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PALYNOLOGICAL ANALYSIS OF SEDIMENTS FROM ZA HÁJOVNOU CAVE

NELA DOLÁKOVÁ
Masaryk University, Faculty of Sciences, Institute of Geological Sciences, Kotlářská 2, 611 37, Brno, the Czech Republic;
e-mail: nela@sci.muni.cz

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Abstract. The sediments of profiles ZH P-2, 5, 7, 8b, 9, 10 and 11 from Za Hájovnou Cave (Javoříčko Karst) were studied from a palynological point of view. Most of layers (except layer 1c/ZH P-10, layer 7e /ZH P-2) were paleontologically dated as Holsteinian Interglacial. The palynospectra confirmed the mild character of the climate during sediment deposition (*Carpinus, Hedera, Acer, Tilia, Corylus,* single *Pterocarya* and *Ilex*). The proportion of individual elements as well as relationship between trees and herbs varied. Changes in number of morphologically different pollen grains (primarily Pinaceae, Asteroideae) in correlated layers (2a, 2b/ ZH P-5 and 2,2b/ZH P-8b, and layer 4 – debris cone) from profiles ZH P-10, ZH P-11and ZH P-8b were recorded in the direction towards the cave interior. This phenomenon is most likely related to the resistance of the pollen grains to chemical and mechanical conditions during transport.

■ Javoříčko karst, Za Hájovnou Cave, Quaternary, Palynology

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Introduction

Palynological study of sediments from Za Hájovnou Cave (Javoříčko karst) was carried out within the framework of a complex multiproxy study of this area headed by Prof. R. Musil.

Results of earlier palynological studies of Moravian (the eastern part of the Czech Republic) karstic areas were published by Seitl et al. (1986), Svobodová (1988), Svoboda (1991), Svobodová (1992), Doláková and Nehyba (1999), Doláková (2002, 2004, 2005, 2007).

Pollen spectra from cave sediments are typified by the absence of in situ plant remains. Palynomorphs are transported into the caves together with sedimentary particles by percolating water or through the activity of animals. Selection, degradation and secondary accumulation of various palynomorphs is clearly due to their different resistances to chemical and mechanical processes, and microbial attack during transport and sedimentation (Elsik 1971, Havinga 1971, Jankovská 1971, Draxler, 1992, Carrión et al. 1999, Doláková and Nehyba 1999, Navarro et al. 2001, Doláková 2002, 2007). The mixing of different age components – especially Quaternary and redeposited Tertiary elements – is also well known (eg. Doláková and Nehyba 1999, Doláková 2002, 2007). This phenomenon causes complications in interpretation of the original surface vegetation. Comparison with the results from other paleontological and geological methods is necessary.

Material and methods

About 50 samples of cave sediments from Za Hájovnou Cave were studied from a palynological point of view. The palynological samples were treated with HCl (20%), HF, KOH and HCl (10%) and heavy liquid $ZnCl_2$ (density = 2g/cm^3) for standard maceration. The omission of acetolyse enabled clearer identification of pollen contamination eg by percolating water. The final residue from each sample was mounted in preparation for biological microscopy, and diluted with glycerol.

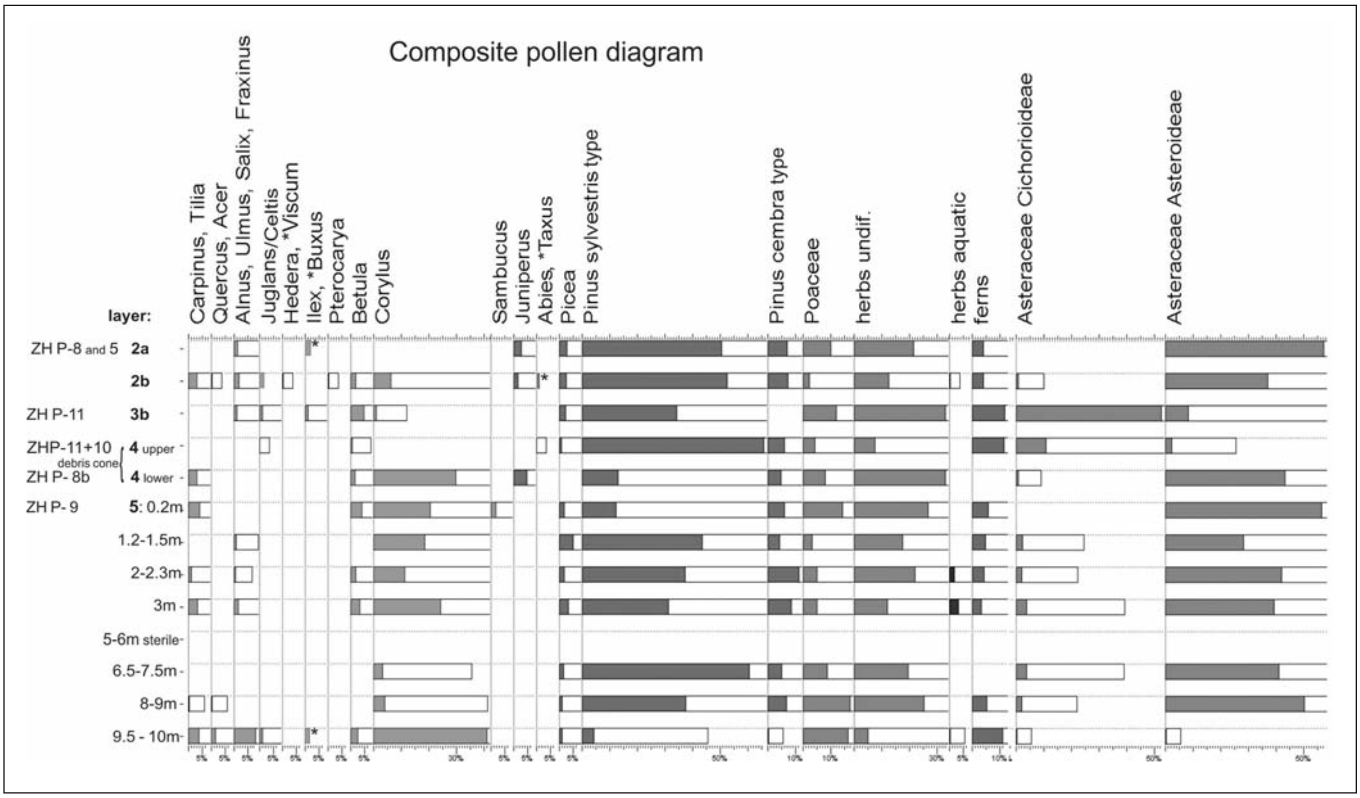
The pollen diagram was calculated from the total of a minimum of 100 determined pollen grains and spores (minimally from 15 taxons) using the POLPAL programme (Walanus and Nalepka 1999). Several plant types were combined according to their ecological grouping (*Carpinus* + *Tilia*, *Quercus* + *Acer*, herbs undif., herbs aquatic, flood plain forest – *Alnus*, *Ulmus*, *Fraxinus*, *Salix*, ferns + *Sphagnum*).

The pollen diagram was separated into two parts due to the over-representation of Asteraceae: in the left section was the pollen sum (100%), excluding Asteraceae. The right section showed the proportion of Asteraceae and was calculated from the sum of all the determined pollen grains. This form of presentation offers clearer visualisation of the basic character of the vegetation changes.

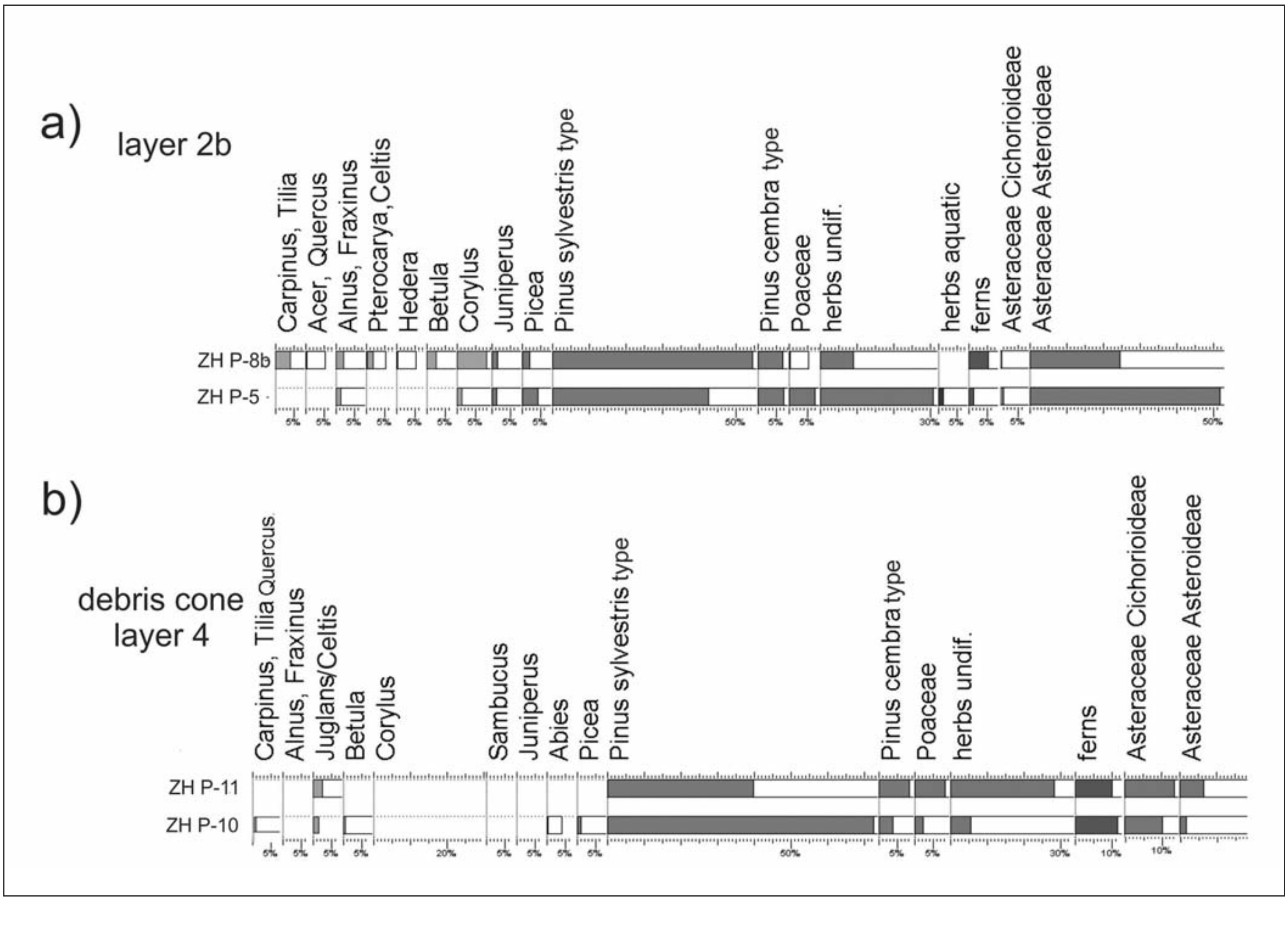
A composite pollen diagram (Text-fig. 1) was constructed on the basis of average representation of elements from single layers (arithmetic mean of samples collected from several places within 1 layer). Other diagrams (Text-figs 2a, b) indicate differences among the palynospectra collected from different spots within a single layer.

Results

The samples from profiles: ZH P-2 (Velikonoční jeskyně (= Easter corridor): Komín I (= Chimney I), ZH P-5 (Vykopaná chodba (= Excavated corridor): Kostnice II



Text-fig. 1. Composite pollen diagram.



Text-fig. 2. Pollen diagram. a – layer 2b from ZH P-5 correlating with 2b of ZH P-8 nd 9; b – layer 4 (debris cone) of profiles ZH P-10 and ZH P-11.

(Charnelhouse II), ZH P-7 (Chodba naděje (=Corridor of Hope)), ZH P-8b and 9 (Spojovací chodba/Narozeninová chodba (=Connection Passage/Birthday corridor)), ZH P-10 and 11 (Narozeninová chodba) were analysed from palynological point of view. Profile descriptions are presented in the contribution by Musil (2014). The first palynological study from Za Hájovnou Cave was published by Doláková (2005, 2007). Not all the palynospectra contained a sufficient number of pollen grains and spores for analysis. Some of the samples were almost sterile, another part contained only a small number of palynomorphs. Samples with the most abundant palynospectra came from profiles ZH P-8b and 9. Only layer 4 of profiles ZH P-10 and ZH P-11 and layers 2a and 2b from profile ZH P-5 contained enough pollen grains and spores to construct a pollen diagram.

Most of the palynologically studied sediments (except ZH P-1, layer1c and ZH P-2, layer 7e) were dated as Holsteinian Interglacial (Musil 2005, Lundberg et al. 2014).

Sample ZH P-10, layer 1c was assigned as a melange of Holocene and older sediments (Musil 2014). It contained only a small amount of pollen from *Pinus*, Asteraceae, Daucaceae and Ranunculaceae.

The sample from layer 7e of ZH P-2 was the only one from the Komín I profile in which palynomorphs were found. There was a large over-estimation of small Asteroideae. Pollen from *Chrysosplenium*/*R.trichophylus* type typical for damp places had also accumulated here along with some other herbs (Poaceae, *Galium*, Ranunculaceae). No pollen from trees or large sized pollen grains were observed. This oryctocoenoses provides evidence of mechanical selection during transport with sediment flow. According to a personal study of cave sediments (Balcarka – Doláková 2004, Pod Hradem – personal data of the author) such palynospectra could support the paleozoological interpretation of development in a colder steppe environment (Musil 2005, Ivanov 2005).

The palynospectra from other studied samples of layer 4 (debris cone) from profiles: ZH P-10 and 11, ZH P-5: layers 2a, 2b and the whole ZH P-8a similarly confirmed the mild character of the climate during sediment deposition, by virtue of the abundant wood elements (*Carpinus*, *Tilia*, *Juglans*, *Quercus*, sporadic *Acer*, single *Hedera*, *Pterocarya*, *Ilex* - Tab.1).

Pterocarya and *Ilex* are the surviving members of Tertiary floras. The presence of *Pterocarya* continued to the Holsteinian Interglacial in Europe. It dissapeared from the palynological record during the Saalian complex Stage and it is not known from any younger warmer phases (Lang 1994, Litt et al. 2008, Roucoux et al. 2008).

The above mentioned plants created the typical vegetation of the climatic optimum of the Holsteinian Interglacial (Dyjakowska 1952, Vodičková-Kneblová 1961, Břízová 1994, Lang 1994, Bińka et al. 1997, Reille et al. 2000, Urban and Sierralta 2012).

The general character of most studied pollen spectra is quite similar, however the proportions of individual elements fluctuate. Composite pollen diagrams indicate changes among pollen spectra in recognised layers (Text-fig. 1). The relationship between trees and herbs varied, herbs mostly prevail. Dominance of arboreal pollen was observed in layers: 2b and 5: 1.2–1.5 m and 9.5–10 m from ZH P-8b and 9, and in part of the debris cone: layer 4 upper. *Pinus sylvestris* type or *Corylus* formed the highest proportion of them. Elements of flood plain forest such as *Alnus*, *Ulmus*, *Fraxinu*s, *Salix* were mostly rare. *Betula*, *Picea* and ferns and *Sphagnum* are observed continuously but at a low percentage. Nonarboreal pollen dominated in most samples. Asteraceae prevailed in these cases. Poaceae were also common. The occurrence of other herbs was also recorded: *Artemisia*, Brassicaceae, *Campanula*, *Galium*, Lamiaceae, Liliaceae, Ranunculaceae, *Delphinium* type, Silenaceae, *Urtica* and single specimens of other herbs. Hygrophilous herbs such as *Chrysosplenium/Ranunculus trichophylus* type and *Valeriana* were common. Pollen from aquatic flora (*Sparganium*, *Potamogeton*) were rare. Ferns mostly represented by the smooth spores of Polypodiaceae, rarely *Polypodium vulgare* and *Pteridium*. Algae such as *Botryococcus*, *Mougeotia* and a single *Pediastrum* were found locally. Algae were absent in samples from the debris cone (layer 4).

The greatest difference in pollen picture was observed in layer 5, the deepest studied layer: 9.5-10 m in profile ZH P-9. Trees prevailed over herbs (67:33%) with the most abundant being *Corylus* together with *Carpinus*, *Tilia* and *Alnus*. *Juglans* also occurred here. In this layer was the lowest proportions of *Pinus* and Asteroideae from all the samples. Only Poaceae represented the more abundant herbs. This palynospectrum probably represented the vegetation of deciduous woodland with only a small admixture of conifers. In the overlying samples there was an increased proportion of *Pinus*, Asteroideae and other herbs and a decrease in *Corylus*, *Alnus* and *Tilia* until they became absent at the 6.5–7.5 m level. It is difficult to decide whether this phenomenon is a result only of climate deterioration or also due to taphonomic reasons.

The highest percentage of *Pinus* (over 60%) together with a minority of other trees was recorded in the upper part of the debris cone (layer 4 upper). The pollen picture in the lower part of the debris cone differs with *Pinus* representing only 10% of the pollen found, *Corylus* over 25%, *Carpinus* and *Tilia* also occured, but more herbs were common (Text-fig. 1). This difference could indicate climatic variations during deposition of the debris cone.

According to paleontological results, layers 2a and 2b from ZH P-5 correlate with 2a and 2b from ZH P-8b. The pollen diagram from these layers indicates a decreasing number of Pinaceae and dominance of tree pollen, and increasing number of herb pollen (mainly Asteroideae) in the direction towards the cave interior (Doláková 2005) (Text-fig. 2a). These facts are most likely related to the resistance of the pollen exines to chemical and mechanical conditions during transport. A similar phenomenon was observed in layer 4 (the debris cone) of the profiles ZH P-10 and ZH P-11 (Text-fig. 2b). Differences in the pollen picture were probably caused by mixing of sedimentary material transported through the former cave entrance and near the chimney. A difference in pollen record between samples of layer 4 (the debris cone) collected from ZH P-10 and ZH P-11 compared to ZH P-8b is evidence enough to indicate that sedimentation of this layer occured over a longer time span during slight climatic oscillation. Therefore the layer was divided into 2 sublayers: layer 4 upper and the underlying: layer 4 lower (Text-fig. 1).

Discussion

Navarro et al. (2001) established that the amount of the anemophilous pollen (eg. *Pinus*) decreased and that the amount of zoophilous pollen (Asteraceae/Cichorioideae) increased in the direction from the cave entrance into the inner parts. They presumed that the anemophilous pollen, often overestimated in surface samples due to massive pollen production and extensive flight range, decreased inside the caves due to their mechanical properties. Conversely, the anemophilous pollen grains (with morphological adaptations for easier attachment to animal hair) more frequently form part of the pollen spectra from the deeper parts of caves. This fact may be caused by transport of pollen grains by animals. In the Ramesh Cave (about 2000 m above sea level, sediments dated 64–32 ka), Draxler (1992) interpreted the existence of pollen from climatically demanding plants among other types to be a consequence of the cave bear nourishment (honey). The decrease in *Pinus* pollen recorded there is in clear agreement with our results from Za Hájovnou Cave (see above, Text-figs 2a, b). An overestimation of Cichorioideae was visible only in layer 3ba (Text-fig. 1). Asteroideae together with *Pinus* prevailed in most of the studied samples from Za Hájovnou Cave.

According to Carrión et al. (1999) the pollen spectra from cave sediments reflect the surface environment reliably only when several requirements are fulfilled: a) taxonomic diversity reliably above 15 taxons per sample, b) pollen counts of more than 200 grains excluding Asteraceae, c) less than 20% indeterminable pollen.

From cave sediments from the Moravian karstic areas not only is the prevailing pollen from the Asteroideae but also a more or less monotonous oryctocoenoses with over-representation of smooth monolete Polypodiaceae spores, *Tilia* and *Corylus* are also known (Doláková 2000, 2002, 2004, 2005). These pollen types are small and compact and are known to be both mechanically and chemically resistant (Havinga 1971, Jankovská 1971, Draxler 1992).

According to this information , the most reliable pollen spectra which reflected the vegetation cover outside the caves came from layers 2a and 2b (ZH P-8b and ZH P-5), the debris cone, layer 4 (ZH P-10), and layer 5: 9-10m (ZH P-8b and 9). Care must be taken in interpretation of the vegetation and climatic character of other studied palynospectra. In some other site even a single common pollen grain could provide useful information.

The wide variety and selectivity of the palynological record from Za Hájovnou Cave did not allow accurate reconstruction of changes in vegetation. The general character of the pollen pictures corresponds to the climatic optimum of the Holsteinian interglacial when compared to studies of several localities in Central Europe (eg. Dyjakowska 1952, Vodičková-Kneblová 1961, Břízová 1994, Lang 1994, Kondratienė and Šeirienė 2003, Urban et al. 2011, Bittmann 2012, Urban and Sierralta 2012). The findings of *Pterocarya* (often taken as a marker for the Holsteinian) in the upper parts of the profile observed after deterioration of the climate as reflected in the section of layer 5: 6.5–9 m from ZH P-9 (Text-fig.1) also support this interpretation.

The samples from layer 5: 9.5–10 m of profile ZH P-9 and layer 4 lower of ZH P-8b support the *Corylus* expansion described by Urban et Sierralta 2012 from Schöningen lignite mine profile 12B LPAZ R 3b (MIS 9). The limited palynological results from Za Hájovnou Cave do not provide sufficient data to clearly differentiate if the sediments could be related to MIS 11 or MIS 9; the assumption that they are Holsteinien is a topical theme for discussion (eg. Geyh and Müller 2005, Scourse 2006, Nitychoruk et al. 2006, Roe et al. 2009, Bittmann 2012, Urban and Sierralta 2012).

The overall characteristics of the environment and stratigraphic position based on other paleontological methods is discussed in detail in a contribution by Musil et al. (2014). According to faunistic and sedimentological characteristics, the studied sediments can be divided into two groups. Sediments older than the debris cone contained bones which were nearly always complete, never weathered, and often even in the correct anatomical positions. In sediments above the debris cone the bones were invariably fragmentary, many of them covered by sinter crusts. No fossils except palynomorphs have been found inside the debris cone. The difference between the palynospectra from the upper and lower parts of the debris cone sediments could indicate climatic variations during deposition of the debris cone (see above, Text-fig. 1). Pollen spectra from lower layers and the debris cone contained a limited number of Tertiary pollen relics such as *Pterocarya*, *Ilex*, *Celtis*, which were not observed in the older part of the sediments. These data are in clear agreement with other Holsteinian localities (see above).

Conclusions

About 50 samples from profiles: ZH P-2, 5, 7, 8 and 9, 10 and 11 from Za Hájovnou Cave were assessed palynologically.

The pollen spectrum of layer 7e is without any tree pollen but with an accumulation of Asteroideae and several hygrophilous herbs and thus may support the paleozoological results suggesting development in a colder steppe environment.

The general character of other palynospectra confirmed the mild character of the climate during the Holsteinian Interglacial due to the occurence of plants such as *Carpinus*, *Hedera*, *Tilia*, *Pterocarya* and *Ilex* which are typical for the climatic optimum of this time span. Such a pollen picture is in clear accordance with other similar localities from Central and Western Europe.

The difference in pollen record inside the debris cone (layer 4) prompts division of layer 4 into 2 sublayers (layer 4 upper and layer 4 lower) which developed during varying climatic conditions.

Detailed reconstruction of vegetations cover, their changes and development is difficult to interpret from the cave sediments. Selection, degradation and secondary accumulation of various palynomorphs, due to their different resistances to chemical and mechanical processes and microbial attack during transport, were recorded. This phenomenon was documented by numerical changes in the different pollen grains from several spots within a single layer in a direction towards the inner cave parts (primarily a decrease in Pinaceae, and increase in Asteroideae).

The overall characteristics of the environment and stratigraphic position based on other paleontological methods will be discussed in the contribution Musil et al. (2014)

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Explanations of the plate

PLATE 1

Typical pollen grains (all magnifications 1 000 x)

1. *Hedera* sp. - layer 2b, profile ZH P-8b.
2. *Pterocarya* sp. - layer 2b, profile ZH P-8b.
3., 4. *Tilia* sp. - layer 5–9.5 m, profile ZH P-9.
5., 6. *Carpinus* sp. - layer 5–9.5 m, profile ZH P-9.
7. *Juglans* sp. – layer 4, profile ZH P-11.
8. *Celtis* sp. - layer 5–9.5 m, profile ZH P-9.
9. *Quercus* sp. - layer 4, profile ZH P-10.
10. *Salix* sp. - layer 5–10 m, profile ZH P-9.
11., 12. *Corylus* sp. - layer 5–9.5 m, profile ZH P-9.
13. *Galium* sp. - layer 3ba, profile ZH P-11.
14. Asteraceae Cichorioideae - layer 3b, profile ZH P-11.
15. Asteraceae Asteroideae - layer 2b, profile ZH P-8b.
16. *Chrysosplenium*/*Ranunculus trichophyllum* type - layer 5–8.5 m, profile ZH P-9.
17. Poaceae - layer 5–9.5 m, profile ZH P-9.
18. *Alnus* sp. - layer 5–9.5 m, profile ZH P-9.
19. *Pinus sylvestris* type - layer 4, profile ZH P-11.

PLATE 1