Precultural vegetation in the western foothills of the Kremnické vrchy Mts in central Slovakia and its transformation by man

Původní vegetace západního úbočí Kremnických vrchů a její proměny v důsledku lidských zásahů

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Pollen and macroscopic analyses of two Upper Holocene spring fen sites in the vicinity of the Turček village in the south-western foothills of the Kremnické vrchy Mts (central Slovakia) revealed new and unique information on the precultural and natural climazonal forests, and the origin and development of local meadow fen vegetation. Pollen-analytical data indicate the prevalence of natural spruce (*Picea abies*) and fir (*Abies alba*) forests in this region. The mixed beech forests depicted on the geobotanical map of Slovakia must have, therefore occupied much smaller areas than previously thought. After human colonization of the region during the 13th and 14th centuries natural forests were transformed mainly into grasslands and pastures, and to a lesser extent into arable fields. These changes were connected with gold and silver mining in the vicinity of the nearby town of Kremnica, with Turček one of the important areas producing timber for the mining industry. The development of these fen mires is also connected with deforestation and transformation of the landscape. They originated as forest springs but after human colonization of the area they were transformed into treeless fen meadows by the direct or indirect effect of man cutting of trees, grazing livestock and mowing.

K e y w o r d s: autochthonous fir forests, central Slovakia, spring fen development, human impact, macroscopic analyses, palaeoecology, pollen analyses, precultural vegetation, Upper Holocene

Introduction

The palaeogeobotany and vegetation history of the Kremnické vrchy Mts in central Slovakia are unknown as there are no suitable classic sites there for such investigations. Therefore, the finding of two small sites with spring fen sediments, in an area where there is currently no fen vegetation, was of a great interest because they might provide information on the recent history of the vegetation in these mountains. Both sites were found by Vlastimil Tlusták during an inventory of the flora and fauna in the area of the then planned Turček water reservoir (Tlusták & Havránek 1995), and are now either flooded or located on the shore of the reservoir and periodically flooded.

Our research in this area started in 1996 and a summary of the preliminary results was presented in an unpublished report in 1998. This work was continued and the complete results are presented in this paper. By means of pollen and macroscopic analyses, (i) the age of the spring fens, their origin and development, (ii) the character of the natural precultural vegetation in the vicinity of the fens and/or neighbouring areas of the Kremnické vrchy region, and (iii) the extent and intensity of the impact of man on the past vegetation and landscape, was determined.

Region and sites investigated

The mountains of western central Slovakia (i.e., the Kremnické vrchy and neighbouring Štiavnické vrchy), located between the Tatra and Fatra Mts to the north and Danubian lowlands to the south, are part of the Western Carpathians and composed of volcanic material (different kinds of andesites and rhyolites) of Miocene age (Kodym et al. 1967). As a result, soils are generally very rich in nutrients. Average altitude of the Kremnické vrchy Mts varies between 800 and 900 (–1000) m a.s.l., the highest point, Flochová, reaches 1317 m. The climate is moderately cold and humid with mean January temperatures varying between –5 and –7 °C and those of July between 16 and 18 °C. Annual precipitation varies between 700 and 800 mm at middle altitudes (Quitt 1971). On the basis of the present phytosociological situation Michalko et al. (1987) argue that the native vegetation of the region is beech and mixed beech forest.

Both sites (Turček A, SS-1-A and Turček B, SS-1-B), latitude 48°46'15" N, longitude 18°56'16" E, altitude ca 780 m a.s.l., are located close to the right bank of a little brook, Studená voda ("Kaltwasser" on older maps), ca 2 km north-east of the village of Turček and ca 7 km north of the town of Kremnica (Fig. 1). Samples for analyses were collected in September 1996.

The larger spring fen, Turček A, is ca 25 × 20 m in size and varies in depth from between 90 and 100 cm. Its surface is slightly convex with a slight slope to the south-east. The vegetation consists mainly of *Carex nigra* and *C. echinata*, but *Carex rostrata, Agrostis canina, Filipendula ulmaria, Succisa pratensis, Crepis paludosa, Potentilla erecta, Galium uliginosum, Lysimachia vulgaris, Trollius altissimus, Equisetum palustre* and *E. fluviatile* were also important components of this plant community. *Geum rivale, Carex panicea, C.* sect. *Flavae, Veronica chamaedrys, Melampyrum nemorosum, Scirpus sylvaticus, Cirsium palustre, Epilobium palustre, Mentha arvensis, Chaerophyllum hirsutum, Hypericum maculatum, Deschampsia cespitosa, Juncus conglomeratus, Myosotis nemorosa, Scutellaria galericulata, Stellaria alsine, Parnassia palustris* were also present. Among the rare and protected plants that occurred there were *Drosera rotundifolia, Gladiolus imbricatus, Carex hartmanii. Epipactis palustris* and *Dactylorhiza maculata* subsp. *transsylvanica.* The moss layer was poorly developed with only scattered plants of *Philonotis fontana, Plagiomnium* sp., *Calliergonella cuspidata, Brachythecium* sp., *Climacium dendroides, Camptothecium nitens, Bryum pseudotriquetrum, Sphagnum flexuosum, S.* sect. *Subsecunda* and *S. capillifolium.* For further information see Hradílek (2002). After traditional mowing and grazing ceased in the second half of the 20th century, *Molinia caerulea* and seedlings of trees (*Betula pendula, Salix aurita, Alnus incana, Picea abies, Pinus sylvestris*) appeared. The sediments in the profile consist of herb and moss peat with the rootlets of sedges and remains of mosses, the lowest layers contain a considerable admixture of wood. The basal layers are clayey with small admixtures of peat and wood. The sequence of layers of sediment, their physical characteristics and composition are given in Table 1.

Spring fen Turček B measures ca 10 × 15 m and in its deepest parts there is about 50–60 cm of organogenic sediment. The surface is indistinctly convex and slopes to the south. Most of the spring fen is covered with secondary *Alnus incana* trees aged between 10 and 15 years, only the lower southernmost margin is still open and with remains of the earlier fen vegetation. The herb layer in the stand of trees consists of *Filipendula ulmaria, Lysimachia vulgaris, Heracleum sphondylium, Angelica sylvestris, Veratrum album* s.l.,

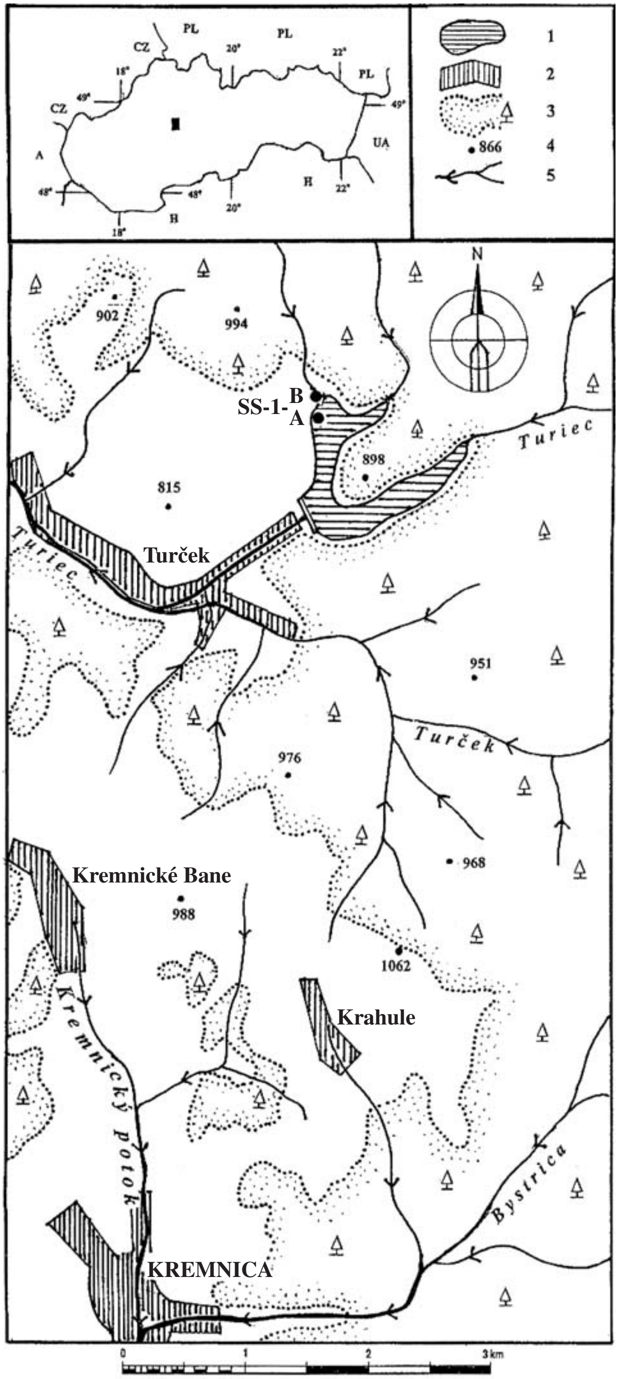


Fig. 1. – Location of the region and the sites SS-1-A and SS-1-B from which the peat profiles were collected (Turček A and Turček B). Legend: 1 – water reservoir at Turček, 2 – settlements, 3 – forests, 4 – geodetic points and altitudes (in m a.s.l.), 5 – brooks.

Table 1. – Stratigraphy of the profiles Turček A (SS-1-A) and Turček B (SS-1-B) and description of their sediments according to Troels-Smith (1955). Abbreviations: Lim – upper border of the layer; Strf – stratification; Elas – elasticitas; Sicc – dryness; Nig – darkness; Tb(b) – moss peat; Tl – wood peat; Th – herbaceous peat; Dl – wood detritus; Dh – herbaceous detritus; Dg – granulated detritus; As, Ag – clay; Ga, Gs – sand.

Profile	Depth (cm)	Physical properties						Components									
		Lim	Strf	Elas	Sicc	Nig	Color	Tb (b)	Tl	Th	Dl	Dh	Dg	As	Ag	Ga	Gs
Turček A	0–3		0	1	1	2	7,5 YR 3/0	+		2^1			2		+	+	
	3–10	1	1	1	1	2	7,5 YR 4/2	++		2^2			1		1	+	
	10–19	3	1	1	1	2	7,5 YR 3/2	+		1^2			2		1	+	
	19–55	2	1	2	2	2	2,5 YR 3/4	2^3	+	1^2			1	+	+		
	55–63	2	1	2	2	2	5 YR 3/3	1^2		1^2	+	+	2			+	
	63–97	1	1	1	2	2	2,5 YR 2/2	+	1	1^2	1		1			+	
	97 <	2	0	0	2	1	10 YR 3/3					+		3	1	+	+
Turček B	0–5		1	1	2	3	7,5 YR 4/2		+	2^2	++	++	2	+	++	+	+
	5–27	0	1	1	2	3	10 YR 3/3	+		1^2		+	3		+	++	+
	27–55	1	1	1	2	3	5 YR 3/2	++		2^3		+	2		+	++	++
	55 <	1	0	0	2	1	7,5 YR 4/0	++		+	+	+	1	1	2	++	++

Cirsium palustre, C. rivulare, Scirpus sylvaticus, Caltha palustris and *Equisetum palustre*, with *Carex nigra, C. hartmanii, Eriophorum angustifolium, Agrostis canina, Galium uliginosum, Succisa pratensis, Centaurea jacea, Epilobium palustre, Epipactis palustris, Parnassia palustris* and *Gladiolus imbricatus* in the areas not covered by trees.

The following moss taxa were present in this fen: *Plagiomnium* sp., *Climacium dendroides, Eurhynchium* sp., *Sphagnum teres, S. contortum* and *S. capillifolium.* The whole of the profile except the basal layers, which contain an admixture of clay, consists of fen peat. The lowest layers are clayey with pieces of wood. The sequence and description of the layers is given in Table 1.

Methods

Field research

Blocks of peat, 50 × 10 × 10 cm, were extracted from the cleaned sides of pits dug into the sediments for the pollen and macroscopic analyses. The sequence of layers and properties of the sediments were described in the field according to Troels-Smith (1955). Munsell soil colour charts (Munsell Color Company 1954) were used for determining the colours.

Laboratory analyses

Samples for pollen analyses were extracted from the blocks of peat mostly at 5 cm intervals and subjected to acetolysis. Sediments containing mineral matter were pretreated with HF. A minimum of 1000 pollen grains and spores were counted. Standard percentage diagrams were constructed using Tilia and Tiliagraph programs (Grimm 1990). The total sum (TS) of arboreal pollen (AP) and non-arboreal pollen (NAP) was used as the basis for calculating the percentage pollen representation. Percentages of spores of pteridophytes and mosses were calculated on the basis of AP + NAP + sum of corresponding spores = 100%.

Samples for macroscopic analyses from profile SS-1-A (Turček A) were extracted from the same material mostly at 10 cm intervals.The minimum volume of sediment analysed was usually 200 ccm. Visible borders between layers were respected and samples extracted either above or below a border. The samples were processed by washing through a stack of three sieves with meshes of 0.5, 0.8 and 1.6 mm. Plant remains were picked out and stored in a mixture of ethanol, glycerol and water.

Radiocarbon dating and zonation of pollen diagrams

Two important horizons from the reference profile SS-1-A were dated in the Polish Radiocarbon Laboratory of the Silesian University Gliwice using samples of bulk peat. Data are expressed in conventional ^{14}C dates B.P. in pollen diagrams, approximate callibrated dates (after Stuiver & Pearson 1993, Stuiver & Becker 1993) are appended.

1. SS-1-A; 94–96 cm; Lab. no. Gd 10899; 3370±60, i.e. ca cal. 1625 B.C.
2. SS-1-A; 65–66 cm; Lab. no. Gd 12126; 740±20, i.e. ca cal. 1280 A.D.

Using OxCal programe (Bronk Ramsey 2001) we did not identify any big differences between the estimates obtained using the different callibration methods. In the case of the older date (3370±60 conv. B.P.) the difference is ca 18 years, in the second (740±20 conv. B.P.) it is only 2 years. Estimated rough data of conv. radiocarbon years B.P. from the age–depth accumulation curve are presented in brackets on pollen diagrams and in Table 2.

Relative time zonation of the profiles follows that of the Nordic division of the Holocene by Mangerud et al. (1974). However, certain local refinements were introduced for the Subatlantic, in order to better reflect human activities in the vicinity of Turček. Thus the upper limit of the older Subatlantic (SA1) period coincides with colonization and first transformation of the landscape, whereas the younger Subatlantic (SA2) period was divided into two subzones (SA2a and SA2b), dependent on the extent to which man altered the landscape in the vicinity of study sites.

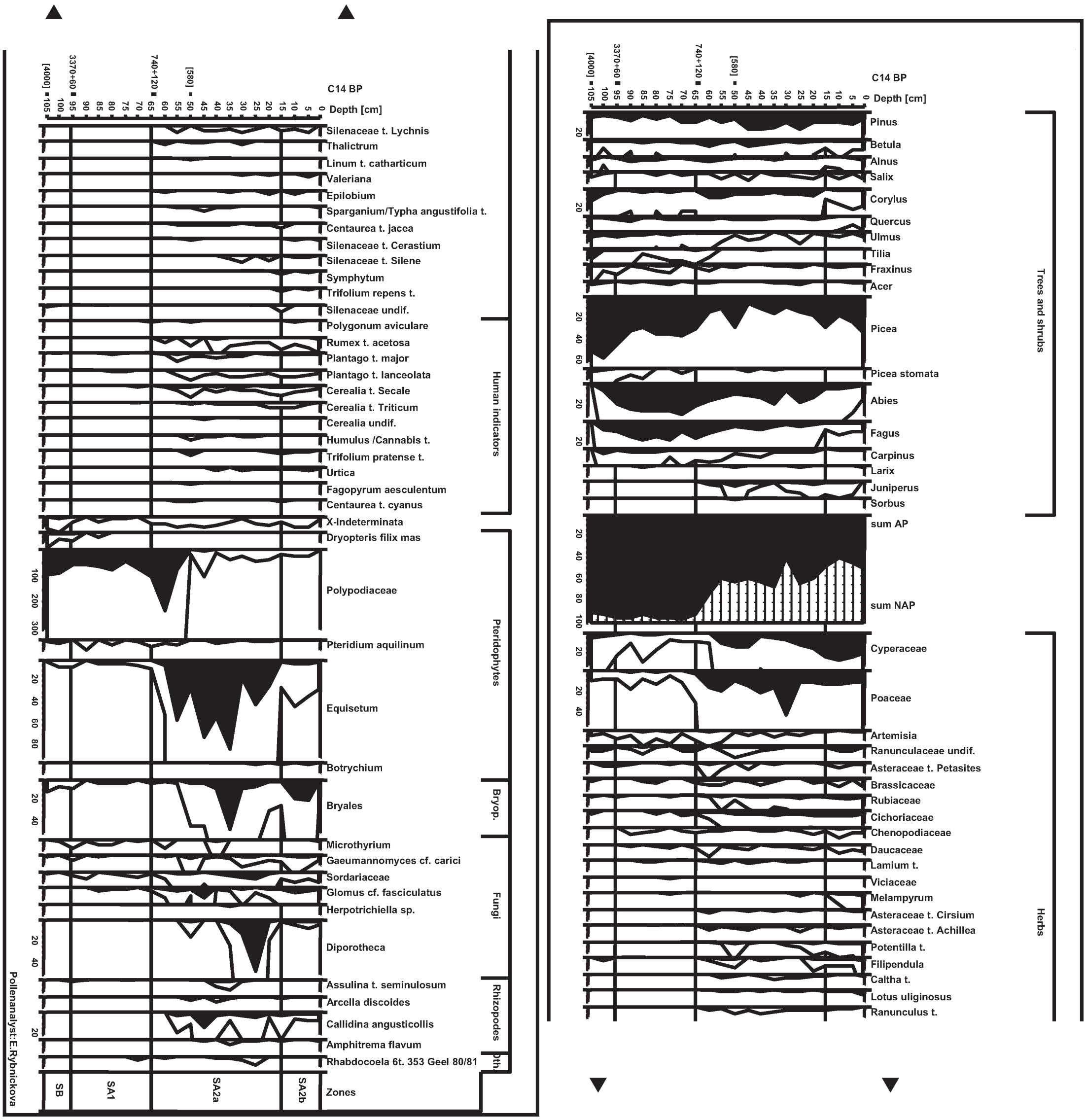
Nomenclature

Nomenclature of vascular plants follows Kubát et al. (2002). Names of bryophytes correspond to those in the catalogue of Neuhäuslová & Kolbek (1982). Nomenclature of sporomorphs corresponds to conventional names used in the database of our laboratory (and not always to current valid names of their producers), whereas that for microscopic non-palynological objects follows that in the papers of Van Geel and his colleagues (Van Geel 1978, Van Geel et al. 1989).

Results and discussion

Pollen-analytical reconstruction of dry-land vegetation

The pollen diagram for the deeper profile SS-1-A (Turček A, Fig. 2), records the vegetation development since the very end of the Subboreal (SB), roughly between ca 4000 and 3400 conv. years B.P. Pollen assemblages of this chronozone are rich in *Picea abies* (around 50% of TS). Other characteristics are a decreasing representation of *Corylus avellana* and *Tilia* pollen (from ca 15–10 % to 5–3% of TS) and a high incidence of (local?) fern spores. Immigration of *Fagus sylvatica* and *Abies alba* began during this period, which is denoted by an increase in their pollen percentages from zero to ca 10%. Pollen of *Carpinus betulus* also increases at the same time, but this pollen, together with that of oak, was probably transported from the neighbouring Turčianská kotlina basin (altitude around 500 m), located just 7–10 km west and north-west from the study site. Rather high percentages of *Alnus* pollen indicate the existence of alder stands (*Alnus incana*?) along streams.



Fig, 2. – Standard pollen diagram for Turček A (SS-1-A). Scarce pollen/spore types (depth cm/absolute number of finds): **AP:** *Taxus* 1/1; *Juglans* 1/1, 30/1, 40/1; *Rhamnus* t. 15/1; *Frangula* 20/1; *Ephedra fragilis/campylopoda* 25/1; *Lonicera* 25/1, 65/1, 85/1; *Sambucus* 95/1. **NAP:** *Gentianaceae* 1/1; *Heracleum* t. 1/1; *Lycopus* 1/1; *Vacciniaceae* 1/1; *Ambrosia* 5/6, 10/2; *Symphytum* 5/1, 15/2; *Campanula* 10/1, 45/1; *Polygonum bistorta* 10/1; *Mentha* t. 15/1, 50/1; *Menyanthes trifoliata* 15/1, 50/1; *Scleranthus perennis* 25/1; *Polygonum persicaria* t. 30/1; *Typha latifolia* 30/2, 35/1; *Bupleurum* 50/1; *Geranium* 75/1. **Spores:** *Sphagnum* 50/1; *Lycopodium annotinum* 45/1; *L. clavatum* 45/1, 70/1; *Polypodium vulgare* 80/1, 90/1; *Gymnocarpium dryopteris* 105/1; *Huperzia selago* 105/1.

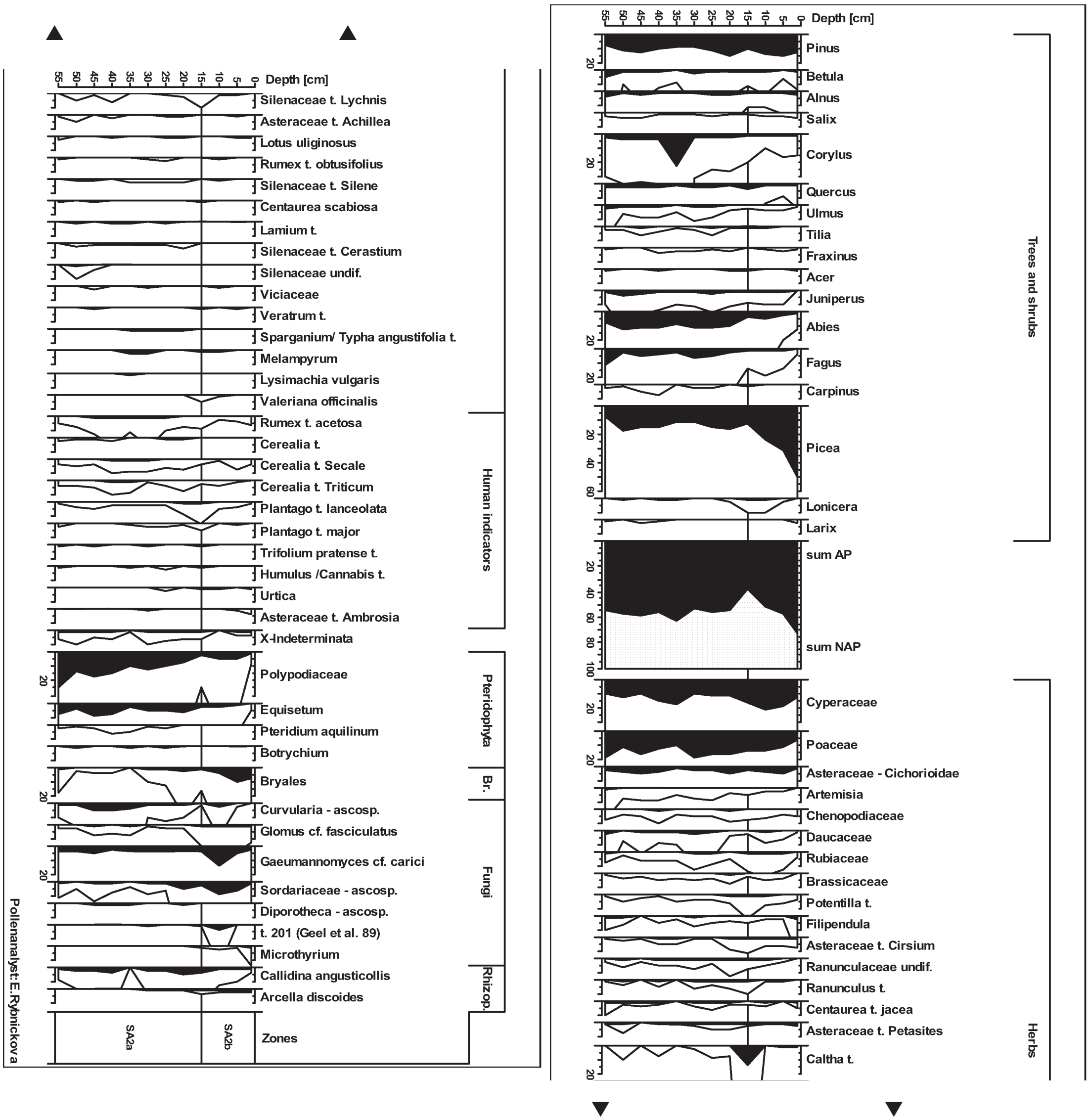


Fig. 3. – Standard pollen diagram for Turček B (SS-1-B). Scarce pollen types (depth/absolute number of finds): **AP:** *Sorbus* 40/1; *Juglans* 55/1; *Frangula* 55/1. **NAP:** *Calluna* 15/1; *Campanula* 15/1; *Linum catharticum* 15/1; *Polygonum aviculare* 15/1; *Mentha* t. 25/1; *Pulmonaria* t. 30/1; *Lycopus* t. 35/1; *Stachys* t. 40/1, 50/1; *Loranthus* 55/1.

These pollen assemblages are not very similar to those of comparable age from most other parts of the Western Carpathians. Abundance of spruce pollen, decreasing amounts of hazel and slowly increasing *Fagus* and *Abies* pollen in pollen diagrams from the present *Fagus-Abies* vegetation belt (ca 500–1100 m a.s.l.) can be found only in a few other pollen analyses from mainly the most westerly Carpathians, namely from the Moravskoslezské Beskydy Mts (Podolánky – Salaschek 1935; Bílý kříž area – Rybníček & Rybníčková 1995; Horní Lomná – Rybníček & Rybníčková 2008 and the Oravské Beskydy Mts – Rybníček & Rybníčková 2002). Similar assemblages are also known from other mountainous parts of Europe, other than the Carpathians.

Certain exceptions are the pollen diagrams for the High Tatras and their surroundings, which record a prevalence of coniferous pollen (spruce, pine, juniper), even at "beech altitudes", since the very beginning of the Holocene up to the present and an absence of *Fagus* and low representation of *Abies* in the Upper Holocene (Krippel 1963, Jankovská 1972, Rybníček & Rybníčková 1987, 2002, Rybníčková & Rybníček 2006). The reason for this are the specific climatic (thermal inversions) and edaphic conditions of this region.

On the other hand, pollen diagrams from the north-western parts of the neighbouring Eastern Carpathians indicate that the role of conifers, namely *Picea abies,* is reduced. Pollen diagrams for eastern Slovakia (Krippel 1971), the Bieszady Mts in Poland (Ralska-Jasiewiczowa 1980) and Ukrainian Carpathians (Tasenkevic & Bezusko 1982) clearly indicate the relative prevalence of *Fagus sylvatica* and an absence or low representation of spruce pollen. *Picea* grows there in azonal waterlogged sites rather than in climazonal mixed beech forests.

Pollen assemblages from between 95 and 65 cm in the profile represent the period ca 3400 and 750 conv. years B.P. (ca 3590±674 cal B.P.), and reflect the nature of the precultural forest vegetation. The untouched forests at that time must have been very dense (see more than 90% of AP). Pollen of *Picea abies* and *Abies alba* (in both cases between 25–30% of TS) are the most abundant, whilst values for *Fagus sylvatica* reach only 10–15% of TS. Even though some spruce and fir pollen could have come from local waterlogged sites, we suggest that coniferous trees generally prevailed in the regional climazonal vegetation of the Kremnické vrchy Mts, whilst beech was present only as an admixture and typical beech forest were infrequent. Other deciduous trees, *Ulmus* (*glabra*?), *Fraxinus excelsior, Tilia* (*cordata* vel *platyphyllos*) and *Acer* (*pseudoplatanus*?) were probably scattered in scree and rocky biotopes.

Our palynological reconstruction of precultural vegetation does not correspond to the geobotanical map of natural vegetation mentioned above (Michalko et al. 1987), which is based largely on herbaceous indicators, surviving in the ground layer of forests from the earlier periods. This map indicates the previous existence of herb-rich beech forests with some admixture of coniferous trees in the Kremnické vrchy Mts, with just a few patches of spruce and fir-spruce stands at higher altitudes. The idea of including herb-rich fir and spruce forests amongst *Fagus sylvatica* communities (alliance *Eu-Fagion*) was generally accepted for the geobotanical mapping of former Czechoslovakia, which was done in 1960s in the Czech Republic (Mikyška et al.1968) and 1970s in Slovakia (Michalko et al. 1987). This concept was based on phytosociological studies of forest communities in the Štiavnické vrchy Mts (to the south of our region) by Mikyška (1930, 1934). All fir forests were considered to be either a result of degradation or secondary man-made stands, replacing the original and natural deciduous forests of *Fagus sylvatica* and partly also those of *Quercus*. This occured over the last ca 800 years and is connected with past mining activities. Not only mining but also forest grazing (Málek 1970) can certainly influence the natural composition of forests and could even promote the spread of conifers. However, pollen and macroscopic analysis as well as toponomastic evidence clearly document the existence of natural, untouched precultural fir and spruce forests in several regions at middle altitudes, both in the Czech and Slovak Republics (Rybníček & Rybníčková 1978). In addition, recent studies of the genetic variation in silver fir populations in relation to their Holocene migration history indicate that Slovakia and part of the Czech Republic was a location where in postglacial times *Abies alba* spreading out from refugia in the Balkans and Apennines met and intermixed. Here they formed specific introgressive and strong populations (Konnert & Bergmann 1995). The migration history of silver fir was studied using similar methods also by Gömöri et al. (2004), who conclude that *Abies alba* from Balkan and Apennine refugia met somewhere in the middle of the Ukrainian Carpathians and did not form mixed populations. However, these authors only analysed samples from the Balkan Penninsula and two marginal fir sites in easternmost Slovakia and two in south-eastern Poland. Therefore, we are of the opinion, that the conclusions of Konnert & Bergmanns (1995), based on samples from almost the entire present European distribution of fir are more realistic and that there were natural coniferous forests within this extensive introgressive zone, including the Kremnické vrchy Mts.

The beginning of the older part of the younger Subatlantic (SA2a) period is associated with human colonization and marked by the appearance of anthropogenic indicators in the pollen assemblages. The colonization of the south-western parts of the Kremnické vrchy Mts led simultaneously to a transformation of both the landscape and the vegetation. These changes can be dated to the 13th century A.D., when intensive exploitation of sources of valuable metals (gold, silver) in the vicinity of Kremnica began. The first written evidence of the settlement of the region also date from the beginning of the 13th century, the town of Kremnica being awarded its status as a royal mint in 1328 (Bradnová et al. 1993). The village of Turček was also involved, though indirectly, in mining activities from the very beginning. The village supplied timber for the gold mines and later also water (a special water pipe was constructed during the first half of the 15th century), whereas agriculture was less important and concentrated mainly on animal husbandry.

According to the village chronicle Turček is first recorded as a village in 1371. However, our radiocarbon dated pollen analyses indicate that the first and rather extensive human activities in the Turček area began somewhat earlier. The older pollen diagram, Turček A (Fig. 2), records the beginning of settlement and transformation of the landscape between 60 and 65 cm at a date of ca 740 conv. years B.P. (calib. age ca 1278 A.D.). Here we observe a sudden decrease in AP pollen, reflecting a reduction in the extent of the forests. Coniferous trees were cut for mine and house construction and beech for charcoal production. Grazing is indicated especially by the presence of *Juniperus* pollen, reaching 3–5% of TS, *Urtica* and *Plantago lanceolata* pollen are also common. In addition, the existence of grasslands is generally documented by grass pollen, grains of *Trifolium* sp. div., *Plantago major, P. media, Ranunculus, Lathyrus, Polygonum bistorta, Sanguisorba officinalis* and other heliophilous herbs. On the other hand, the low representation of cereal pollen (*Secale, Triticum*) documents the secondary role of arable farming.

Table 2. - Macroscopic plant remains and selected pollen finds in the profile Turček A (SS-1-A). Explanations: A – charcoal (anthrax); m% – mosses (volume %); n – needle; p – pollen; + low, ++ high representation; r – rhizoms, roots; s - seed; sc - scale; w% - wood and bark (volume %); T - transitional phase, stage.

Depth (cm)	From	92	85	78	71	65	60	57	53	47	40	33	26	19	10	6	0
	To	100	92	85	78	71	65	60	57	53	47	40	33	26	19	10	6
Radiocarbon age conv. B.P.		(4000) 3370					740								(200)		
Zone		SB	SA 1				SA 2a								SA 2b		
Developmental	Phase	Forest spring						T		Spring meadow							
	Stage							Grazed meadow				T			Fen meadow		
Equisetum	r %	5	5	3	5	2		1									
	nod	2		3		2			2								
Lysimachia vulgaris	s (p)	1							(+)						1		
Ranunculus flammula	s				1		2								1	1	
Picea abies	w % /A	10 (1)	5		10	10	(1)									+	
	n (s)							(1)	5	2							
Abies alba	w % /A	3	5		1		1	(3)	1								
	n		1	1		1											1
Sambucus cf. *racemosa*	s	2		2		1	1										
	w %					3	1										
Polypodiaceae	p	++	++	++	++	++	++	++	++								
Ajuga reptans	s	3	1	3	1	1		3		3							1
Rubus cf. *idaeus*	s	3		2	1	5	16	13		1							1
Ranunculus repens	s	1		1		1	1										
Carex sp. div.	r %	+	3	3	3	5	3	3	3	3	3	3	5	5	5	20	20
Carex canescens	s				1	2				1	12	4					
C. remota	s		1		1						1						
Urtica	s					1				5							
Equisetum	p						+	++	++	++	++	++	++	++	+	+	+
Salix sp.	w % (b)											1	2			1	2 (2)
Cirsium palustre	s							1	2	1	4	1			2		
Asteraceae t. *Cirsium*	p							+	+	+	+	+	+	+	+	+	+
Carex rostrata	s										1			2	3		
Lychnis flos-cuculi	s							1	10	19	14	15	5		1		2
Silenaceae t. *Lychnis*	p								+		+	+	+	+	+	+	+
Carex sect. *Flavae*	s	1							5	11	15	9	5	63	7	5	2
Scirpus sylvaticus	s						1	1	1		4		1	1		1	
Rumex acetosa	s (p)							(+)			7	4			2		1
Poaceae	p							++	++	++	++	++	++	++	++	++	++
Alopecurus pratensis	s										3		3				1
Agrostis canina	s										8	7				3	6
Lotus sp.	s											1			4	2	
Lotus uliginosus	p								+	+	+		+	+	+	+	+
Eriophorum angustifolium	s									1		1	1	1		3	3
Myosotis sp.	s									2						2	2
Linum catharticum	s								1	8	5	1	1	9	1	2	3
Linum t. *catharticum*	p									+	+				+	+	
Ranunculus acris	s								2		5	3	1	10	11		
Carex panicea	s								1	1	1			3	4	3	1
Bryales	p									+	+	++	+	+	++	++	+
Plagiomnium sp.	m %							+	1	+	2					2	
Camptothecium nitens	m %							+	1		2		3	5		1	
Philonotis fontana	m %									2	2				1		

Depth (cm)	From	92	85	78	71	65	60	57	53	47	40	33	26	19	10	6	0
	To	100	92	85	78	71	65	60	57	53	47	40	33	26	19	10	6
Betula pendula	s, sc							3	16	41	71	22	7	3			
Carex echinata	s			1	1	1		14	76	67	103	129	90	81	9	3	2
Stellaria alsine	s							1		26	3	3		2			1
Alnus cf. *incana*	s										2	3					
Caltha palustris	s									1		1					
Calliergonella cuspidata	m %									2	3		1		+		
Bryum pseudotriquetrum	m %								1	1				+			
Thuidium cf. *philibertii*	m %										2		1				
Pinus sylvestris	n (w)												1	1	1 (+)		
Potentilla erecta	s						1			1		1	5	24	33	37	26
Potentilla t.	p								+				+	+	+	+	+
Carex nigra	s									1		1	2	5	25	25	6
Trifolium sp.	s									1				1		2	
Trifolium spec.div.	p									+				+	+		+
Melampyrum	p														+	+	++
Valeriana cf. *dioica*	s													5	1		
Valeriana	p												+	+			+
Eurhynchium sp.	m %													+			1
Sphagnum sect. *Acutifolia*	m %														+	+	1
S. sect. *Subsecunda*	m %														+		+
Deschampsia cespitosa	s															1	1

The following species also occur: *Viola* sp. 78–85/1 s; *Carex pallescens* 56–57/5 s; *Carex sylvatica* 40–47/1 s; *C. hartmanii* 19–26/1 s; *Alchemilla* sp. 19–26/1 s; *Molinia caerulea* 10–19/2 s; *Carex pilulifera* 10–19/1 s; *Galium* cf. *uliginosum* 10–19/1s; *Polygonum bistorta* 10–19/1 s; *Polygonum aviculare* 10–19/1s; *Mentha arvensis* 6–10/1 s; *Filipendula ulmaria* 0–6/2 s.

The second site, Turček B (pollen diagram in Fig. 3), is much younger and the pollen analysis does not record the initial phases of landscape transformation. However, by comparing the respective diagrams it is possible to estimate the beginning of fen peat formation at this site, which was ca 500–600 years ago, that is, the 15th century A.D. Therefore, although younger this site provides detailed information on the more recent develoment of the cultural landscape and vegetation.

Pollen assemblages from the uppermost layers at both sites (in SS-1-A, 1–15 cm, in SS-1-B, 0–10 cm) represent the youngest part of the Subatlantic (SA2b). In our diagrams this subzone is denoted especially by an increase in *Picea* pollen, finally reaching 20–40% of TS, which reflects the establishment of modern spruce plantations during the 19th and 20th centuries. A simultaneous decline in cereal pollen is probably connected with a continuous reduction in the earlier, though limited arable farming, and transformation of remaining fields into fallow and their subsequent use for grazing.

Development of local vegetation

Results of macroscopic analyses of the reference profile SS-1-A are presented in Table 2. The list of subfossil finds is arranged according to their phytosociological similarities and time of appearance. The table records a group of forest species in the deepest and oldest layers, indicating the existence of an initial phase of forest spring vegetation with *Picea abies* and *Abies alba. Sambucus racemosa* and *Rubus* cf. *idaeus* present in the shrub layer and *Ajuga reptans, Ranunculus repens* and *Lysimachia vulgaris* in the herb layer. The very high representation of *Polypodiaceae* spores in the pollen diagram probably indicates that there was a rather dense cover of ferns in the initial forest spring vegetation. On the other hand, it is also likely that rhizomes of *Equisetum,* which are commonly present in the same layers, actually grew down into the lower peat from upper treeless developmental stages of the present spring fen (note the absence of horsetail spores and, vice versa, their high frequencies in the upper parts of the pollen diagram; Fig. 2).

Colonization of the surrounding landscape, deforestation and transformation of earlier forest stands into grazing pastures, meadows and some fields was also accompanied by changes in the local vegetation (for the dating of these events see above). The remaining trees and shrubs and the associated herb cover disappeared and the fen surface was rather rapidly colonized by low sedges (*Carex echinata, C.* sect. Flavae*, C.rostrata, C. panicea*) and grasses (see the pollen curve of *Poaceae*)*,* i.e. plants characteristic of the secondary meadow spring phase. *Lychnis flos-cuculi, Cirsium palustre, Linum catharticum, Ranunculus acris* were abundant and the mosses *Plagiomnium* sp.*, Philonotis fontana* and *Camptothecium nitens* documented. However, this meadow phase consisted of two developmental stages. In the first, the heliophilic *Betula pendula* occured probably at the margins of the fen or nearby, *Carex echinata* was very common, and seeds of *Stellaria alsine, Caltha palustris,* and remains of *Calliergonella cuspidata, Bryum pseudotriquetrum* and *Thuidium* cf. *philibertii* were found. The second stage of meadow fen is characterized by *Carex nigra, Potentilla erecta,* some *Trifolium* species*, Melampyrum* cf. *nemorosum* and *Valeriana dioica* vel *simplicifolia.* In the uppermost samples, scattered leaves of *Sphagnum* sect. *Acutifolia* and *Subsecunda* were found*,* indicating acidification of the habitat. *Sphagnum capillifolium* and *S. contortum* grow there even today. Pines probably occured at the margins and/or close to the site (see finds of needles and small pieces of wood). Communities of similar plant composition as found in our spring meadow phase, are classified by Central European phytosociologists as belonging to the alliance *Caricion fuscae*.

Similar successional trends in development of spring fen communities are also found in several other regions. In Central Europe, e.g. in the foothills of the Šumava Mts – Bohemian Forest (Rybníček & Rybníčková 1974), the Moravskoslezské Beskydy and Bílé Karpaty Mts (Rybníčková et al. 2005), the Bohemian-Moravian Uplands (Peichlová 1977) and in Eastern Germany (Brande 2007). Pollen analyses of peat from other Upper Holocene mire sites (no macrofossil evidence available) indicate similar trends. In all these cases the formation of organogenic sediments begins in waterlogged or forest stands associated with springs, usually with alder (*Alnus glutinosa,* substituted by *A. incana* in our region), *Picea abies, Salix* sp. div. and sometimes even *Abies alba.* These habitats were transformed into open heliophilic fen communities after human colonization of these regions.

Conclusions

Summarizing the results and addressing the questions posed in the introduction we conclude:

(i) The two fen sites differ significantly in age. Accummulation of organic sediments began in the deeper spring fen (Turček A) about 4000 years ago. The fen originated as a spring in a forest or a waterlogged tree stand of *Picea abies* and *Abies alba.* Transformation into open fen or fen meadow occured following human colonization and transformation of the sourrounding lanscape and subsequent human activities beginning some 700 to 800 years ago. The smaller site (Turček B) originated much later in a waterlogged meadow, its estimated age is 600–500 years. In the absence of macroscopic analyses we can only assume that the development of open fen vegetation was similar to that at Turček A. The present alder stand was planted very recently.

(ii) The pollen diagram for Turček A indicates that the climazonal precultural forests in the south-eastern part of the Kemnické vrchy Mts were characterized mainly by the coniferous trees *Abies alba* and *Picea abies*, with mixed beech forests less important. Alder stands with spruce and scree forests occured in specific, rather azonal habitats. These results differ from those of earlier geobotanical mapping, which indicated mainly beech and mixed beech forests.

(iii) Human colonization of this region was connected with mining in the south-eastern margins of the region and began in the second half of the 13th century A.D, which resulted in deforestation and transformation of the forests into grazing pastures, and to a lesser extent, arable fields. Coniferous trees were used as a timber for mines and house construction, and beech for charcoal. The uppermost pollen assemblages record the plantations of spruce planted over the last 100–150 years.

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Souhrn

Pylové a makroskopické analýzy dvou mladoholocenních profilů prameništních a slatinných sedimentů v okolí obce Turček v Kremnických vrších přinesly vůbec první informace o původní předkulturní klimazonální vegetaci této oblasti a také o vývoji lokální vegetace prameništních slatinišť, která jsme studovali. Pyloanalytická data dokazují, že původní lesní vegetaci tvořily především jehličnaté lesy jedle a smrku. Smíšené květnaté bučiny, které zde rekonstruuje na základě fytocenologických analýz bylinného patra geobotanická mapa, mohly být zastoupeny jen druhořadě (viz menší zastoupení pylových zrn buku). Přirozené lesy byly výrazně ovlivněny při a po kolonizaci oblasti, úzce spojené s intenzivním dolováním zlata a stříbra v širším okolí Kremnice někdy v průběhu druhé poloviny 13. a první poloviny 14. století. Okrajová jihozápadní část lesního komplexu Kremnických vrchů byla odlesněna a přeměněna v pastviny a louky, jen v menší míře v polní pozemky. Ze zbývajících lesů bylo dodáváno smrkové a jedlové dřevo pro potřeby důlních děl a pro stavebnictví; buk byl nejspíš z lesů vybírán pro výrobu dřevěného uhlí. S kolonizací oblasti a současně s jejím odlesňováním je spojen i vznik prameništních slatinných

ploch, které jsme analyzovali. Akumulace organogenních sedimentů začala už asi před 4000 lety v lesním prameništi s jedlí a smrkem, ale k přeměně v luční slatinnou louku došlo až v důsledku přímého či nepřímého působení člověka při a po kolonizaci. Přeměna začala odstraněním dřevin, pokračovala pastvou a posléze kosením slatinné louky.

References

Bradnová H. (ed.) (1993): Geografický slovník [The geographic vocabulary]. – Academia, Praha.
Brande A. (2007): The first pollen diagram from the Hoher Fläming. – Veget. Hist. Archaeobot. 16: 171–181.
Bronk Ramsey C. (2001): Development of the radiocarbon program OxCal. – Radiocarbon 43/2A: 355–363.
Gömöri D., Longauer R., Liepelt S., Ballia N. D., Brus R., Kreigher H., Parpan V. I., Paule L., Stupar V. I. & Ziegenhagen B. (2004): Variation patterns of mitochondrial DNA of *Abies alba* Mill. in suture zones of postglacial migration in Europe. – Acta Soc. Bot. Polon. 73: 203–205.
Grimm E. C. (1990): Tilia and Tiliagraph: PC spreadsheet and graphics software for pollen data. – INQUA Comission of the Study of the Holocene, Working group for data-handling methods, Newsletter 4: 5–7.
Hradílek Z. (2002): Mechorosty (*Bryophyta*) nivy potoka Kaltwasser u Horního Turčeku – Kremnické vrchy [Bryophytes of the Kaltwasser brook valley near Horný Turček, the Kremnické vrchy hills, Slovakia]. – Bull. Slov. Bot. Spoloč. 24: 43–46.
Jankovská V. (1972): Pyloanalytický příspěvek ke složení původních lesů v SZ části Spišské kotliny [A pollenanalytical estimation to the composition of original forests in the NW part of the Spiš Basin]. – Biológia 27: 279–292.
Kodym O., Fusan O. & Matějka A. (1967): Geological map of Czechoslovakia 1:500 000. – Geological Survey, Prague.
Konnert M. & Bergmann F. (1995): The geographical distribution of genetic variation of silver fir (*Abies alba, Pinaceae*) in relation to its migration history. – Pl. Syst. Evol. 196: 19–30.
Krippel E. (1963): Postglaciálny vývoj lesov Tatranského Národného Parku [Postglacial development of the forests of Tatra National Park]. – Biol. Pr. 9/5: 1–41.
Krippel E. (1971): Postglaciálný vývoj vegetácie východného Slovenska [Postglacial development of vegetation of eastern Slovakia]. – Geogr. Čas. 23/3: 225–241.
Kubát K., Hrouda L., Chrtek J. jun., Kaplan Z., Kirschner J. & Štěpánek J. (eds) (2002): Klíč ke květeně České Republiky [Key to the Flora of the Czech Republic]. – Academia, Praha.
Málek J. (1970): Entwicklung der Wälder Südwestmährens unter dem Einfluss des Menchen. – Acta Sc. Nat. Brno 4/5: 1–45.
Mangerud J., Andersen S. T., Berglund H. B. & Donner J. (1974): Quaternary stratigraphy of Norden, a proposal of terminology and classification . – Boreas 3: 109–128.
Michalko J., Magic D., Berta J., Rybníček K. & Rybníčková E. (1987): Geobotanical map of CSSR. Slovak Socialist Republic. – Veda, Bratislava .
Mikyška R. (1930) Lesní typy přirozených porostů ve Štiavnickém středohoří [Forest types of natural stands of Štiavnické stredohorie]. – Sborn. Čs. Akad. Zeměd. 5 A/ 4: 423–480.
Mikyška R. (1934): Jedliny ve Štiavnickém středohoří – studie o degradaci lesa [Fir forests in Štiavnické stredohorie: a study on forest degradation]. – Věstn. Kral. Čes. Spol. Nauk, cl. 2. 1934: 1–19.
Mikyška R. (ed.) (1968): Geobotanische Karte der Tschechoslowakei. 1. Böhmischer Ländern. – Vegetace ČSSR B2, Academia Praha.
Munsell Color Company (1954): Munsell soil color charts. – Munsell Color Company, Baltimore.
Neuhäuslová Z. & Kolbek J. (eds) (1982): Seznam vyšších rostlin, mechorostů a lišejníků střední Evropy užitých v bance geobotanických dat BÚ ČSAV [A list of higher plants, bryophytes and lichens of Central Europe used in the bank of geobotanical data in the Botanical Institute of Czechoslovak Academy of Sciences]. – Botanický ústav ČSAV, Průhonice.
Peichlová M. (1977): Paleogeobotanický výzkum mladoholocenního profilu u Rváčova, východní Čechy [Palaeogeobotanical investigation of a Young Holocene profile near Rváčov, eastern Bohemia]. – Preslia 49: 67–90.
Quitt E. (1971): Climatic regions of Czechoslovakia. – Stud. Geogr. 16: 1–74.
Ralska-Jasiewiczowa M. (1980): Late Glacial and Holocene vegetation of the Bieszady Mts., Polish Eastern Carpathians. – Inst. Bot. Pol. Akad. Nauk, Kraków.
Rybníček K. & Rybníčková E. (1974): The origin and development of waterlogged meadows in central part of the Šumava Foothills. – Folia Geobot. Phytotax. 9: 45–70.

Rybníček K. & Rybníčková E. (1978): Palynological and historical evidence of virgin coniferous forests at middle altitudes of Czechoslovakia. – Vegetatio 36: 95–103.
Rybníček K. & Rybníčková E. (1987): Postglacial development. – In: Michalko J., Magic D., Berta J., Rybníček K. & Rybníčková E., Geobotanical map of CSSR, Slovak Socialist Republic. Text part, p. 38–44, Veda, Bratislava.
Rybníček K. & Rybníčková E. (1995): Palaeoecological and phytosociological reconstruction of precultural vegetation in the Bílý Kříž area, the Moravskoslezské Beskydy Mts, Slovakia. – Veget. Hist. Archaeobot. 4: 161–170.
Rybníček K. & Rybníčková E. (2002): Vegetation of the Upper Orava region (NW Slovakia) in the last 11000 years. – Acta Palaeobot. 42/2: 153–170.
Rybníček K. & Rybníčková E. (2008): Upper Holocene dry land vegetation in the Moravian-Slovakian borderland (Czech and Slovak Republics). – Veget. Hist. Archaeobot. 17: 701–711.
Rybníčková E., Hájková P. & Rybníček K. (2005): The origin and development of spring fen vegetation and ecosystems: palaeogeobotanical results. – In: Poulíčková A., Hájek M. & Rybníček K. (eds), Ecology and palaeoecology of spring fens of the West Carpathians, p. 29–62, Palackého Universita, Olomouc.
Rybníčková E. & Rybníček K. (2006): Pollen and macroscopic analyses of sediments from two lakes in the High Tatra mountains, Slovakia. – Veget. Hist. Archaeobot 15: 345–356.
Salaschek H. (1935): Paläofloristische Untersuchungen mährisch-schlesischer Moore. – Beih. Bot. Zbl. 54:B /1–2: 2–58.
Stuiver M. & Becker B. (1993): High precision decadal calibration of the radiocarbon scale, AD 1950–6000 BC. – Radiocarbon 35/1: 35–65.
Stuiver M. & Pearson G. W. (1993): High precision bidecadal calibration of the radiocarbon time scale, AD 1950–500 BC and 2500–6000 BC. – Radiocarbon 35/1: 1–23.
Tasenkevic L. O. & Bezusko L. G. (1982): Istoria rozvitki flori i rostitelnosti [History of development of flora and vegetation]. – In: Stojko S. M. (ed.), Flora i rastitelnost Karpatskogo zapovidnika [Flora and vegetation of the Carpathian nature reserve], p. 174–177, Naukova Dumka, Kiiv.
Tlusták V. & Havránek P. (1995): Aktivní ochrana ohrožených rostlin fytogenofondu České Republiky a Slovenské Republiky [Active protection of threatened plants in Czech Republic and Slovak Republic]. – Zborn. VI. Sjazdu SBS při SAV, Blatnica 1994, p.184–188, Slov.Bot. Spoloč., Bratislava.
Troels-Smith J. (1955): Characterization of unconsolidated sediments. – Danm. Geol. Unders. 4R 3/10: 1–73.
Van Geel B. (1978): A palaeoecological study of Holocene peat bog sections in Germany and the Netherlands. – Rev. Palaeobot. Palynol. 25: 1–120.
Van Geel B., Coope G.R. & Van der Hammen T. (1989): Palaeoecology and stratigraphy of the Lateglacial type section at Usselo (the Netherlands). – Rev. Palaeobot. Palynol. 60: 25–129.

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