvíz bog. Therefore, it is concluded that SML is probably continuously supplied by spring water, which is supported by several other indices: (i) The shape of the deposit (Fig. 1B) and its location – the deepest part is not situated below SML and it extends downhill. The shape of the deposit suggests the outflow from a permanent spring and that the gentle

Table 4. – Summary and interpretation of pollen and macrofossil analyses. Estimated ages of lower zone boundary rounded to decades (AD = Anno Domini – after Christ, BC = before Christ, BP = before present).

Zonation					Pollen stratigraphy		Plant macrofossil analysis		Vegetation type	
Local pollen zone	Lower zone boundary	Interpolated age of lower zone boundary: uncal. yr	Interpolated age of lower zone boundary: cal. yr	Chrono-zones	Increasing (or maximum) pollen percentages	Decreasing (or minimum) pollen percentages	Relevant macrofossils	Presumed water level change	Local	Extralocal
RE7	40 cm	(540 BP)	(1390 AD)	SA	*Pinus*, *Poaceae*, *Vaccinium*, cereals, human indicators	*Fagus*, *Abies*, *Carpinus*, *Ulmus*, *Quercus*, *Corylus*	*Eriophorum vaginatum*, *Sphagnum magellanicum*, dwarf shrubs		pine raised bog	meadows, fields, ruderals, spruce plantations
RE6	260 cm	2780 BP	1020 BC	SA	*Fagus*, *Abies*, *Carpinus*, *Betula*, human indicators	*Picea*, *Corylus*	*Eriophorum vaginatum*, *Sphagnum magellanicum*, *Picea/Larix*, *Pinus*, *Betula/Alnus*		open bog	beech-fir woodland
RE5	320 cm	3530 BP	1960 BC	SB	*Pinus*, *Fagus*, *Abies*, *Carpinus*, *Melampyrum*, *Vaccinium*	*Corylus*, *Quercus*, *Ulmus*, *Cyperaceae*			pine raised bog	mixed woodland with dominant spruce
RE4	390 cm	5320 BP	4060 BC	SB	*Picea*, *Corylus*, *Pinus*, *Melympyrum*, *Vaccinium*	*Ulmus*, *Tilia*, *Fraxinus*, (semi)aquatics, *Equisetum*			fen-bog transition	mixed woodland with dominant spruce
RE3	470 cm	7300 BP	6170 BC	AT	*Picea*, broadleaved trees, (semi)aquatics, *Equisetum*	*Cyperaceae*, *Poaceae*			watterloged fen with pools	mixed broadleaved woodland
RE2	520 cm	7840 BP	6720 BC	AT	*Quercus*, *Ulmus*, *Tilia*, *Fraxinus*, *Acer*, *Poaceae*, *Cyperaceae*, *Equisetum*	*Pinus*, *Corylus*, *Filipendula*, *Cichoriaceae*			fen	mixed broadleaved woodland
missing sediment							(woody-rich layer)		(fen woodland)	
RE1	643 cm	more than 8530 BP	more than 7520 BC	BO	*Pinus*, *Corylus*, *Picea*, *Filipendula*, *Cichoriaceae*, ferns		*Dichodontium palustre*, various *Carex* sp., *Pinus*, *Picea/Larix*, *Betula/Alnus*, *Coenococcum geophilum*		spring covered by open canopy mixed woodland	open canopy spruce woodland with hazel shrub

slope prevented the formation of a large lake. (ii) High current representation of *Eriophorum angustifolium*, *Carex canescens* and *Sphagnum riparium* indicate minerotrophic rather than ombrotrophic conditions (Hájek et al. 2006, Proctor et al. 2009) and (iii) plant macro-remains found at the base of the profile indicate presence of spring-like vegetation.

The spring origin of SML and the adjacent peat deposit probably does not apply to BML, situated in the western peat deposit of the Rejvíz bog. Its sediment lies in a very flat saddle, where peat started to form during the Atlantic period (Fahl 1926), when conditions were generally very humid. Since woody-rich sediment was found at the bottom of the profile it is likely the site was previously wooded (Fahl 1926). It is unlikely there is a spring under BML, considering the shape of the sediment (Fig. 1B).

Water chemistry of both SML and BML (Oulehle 2002) indicate that the concentrations of natrium (sodium) and chloride ions differ in autumn, while in spring and summer they are comparable. This may indicate that in spring and summer the supply of water to both bogs comes mainly from rain, while in autumn at SML it is mainly from spring water.

History of local vegetation and hydrological changes

The results suggest that at the beginning of peat accumulation, before ca 7520 cal. yr BC (8530 uncal yr BP), the site might had been an open waterlogged woodland composed of spruce and pine with an admixture of birch and/or alder (Table 3). In the initial phase acidicole herbaceous plants and mosses characteristic of poor fens, bogs and bog woodlands occurred: *Eriophorum vaginatum*, *Sphagnum magellanicum* and *S.* cf. *fallax*. Later the moss *Dichodontium palustre* became abundant. This species is known as an indicator of permanent open springs, responds negatively to desiccation and shading (Seel et al. 1992) and its optimum conditions occur in springs within tundra or alpine zones (Hadač 1983). This species is tightly linked with a slightly acidic pH of about 6.0 and extremely low mineral richness (Hájek et al. 2007), which are characteristic of spring outflows on crystalline mountains. Its occurrence, together with fen sedges *Carex panicea*, *C. echinata* and *C. rostrata*, light-demanding herbaceous plant *Potentilla erecta*, horsetails and *Cichoriaceae* (cf. *Crepis paludosa*) indicates the high activity of many springs, which reduced the tree stands and allowed light-demanding herbaceous plants and bryophytes to thrive and caused an increase in pH (Hájková et al. 2006). Spring water was probably also the main factor initiating the start of peat accumulation and paludification of adjacent forest soils. The only information on the 610–520 cm layer is that in Fahl (1926), who cites several indicators of a minerotrophic mire (*Equisetum fluviatile*, *Phragmites australis*, *Carex* and *Sphagnum* species. div.) at 560 cm. These species could have formed the next succesional stage in the development of the Rejvíz bog.

In several test holes Fahl (1926) detected a distinct stratigraphic boundary at 500 cm, where sedge peat suddenly changed into wood-rich peat. This layer consists of the wood from a number of tree generations and is up to 60 cm thick. In the current study the same boundary was located at 520 cm (estimated age 6720 cal. yr BC, 7840 uncal. yr BP). Although no continuous sediment was obtained from below this boundary, it is likely the ground became too waterlogged to support tree growth. The wood layer was probably formed by pine, spruce and birch; species that occur throughout the entire profile.

Peak in *Cyperaceae* pollen in the sediments above the woody-rich layer indicates an increase in the level of the water table. Minerotrophic conditions are indicated by

Potentilla pollen (probably *Potentilla erecta* or *P. palustris*, see Appendix 1) and *Equisetum* spores (most likely *E. fluviatile*). Next distinct hydrological change was detected at about 470 cm (ca 6170 cal. yr BC, 7300 uncal. yr BP), where pollen grains of *Menyanthes trifoliata* and *Scheuchzeria palustris* became abundant indicating an inundated minerotrophic habitat with the water table permanently above the soil surface. Single occurrences of various (semi)aquatic species in the zone starting at this point reveal the changes in vegetation. *Utricularia* and later *Myriophyllum spicatum* pollen, indicating an aquatic rather than mire habitats, were initially more abundant than those of *Menyanthes trifoliata* and *Scheuchzeria palustris*. *Sparganium* (cf. *natans*) and *Typha* were also found in this layer. Later, species indicating gradual terrestrialization (*Scheuchzeria palustris, Menyanthes trifoliata, Equisetum* cf. *fluviatile*) increased in abundance. Although *Scheuchzeria palustris* is currently considered to be a specialist species of ombrotrophic bog hollows in the Czech Republic, the accompanying species indicate minerotrophic conditions (Rybníček et al. 1984, Hájek et al. 2006). This is supported by the fact that in many especially northern regions of Europe, *Scheuchzeria* also occurs in minerotrophic mires; there is also a recent case recorded from neighbouring Slovakia (Dítě & Kubandová 2005). Tallis & Birks (1965) describe *S. palustris* as an indicator of a flooded mire surface because of its very high susceptibility to desiccation. Thus, its current presence only at Small Moss Lake at the Rejvíz site makes sense. The terrestrialization in the second half of RE3 is indicated by peaks in the pollen of *Drosera, Melampyrum* and *Vaccinium*, species which do not tolerate flooding. The abrupt peak in *Bryales* spores may consist mainly of some *Warnstorfia* species, which indicates a transition between an aquatic and semi-terrestrial habitat at mineral-poor mires (Štechová et al. 2008). In around 4060 cal. yr BC (5320 uncal. yr BP) there was an abrupt decrease in the pollen of semi-aquatic species, mainly *Scheuchzeria* and *Equisetum*, and consequent increase in *Sphagnum* spores, which probably signifies a fen-bog transition, when the hydrology switched to ombrotrophic conditions. The continuing and gradual accumulation of peat above the water table in the RE4 zone (4060–1960 cal. yr BC, 5320–3530 uncal. yr BP) is indicated by peaks in the pollen of *Melampyrum* and *Vaccinum,* species that currently occur on bog hummocks. Further drying out in the RE5 zone (1960–1020 cal. yr BC, 3530–2780 uncal. yr BP) is indicated by the *Calluna, Vaccinium* and *Melampyrum* pollen. The increase in the *Pinus* pollen curve may also indicate a continuing decrease in the level of the water table and local spread of pine. A similar peak in *Picea* pollen suggests local increase in spruce. This drier forested phase was followed by a wetter phase, which is indicated by a decrease in tree and shrub pollen and increase in *Sphagnum* spores. This wetter phase (RE6) lasted the whole of the Subatlantic period (1020 cal. yr BC or 2780 uncal. yr BP until the present) during which the tree composition was relatively stable. Peat accumulated rapidly due to favourable conditions for *Sphagnum* growth and low decomposition (Fig. 3). Nevertheless there was a change in *Sphagnum* (*S.* cf. *magellanicum*, Table 3) spore production at 200 cm, since in this sample the abundance of *Amphitrema flavum*, the *Sphagnum*-dwelling testate amoebae typical of wet bogs (Woodland et al. 1998, Lamentowicz et al. 2008) increased. However, this hydrological change was too small to alter the representation of trees. The uppermost zone, RE7, representing the most recent history of the Rejvíz bog, is characterized by the macrofossils of several plant species not found in the previous zone. Most of them are of species currently growing on the bog. Their absence from the RE6 zone can be due to either, seed germination, predation or decomposition or the absence of this vegetation. The latter is the most likely and accords with the hypothesis that the shrub and tree canopy on the bog closed recently.

Dynamics of the Rejvíz bog woodland

Bog pine woodlands with *Pinus uncinata* s. str. (Freléchoux et al. 2003, 2004) and *P. uncinata* subsp. *uliginosa* (Neuhäusl 1972, 1992, Rybníček et al. 1984) occur at the central part of the bog, filling a specific ecological niche on deep peaty soil. Towards the drier and shallower margin of the bog spruce woodlands develop, whereas in wet lagg areas birch carrs occur. Transition between bog pine woodland and spruce woodland is relatively sharp and the colonization of the former by spruce is often facilitated by human disturbance, such as drainage (Neuhäusl 1992), woodland clearance and peat cutting (Freléchoux et al. 2003). Both the pollen and macrofossil analyses described in the previous chapter indicate there were three shifts between open mire and mire woodland during the history of the Rejvíz bog. The first shift, probably from mixed pine-birch-spruce woodland, is indicated by the thick woody layer below 520 cm and confirmed by Fahl's data (Fahl 1926). The second expansion of forested area is better documented by pollen and macro-remains in the RE5 zone. Generally, current pine bog woodlands were formed during the Subboreal period (in southern Bohemia, Jankovská 1980) or later (Rybníček 1973). This is confirmed for the Rejvíz pine bog by the indicators present in the RE5 zone (samples 295 cm and 270 cm). The third shift from open bog vegetation to wooded bog in the recent past (RE7) is not so clear. The peak in *Pinus* pollen could result from determining abundance in terms of percentage when the number of pollen grains of *Fagus*, *Abies* and other trees was decreasing. In addition, the few woody remains in RE7 could be a result of selecting more open place for digging the excavation pit. Nevertheless, increase in *Vaccinium* pollen indicates a fall in water level and consequent bog pine expansion several hundred years ago.

Recent bog pine expansion has probably been partly due to man. There is a study of the bog pine population at Rejvíz that indicates a close relationship between the height of the individual bog pine trees and the depth of the water table: the lower the water table the higher the individual bog pines (Musil 1968). A similar relationship between pine expansion and drainage is documented in many studies. Freléchoux et al. (2003) found that drainage can result in the expansion bog pine woodland at the detriment of spruce. Mitchell et al. (2001) found that *Pinus uncinata* s. str. became abundant on a Swiss raised bog after draining, although the species was naturally present on the bog long before this event. Recent *Pinus uncinata* subsp. *uliginosa* dominance at the Rejvíz bog could have been a consequence of the several drainage channels dug by man in 1883. This palaeoecological study demonstrates that there is a natural alternation between open mire and pine bog driven by hydrological changes that result from changes in the local climate (see the next chapter). The results demonstrate for the first time that this alternation can occur in both the minerotrophic and ombrotrophic phases of a single bog. However, well-developed pine bogs may be a result of current human activities that have caused a fall in the water level, which has facilitated the expansion of pine. This scenario is confirmed not only by the final phases of the Rejvíz bog, but also of a Swiss raised bog (Mitchell et al. 2001). The results also confirms that pine bogs with *Pinus uncinata* subsp. *uliginosa* often originated as minerotrophic poor fens (Neuhäusl 1992).

Pinus uncinata subsp. *uliginosa* is considered to be a natural relict of the vegetation on Central European bogs and poor fens in early Holocene (Neuhäusl 1972, Jankovská 1980). In this study, pine needles were found throughout the whole profile, but species-level determination was possible only in the uppermost layers. Taking into account the fact that there is only one specimen of *Pinus sylvestris* currently growing in the Rejvíz bog area, all the pine macro-remains were attributed to *Pinus uncinata* subsp. *uliginosa,* but this premise may not be valid, especially for the oldest deposits. We presume that *P. uncinata uliginosa* has been present at the Rejvíz bog for at least two thousand years.

History of the vegetation in the surrounding landscape

As there are some important differences in the pollen records of several small summit bogs (Rybníček & Rybníčková 2004) situated only a few km apart it is assumed that pollen records from peat bogs reflect the surrounding landscape rather than the whole region. In the case of the Rejvíz bog it is assumed that the pollen (other than local pollen) came mainly from an area within a few kilometers of the bog.

The simplest indicator of the character of past landscape is given by the arboreal/nonarboreal pollen ratio, but this is not easy to evaluate (Sugita et al. 1999). Generally, tree pollen is overrepresented in an open landscape and often prevails over that of herbaceous plants, even if the landscape is mostly unforested (Faegri & Iversen 1989). The AP/NAP ratio (excluding local herbaceous plants, Fig. 5) of the pollen in the Rejvíz deposits signifies that the surrounding landscape was forested and not subjected to any significant human disturbance until the last several centuries. The RE2 pollen zone with its high values for local and other herbaceous plants probably represents the period when the area of open mire vegetation was greatest.

The pollen assemblage in the deepest sample of peat sediment (643 cm) consists of 70% *Pinus* and low percentages of *Corylus*, *Betula*, *Ulmus* and *Picea*, and was deposited probably at the time of the transition between the Preboreal and Boreal periods. In contrast, the rest of the RE1 zone (640–625 cm) was deposited in the Boreal period, which is confirmed by the different pollen composition and the age of the peat from 630–632 cm (7960–7190 cal. yr BC, range 68.2%). In the RE1 zone *Pinus* pollen decreases because of the increased presence of the pollen of other trees, particularly *Corylus* and *Picea.* A high presence of *Picea* pollen relative to expected representation of spruce in this region (Huntley & Birks 1983, Rybníčková & Rybníček 1988, Ralska-Jasiewiczowa et al. 2004) is a specific feature of the RE1 pollen assemblage. Nevertheless it accords with recent studies dealing with the postglacial expansion of spruce (Latałowa & van der Knaap 2006), which came from the Western Carpathians, where it locally persisted during the last full glaciation (Willis et al. 2000, Jankovská et al. 2002). Spruce probably migrated during the Preboreal from the northern part of the Western Carpathians (Upper Orava region, Rybníček & Rybníčková 2002) through the Moravskoslezské Beskydy Mts (Salaschek 1935) to the Jeseníky Mts and further on to the western Sudetes. Increase in *Picea* pollen in the Orlické Mts as recorded at Zieleniec (Madeyska 1989, 2005) took place later than in Rejvíz, which accords with this assumption.

In the Boreal period it is likely that the area surrounding Rejvíz was covered with open coniferous woodlands, with pine dominating in the dry and spruce in the wetter places, with an admixture of hazel shrubs and a few birch trees. Various ferns and *Cichoriaceae* occurred in these woodlands, with the tall *Filipendula ulmaria* growing along streams and around springs.

In the next zones (RE2 and RE3) the prevalence of woodlands with a completely different tree composition is recorded. The so-called *Quercetum mixtum* trees (Firbas 1949), such as *Ulmus*, *Quercus*, *Fraxinus*, *Tilia* and *Acer,* are abundant, but spruce pollen dominates making up 15–20% of the total. It is assumed that in the surroundings of Rejvíz mixed woodlands of *Ulmus* cf. *glabra*, *Tilia* cf. *cordata* and *Acer* cf. *pseudoplatanus* spread mainly on dry soils, with probably an admixture of oak. It is highly likely that there were local stands of spruce growing on wet and slightly peaty soils in the Rejvíz basin, nevertheless spruce is likely to have dominated at high altitudes in the mountains. Hazel is likely to have been in the shrub layer of mixed and spruce woodlands at high altitudes, even up to the subalpine belt at this time (Firbas 1949). Treeless habitats were arguably limited to woodland gaps and stream banks, where species of *Caltha*, *Thalictrum* and *Galium* occurred. Other herbaceous pollen is considered to be of local origin.

The climatic deterioration that occurred in the following period, the Subboreal, is associated with maximal occurrence of *Picea* pollen (430–320 cm depth). As a consequence of the decline in the abundance of deciduous trees due to the general decline in temperature and fluctuations in precipitation, spruce probably colonized lower altitudes. The high pollen values for hazel indicates it is an important component even of the Subboreal mountain woodlands not only on the highest mountain ridges in the Hrubý Jeseník Mts (Rybníček & Rybníčková 2004) but also at middle altitudes.

A complete change in tree pollen composition (considered as the beginning of the Subatlantic period) occurs in the Rejvíz profile at approximately 1020 cal. yr BC (2780 uncal. yr BP): the late-Holocene migrants such as beech, fir and hornbeam (in the lowlands), already previously present in the landscape, expanded their ranges and displaced mid-Holocene broad leaved trees. That mixed beech-fir-spruce woodland formed at middle altitudes, including the Rejvíz basin, is also confirmed by the presence of *Abies* seeds (Table 3). The low values for herbaceous plant pollen indicates extensive woodlands in the Rejvíz basin in the older Subatlantic at a time when the lowlands were already subject to significant human pressure. Wind-transported pollen indicating anthropogenic activities in the landscape are present – initially indirect indicators such as *Rumex acetosa* type and *Plantago lanceolata* type pollen from pastures and meadows (Behre 1981) and later also the direct indicators *Secale* and *Triticum* type pollen.

The surrounding landscape was not affected by man until late in modern history. According to historical sources the whole region has been a gold, iron and copper ore mining area since the 13th century (and probably earlier). Mines and smelting works were concentrated below ca 850 m a.s.l. (Rybníček & Rybníčková 2004), therefore the abundance of beech, the climax tree at these altitudes, was affected by these activities (*Fagus* pollen decrease in the last third of RE6 zone). People from villages situated in the valleys mowed the lower slopes of the surrounding hills forming alluvial meadows, as is obvious from old maps. This land-use is reflected in the pollen diagram by a decrease in alder pollen and increase in that of *Salix* and *Poaceae*. Similar activities probably occurred in the vicinity of the Rejvíz site; the development of an area of meadows along the Černá Opava river in the 14th century (Joanidis 2004). Local presence of man is apparent in the pollen assemblage from 39 cm upwards, where there are indicators of extensive woodland clearance in the Rejvíz basin and a rapid decline in the abundance of middle-altitude trees

(*Fagus*, *Abies*, *Picea*) and consequent increase of human indicators, which correspond with the historical records for the area.

The pollen analysis is representative of middle altitudes of not only the Hrubý Jeseník Mts but the whole of the eastern Sudetes. It is very similar to that from the Zieleniec bog (Góry Bystrzyckie/Orlické hory Mts 750–764 m a.s.l.) analysed by Madeyska (1989, 2005), which is 750 cm deep and originated 8735±100 uncal. yr BP, so is well comparable to the Rejvíz bog. The pollen assemblages are similar, except for the Pre-boreal/Boreal transition with abundant *Betula*, *Salix* and *Poaceae*, which was not so completely recorded at Rejvíz. Surprisingly the values for some herbaceous plant pollen are also similar. The zone with (semi)aquatic species, such as *Scheuchzeria palustris*, *Equisetum* and *Typha*, recorded at Rejvíz occurred at the same time at the Zieleniec bog. This coincidence implies that inundating was probably not only conditioned by local hydrological dynamics but also by changes in macroclimatic humidity.

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Souhrn

Studie odhaluje způsob vzniku a vývoj rozsáhlého blatkového rašeliniště Rejvíz v Hrubém Jeseníku a změny vegetace okolní krajiny během téměř celého Holocénu. Hlavními metodami jsou stratigrafický popis sedimentu, radiokarbonové datování, pylová analýza a analýza rostlinných makrozbytků. Organický sediment se na Rejvízu začal ukládat před více než 9000 lety v blízkosti pramenišť v řídkém smíšeném lese. Postupně se zde vyvinulo živinami chudé slatiniště, které bylo v době od 6170 do 4060 př. n. l. mělce zaplaveno. Později došlo k poklesu vodní hladiny a přeměně minerotrofního chudého slatiniště na oligotrofní rašeliniště, ze kterého se během posledních tří tisíc let postupně vyvinulo vrchoviště. Na rašeliništi pravděpodobně třikrát došlo k přirozenému rozšíření a ústupu lesa: první fáze skončila před asi 6720 př. n. l., druhá nastala v období 1960–1020 př. n. l. a třetí probíhá od nedávné minulosti. Vegetace v okolí rašeliniště se vyvíjela přirozeně bez významného vlivu člověka až do doby před asi šesti až pěti sty lety, kdy byla okolní krajina postupně odlesňována a později osídlována. Vývoj vegetace ve středních polohách probíhal obdobně a za stejných podmínek v celých východních Sudetech, jak je patrné z podobných výsledků z polské části Orlických hor.

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Appendix 1. – List of pollen types cited in the text.

Pollen type	Genera and species included according to Beug (2004)
Caltha type	*Caltha palustris, Isopyrum thalictroides*
Cichoriaceae	*Arnoseris, Chondrilla, Cicerbita, Crepis, Cichorium, Hieracium, Hypochaeris, Lactuca, Lapsana, Leontodon, Mycelis, Prenanthes, Scorzonera, Sonchus, Taraxacum, Tragopogon*
Leucojum type	*Leucojum, Galanthus*
Lysimachia vulgaris type	*Lysimachia vulgaris, L. nummularia, L. punctata*
Matricaria type	*Achillea, Anthemis, Chrysanthemum, Cotula, Leucanthemopsis, Leucanthemum, Matricaria, Tanacetum, Tripleurospermum*
Potentilla type	*Fragaria, Potentilla*
Primula clusiana type	probably species *Chrysosplenium alternifolium*
Prunus	*Crataegus, Malus, Mespilus, Prunus, Pyrus*
Rhinanthus type	genera *Euphrasia*, *Rhinanthus*, species *Bartsia alpina*
Rubiaceae	*Asperula, Cruciata, Galium, Sherardia*
Rumex acetosa type	*Rumex acetosa, R. acetosella, R. arifolius, R. conglomeratus, R. crispus, R. maritimus, R. obtusifolius, R. palustris, R. pseudoalpinus, R. sanguineus, R. thyrsiflorus*
Sambucus nigra type	*Sambucus nigra, S. racemosa*
Senecio type	*Adenostyles, Antennaria, Arnica, Aster, Bellis, Bidens, Buphtalmum, Conyza, Doronicum, Erigeron, Eupatorium, Filago, Galinsoga, Gnaphalium, Helianthus, Helichrysum, Homogyne, Inula, Ligularia, Leontodon, Petasites, Pseudognaphalium, Pulicaria, Rudbeckia, Silphium, Solidago, Senecio, Telekia, Tephroseris, Tussilago*
Sparganium type	genus *Sparganium*, species *Typha angustifolia*
Typha latifolia type	*Typha latifolia, T. laxmanni, T. minima, T. shuttleworthii*
Urticaceae	*Urtica dioica, U. urens, Parietaria officinalis*
Vaccinium type	*Vaccinium, Oxycoccus, Erica, Andromeda, Ledum*
Valeriana dioica type	*Valeriana dioica, V. simplicifolia*
Viola odorata type	species of genus *Viola* except those of *Viola tricolor* type
Viola tricolor type	*Viola arvensis, V. cornuta, V. lutea, V. tricolor*