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Pollen Taphonomy and Hydrology at Vranský potok versus Zahájí Alluvial Pollen sites: Methodological Implications for Cultural Landscape Reconstruction in the Peruc Sandstone Area, Czech Republic[1]

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A B S T R A C T

Analyses of pollen samples in a 4.5 m sediment core at Vranský potok in the Peruc Sandstone region of North Bohemia demonstrate the potential of alluvial sites towards reconstruction of vegetation history in lowlands settled intensively by prehistoric and medieval farmers. The radiocarbon chronology indicates continuous sedimentation from the Bronze Age. For this sequence, a method of relating pollen taphonomy to fluvial hydrology, deforestation and soil erosion is described. Anthropogenic indicators are abundant in the pollen record, reflecting the intensity of early farming regimes as well as inferred taphonomic modes to be considered in detail here. The methods of site interpretation are validated via a comparative exercise with the Zahájí pollen site, as well as with the Peruc area.

1. Introduction

This study compares pollen data of an alluvial sediment core of the low-energy accretion surface of the second-order drainage of Vranský potok (245 m a.s.l.), in the district of Slaný in the northern Bohemian Peruc Sandstone region with those of a second site, namely the largely organic sediment core at Zahájí (232 m a.s.l.) near Lázně Mšené (7 km ENE of Vraný) initially reported by the first author of this article (Pokorný 2005). These pollen sites combined comprise an important part of the historical database for vegetation and land-use in lowland Bohemia as a whole, and the main intention of this study is to introduce the pollen data from the Vranský potok site and establish a general framework interpretation of its pollen taphonomy as a basis for further comparative analyses. Unlike oxbow sites of large river valleys often employed in alluvial pollen studies, Vranský potok is distinct in that sedimentation occurs on the alluvial accretion surface of an active channel. Sites of this type in particular have been examined on a pilot basis in the United Kingdom (Howard *et al.* 2000, Brown 2009), although the volume of actual pollen work considered here is low.

Based on the work of the original type-site in Bohemia (Albert 2005), alluvial sediments similar to those of Vranský potok have also been examined by the first author of this article in the sub-humid lowlands Texas (USA) in studies comprised of up to 100 samples (Albert 2007, 2011). These studies from larger order drainages (catchments in the order of 100 km^2) established the rationality and reproducibility of alluvial pollen data in adjacent sediment cores, although differential representation of pollen types was not encountered. As will be discussed in this (by volume of work) globally significant comparison of 176 alluvial pollen samples from two proximal sites in the Peruc sandstone region, the taphonomy of pollen grains is different at each site. Since the sediments at Vranský potok originate largely from water transport (alluviation), water transport is most important for pollen taphonomy here, while at Zahájí, high local water tables are partly a result

[1]We dedicate this paper to Marek Zvelebil. In early 1990's, in the times of ALRNB, Marek was at the beginning of this research.

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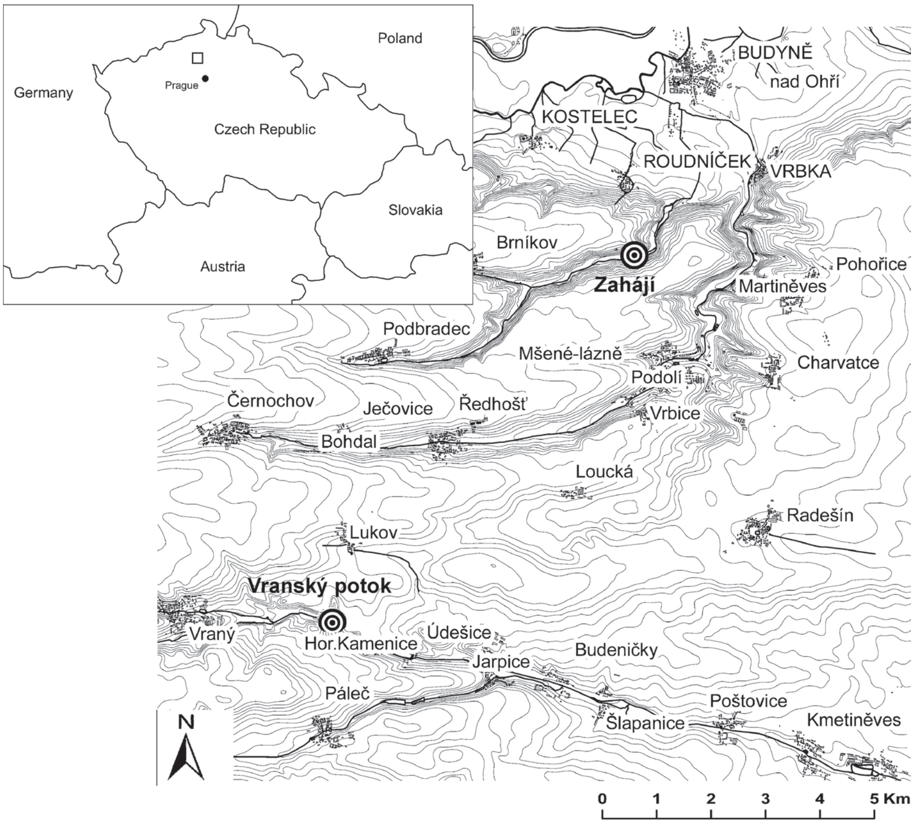

Figure 1. Location of the study area (square) within the Czech Republic and location of the two study sites shown in a hypsometric map of this area.

of spring activity where alum content is unusually high (alum levels are toxic to micro-organisms including many bio-degraders and thus diminish the biotic degradation of organic material, including pollen). Sedimentation at Zahájí is more organic due to a special local situation and less subject to factors of erosion upstream.

The first alluvial pollen site – Vranský potok – lies in a moderately incised gorge at a break in the slope in the long-valley profile of Vranský creek. Here, reduction conditions allow for preservation, while acidity induced by local sandstones also deters the degradation of pollen grains. In hydrology, flow-velocity declines at the locality, promoting the deposition of pollen and other fine sediments from surface run-off within a basin of only 10 km^2. The entire Vraný basin has also been the subject of a major and systematic archaeological survey (Ancient Landscape Reconstruction North Bohemia or ALRNB) by the Institute Archaeology of the Czech Academy of Sciences in Prague with the cooperation of the late Marek Zvelebil of the Department of Archaeology and Prehistory at the University of Sheffield, United Kingdom. A general assessment of land-use data after systematic palynology combined with systematic archaeology of 184 hectares within a strictly circumscribed area is thus possible around Vraný.

It is noted that in lowland North Bohemia, Pokorný (2005) and others (Pokorný *et al.* 2000, Kozáková, Pokorný 2007, Dresslerová, Břízová 2004) have examined multiple Late Glacial and Holocene pollen sites from oxbow-type fluvial settings that reconstruct a variety of local and regional vegetation types in the Middle Elbe and Lower Vltava valleys. The recovery of Middle Holocene materials is impressive here as oxbow deposits such as these are often destroyed by river meanders after fluvial systems attain a dynamic equilibrium following major climatic changes of the Early Holocene. Major land-use patterns in this North Bohemian region discerned according to pollen data include increased cultivation in the medieval period, although signs of intensive agriculture occur at some sites as early as the Bronze Age.

Unlike Vranský potok, these major river valley pollen sites primarily consist of organic sediment (like our second study side – Zahájí), and are differentially influenced by local oxbow sub-environment sedimentation or else an inwash of pollen grains from much larger land areas in the river valley during periodic flood stages (*cf.* Wojcicki 2006). As with Vranský potok however, the Zahájí site, only 7 km removed from Vraný, is situated in a czernozem zone particularly favored by early farmers (Pokorný 2005). Thus, similarities of land-use, ecology and proximity itself make Zahájí of special comparative interest for Vranský potok. Because the data patterns discussed below suggest that water-transport also influences pollen taphonomy at Vranský potok, and thus modes of data interpretation, a statistical comparison of the full pollen database of both sites has been carried out based upon identical methods. This initial comparison between Vranský and Zahájí sites will affirm the interpretation, including

Figure 2. Vranský potok south-oriented valley slope in a location just above the studied alluvial pollen site. Natural outcrop of Peruc sandstones shown. Photo B. M. Albert.

that of the palaeo-hydrological change at the primary site through the demonstration of the non-significance of these same statistical patterns at the Zahájí site of a different taphonomic type (where regional vegetation types are expected to be the same). The concentration of synanthropic pollen at Vranský potok, because of the importance of water transport over fields here, is also considered with a view to the relative prominence of synanthropics at the two sites.

2. Materials and methods

2.1 Pollen-analytical method

The non-mechanized coring (by a three-man team in 1992) at Vranský potok is achieved in semi-consolidated sediments to a depth of 4.5 meters below the surface using a gouge and extension rods. The gouge is one meter in length, 10 cm in diameter and of a Hillier-type. Core segments were transported to the United Kingdom for pollen analysis at 4 cm intervals at the University of Durham. The objectives of this analysis include the reconstruction of the forest history and the agricultural history, although possibilities of reconstructing a further history of hydrological variation at Vranský potok also emerged over the course of the analysis. The laboratory processing of (1 cc) pollen samples (at the Department of Geography, University of Durham) employs a standard HCL-KOH-HF-acetolysis sequence with final mounting in silicone oil (Zahájí slides are mounted in glycerol). It is noted that the use of silicone oil avoids the (ca. 10%) expansion of certain *Poaceae* pollen grains under glycerol preparations and aids in the analyst in the distinction of cereal

Figure 3. Zahájí alluvial pollen site. This location is now covered by alluvial forest (domined by Alnus glutinosa and Fraxinus excelsior). Photo P. Pokorný.

from grass grains by size criteria (Faegri *et al.* 1989). One *Lycopodium* tablet (spore count 13,400 per tablet) produced by the Department of Lund University, Sweden is added to each sample for purposes of calculating pollen concentration (inversely related to the incidence of *Lycopodium* spores at a given pollen count).Pollen counting is performed with a Zeiss light microscope at ×400 magnification, with ×1,000 (immersion oil) being used for fine observation. Pollen type-slide collections used in analyses of Vranský potok include that at the Department of Geogarphy at Durham University, Durham City, United Kindom, the Wadyslaw Szafer Institute of Botany of the Polish Academy of Sciences, Kraków, Poland and the Institute for Systematic and Ecological Biology, Brno, Czech Republic. Cultigens in particular are differentiated on the basis of columella patterns discernible on the pollen exine at ×1,000 magnification with phase-contrast after instruction by Krystyna Wasyłikowa at the Institute of Botany of the Polish Academy of Sciences in Kraków (as well as on the basis of other characteristics of these grains, *cf.* Anderson and Bertelsen 1972). In this analysis, it is also noted that *Triticum* includes the *Avena*-type previously used by Pokorný (2005) for Zahájí. Here, a uniform *Triticum* term is used, although in actuality, it is difficult to differentiate these respective types.

Pollen zonation, for uniformitarian purposes, is carried out using a stratigraphically constrained incremental sum of squares cluster analysis according to percentage data of all pollen taxa, facilitated by the CONISS program developed by Grimm (1987). This measures the dissimilarity of sample clusters in terms of Edwards and Cavalli-Sforza's chord distance, plotted on the right-hand side of pollen diagrams. For the present purposes, a chord distance of less-than forty is required for the grouping of pollen assemblages into stratigraphic zones. This threshold has been selected based on subjective criteria, and it is emphasized that the larger number of samples examined at Zahájí relative to Vranský potok, as well as the longer time frame of sedimentation at Zahájí should favor a higher level of zonation at Zahájí on both statistical grounds (the number of analysed samples is 30% greater, *cf.* Bennett 1996) and an increased probability of significant actual vegetation change (the temporal span of the Zahájí pollen site is greater than Vranský potok by a factor of at least one millennium).

Pollen data are also grouped according to general ecological values relating to climax, sub-climax and heavily disturbed vegetation communities relating to human impacts. In order of increasing impact, the groups defined in the main sum (adjusted land pollen or ALP) are designated (1) trees, (2) shrubs, (3) herbs-general, (4) herbs-ruderal, (5) weeds of cultivation and (6) cultigens. A certain over-lap of indicative values is noted (Ellenberg 1978). Excluded from the adjusted pollen sum are telmatic to aquatic communities of a local indicative value, as well as air-sack (saccate) pollen types (all conifers) which appear to co-vary with respect to each other (*Pinus*, *Picea* and *Abies*) as well as to telmatic taxa such as *Cyperaceae* at the primary pollen site of Vranský potok. It is thought that this co-variation reflects hydrological change, an assumption to be assessed by comparisons with the non-accretion surface, the organic sediment site of Zahájí. Co-variations of these pollen taxa and groups at Vranský potok have been subjected to base-level significance tests (Albert 2005, related to the relative magnitude of pollen representation, the numbers of grains counted and the relative degree of taxon or combined group variation at 1/1 and 2/5 95% confidence intervals as discussed by Faegri *et al.* 1989) before the present comparative exercise with the Zahájí pollen site.

Regarding cultivation indicators, the disturbance-resistant weeds of cultivation are indicative of intensive agrarian regimes. Such plants favored under ard/plough either exhibit an annual life cycle, or are capable of extensive vegetative growth at root level, such as *Polygonum convolvulus*. Further weeds usually occur in winter fields, like *Centaurea cyanus* (Behre 1981, Ellenberg 1988), and indicate the extension of the planting season. The majority of synanthropics are classed, however, as ruderal, and included here are also plants promoted by herbivore grazing, such as *Plantago lanceolata.* In alluvial situations, such taxa may be preferentially deposited into sediment through increased surface run-off on arable fields within site watersheds (Butzer 1982, Brown *et al.* 2007), although it is further proposed (*cf.* the effect noted by Hopkins 1950) that saccate pollen types are differentially represented due to floodplain geometry and hydrology.

2.2 Archaeological materials

The first archaeological investigations in the Vranský potok micro-region began with excavations by Knor (n.d.) at the Eneolithic settlement of Vraný-Hradiště, where materials of the Řivnáč Culture are prominent. These data has been augmented through systematic surface surveys conducted by ALRNB (Kuna 1998). Pottery has been analysed, and in diagnostic cases, assigned to *circum* 2/400 year time periods (undated finds are not considered here). This record provides a highly objective basis whereby evidence for human settlement might be compared to synanthropic pollen data. For general analytic purposes, surface pottery recovered by the ALRNB is expressed in terms of five modal values that equate to finds per hectare ranging from (Mode 1) one to (Mode 5) more than twenty pottery sherds. Within the basin of Vranský potok itself, about 50% of the primary farming area as defined by Kuna and Slabina (1987) is surveyed by ALRNB.

2.3 Lithological and malacological materials

Vranský potok sediments are described (Table 1) according to the Troels-Smith (1955) method, and may be divided into three main sedimentary zones, capped by a massive mixed layer. A lower zone ranging in depth from 450 to 405 cm consists of partially oxidized clay with small quantities of reduced silt. Conditions here are more terrestrial. In contrast, a middle sedimentary zone (405–146 cm) in depth consists of alternate layers of reduced silt, indicative of more aquatic conditions and higher, and a more telmatic detrital peat,

Table 1. Vranský potok lithology (and malacological observations), all lim=0.

Depth (zone) and sediment description after Troels-Smith (1955)	
416–450 cm (L):	Brown-orange clay, *As4, Aa+, Elas1, Nig1*(with malacofauna: *Pupilla muscorum*[1], *Cepaea hortensis*[1], *Vertigo angustior*[1], *Vertigo antivertigo*[1], *Radix peregra*[6] and *Pisidium casertanum*[10]at 430 cm)
373–405 cm (M):	Grey-brown organic silt, *Ag3, Sh1, Aa+, Gs+, Elas1, Nig2*
355–373 cm (M):	Grey silt, *Ag4, Sh+, Aa+, Gs+, Elas1, Nig2*
327–355 cm (M):	Dark grey detrital peat with silt, *Dh2, Ag2, Aa+, Gs+, Elas2, Nig3* (with malacofauna: *Vallonia costata*[1], *Vallonia enniensis*[1], *Succinea/Oxyloma*[1] and *Pisidium casertanum*[5] at 350 cm)
320–327 cm (M):	Brown-grey detrital peat, *Ag1, Dh2, Dl1, Elas2, Nig2*
243–320 cm (M):	Grey-brown organic silt, *Ag3, Sh1, Aa+, Gs+, Elas1, Nig2* (with malacofauna: *Vallonia costata*[5], Pupilla *muscorum* [1], cf. *Helicopsis striata* [1], cf. *Euomphalia strigella*[1] *and Vertigo angustior*[3] at 300 cm)
218–243 cm (M):	Grey-brown detrital peat with silt, *Ag2, Dh1, Dl1, Elas2, Nig3*
195–218 cm (M):	Dark grey organic silt with detrital peat, *Ag2, Sh1, Dh1, Aa+, Gs+, Elas2, Nig3*
149–195 cm (M):	Dark grey organic silt, *Ag3, Sh1, Aa+, Gs+, Elas1, Nig3*
146–149 cm (M):	Dark grey organic silt with detrital peat, *Ag2, Sh1, Dh1, Aa+, Gs+, Elas2, Nig3*
127–146 cm (U):	Grey silty clay, *As2, Ag2, Aa+, Gs+, Elas1, Nig2*
125–127 cm (U):	Light grey sand, *Aa4, Gs+, Elas1, Nig1, Lim2*
113–125 cm (U):	Grey silty clay, *As2, Ag2, Aa+, Gs+, Elas1, Nig2*
77–113 cm (U):	Grey clayey-silt, *Ag3, As1, Sh+, Aa+, Elas1, Nig2*
Surface–77 cm:	*Stratum confusum*

Table 2. Zahájí lithology (generalized).

500–570 cm:	*Phragmites* peat with clay
480–500 cm:	*Phragmites* peat
455–480 cm:	Iron oxides with *Phragmites* remains
425–455 cm:	*Phragmites* peat with chemical precipitate (alum)
300–425 cm:	*Phragmites* peat
265–300 cm:	Chemical precipitate (alum) with *Phragmites* remains
175–265 cm:	*Phragmites* peat
165–175 cm:	Clayey organic sediment
155–165 cm:	*Phragmites* peat
0–155 cm:	Clayey organic sediment

indicative of lower water tables. An upper zone (77–146 cm) consists of reduced, poorly sorted silt/clay. Here increasing sediment load reduces the hydrological competence of the creek.

Selective malacological observations in Vranský potok sediment cores returned to the Czech Republic in 2011, and examined courtesy of Lucie Juřiková of the Department of Zoology, Faculty of Science at Charles University, Prague are inserted parenthetically at three intervals (430, 350 and 300 cm) within this sequence. The numbers of individual finds are indicated in brackets herein (Table 1). These zoological data of hydrological significance will be used in a limited test of hydrological interpretation methods discussed (below) in the light of the palynological and lithological data. It is noted that sites with dual palynological and malocological databases are a rarity in the Czech Republic.

Significantly, the comparative lithology from the Zahájí alum fen (Table 2) is dominated by organic sediments (and chemical precipitates) to a much greater extent than as is the case at Vranský potok. Autogenic sedimentation is thus greater at the alum fen site. Also significant is the relative scarcity of silt at Zahájí (at least in the prehistoric section from 570 to 155 cm), reflecting lower alluvial inputs here relative to the situation at Vranský potok above.

2. 4 Radiometric dates

To provide chronometry to the Vranský potok pollen core, two peat samples and one wood sample were submitted for standard (decay-counting) radiocarbon dating. A fourth

Table 3a. Vranský potok radiometric dates (AMS and standard).

AMS-Poz-37847 (380 cm, pollen) 3675±35 BP (4140–3900 cal. BP) materials dated: pollen residue
Standard -Beta 82510 (345/341 cm, peat) 3070±60 BP (3420–3080 cal. BP) materials dated: bulk peat *sans* rhizomes
Standard -Beta 81677 (312/308 cm, peat) 2790±50 BP (3050–2780 cal. BP) materials dated: bulk peat *sans* rhizomes
Standard-Beta 82511 (202/200 cm, wood) 2020±50 BP (2135–1870 cal. BP) materials dated: wood twigs

Table 3b. Zahájí radiometric dates (all AMS).

Erl-3011 (555 cm) 4788±49 BP (5615–5330cal. BP) materials dated: non-rhizomatous cf. *Molinia coerulea* and wood twigs
Erl-3013 (498 cm) 4134±50 BP (4625–4525cal. BP) materials dated: non-rhizomous cf. *Molinia coerulea*
Poz-29572 (430–435 cm) 3140 ± 40 BP (3450–3260cal. BP) materials dated: *Panicum miliaceum* seeds
Erl-3012 (298 cm) 2830±44 BP (3100–2800 cal. BP) materials dated: non-rhizomous cf. *Molinia coerulea*
Erl-3008 (185 cm) 1005±39 BP (1040–800 cal. BP) materials dated: wood twigs
Erl-3007 (98 cm) 665±38 BP (675–560 cal. BP) materials dated: *Alnus* twigs

sample of mineragenic sediment was reduced to pollen residue and dated by the AMS method. Importantly, all the dates are sequential with respect to depth, and demonstrate a mean sedimentation rate of 9.2 cm per century. A chronological cross-check also comes from a dual rise in the curves of *Secale cereale* and *Centaurea cyanus* pollen at 146 cm. Interpolating after Beta 82511, this level dates to *circa* AD 560/80 (Pleiner, Rybová 1978, Jiráň, Venclová 2007–2008), while development of *Secale cereale*-dominated farming with the same weeds is dated to the same period in the Czech and (western) Slovak Republics according to archaeo-botanical data (Kočár, Dreslerová 2010, Hajnalová 1989, 1990). All the dates (including the comparative dates from Zahájí plotted on diagrams, *cf.* Pokorný 2005 for details of AMS dates) are calibrated to 2 Sigma ranges according to the POLPAL program of Adam Walanus (Table 3a, Table 3b). Peat materials dated at Vranský potok have been sorted with a view to removing all rhizomatous material (a similar standard to avoid young dates is observed at Zahájí with respect to *cf. Molinia coerulea*).

An age-depth model for both sites will be calculated here based on the arithmetic midpoints of the calibrated 2-Sigma date ranges and used in general comparisons between sites. A detailed comparison (Figure 11) will focus on only the best-dated and coeval aspects of both sites (interpolated date estimates here are rounded to the nearest decade BP).

At Vranský potok, the lower pollen zones lack dates at present. Here it is assumed that the rates of sedimentation of clays are lower than the silty layer average. It is consequently proposed on a provisional basis that Pollen Zones 1 and 2 date to Eneolithic times. It is also noted that Zone 2 (416 cm) produces data for major cultivation, while the three sites of the Řivnáč Culture are recorded within 200 m. These Eneolithic sites date to 2800 BC or before (*cf.* dating of Buchvaldek's

Table 4. Vranský potok sedimentation rates.

Depth range (cm)	Net rate (cm/century)
343–380	5.0
310–343	8.4
201–310	11.5
0–201	10.1

A-Horizon of slightly later Corded Ware Culture according to Hardmeyer 1992). This correlation would be suggestive then of a basal (3.8+ m) sedimentation rate of 5 cm per century or lower.

A significant increase in sedimentation rate is noted after *circa* 1335 BC (Knovíz Culture or early part of the Late Bronze Age). A decline in the accumulation rate in the upper two meters of the core needs to be considered, however, in conjunction with floodplain geometry. A higher total volume of sediment is required to maintain the same vertical sedimentation rate as the base of the incised valley effectively widens with progressive alluviation (Table 4).

3. Results

3.1 Pollen concentration and inferred taphonomy

As assessed by *Lycopodium* tablets, pollen samples at Vranský potok contain high concentrations of pollen for alluvium, with values ranging from 1,000 to 2,000/cc in the lower, 2,000 to 142,000/cc in the middle, and 4,000 to 12,000/cc in the upper sedimentary zone. The pollen of locally over-represented aquatic, semi-aquatic and telmatic taxa is excluded from the main pollen sum (ALP, all pollen percentages expressed in these terms) due to the tendency for over-represented local types to distort the statistical response of regional taxa (Rybníčková, Rybníček 1971). A further distortion is exhibited by floating saccate pollen, consisting of *Pinus*, *Picea* and *Abies*, which are buoyant on water surfaces in low-energy situations (Hopkins 1950, *cf.* high relative pine pollen levels on water surfaces limited to slack water margins along sampled water columns in the Mississippi River by Smirnov *et al.* 1996). A modulation of saccate pollen might then occur as a result of low turbidity water table fluctuation above a *level* accretion surface.

It is consequently proposed that conifer or saccate pollen floats on water surfaces at Vranský potok and is preferentially deposited onto the accretion surface when water tables are low. It is noted that *circa* 90% co-variation (defined by a 95% significant 1/1 confidence interval) exhibited by saccates suggests that these taxa are deposited as a group regardless of conifer ecology (Albert 2005). This differential representation determines the exclusion of saccates from the main pollen sum. In view of this novel method, the term adjusted land pollen or ALP is thus used in analyses at Vranský potok. According to findings from higher energy alluvial sites with different floodplain geometries (Albert 2007, Albert 2011), this method of ALP definition is presumed to be valid in lower order drainages with lower (~50 cm) water-table variation atop level surfaces. At Vranský potok, semi-aquatic and telmatic representation is predicted to be low in conjunction with low saccate pollen levels due to the distal position of *Typha* and *Cyperaceae* growth, given a less telmatic, strictly aquatic, site condition. It is possible that this co-variation will be insignificant in initial sedimentation, prior to development of a level surface, or during high-energy events like floods, when buoyancy is inoperative.

The relationships of reconstructed hydrological change will be compared to arboreal and synanthropic flora. If human impact is a major factor in hydrological change, with disturbance of the canopy and rhizosphere that imposes a limit on the interception of run-off and evapo-transpiration, then major farming episodes should be coeval with a rise in the water table (Butzer 1982). A reduction of impact with a floral succession would be coeval with lower water tables. These modes of interpretation will be evaluated by statistical comparisons with the Zahájí site, using identical methods of pollen curve calculation. The non-alluvial accretion surface setting at Zahájí should lead to a non-co-variation of saccates and telmatic pollen types, as opposed to the quantitative characteristics described above.

3.2 Pollen zonation

Hydrological sensitivity may be reflected in the Vranský potok CONISS zonation at the 40 (Total sum of squares) chord-distance, because on a percentage basis, this zonation is strongly influenced by taxa excluded from the adjusted sum (ALP). Fourteen zones over somewhat more than 4,000 years are thus identified, and here also correlated with Czech archaeological periods, although associations within the Eneolithic are quite provisional.

Vranský potok Zone 1, 424 cm, *earlier* Eneolithic (?): low saccate pollen is recorded in this sub-zone, along with a poverty of aquatic and telmatic species. A site maximum of *Sphagnum* (5.6%) spores is noted here. Low levels of arboreal pollen are represented, with *Fagus* (2.8%), *Alnus* (5.6%) and *Salix* (5.6%) being most prominent. Significant ruderal pollen types in this sub-zone include *Artemisia* and *Polygonum aviculare*.

Vranský potok Zone 2, 412–416 cm, *later* Eneolithic (?): saccate pollen rises in this level, led by *Picea* (62.5% max.). Aquatic to telmatic taxa are poorly represented here. A rise of arboreal pollen is noted, with higher values of *Alnus* (10.9% max.), *Betula* (13.3% max.) and *Corylus* (14.1% max.). *Melampyrum*, among shade-tolerant herbs, occurs in this zone. Significant ruderal pollen types here include *Artemisia*, *Chenopodium* and *Polygonum aviculare*. Among cultigens, *Hordeum* (1.7%) and *Cerealia* (1.7%) are notable, these deriving from 416 cm.

Vranský potok Zone 3, 375–400 cm, *circum* Proto-Únětice Culture (?) to 1975 BC (Early Únětice Culture): saccate pollen levels are high, led by a rise of *Abies* (87.8% max.). The last high values of *Picea* (52.3% max.) are expressed here until the terminal zone (14). A major rise of *Cyperaceae* (103.6% max.), a rational representation by *Filipendula* and isolates of *Lythrum* are noted here. Relatively high levels of arboreal pollen occur, with higher and terminally rising values of *Quercus* (31.7%), high *Fagus* (12.9% max.), declining *Alnus* (4.9% min.), *Betula* (10.7% max.), *Corylus* (23.2% max.), and terminally rising *Salix* (17.1%). *Melampyrum*, among shade-tolerant herbs, attains a site maximum in the terminus of this zone (9.8%), along with high *Quercus*. Significant ruderal pollen types include *Artemisia*, *Chenopodium* and *Polygonum aviculare*. Of cultigens, *Linum usitatissimum* (1.1%) appears; this deriving from 380 cm.

Vranský potok Zone 4, 348–372 cm, 1915 to 1435 BC (Classical Únětice Culture and Middle Bronze Age): saccate levels are low, and *Picea* in particular declines precipitously initially (1.7% min.). A major decline of *Cyperaceae* (21.7% min.) is also noted. A decline of arboreal pollen occurs here, with initially low, but rising *Quercus* (19.1% max.), low *Fagus* (2.5% min.) and initially low but rising *Betula* (15.7% max.). Initial *Carpinus* appears along with *Hedera*. *Poaceae* furthermore rises significantly at the beginning of this zone (58.0%). Significant ruderal pollen types include *Artemisia*, *Chenopodium*, *Polygonum aviculare* and *Rumex acetosella*. A rise of *Plantago lanceolata* (6.2% max.) and *P. major* (2.7% max,) is moreover noted, with both curves peaking at 360 cm. Among arable weeds, the first appearance of *Centaurea cyanus* (0.7%) at 372 cm is notable. Three consecutive samples with *Triticum* occur between 372 and 360 cm, and a sample at 368 cm also contains *Hordeum* and *Humulus*. The upper part of this zone (with a higher tree pollen) lacks primary cultivation indicators, although the first arable weeds of the *Scleranthus* (356 cm) and *Polygonum convolvulus* (348 cm) types occur here. The most unusual finds in this upper part (Middle Bronze Age) include one grain of *Hippophaë* and five of *Ephedra*.

Vranský potok Zone 5, 310–346 cm 1395 to 940 BC (Knovíz and Early Štítary Culture): saccate pollen rises, led by *Abies* (66.7% max.). A major rise of *Cyperaceae* (169.8% max.) is noted. In addition to a high of *Typha latifolia*, maximum representation by *Filipendula* and isolates of *Lythrum* are noted, along with several grains of *Myricaria*. Variable levels of arboreal pollen are recorded here, although *Quercus* (22.5%) and *Fagus* (16.4%) achieve maxima around 324 to 328 cm. *Betula* (1.8% min.) declines significantly, however *Salix* (12.1% max.) maintains high values. A further appearance of *Hedera* is noted. *Calluna vulgaris* appears for the first time. A maximum of *Ranunculaceae* is further noted. Significant ruderal pollen types include *Artemisia*, *Chenopodium*, *Polygonum aviculare*, *P. persecaria*, *Galium*, and *Plantago lanceolata*. Major representation is achieved by combined (3.8%) *Humulus* and *Cerealia*.

Vranský potok Zone 6, 260–308 cm, 920 to 510 BC (Late Štítary and Late Hallstatt Culture): all saccate pollen types decline, with *Picea* being reduced to negligible values (0.0% min.). A major decline of *Cyperaceae* (1.3% min.) and a presence of *Mentha* is noted. A general decline of arboreal pollen occurs also, including *Fagus*, *Quercus*, *Alnus* and *Salix*. *Melampyrum* appears in samples with higher arboreal pollen. A rational representation of *Umbelliferae* and rise of *Aster* (26.0% max.) are mentioned. Significant ruderal types include *Artemisia*, *Chenopodium*, *Polygonum aviculare*, *P. persecaria* and *Silene*. A rise of *Plantago lanceolata* (4.8% max.), *P. major* (1.6% max.) and *P. media* (2.6% max.) is further noted. Among arable weeds, a rational representation by *Scleranthus* and isolates of *Anagalis arvensis* and *Centaurea cyanus* (286 cm) are noted. Prior to (est. 15–20 y) the latter weed, the first *Secale cereale* appears at 288 cm. *Hordeum* and *Triticum* are the most common cultigens at this time, however.

Vranský potok Zone 7, 200–250 cm, 420 BC to AD 5 (La Tène Culture): saccate pollen rises, led particularly by *Abies* (95.7% max.). *Cyperaceae* increases to modest levels, although *Typha latifolia* (15.1% max.), and particularly *Typha angustifolia* (26.4% max.) are extremely prominent here. Initially, arboreal pollen rises, including curves of *Quercus* (14.0%) and *Fagus* (10.5%). A further appearance of *Calluna vulgaris* is noted in this zone, while *Melampyrum* occurs in samples with higher arboreal pollen levels. A major decline of *Poaceae* (to 16.3%) marks the beginning of this zone. *Aster* also declines. Significant ruderal pollen types include *Artemisia*, *Chenopodium*, *Polygonum aviculare*, *P. persecaria* and *Silene*. Among arable weeds, a site maximum of *Scleranthus* (12.8%) is noted, along with

Adonis aestivalis (1.2%) and *Polygonum convolvulus* (2.2%). Cultivation pollen in this zone is comprised of a sporadic mix of *Hordeum*, *Triticum* (2.1% max.) and *Secale cereale*.

Vranský potok Zone 8, 192 cm, AD 85 (Early Roman Age): moderate saccate and telmatic levels are expressed in this sub-zone. A major rise of *Quercus* (12.2%) and *Fagus* (16.3%) is noted here. Significant ruderal pollen types include *Artemisia*, *Chenopodium*, *Polygonum aviculare* and *Stellaria*. A major rise of *Plantago lanceolata* (4.1% max.) is further noted. Finds of *Triticum* (2.0%) are noted.

Vranský potok Zone 9, 160–188 cm, AD 120 to 400 (Early and Late Roman Age): saccate pollen maintains a moderate level of representation, although *Typha latifolia* rises terminally to a site maximum (34.8%). *Mentha* also attains a site maximum here (4.4%). A decline of *Quercus* (2.4% min.) and *Fagus* (0.0% min.) occurs in this zone, although maxima of *Carpinus* (3.5%) and particularly *Fraxinus* (12.2%) are noted. *Calluna vulgaris* occurs sporadically. *Poaceae* rises significantly at the beginning of this zone (54.1%). *Aster* continues to decline, although *Asteraceae Subfam*. *Cichoriodeae* rises at the terminus of this zone. Significant ruderal pollen types include *Artemisia*, *Chenopodium*, *Polygonum aviculare*, *P. persecaria* and *Silene*. A rise of *Plantago major* (1.9% max.) is further noted, while *Galium* (11.3%) achieves a site maximum here. Among arable weeds, *Scleranthus* and the *Agropyron* type are notable throughout this zone and *Polygonum convolvulus* (2.2% max.) and *Agrostemma githago* (1.1% max.) in the later part of this zone. The early part of this zone sees a peak of cultivation (6.5%). In addition to *Humulus*, *Hordeum* and *Triticum*, multiple finds of *Secale cereale* (1.8% max.) are notable in this zone.

Vranský potok Zone 10, 110–150 cm AD 500 to 900 (Early Middle Ages): saccate pollen, particularly *Abies*, declines here. *Typha latifolia* declines to negligible values here, along with *Typha angustifolia*. A decline of *Quercus* (2.2% min.) and *Fagus* (0.0% min.) continues in this zone, although a rise of *Salix* is noted. *Potentilla* and *Trifolium* achieve site maxima. *Asteraceae Subfam. Cichoriodeae* rises at the beginning of this zone (26.7% max.), but declines at the terminus. Significant ruderal pollen types include *Artemisia*, *Chenopodium*, *Polygonum aviculare* and *Silene*. *Galium* (2.6% max.) maintains a presence throughout most of this zone. Among arable weeds, multiple *Agropyron* and *Scleranthus* grains are noted. Significantly, *Centaurea cyanus* (9.7% max.) achieves a nearly rational expression here. Cultivation pollen is extremely prominent in this zone (10.4% max.), comprised of *Hordeum* (1.8% max.), *Triticum* (3.9% max.) and *Secale cereale* (6.5% max.), in addition to *Cannabaceae* and *Humulus*.

Vranský potok Zones 11–14, 77–105 cm, AD 950 to 1230 (High Middle Ages): Variability of pollen representation occurs in terminal sub-zones. Oscillating saccate pollen types are dominated by *Pinus* here, with a relative decline of *Abies* and a terminal rise of *Picea* (33.9% max. in Zone 14) being expressed. Site maxima are expressed in aquatic taxa, such as *Nymphaea* (4.8%) and *Potamogeton* (4.8%), in Zone 12. *Cyperaceae* pollen rises to a site maximum in Zone 14 (185.9%), declining in the terminal level (13.6%). Maxima of *Pteridium* spores are noted in alternate zones (11, 13). Arboreal pollen also oscillates in these zones, with maxima of *Quercus* (17.2%) and *Fagus* (4.7%) occurring at 85 cm, and final finds of *Corylus* in Zone 11. Zone 13 contains a site maximum of *Asteraceae Subfam. Cichoriodeae* (33.3%). Significant ruderal pollen types include *Artemisia*, *Chenopodium* and *Polygonum aviculare*. *Cerealia*, *Triticum* and *Humulus* together comprise 15.3% of ALP in the final zone-level.

In comparison, an identical (statistical) CONISS zonation of Zahájí (analytic pollen zones described in vegetation ecology terms by Pokorný 2005) produces six statistical zones over a period somewhat greater than 5,000 years. A lower stratigraphically constrained zonal sensitivity (*cf.* 14 zones over 4,000+ years at Vranský potok) of zonation in a non-alluvial accretion surface setting at a proximal site in a similar ecological setting (Zahájí) thus logically supports a hydrological interpretation of the discerned Vranský potok pollen zones. It is further noted that the lower zonal sensitivity at Zahájí is expressed contrary to primary (statistical) bias (*cf.* Bennett 1996), reinforcing the importance of the former observation.

3.3 Comparison: synanthropic palynology and palaeohydrology

The zonation of both pollen cores allows for a systematic comparison of Vranský potok pollen zones with expected

Table 5. Vranský potok, summary palynology and granulometry. For description of symbols see text.

PAZ	Sc	Aq	Tl	Qu	Fa	Cult.	Granulometry (organics excl.)
2	P	0	0	0	0	3.3	~75%clay–25%silt
3	P	0	P	P	P	1.1	~100%silt
4	N	0	N	N	N	2.0	~100%silt
5	P	0	P	P	P	3.8	~100%silt
6	N	0	N	N	N	2.3	~100%silt
7	P	0	P	P	0	2.1	~100%silt
9	0	0	0	N	P	6.5	~100%silt
10	N	P	N	N	N	10.4	~100%silt /50%silt–50%clay

pollen responses to possible hydrological variation above. In Table 5 below, rows are delimited by pollen zones, against which a simplified (Troels-Smith) lithology is adjudicated. CONISS defined pollen zones are described in terms of pollen groups or key taxa, and the curves of all the pollen groups are described in terms of positive (P), negative (N) or indeterminate (0) trends. Cultivation pollen is noted by maximum percentages within the zone, as assessed by all cereal and textile pollen combined in the maximal level. Other groups (taxa) considered include saccates (Sc), aquatics (Aq), semi-aquatics or telmatics (Tl) *Quercus* (Qu) and *Fagus* (Fa). The lithology is simplified here in granulometric terms (including mineragenic aspects only), reflecting sorting characteristics (Allen 1965). Only pollen assemblage zones consisting of multiple spectra are (selectively) considered here as zones consisting of a single spectrum (PAZ 1, 11–14) self-evidently provide a less-reliable statistical basis for assessment of zonal averages of pollen response of different types or groups (Sc, Aq, Tl, Qu, Fa, Cult.). Further analyses to test the proposed interpretation based on visual pattern recognition in the pollen curves below might include a Principle Components Analysis of all pollen taxa from Vranský potok as well as particle size analysis for more precisely define organic content and granulometry.

With the exception of Zone 2, when floodplain geometry may not be evolved into a level and perennially submerged accretion surface (note oxidation here), a high correlation exists between saccate and telmatic pollen responses at Vranský potok. Individual taxa within the telmatics, for example, *Typha latifolia*, *Typha angustifolia* and *Filipendula* moreover rise and fall in close alignment to CONISS defined zonal boundaries. These trends conform to the expectation that water tables at the pollen core spatially transpose telmatic plant communities, as well as modulate floating saccate pollen representation. Such observations thus further support the inference that hydrological change importantly influences pollen zonation, as well as the inference that saccate pollen is differentially represented in much of the diagram. It is noted that in reference to lithology, mineragenic sediments between Zone 2 and Zone 10 at Vranský potok are reduced, well sorted and importantly comprised of fine silts, indicative of low energy deposition. Granulometric data for lower creek competence with poor sorting of the mineragenic sediments are limited to the Middle Ages (Zone 10 and later). Here it is inferred that the sediment load has increased due to high rates of land-erosion.

Regarding inferences that human impact on the environment enhances water tables by increasing run-off, it is noted that with the exception of Zone 5 (dated to the Knovíz period), increased cultivation and reduced hard wood pollen representation are coeval with reconstructed higher water tables. With a view to complexities, it is probable, in spite of the small area of hydrological catchment (10 km^2), that natural variation in effective precipitation influences water tables significantly if such change is emphatic. The Knovíz Bronze Age (Zone 5), being a period of warm climate according to other proxies (Ložek 1998), might experience lower water tables despite higher human impact due to the magnitude of climate changes. It is further noted that malacological data (Table 1) between intervals at 350 and 300 cm indicate an expansion of steppic types over the course of the Urnfield Bronze Age, providing significant independent zoological support for this interpretation.

A significant expression of full aquatic vegetation, such as *Nymphaea* and *Nuphar*, does not occur until the Middle Ages, a period of highest human impact according to the pollen and archaeological data below (Table 6). This is suggested by the absence of *Nymphaea* and *Nuphar* in the pre-Medieval period, as well as the edaphic characteristics of the telmatics which means that the water table fluctuation in prehistory is constrained in this small catchment, of a magnitude no greater than 20 to 30 cm amplitude. However, greater variability is indicated in the Middle Ages based on the emergence of aquatic plants. The latter plants may be promoted by a low interception of surface run-off, as very low tree and extremely high cultivation pollen is found in Zones 10 to 14. It is further suggested along these lines that the pure sand lens evident (noted in Table 1) in the middle

Table 6. Vranský potok deforestation, cultivation and ALRNB index (bold).

Levels/Culture	Que. & Fag.	Cultigens	ALRNB
375-90/E. Únětice	min. 16.9%	max. 1.1%	**2.9**
360-72/Lt. Únětice	min. 5.0%	max. 2.0%	**7.0**
348-56/M. Bronze A.	min. 12.2%	max. 0.0%	**2.9 (w/E. Ún.)**
332-46-Knovíz	min. 11.4%	max. 3.8%	**8.3**
310-28-Štítary	min. 13.3%	max. 2.3%	**14.4**
260-308-Lt. Hallstatt	min. 3.4%	max. 1.4%	**4.0**
230-50-M. La Téne	min. 9.8%	max. 2.1%	**1.3**
176-88/E. E. Roman	min. 2.4%	max. 6.5%	**15.0**
160-172/Lt. Roman	min. 8.7%	max. 3.7%	**13.0**
110-50/E. Medieval	min. 2.2%	max. 10.4%	**28.0**
77-105/H. Medieval	min. 0.0%	max. 15.3%	**153.7**

of Pollen Zone 10 is a result of a high-energy flood event exacerbated by denudation of the tree canopy and the rhizosphere generally as produced by human impacts.

A detailed comparison of pollen cores at Vranský potok and Zahájí (delineated on the y-axis in terms of the estimated chronometry) is limited in temporal terms to the better-dated (coeval) part of the former core as defined by lower and upper (Poz-37847) AMS and (Beta 82511) radiocarbon dates at the former site. This period (ca. 4000–2000 cal. BP) is illustrated in Figure 11 and considered from the point-of-view of development of key pollen types, including (potentially) flotational saccates pollen types (here *Pinus* and *Abies*), the sensitive telmatic *Typha latifolia* (favored on exposed mud-flats but excluded from perennially flooded areas) and major regional tree pollen types (here *Quercus* and *Fagus*). Comparative pollen curves (Figure 11) at Zahájí reflect no co-variation of saccates and various telmatic to aquatic flora (the latter are of far lower in representation), although a certain covariation of the saccates is possibly significant. Obviously, pollen preservation at Zahájí has largely resulted from alum toxicity as a factor limiting biotic degradation as opposed to the more common factor of reduction, under conditions of a lower water table. There is very little agreement, nevertheless, between the saccate curves at the two sites, and the same is apparent with respect to the mixed-oak woodland types. This poor overall correlation affirms other lines of evidence pointing to significantly different taphonomic regimes at the compared pollen types. It is inferred that the non-alluvial nature of sedimentation here also involves a greater importance for air-transport in pollen taphonomy. Given the proximity and ecological similarity of the Zahájí site to Vranský potok, it is likely then this non-correspondence reflects taphonomic differences and not major differences in the local and regional vegetation structure.

3.4 Archaeological and synanthropic pollen data compared

The ALRNB database produced by Martin Kuna, Dagmar Dreslerová and others of the Institute of Archaeology in Prague in cooperation with a University of Sheffield (UK) student team under the late Professor Marek Zvelebil serves here as the archaeological basis of the comparison with alluvial pollen evidence for agricultural settlement intensity. During the execution of the ALRNB, half of the entire prehistoric farming area in the upper drainage basin (the above pollen site) of Vranský potok, has been surveyed and no major land area of primary farming has remained unexamined herein. For purposes of initial comparisons here, this database is simplified into an index based on the extent and quantity of ceramic finds per century per individual period in a manner that attempts to balance both finds extent and finds density parameters with a view to the fact that archaeological periods represented in ALRNB data are of different duration.

The values of pottery quantity follow from the above noted modal values (MV 1–5), with MV1 equating to one, MV2 equating to two, MV3 equating to three, MV4 equating to four to twenty and MV5 equating to more than twenty sherds recovered per hectare (MV5 only in the High Medieval). Here, the settlement intensity index (ALRNB) is calculated simply as A + B/C, where A equates to the number of one-hectare survey quadrants with pottery finds of the given cultural period, B equates to the cumulative total of modal values (1–5) of pottery finds of the cultural period and C equates to the time-elapse in centuries represented by the given cultural period. For example, during the Knovíz period or earlier part of the Urnfield Bronze Age, an archaeological period of approximately 3.5 centuries duration according to calibrated radiocarbon timescales, ALRNB has recovered pottery in relatively high densities (4–20 sherds per hectare or MV4) from five quadrants. Here A+B equals 5+20 for a 25 numerator. The denomnator (centuries of cultural duration) is subject to uncertainty based on the error-factors of the archaeological chronology, however (here, a high Knovíz chronology ranging from 1400 to 1050 cal. BC is used). In palynological terms, cultivation maxima are defined by level with maximum relative percentages of combined cereals and textile crops. In this comparison (Table 6 and select pollen diagrams), the chronological system of Harding (2000) is employed for the Bronze Age period (an earlier establishment of Urnfield cultures is an important feature here) while Jiráň and Venclová (2007–2008) is used for other archaeological periodizations.

The cultural periods before the Bronze Age are not considered due to poor dating controls. Also, obtrusive graphite pottery which spans the Štítary and Late Hallstatt (inclusive of La Téne A) is not included in the ALRNB index, as these are hard to separate into Bronze *versus* Iron Age time periods, and are over-represented due to high

Table 7. Number of taxa by group compared: Vranský potok and Zahájí.

Group (taxa in main sum only)	Vranský potok (%)	Zahájí (%)
Tree pollen types	11 (13.7)	12 (10.2)
Shrub pollen types	12 (15.0)	21 (17.9)
Herb pollen types	28 (35.0)	56 (43.1)
Ruderal pollen types	16 (20.0)	18 (15.3)
Weed of cultivation pollen types	7 (8.8)	6 (5.1)
Cultivation pollen types	6 (7.5)	4 (3.4)

visibility of such sherds. In general, Table 6 data suggest that ALRNB pottery recovery is matched by palynological trends of cultivation extent and intensity. Divergences from this co-variation include the finds of the Štítary and La Téne Cultures, where pottery is over- and underrepresented, respectively. This may be related to differential preservation of pottery based on depth of settlement features (*cf.* Turková, Kuna 1987; Salač 1995).

With these exceptions, as well as the high densities of less weathered High Medieval finds, it is noted that cultivation levels, expressed by percentages, are about 30% of the ALRNB index value. This regularity enhances confidence in the ability of palynology and systematic archaeology proxies to represent actual trends of settlement. Comparability between these data sets also reflects the micro-regional pollen recruitment at Vransk*ý* potok, as well as the high level of synanthropic flora, which lowers randomness of expression of (para-)cultural flora in the pollen diagram. Indeed, higher percentage levels and taxonomic varieties of synanthropic flora are noted at Vransk*ý* potok as compared to Zahájí (Table 7). Modern cultivated varieties such as *Zea* are excluded. It is noted that the general herbaceous group at Zahájí is enlarged by a factor of five taxa due to the superior analytical separation by the second author of this article (P. Pokorný) of certain families like the *Apiaceae*.

It is further noted that tree pollen at Vransk*ý* potok as compared with Zahájí, is extremely low generally and oscillates irregularly at this low base level (due to the lower number of tree pollen grains actually encountered, this sub-total is less-significant in statistical terms). This differential pattern affirms the importance of water transport as an agency for transforming values of AP and NAP at the two sites. It is thought that increased surface run-off from fields with resultant sediment and pollen deposition at Vransk*ý* potok reduces the relative contribution of pollen from trees as (para-)cultural taxa will be locally over-represented in the same fields which will be the main source of pollen in the taphonomic regime where water transport is most important. In contrast, woodlands will intercept a much larger percentage of precipitation *via* evapotranspitation as well as reduce kinetic levels of water flow through physical interception of rainfall by the canopy (Butzer 1982). Arboreal pollen percentages are thus most likely transformed by linear factors such as the woodland extent as well as complex factors of AP under-representation by virtue of hydrologically modulated variability of sediment sources.

Affirmably, synanthropic herbs achieve higher general base levels at Vransk*ý* potok, with taxa such as *Polygonum aviculare* and *Chenopodium* regularly achieving values in excess of 5% (the values of these common ruderals at Zahájí generally oscillate around 1–2% until the Middle Ages, when *circum* 5% levels are finally encountered). Also significant is the more continuous representation of cultigens at Vranský potok. These types are represented only sporadically at Zahájí, although it is noted that the timing of high cereal representation at Zahájí coincides with cultivation maxima at Vranský potok.

4. Conclusions

4.1 Unusual vegetation patterns in Peruc Sandstone area

Due to high base level percentages and the relative distance from the Czech Middle and Ore Mountains, it is thought that *Picea* and *Abies* pollen is significantly of local origin, probably from stands in sheltered areas of the gorges above both the discussed pollen sites. Such a sheltered alluvial situation of *Abies* and *Picea* is affirmed in analogous medieval records of these conifers growing in lowland valleys of Central Bohemia (Pokorný 2005, Kozáková *et al.*2011) and the unusual importance of *Abies* near cliff-sheltered margins of a floodplain at the Horákov Culture site of Vojkovice near Brno (Albert 2005). It is additionally interesting that a replacement of *Picea* by *Abies*, not accomplished in the uplands and highlands of the Czech Republic until the First Millennium BC (Rybníčková, Rybníček 1988), is accomplished at Vranský in the prior millennium. It is possible that an accelerated replacement of lowland *Picea* by *Abies* is conditioned by human impact on the environment; this also being a consideration in lowland *Fagus* (below).

With the exception of isolated *Ulmus*, *Tilia*, *Carpinus*, *Taxus*, *Juglans* and *Acer*, hardwoods are represented largely by *Quercus* and *Fagus* at Vranský potok. The latter express similar values, and it is noted moreover, that *Quercus* is competitive until the High Middle Ages in floral succession after human impacts. *Fagus*, on the other hand, sees a less emphatic decline with phases of human impacts, particularly between 500 BC and AD 500. An anthropogenic role in the rise of *Fagus*, expressed by Küster (1997) and supported by Sádlo and Pokorný (2003) and Pokorný (2005), is thus further supported by data at Vransk*ý* potok. It is suggested that limited forest clearance by farmers will favor *Fagus* through disturbance of the forest meta-stable equilibrium.

Softwoods such as (local) *Alnus* and *Betula* decline after the Second Millennium BC (also note a decline of local malacofauna of arboreal environments as indicated in lithology), while *Corylus* is in particular only sporadically represented after the Early Bronze Age. An appearance of steppic taxa such as *Hippophaë* and *Ephedra* as late as the Middle Bronze Age is a curiosity, and strong efforts have been made to verify identification. Notably, *Ephedra* (constituting its own morphological class) is also found as an isolate in Holocene contexts in South Moravia (Břízová 2009) and at Zahájí itself. Five such grains occurring on one level at Vranský make a secondary origin less likely. As these relicts are competitive on poorly developed soils (more common in Pleistocene), it is thought that *Hippophaë* and *Ephedra* survive along steeply sloped margins of the gorge above the pollen site (see Figure 2), up until the Knovíz period.

Among herbs, *Poaceae* (including *Phragmites*) is usually dominant in the sequence, with *Aster* rising to importance in the earlier First Millennium BC, to be replaced by *Asteraceae Subfam*. *Cichorioideae* in the later First Millennium AD. *Poaceae* and *Aster* are of only general indicative value, although a dominance of sub-27 micron-sized *Poaceae* in particular might reflect the importance of *Phragmites*. It is thought, however, that *Asteraceae Subfam*. *Cichorioideae*, if indicating *Taraxacum*, may reflect hay meadow production in the Early Middle Ages. Such production would favor *Taraxacum* by increasing PPFD (photosynthetic photon flux density or sunlight levels) and thus its competitiveness *versus* other herbs if harvesting done is soon after florescence and seeding. Important for such an interpretation in the Central European context are the *circum* AD 848 writings of Wandelbert of Prüm, who sets the Rhineland hay harvest in the period in June, soon after the flowering of most *Taraxacum* species (Ellenberg 1988, Butzer 1993). It is further noted that a similar episode with high values of *Asteraceae Subfam*. *Cichorioideae* from a similar time (beginning 1040–800 BP and continuing into the Late Middle Ages where this taxon exceeds 10%) is further discerned at Zahájí (see Figure 9). An analogous phenomenon is also encountered in unpublished alluvial pollen spectra of a medieval date at the Mitterfecking Meadow site near Kellheim, Bavaria analysed by the primary author for Karl Butzer of the Department of Geography and Environment at The University of Texas at Austin. It is possible that these three local expressions of *Asteraceae Subfam*. *Cichorioidae* rise are part of a wider regional land-use development related to the emergence of hay meadow production in Central Europe in *circum* Carolingian times and are empirically discernible by virtue of the extreme proximity to actual farming areas at the 10^{0-1} m spatial scale.

4.2 Synopsis

1. Hydrological change influences pollen taphonomy in the alluvial accretion surface at Vransk*ý* potok to a significant degree, leading to differential representation of (buoyant) saccate pollen types. This ‘Hopkins effect’ is not observed at the organic accretion site of Zahájí, 7 km distant from Vranský potok.
2. Hydrological change at Vransk*ý* potok is significantly correlated with increased human impacts on vegetation in terms of pollen data, as well as increased settlement density according to systematic archaeological survey data (ALRNB).
3. Past vegetation is differently represented at Vransk*ý* potok and Zahájí pollen records due to taphonomic factors, with synanthropic taxa being more common at the former site.
4. More remarkable Peruc Sandstone area vegetation features indicated at both sites include increased *Fagus* with human impacts, a lowland presence of *Abies* and *Picea* and isolated relicts of Late Glacial steppe (*Ephedra* or *Hippophaë*).

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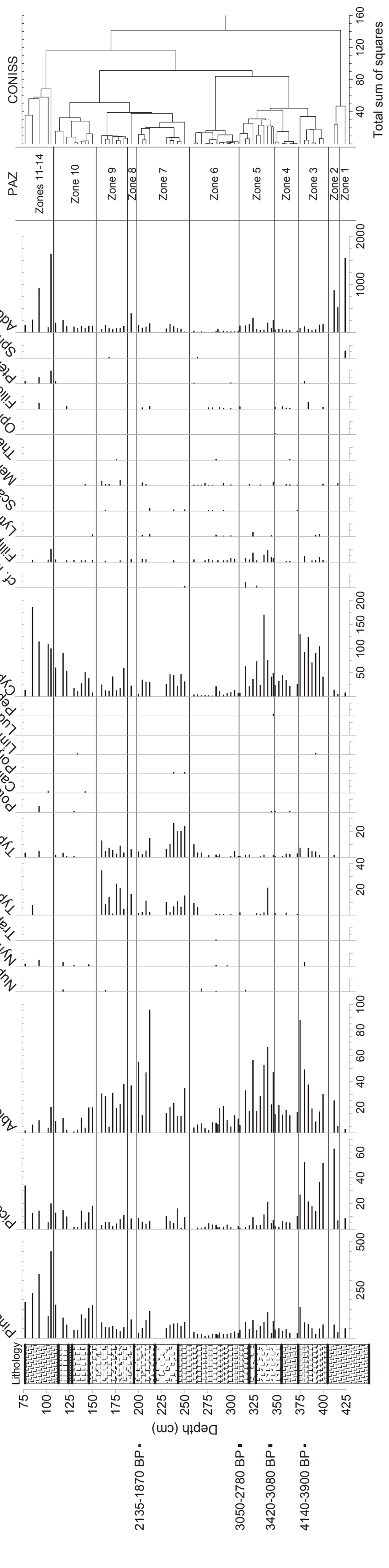

Figure 4. Vranský potok (50°19'33" N, 14°02'59" E, 247 m), groups excluded from main sum (ALP).

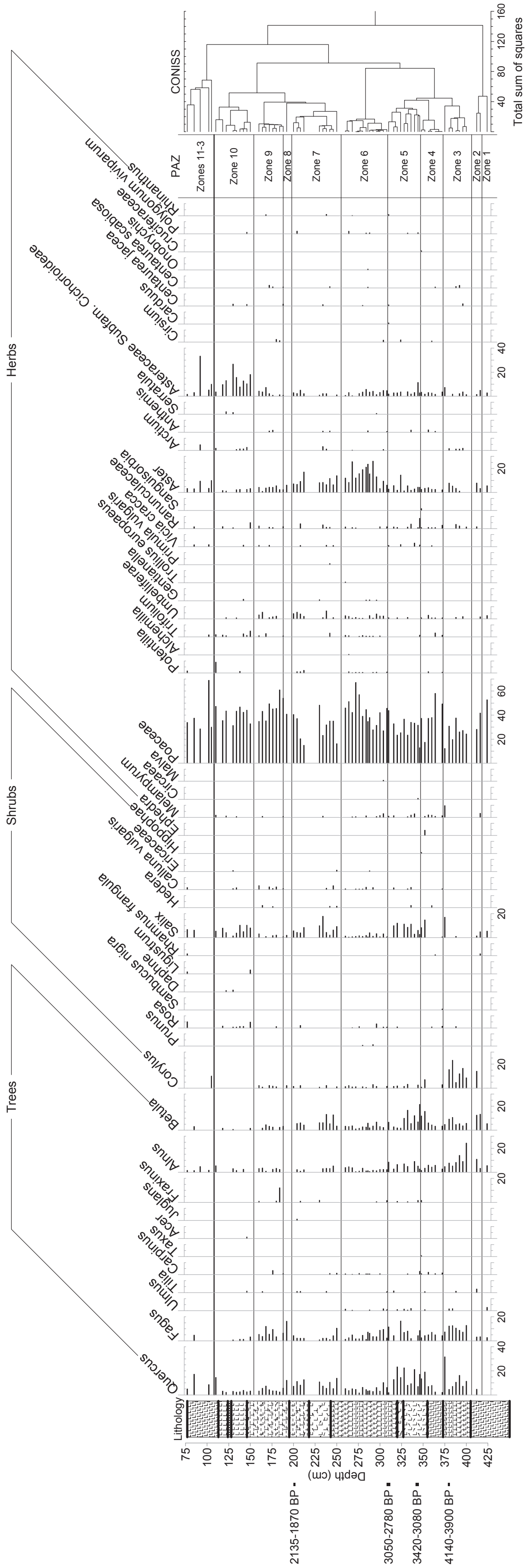

Figure 5. Vranský potok (50°19'33" N, 14°02'59" E, 247 m), trees, shrubs and herbs (ALP).

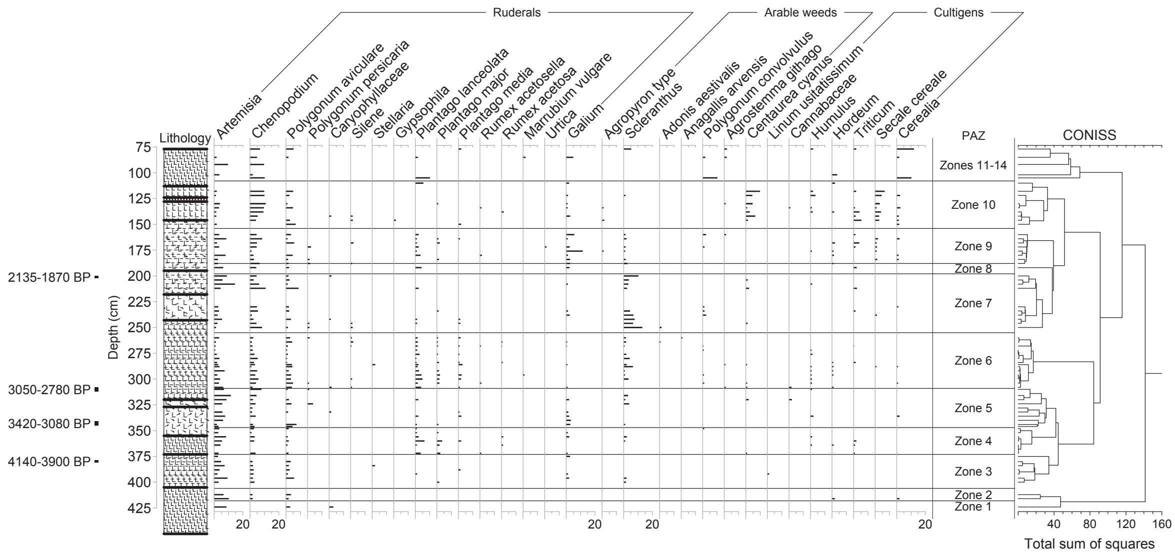

Figure 6. Vranský potok (50°19‘33“ N, 14°02‘59“ E, 247 m), synanthropic groups (ALP).

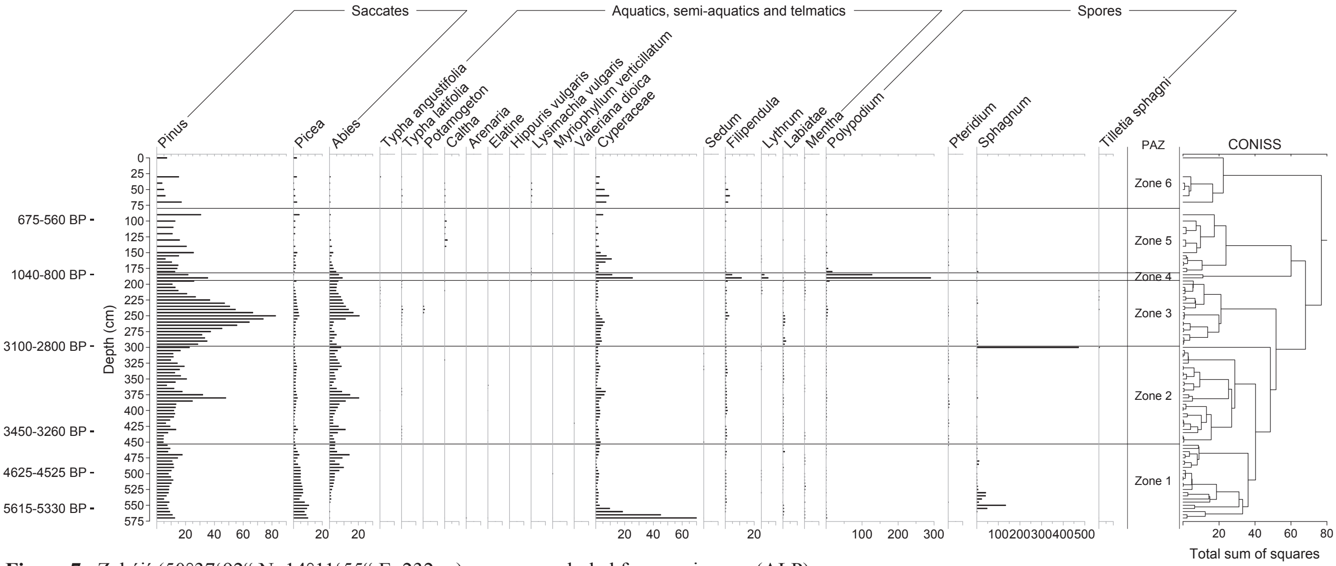

Figure 7. Zahájí (50°37‘92“ N, 14°11‘55“ E, 232 m), groups excluded from main sum (ALP).

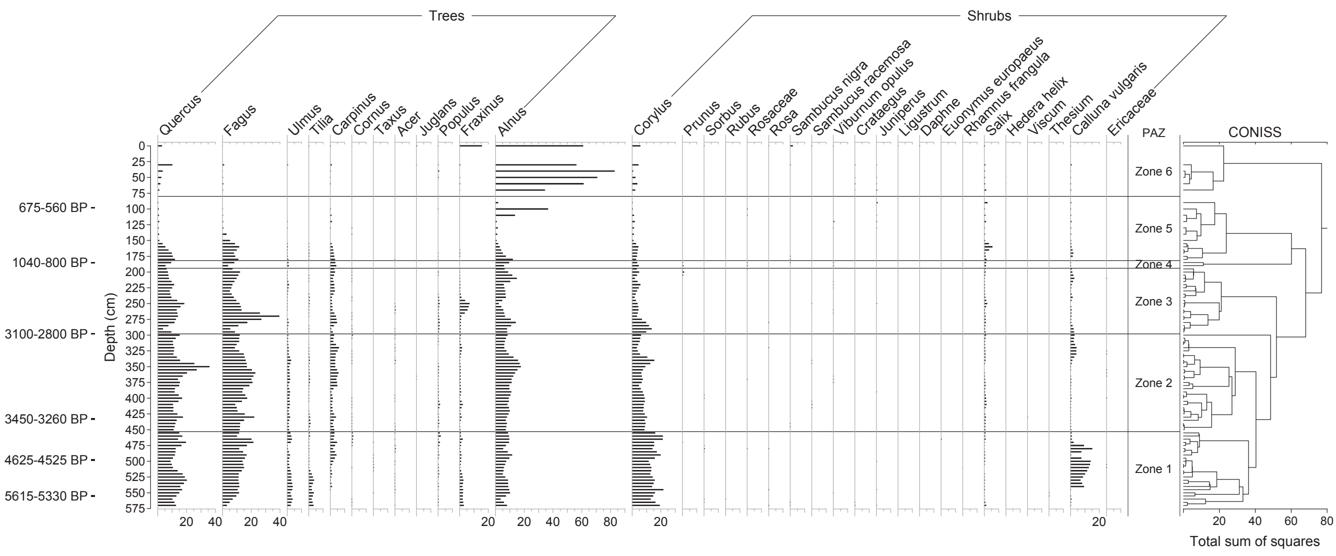

Figure 8. Zahájí (50°37‘92“ N, 14°11‘55“ E, 232 m), trees and shrubs (ALP).

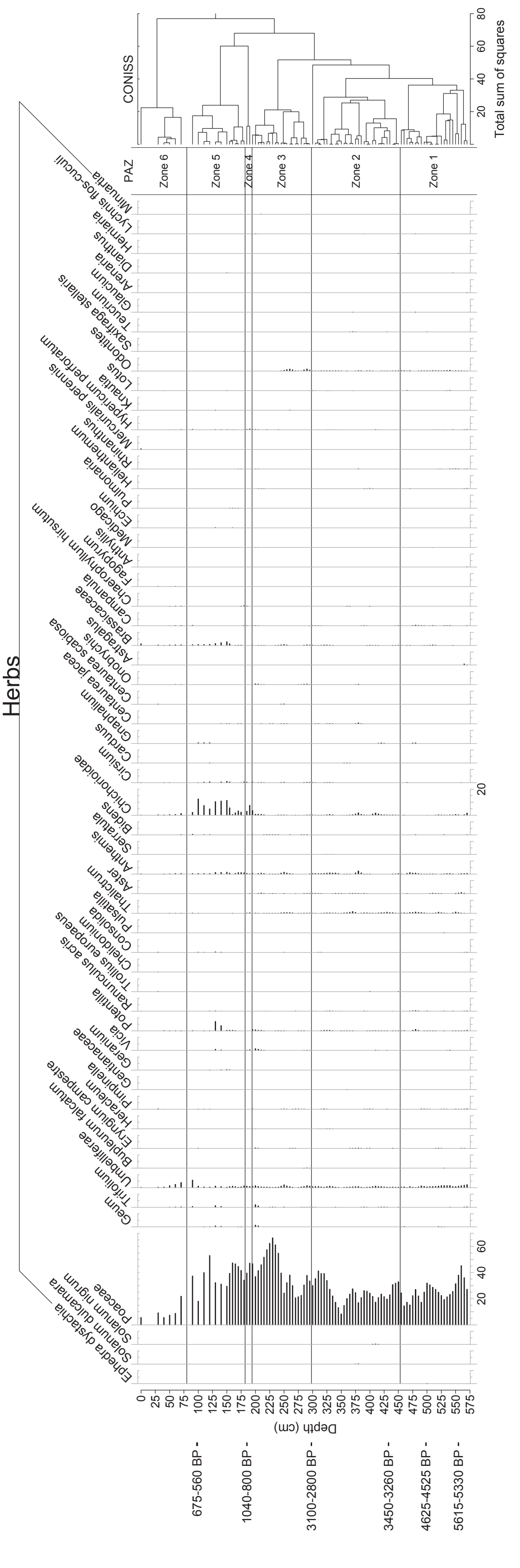

Figure 9. Zahájí (50°37'92" N, 14°11'55" E, 232 m), herbs (ALP).

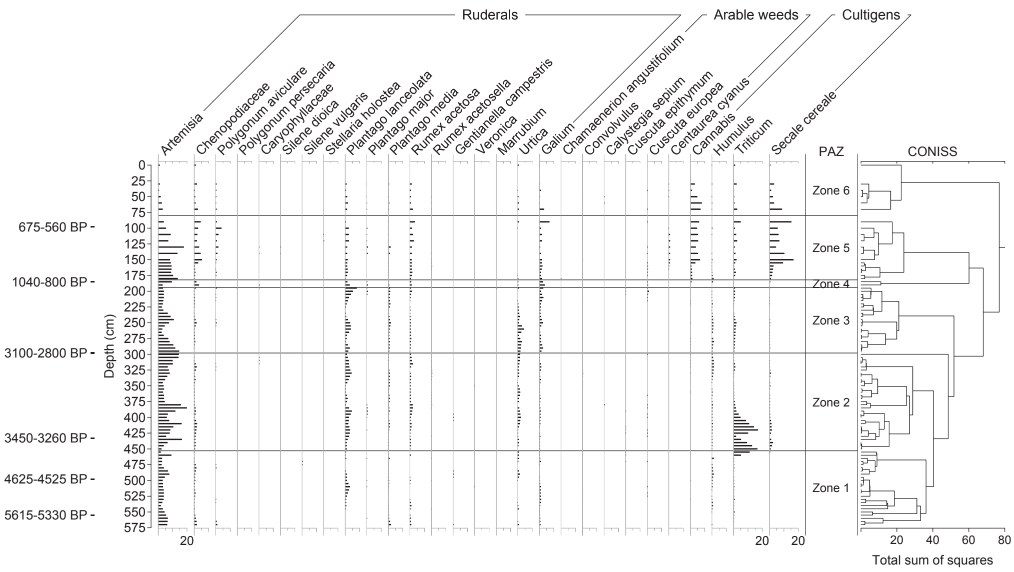

Figure 10. Zahájí (50°37‘92“ N, 14°11‘55“ E, 232 m), synanthropic groups (ALP).

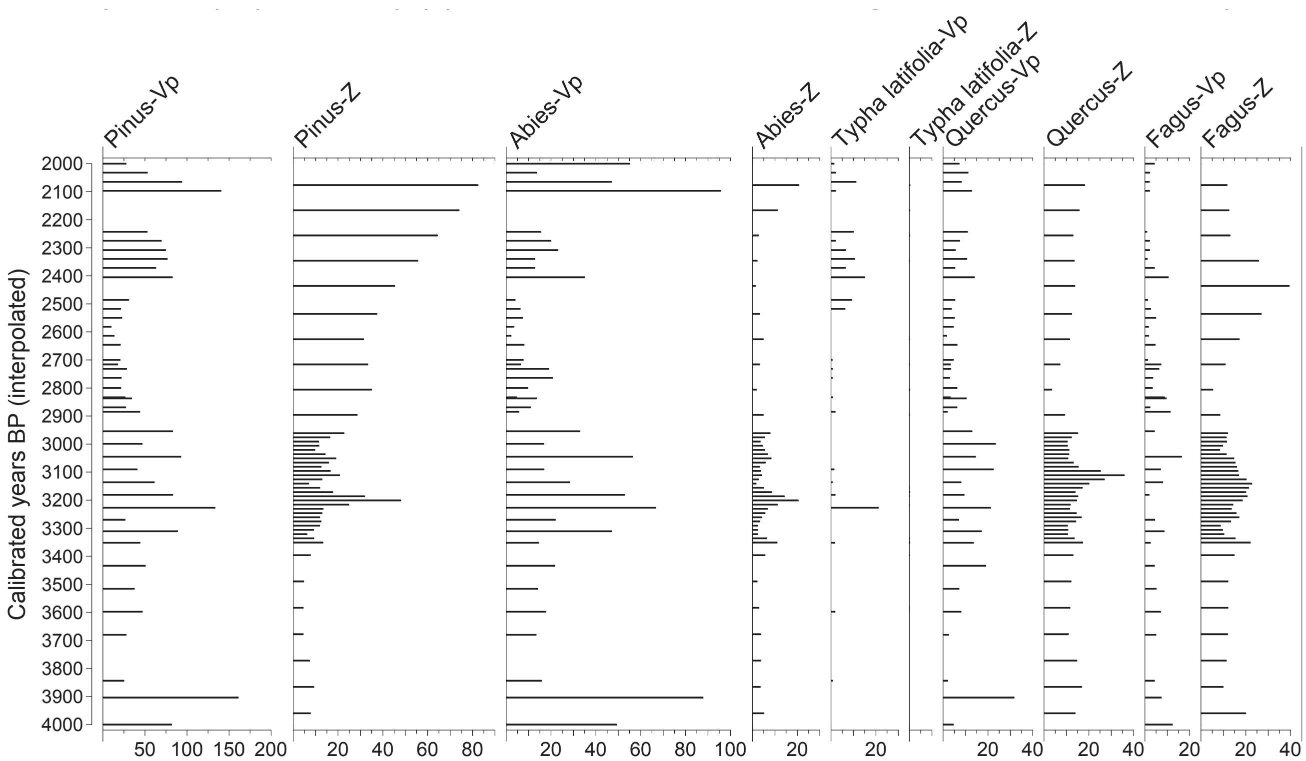

Figure 11. Vranský potok (Vp) and Zahájí (Z), comparative chrono-scale diagram of select pollen taxa (Vp & Z).