Hydrobiologia (2014) 730:191–213
DOI 10.1007/s10750-014-1837-1

PRIMARY RESEARCH PAPER

The oldest Czech fishpond discovered? An interdisciplinary approach to reconstruction of local vegetation in mediaeval Prague suburbs

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Received: 26 November 2013 / Revised: 10 February 2014 / Accepted: 13 February 2014 / Published online: 9 March 2014

Abstract Wet sediments of a former water reservoir were discovered during an archaeological rescue excavation. Vegetation and environmental changes taking place in the mediaeval suburbs of Prague, Czech Republic, from the tenth to the middle of the fourteenth century were investigated. The origin and function of the water reservoir was revealed using a multi-proxy approach that combined the results of macrofossil, pollen, diatom, antracological, archaeo-zoological and sedimentological analyses. Gradual changes of the surrounding vegetation were documented. Field indicators increased in time, whereas proportions of broad-leaf trees and shrubs decreased; proportions of ruderal plants increased continually. A gradual decline of semi-natural hygrophilous vegetation was accompanied by an inverse tendency in trampled vegetation. All these trends indicate an intensification of human activity around the pool. A similar intensification of anthropogenic influence is clearly visible in the development of the aquatic environment. According to the diatom composition, the base of the profile is the result of sedimentation in considerably oligotrophic conditions. A successive deterioration of water quality was documented by various organisms (diatoms, green algae, water macrophyta, fishes and intestinal parasites). The high content of dissolved nutrients, probably connected with anoxia, could have caused the disappearance of both diatoms and fishes.

Handling editor: M. Power

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Keywords Archaeobotany · Archaeozoology · Environmental changes · Human impact · Fishpond · Hydrobiology · Prague · The Middle Ages · Vegetation diversity

Introduction

Fish farming has a long and rich tradition in the Czech lands. The spreading of carp (and knowledge of carp breeding) was probably connected with cultural influences coming from West Europe (Makowiecki, 2001). The progressive development of fishpond building in thirteenth century further culminated in fifteenth to sixteenth centuries (Hurt, 1960; Andreska, 1987; Čítek et al., 1998). However, there are indications that some kind of artificial water reservoirs containing fishes existed here already before the introduction of the carp fishponds. Sporadic written sources (mostly chronicles and legends) mention 'fishponds' already in tenth to eleventh centuries. The oldest known reference is traditionally being identified with a ceased Mediaeval village called Rybník (the Czech meaning of its name is 'the Fishpond') once located in the area of today's New Town of Prague. The Rybník village was first mentioned in 993 in the Donation Deed of the Břevnov Monastery, obliging that the monastery receives tithes from all fields belonging to this village (called Ribnyk in the original Latin text).

A range of palaeoenvironmental techniques was used to study sediments which were supposed to be remnants of a pool once connected with the Rybník village. Among others, diatom analysis and the presence of eggs of intestinal parasites were included in the presented research. Structure of diatom community is tightly linked with changes in aquatic environment (e.g. Battarbee, 1986) and the rate of artificial pollution has been traditionally expressed in the index of saprobity (Sládeček, 1986). The presence of eggs of intestinal parasites has been used as an indicator of pollution by faeces (Bosi et al., 2011).

Combination of several techniques, above all palynology, anthracology and analysis of plant macro-remains were used for reconstruction of both aquatic and terrestrial vegetation. These analyses already proved their reliability within the palaeoecological and archaeobotanical research (e.g. Smol et al., 2001). Each of these methods naturally has its own advantages as well as limits resulting from different source areas of material, taphonomy and different determination levels (for more details see e.g. Birks & Birks, 2006; Gaillard, 2007; Novák et al., 2012; Théry-Parisot et al., 2010); therefore, it is advisable to combine them (for some examples see Sadori et al., 2010 or Święta-Musznicka et al., 2013).

Good examples of former water reservoirs studied using multi-proxy techniques are investigations of late-Glacial to early-Holocene Lake Švarcenberk (Pokorný, 2002) or a cistern at the pre-Roman Iron Age hillfort Vladař (Pokorný et al., 2006) as well as a Holocene profile from the Řežabinec fishpond (Rybníčková & Rybníček, 1985). However, there are not many palaeoenvironmental studies dealing with Mediaeval fishponds. Several fishponds were investigated in Germany (Hellwig, 1997; Rösch, 1999, 2012). Sediments of Mediaeval fishpond Vajgar (Jindřichův Hradec, Czech Republic), established at the thirteenth century, reflect Mediaeval colonization as well as the development of the fishpond until recent times (Jankovská & Pokorný, 2002).

The study site

The foundation of the New Town of Prague in 1348 had probably posed prominent changes in the environment of the Mediaeval town's suburbs. According to its Foundation Deed, the New Town was established in a suburban area, where 'villages, gardens and fields had been located'. We attempt to examine what the vegetation character of these suburbs must have been like before the site changed to one of building and construction.

The New Town of Prague (as well as the Old Town of Prague) is situated on the right bank of the Vltava River (Fig. 1). The morphology and character of its original terrain, as well as its hydrology, was directly influenced by a system of several riverine terraces, deposited here within the Pleistocene. According to many archaeological records, several moist depressions and a rather dense network of brooks were evidenced in the area outside the Old Town walls (Kaštovský et al., 1999; Starec, 2005; Kašpar, 2007; Starec et al., 2012). The moist depressions were later filled in with the town's domestic waste and likely disappeared even before the foundation of the New Town (Hrdlička, 1984, 1997). The permanently moist sediments of these features represent an optimal environment for the preservation of both plant

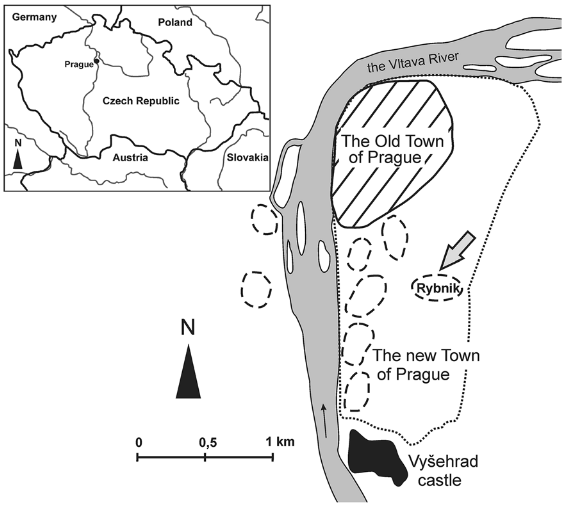

Fig. 1 Schematic representation of the surroundings of the Old town of Prague before 1348. The boundary of the New town of Prague is indicated by *dotted line*. The former settlements' positions are marked by *dashed lines*. The supposed position of Rybnik village is marked by an *arrow*. The course of the Vltava River (*grey*) corresponds to the recent situation. Redrawn according to Mencl (1969)

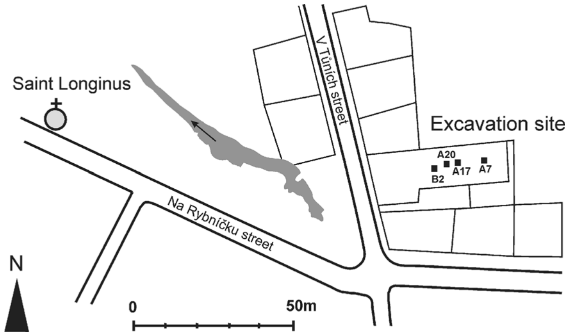

Fig. 2 Surroundings of the excavation site including positions of individual profiles mentioned in the text. The Romanesque rotunda of Saint Stephen (Saint Longinus today) represented the religious centre of the Rybnik settlement. A section of a former stream (*grey*) was documented archaeologically by Kašpar (2007). The supposed direction of the stream (according to the present-day slope direction) is shown by an *arrow*

macrofossils and pollen grains. However, the waste origin of these deposits makes the interpretation of the performed archaeobotanical analyses difficult, as the plant assemblages represent an inseparable mixture of material from several sources.

Having the intention to reconstruct the character of the area's original vegetation, we needed to analyse a different type of sediment, namely the sediment of a water reservoir that had resulted from a natural sedimentation process. In 2009, such sediment was found during a rescue archaeological excavation in the cellar of the house V Tůních no. 1625/II (the excavation being directed by P. Starec, Prague City Museum). The formation of grey clay layers was preliminarily interpreted as the lacustrine sediments of a former pool, promising good preservation of biofacts in the waterlogged conditions. These sediments (and the pool) could have been related to the ceased Mediaeval village Rybník (see above). Archaeological evidence (Kašpar, 2003) supports the existence of the village at a location to the northwest of the investigation site between at least the eleventh and thirteenth century (Figs. 1, 2).

Our aims are to describe the vegetation of the Mediaeval Old Town of Prague's suburbs and to consider the environmental changes that have occurred before the mid-fourteenth century. The second aim of this study is to reveal the origin and function of the investigated water reservoir.

Materials and methods

A trench 1 m wide and approximately 1 m deep had been dug out during the reconstruction of a basement (canalisation trench) of the house V Tůních no. 1625/II. Four profiles, placed subsequently on the line of the trench, and one additional profile placed within the static test pit, were studied (for the position of individual profiles, see Fig. 2). As all the encountered sediments were waterlogged, sediment samples taken from individual layers were wet sieved to obtain biological remains (seeds, charcoal pieces, animal bones, etc.) Two sieves of 1 mm and 0.25 mm were used, sample volumes varying from 0.5 to 3 l. Fragments of wood and animal remains (bones of large- and medium-sized mammals, mussels) when encountered during the excavation were also analysed.

For a more detailed approach, a box profile one metre in length was taken within the profile A20 (the longest of the profiles investigated). Sub-samples of 1 cm^3 were taken for pollen and diatom analyses at 5 cm intervals. In the lowermost part of the profile, the sampling frequency was increased. The remaining sediment was then divided into 5-cm sections (approx. 0.5 l each) and wet sieved to obtain plant macrofossils and fish remains. Three sub-samples for radiocarbon dating were also taken from this profile. Radiocarbon (^{14}C AMS) dating was undertaken using selected *Chenopodium album* seeds by the laboratory CAIS, USA (Center for Applied Isotope Studies, University of Georgia). Calibration of radiocarbon data, based on the calibration curve IntCal 09 (Reimer et al., 2009), was performed using the application OxCal 4.1.6 (Ramsey et al., 2010).

The wet-sieved and dried material was sorted under a binocular microscope and the plant seed/fruit remains were identified in the whole volume, using both a reference collection (Department of Botany, Faculty of Science, Charles University in Prague) and determination literature (Katz et al., 1965; Cappers et al., 2006). The results of the carpological analysis were processed using the *ArboDatMulti* database programme (Kreuz & Schäfer, 2002) and became a part of the Czech archaeobotanical database CZAD (Pokorná et al., 2011). The nomenclature used in the following text was based on Kubát et al. (2002) (vascular plants) and Chytrý & Tichý (2003) (vegetation units).

Pollen grains from sub-samples (1 g) were extracted by chemical treatment according to Faegri & Iversen (1989) including boiling in 10% KOH, sieving, acetolysis and treatment in 40% HF to remove silica. *Lycopodium* spores of a known quantity were added to each sample in order to determine the absolute pollen concentration (Stockmarr, 1971). Pollen grains were counted under a light microscope at a magnification of 400–1000×. A minimum of 500 pollen determinations (where possible) were made for every sample. Taxonomic identifications followed Punt (1976), Punt & Blackmore (1991), Punt & Clarke (1980, 1981, 1984), Punt et al. (1988, 1995, 2003, 2009), and Beug (2004). The presence of non-pollen palynomorphs (e.g. intestinal parasite eggs, algal and invertebrate remains) was recorded (Komárek & Jankovská, 2001; van Geel, 2001); their quantification was related to the total pollen count. Data were processed using Tilia 1.5.12. software (Grimm, 2011). The diversity of pollen spectra was expressed using the Shannon index (Shannon, 1948).

The charcoal and wood analyses were performed only on the largest fraction of fragments (>2 mm). Charcoal pieces were identified using an episcopic interference microscope (Nikon Eclipse 80i) with a 200–500× magnification. The reference collection (Laboratory of Archaeobotany and Paleoecology in České Budějovice) was used for determination. In addition, standard identification keys were also used (Schweingruber, 1990; Heiss, 2000).

The analysis of diatoms was based on methods described by Battarbee (1986). Permanent slides were prepared using hydrogen peroxide for digestion, and Pleurax as a mounting medium (Fott, 1954). Frustules were counted using a light microscope at a magnification of 1000×. A minimum of 400 valves were counted per slide with the exception of the deepest sample where the total only reached 99 valves due to the low concentration of frustules in the sediment. Taxonomic identifications primarily followed Süsswasserflora von Mitteleuropa (Krammer & Lange-Bertalot, 1986, 1988, 1991a, b). Calculation of saprobic indices was based on values of species-specific weights and saprobic indices stated in Sládeček (1986) with corrections proposed by Marvan (unpublished).

Small fish remains (predominantly scales, pharyngeal teeth and vertebrae) recovered by wet sieving were identified using a fish skeleton reference collection (Laboratory of Archaeobotany and Paleoecology in České Budějovice) and determination literature (Baruš & Oliva, 1995; Radu, 2005; Wheeler & Jones, 2009). Fish remains were identified to the lowest taxonomic level possible. The evaluation of representative taxa was calculated using the number of identified specimens (NISP). For the determination of aquatic bivalve molluscs, Pfleger (1988) and Beran (1998) were used. An overview of the identification of mammalian bones is summarized elsewhere (Kovačiková, unpublished report).

A CONISS cluster analysis (Grimm, 1987) and determination of significant pollen accumulation zones (PAZ) based on the broken stick model (MacArthur, 1957, Legendre & Legendre, 1998) were performed using package Rioja (Juggins, 2009) in R 2.11.0 (R Development Core Team, 2010). Canonical correspondence analysis (CCA) of pollen data was realized in the package Vegan (Oksanen et al., 2010). Affiliation of the samples to particular sediment layers was used as an environmental factor. Both cluster and CCA analyses were performed on square root transformed data.

Results

General features

Three main vertically positioned zones were distinguished within the whole profile according to their sedimentary structure and the presence or absence of ecofacts indicating the aquatic environment (Fig. 3, Table 1). Zone 1 overlies the bedrock formed by the Older Palaeozoic marine sediments of the Prague Basin (Barrandien). The gradual decrease of its thickness towards the northwest implies that it could represent deluvio-fluvial sediments transported to the site from the Vinohrady terrace (the edge of this riverine terrace of Pleistocene origin is about 150 m to the southeast). Zone 2 surely represents the aquatic phase of the sedimentation (for more details see below). Zone 3 delineates a well-marked sedimentary stratification, probably the result of an outwash erosion of psammitic material and its subsequent deposition in the water reservoir.

Within the archaeozoological assemblage, 82.6% (NISP = 166) of the total remains ($N = 201$) have been identified as fish (the remains comprising bones, teeth and scales). Scales (both cycloid and ctenoid) and their fragments dominated (55.2% of total finds of fish remains). The identified species included tench (*Tinca tinca*), chub (*Leuciscus cephalus*), bleak (*Alburnus alburnus*) and roach (*Rutilus rutilus*). The ctenoid scales are typical of the order Perciformes. From this order, we take into consideration the following species: European perch (*Perca fluviatilis*), pike-perch (*Sander lucioperca*) or ruffe (*Gymnocephalus cernuus*). For the environmental demands of the

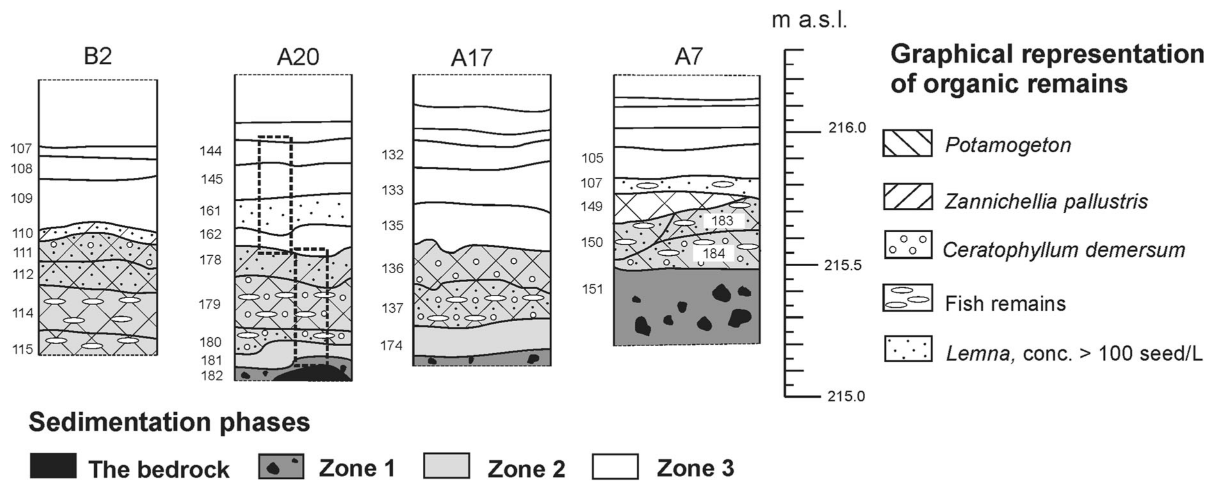

Fig. 3 Illustration of the four profiles mentioned in the text (for detailed position of the profiles see Fig. 2), with representation of organic remains indicating the aquatic phase of sedimentation. The position of sampling boxes is represented by the *two dashed line rectangles* in the profile A20

Table 1 General description of individual zones distinguished within the profile A20

Zone	Mineralogical description	Ecofacts presence
1	Sandy layers with bulky quartz and quartzite fluvial boulders	Very low concentrations of plant macro-remains and no fish remains
2	Grey dusty clays with high admixture of organic material, classified by its character and stratigraphic position as sediments of a pool with standing water	Frequent presence of various indicators of water phase: seeds of various species of aquatic plants (*Z. pallustris*, *Potamogeton* spp., *C.* and *Lemna minor/gibba*), fish remains, mussels, Cladocera, Charales, coccal green algae and diatoms
3	A thick formation consisting of sand with stripes of grey dusty clay in the upper part of the profiles	No fish remains, seeds of *Lemna minor/gibba* in much lesser quantity than in the zone 2, no other aquatic plants

fishes (and other aquatic animals identified) see Table 2.

Profile A20

The profile A20 was used for more detailed investigation because it was the longest one, and also because the zone 2 was the thickest one in this profile. For precise position of the two sampling boxes see Fig. 3. Three samples were chosen for dating using the radiocarbon method (see Table 3). The seeds of *C. album* were used in all cases. The lowermost layer of the profile was not suitable for dating because of a very low concentration of plant macro-remains (and the absence of the terrestrial ones). Therefore, the first sample was taken from the layer 180 (10 cm above the bottom). The second sample was taken from the layer 178 (40 cm above the bottom). Those two dates delimit the duration of the sedimentation of the zone 2 between the end of 10th century and the first half of 14th century. The third sample for dating was located 65 cm above the bottom (the zone 3, layer 161). This sample was chosen to determine the period of sedimentation of the thin clayey layer between the sandy layers overlaying the aquatic sediments.

Two significant pollen accumulation zones (PAZ) were determined using species with minimum abundance of 3%. On the contrary, no significant PAZ occurred if all species were included. The classification of A20 profile according to the sedimentologically defined layers was preferred, since the results of CCA analysis showed their significant ($P < 0.05$, 39.1% of total explained variability) relation to the pollen samples composition.

Layer 182

The lowermost layer was characterised by an absence of pollen grains and a very low occurrence of plant macro-remains. However, *Lemna minor/gibba*, *Zannichellia palustris* and several pieces of *Salix* branches were found here.

Layer 181

The concentration of plant macro-remains was still very low here; the pollen spectrum was composed

Table 2 The environmental demands of fishes and other aquatic animals documented archaeo-zoologically

Taxon	Characteristics
Fishes	
Rutilus rutilus roach—*Cyprinidae*	Prefers deeper water layers; young individuals stay in the shallows; the middle tolerance of oxygen dissolved in water; maximum length 40 cm
Tinca tinca tench—*Cyprinidae*	Prefers warmer parts in shallow shore zone; able to tolerate low oxygen concentrations; present in both stagnant and slow-moving water, often in pools with muddy substrates, covered with abundant vegetation; maximum length 30–63 cm
Leuciscus cephalus chub—*Cyprinidae*	Prefers indented bottoms and banks (it hides both between stones and under the undermined and overgrown shores); it tolerates slightly polluted water, if the amount of dissolved oxygen is sufficient; maximum length 60 cm
Alburnus alburnus bleak—*Cyprinidae*	Occurs near the surface (superficial fish) of both stagnant and slow-moving water, avoiding the parts overgrown by vegetation; maximum length 15–20 cm
Perciformes	Three species could be expected within this family: *Perca fluviatilis* (European perch)—lakes of all types to medium-sized streams; *Sander lucioperca* (pike-perch)—large, turbid rivers and eutrophic lakes; and *Gymnocephalus cernuus* (ruffe)—bottom parts of both lacustrine and flowing waters (depths to 85 m)
Mussels	
Anodonta/Unio mussel—*Unionidae*	Mussels of family *Unionidae* occur mostly in slow-moving watercourses of different types as well as in stagnant water
Cladocera	
Daphnia magna	Typical zooplankton of various types of stagnant water; it tolerates highly polluted water; often being found in enormous amounts (up to 2,000 individuals/L)
Daphnia pulex	In slightly polluted ponds and backwaters

Table 3 List of calibrated radiocarbon data originating from macro-remains of *Chenopodium album* separated from profile A20

Sample ID	layer	δ^{13}C, ‰	^{14}C age	±	Calibrated ^{14}C age
18_A20	180	−28.2	1060 B.P.	25	cal A.D. 945–1023
12_A20	178	−26.8	650 B.P.	25	cal A.D 1282–1362
07_A20	161	−27.5	980 B.P.	25	cal A.D .995–1154

mainly of non-arboreal pollen (NAP). Following macrophytes were documented (both macro-remains and pollen): *Alisma plantago-aquatica*, *L. minor/gibba*, *Myriophyllum spicatum* type, *Potamogeton* (*P. natans* type), *Sparganium erectum* type and *Z. palustris*. The diatom composition (*Amphora pediculus*, *Gomphonema sarcophagus*, *G. angustatum* s.l., *Cymbella aspera*, *Navicula radiosa* s.l. and *Planothidium frequentissimum*) indicates clean water (the index of saprobity equates to 1.2). Among the water algae, Charales, *Pediastrum simplex* and *Tetraedron minimum* were found. The resting eggs of Rotifers appeared here in low quantities, as well as ephippia of *Daphnia* cf. *pulex*.

Among pollen of the terrestrial plants the family Poaceae dominated. Anthropogenic indicators (e.g. crops and numerous ruderal species) as well as grazing indicators (*Plantago lanceolata* and *Calluna vulgaris*) were recorded in the pollen spectrum. The arboreal/non-arboreal pollen ratio (AP/NAP) equals 25%; charcoal of *Quercus* and small *Salix* branches were recorded.

Layer 180

The radiocarbon date from this layer has been calibrated and the resulting interval is A.D. 945–1023 (see Table 3). The layer shows an increasing concentration of macro-remains and pollen of aquatic macrophytes (*Ceratophyllum demersum, Lemna* and *Potamogeton*); green algae (*T. minimum, P. simplex* and *Scenedesmus*) were also abundant here. Fish bones and scales were found in high quantities (e.g. *T. tinca*, *A. alburnus* or *L. cephalus*) as well as mussel shells and ephippia of both *Daphnia magna* and *D.* cf. *pulex*. The composition of diatoms differed markedly from layer 181. Species with a low index of saprobity (*A. pediculus* and *G. sarcophagus*) remained only in minor quantities. A domination of *Stephanodiscus hantzschii*, *Amphora veneta* and *Cocconeis placentula* v. *euglypta* (species with an index of saprobity above 2), along with *Achnanthidium minutissimum*, *Hippodonta capitata*, *Lemnicola hungarica* and *Nitzschia fonticola* was recorded.

Among terrestrial plants, hygrophilous vegetation and wet meadows were indicated (e.g. *Carex*, *Juncus*, *Lysimachia vulgaris* type, *Lythrum salicaria* type, *Persicaria hydropiper*, *Ranunculus sceleratus*, *R. acris* group, *Urtica dioica* type and *Scirpus sylvaticus*). The abundance of pollen types of the family Poaceae and genus *Artemisia* decreased in contrast to the increasing percentage of anthropogenic indicators (*Polygonum aviculare*, *Chenopodium* spp., *Rumex acetosa* type and the family Brassicaceae). Aside from other cereal species, a presence of *Secale cereale* pollen was recorded. Three bones of large mammals were also found here. AP/NAP remained similar to the previous layer.

Layer 179

The layer was characterised by a high number of pollen types and a high absolute concentration of pollen grains. Also the concentration (above 500/l) of plant macro-remains and the number of determined plant species (46 taxa) reached their maximum here. *Lemna* dominated among aquatic macrophytes; *C. demersum*, *M. spicatum* type, *Potamogeton* and *Z. palustris* were abundant too. The number of fish remains (Cyprinidae and Perciformes) also reached its maximum as well as the ephippia of both *Daphnia* species. Both green algae and diatoms showed a very similar species composition to that in layer 180.

Hygrophilous plant species were also abundant here (*Bidens tripartita* type, *Eleocharis palustris* aggr., *Lycopus europaeus*, *P. hydropiper*, *P. lapathifolia*, *R. sceleratus* and cf. *Solanum dulcamara*). However, *Alisma plantago-aquatica* type and *S. erectum* type decreased in the pollen spectrum. Wet meadows were represented by *Chaerophyllum hirsutum* type, *Filipendula* type, *Juncus*, *Lychnis flos*-cuculi, *Peucedanum palustre* type, *R. acris* group, *R. flammula* group, *S. sylvaticus* and *Valeriana officinalis* type.

Field crops (*Horedeum* type, *Triticum* type, *Avena* type and *S. cereale*) and weeds as well as ruderal taxa (e.g. *Artemisia* type, *Anthemis arvensis* type, Brassicaceae, Chenopodiaceae, *P. aviculare* type and *R. acetosa* type) were documented in pollen. Abundance of Poaceae and *P. lanceolata* (grazing indicator) was recorded. Among the macro-remains, the following weeds were found: *Agrostemma githago*, *Anthemis cotula*, *Chenopodium* spp., *Polycnemum arvense*, *Thlaspi arvense* and *Valerianella dentata.* Compared to layer 180, *P. aviculare*, *C. album* and *U. dioica* macro-remains slightly increased. One seed of *Cucumis melo/sativus* and a glume of *Panicum miliaceum* were found here, as well as macro-remains of edible wild species: *Rubus idaeus*, *Rubus fruticosus* aggr., cf. *Fragaria*, *Sambucus nigra* and *Corylus avellana*.

Tree species composition in the pollen spectrum remained similar to the previous layer; however, *Fraxinus* type and *Acer* type appeared here. Besides, occurrence of rare taxa such as *Prunus* type and *Cornus mas* type was recorded. *Salix* pollen grains disappeared in contrast to many small pieces of *Salix* branches found here. This layer contained a high amount of charcoal fragments of *Quercus*, *Pinus sylvestris* and *Fagus sylvatica*. Fragments of wood of *P. sylvestris* were quite abundant and some scarce occurrences of *Abies alba* wood were also recorded.

Layer 178

The radiocarbon date from this layer is cal. A.D. 1282–1362 (see Table 3). It was still rich in both plant macro-remains and pollen types; however, the number of fish remains decreased markedly. *Lemna* and *Z. palustris* remained at comparable high concentrations as in the previous layer. On the contrary, the macro-remains of *Potamogeton* decreased rapidly. All the diatom species disappeared in this layer, as well as the green algae (with the single exception of *P. simplex*). Ephippia of *Daphnia* cf. *pulex* disappeared and the *D. magna* concentration decreased. The occurrence of parasite eggs of *Trichuris* was firstly recorded from the upper half of this layer.

Macro-remains of hygrophilous plant species decreased compared to the previous layer (both the number of species and concentration). The indicators of wet meadows nearly disappeared here, also the pollen ratio of Poaceae decreased. Among the grassland species, only those of dry grasslands (Festuco-Brometea) remained present (macro-remains of *Arenaria serpyllifolia* and *Hypericum perforatum*). On the other hand, the abundance of pollen of field crops increased, as well as *P. aviculare* type (indicator of trampled vegetation). Also the concentration of *C. album* increased markedly in this layer. Weeds were represented by *A. arvensis*, *Centaurea cyanus*, *C. ficifolium*, *Consolida ambigua* type, *Euphorbia helioscopia*, *Fumaria officinalis*, *Papaver rhoeas* type, *P. arvense*, *T. arvense* and *Stellaria media*. One seed of cf. *Vitis vinifera* and two bones from a large mammal were found here.

Layer 162

Contrarily to the previous clayey layers, this layer was characterised by a high admixture of sand. Concentration of both plant macro-remains and pollen decreased markedly here. Further, the pollen curves based on the absolute values of all woody species were lowered. However, the percentage diagram shows an increase in the AP/NAP ratio. This is based on an increase in the *Pinus* proportion in the layers with a sand admixture.

Remains of aquatic macrophytes as well as hygrophilous plants nearly disappeared in this layer (with exception of *Lemna* and *R. sceleratus*), also *Daphnia magna* and rotifers became scarce here, and only two fish bones of Cyprinidae were found. On the other hand, the macro-remains of ruderal plants increased their concentration; this trend was most prominent in *C. album*, *C. hybridum* and *Sambucus ebulus*. The composition of root crop weeds was very similar to that of layer 178, whereas the macro-remains of field weeds were very scarce. Among the NAP pollen curves, an increase in the abundance of Chenopodiaceae, *P. aviculare* type and *C. cyanus* was observed.

Layer 161

This layer differs from both the underlying and the overlaying layers in its sedimentological character. It represents a streak of grey dusty clay between shale and siliceous sands of the layers 162, 145 and 144.

Radiocarbon date (Table 3) from this layer (after calibration) is A.D. 995–1154 (for more details, see "Discussion" section). In the pollen diagram, the total number of species (pollen types) decreased compared to previous layers as well as the number of plant species in the macro-remain assemblage.

The concentration of *Lemna* macro-remains was relatively high but no other aquatic macrophytes were encountered (except for 2 achenes of *Alisma plantago-aquatica*). The following species of natural hygrophilous habitats were found here: *Carex*, *Juncus*, *Lemna*, *P. maculosa*, *R. aquatilis* group, *R. sceleratus*, *R. crispus/obtusifolius*, *S. erectum* and *Typha latifolia*.

The macro-remains concentration of *C. album* (and other species of this genus) culminated here. Composition of the macro-remains of weeds was similar to the previous layers; on the other hand, indications of weeds such as *Dipsacus fullonum* type, *Gnaphalium uliginosum* type, *Jasione montana* type, *Scleranthus annuus*, *Sedum* type, *Teucrium* and *Xanthium strumarium* type appeared among the rare species in pollen spectra. The pollen of crops, weeds and ruderals as well as of species growing on highly disturbed areas increased in abundance in this layer.

The abundance of almost all woody species in the pollen diagram decreased; however, the proportion of *Pinus* in the percentage pollen diagram increased (probably due to a sand admixture in the upper part of this layer). Among both charcoal and wood fragments, *P. sylvestris* dominated.

Layers 145 and 144

In both of these uppermost layers of the profile A20, the concentration of plant macro-remains decreased continually along with the number of determined taxa. The total number of pollen types also decreased. The only remaining aquatic species represented by macro-remains was *Lemna*, while the only remaining hygrophilous species was *R. sceleratus*. The composition of species typical for ruderal habitats was extended by *Atriplex* and cf. *Galeopsis tetrahit,* in addition to the *Chenopodium* species and *Sambucus ebulus* found also in previous layers. Among the weeds, the only remaining species were *F. officinalis* and *P. arvense* (both in gradually decreasing concentrations). *Glaucium corniculatum* appeared for the first time in layer 144; two caryopses of *S. cereale* were also found in this layer. The dominant pollen type was *P. aviculare*, followed by species of the Poaceae, Chenopodiaceae, genus *Artemisia* and *Rumex*. The pollen of crops, ruderals, weeds and species of highly disturbed sites increased in abundance. By contrast, the abundance of pollen of woody species was very low here.

Discussion

The permanently moist sediments comprise optimal conditions for the preservation of environmental information. However, the majority of wet sediments obtained until now in the city of Prague have originated chiefly from pits or wells (Opravil, 1986, 1994; Čulíková, 1987, 1998a, b, 2001a, b, 2005, 2008, 2010), which represent an inseparable mixture of material of various origins (both natural and anthropogenic). Indeed, it is difficult to find a suitable material in urban archaeology as the localities under focus are mostly completely built up. Any research of a former water reservoir located under recent buildings is rare (e.g. Hellwig, 1997; Sasaki & Takahara, 2011; Starec et al., 2012). Within the area of Prague, the only investigated wet sediments of more or less natural origin were those of the so-called Old Town defence system moat (Beneš et al., 2002) and the alluvial sediments of the Vltava River backwaters (Kozáková & Pokorný, 2007; Čulíková 2010).

Time extent of the sedimentation record

The sediments investigated by this study were dated using the radiocarbon method (see Table 3). As for the lowermost part (first 6 cm) of the investigated profile A20, there were not enough macro-remains for dating. Moreover, this material contained almost no pollen; therefore, we cannot make any conclusion concerning the age of the oldest part of the profile. The first date (from the sample located 10 cm above the bottom) corresponds approximately to the oldest known reference to the Rybník village (tenth to eleventh century). The second date (thirteenth to fourteenth century) comes from the sample located 40 cm above the bottom. This material has probably sedimented shortly before the ending of the pond existence, which could be causally related to the demise of the Rybník village after the New Town foundation in 1348. This period was characterised by an extensive building activity in the neighbourhood.

The third date (tenth to eleventh century) was obtained from the clayey layer 161, set between the sandy layers above the aquatic sediments. According to the correspondence analysis, this sample is much more similar to the samples from layer 178 than to the samples originated from the adjacent layers. Therefore, we can assume that this material was the result of redeposition of older sediment, perhaps connected with the later increased building activity at the site. Another explanation takes into consideration an outwash from some higher positions of the drainage area. Either way, this peculiar date must lead us to extreme caution when interpreting the upper half of the profile.

Still, we consider the two dates from the lower half of the profile as being plausible. They are in accordance with our expectations, the succession between them is uninterrupted, and the fragments of ceramic found between them correspond to the twelfth century. Besides, the emergence of *C. cyanus* pollen by the end of the tenth century and the gradual growth of its curve in the course of the following centuries accords with the results of other investigations in the Czech Republic (Jankovská, 1997; Kozáková et al., 2009).

Vegetation types

The classification of vascular plant species was based on the recent vegetation of the Czech Republic characterised by the diagnostic species (Chytrý & Tichý, 2003). The Following vegetational units were identified (see Table 4): aquatic vegetation, hygrophilous herbaceous vegetation, hygrophilous woodland vegetation, grassland vegetation (meadows, pastures and dry grasslands), annual vegetation of ruderalised sites, and weeds.

Aquatic vegetation

Among aquatic macrophytes, the following species were documented: *C. demersum*, *Lemna minor*, *M. spicatum*, *P. crispus*, *P.* cf. *natans* and *Z. palustris*. Classes of Lemnetea and Potametea (Nymphaeion albae, Magnopotamion and Parvopotamion) could be identified according to the diagnostic species. These are common vegetation types of standing water extending nearly all over the world. Nevertheless, the macro-remains of these species are not very common in other documented archaeobotanical assemblages from Prague. For a more detailed description of the development of the water environment of this site see the following section.

Hygrophilous herbaceous vegetation

The following species of hygrophilous herbs were found: *Alisma plantago-aquatica*, *Bidens cernua*, *Bidens* cf. *tripartita*, *Butomus umbellatus*, *E. palustris*, *G. uliginosum*, *L. europaeus*, *L. salicaria*, *P. hydropiper*, *R. sceleratus*, *Rorippa palustris*, *Saggitaria sagittifolia*, *S. erectum*, *Sparganium emersum* and *T. latifolia*. Classes of Isoeto-Nanojuncetea (Eleocharition ovateae), Phragmito-Magnocaricetea (Phragmition communis and Oenanthion aquaticae) and Bidentetea tripartitae (Bidention tripartitae) could be identified according to the diagnostic species.

The species of hygrophilous vegetation culminated (both quantitatively and qualitatively) in the lower half of the profile, and showed a decreasing tendency. This trend was prominent both in the macro-remains and pollen. These plants were probably growing on sites connected immediately with the pond. Similar vegetation was detected near a backwater in Malá Strana (Kozáková & Pokorný, 2007; Čulíková, 2010). However, *Eleocharis* and *Lycopus* have been found in nearly all sites in Mediaeval Prague, including pits (Opravil, 1986, 1994; Čulíková, 1998a, b, 2001a, b, 2005, 2010).

Hygrophilous woodland vegetation

The following taxa of hygrophilous woodland vegetation were found: *Salix*, *Alnus* cf. *glutinosa*, *Aegopodium podagraria*, *C. hirsutum*, *Fraxinus exelsior*, cf. *Myosoton aquaticum* (*Cerastium fontanum* group), *R. idaeus*, *Rumex crispus/obtusifolius*, *S. nigra* and *U. dioica*. Classes of Salicetea purpureae (Salicion triandreae) and Querco-Fagetea (Alnion incanae) could be identified according to the diagnostic species.

These species were represented mostly by pollen or wood (charcoal). Only *Rumex*, *Urtica*, *R. idaeus* and *S. nigra* (edible fruits) were also found in the macro-remains. This could be intepreted as a consequence of a situation when this type of vegetation was growing nearby, but not directly on the site.

Wet meadows

The following species (or pollen types) indicating wet meadows were found: *Angelica sylvestris*, *Alchemilla pentaphyllea*, *Alnus*, *Caltha palustris*, *Carex* cf. *hirta*, *Carex* cf. *pallescens*, *C. hirsutum*, *Cichorium intybus* type, *Cirsium palustre* type, *Filipendula ulmaria*, *Geranium molle* type, *Heracleum sphondylium*, *Lathyrus*, *Leucanthemum vulgare* aggr., *Lychnis flos-cuculi*, *L. vulgaris* type, *R. acris*, *R. repens*, Rubiaceae,

Table 4 Vegetation units identified according to (recent) diagnostic species (classification of plant taxa into syntaxa follows Chytrý & Tichý 2003) based on finds of macro-remains

Ecological groups	1		2			3	4					5	6	7	8			9
Syntaxa	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
Aethusa cynapium	.	.	.	.	.	.	.	.	.	.	.	.	.	o	.	.	.	.
Agrostemma githago	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.
Ajuga cf. *reptans*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	o	+
Alisma plantago-aquatica	.	.	+	.	o	.	.	.	.	.	.	.	.	.	.	.	.	.
Anagallis arvensis	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.
Anthemis arvensis	.	.	.	.	.	.	.	.	.	.	.	.	.	o	.	.	.	.
Anthemis cotula	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.	.
Aphanes arvensis	.	.	.	.	.	.	.	.	.	.	.	.	.	o	.	.	.	.
Arenaria serpyllifolia agg.	.	.	.	.	.	.	.	.	.	o	.	.	.	+	.	.	.	.
Atriplex sp.	.	.	.	.	.	.	.	.	.	.	.	.	o	.	.	.	.	.
Bidens cernua	.	.	.	.	.	o	.	.	.	.	.	.	.	.	.	.	.	.
Bidens cf. *tripartita*	.	.	+	.	.	o	.	.	.	.	.	.	.	.	.	.	.	.
Bupleurum rotundifolium	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.
Capsella bursa-pastoris	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.
Carex cf. hirta	.	.	.	.	.	.	o	.	.	.	.	.	.	.	.	.	.	.
Carex cf. *pallescens*	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Carex leporina	.	.	.	.	.	.	o	.	.	.	.	.	.	.	.	.	.	.
Centaurea cyanus	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Ceratophyllum demersum	o	o	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chenopodium album agg.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.
Chenopodium ficifolium	.	.	.	.	.	.	.	.	.	.	.	.	o	.	.	.	.	.
Chenopodium hybridum	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Chenopodium polyspermum	.	.	.	.	.	.	.	.	.	.	.	.	o	.	.	.	.	.
Cirsium cf. *palustre*	.	.	.	.	.	.	o	.	.	.	.	.	.	.	.	+	.	.
Dianthus armeria/deltoides	.	.	.	.	.	.	.	.	.	.	o	.	.	.	.	.	.	.
Echinochloa crus-galli	.	.	.	.	.	.	.	.	.	.	.	.	o	.	.	.	.	.
Eleocharis palustris agg.	.	.	.	.	o	.	.	.	.	.	.	.	.	.	.	.	.	.
Euphorbia helioscopia	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.
Fallopia convolvulus	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.
Filipendula ulmaria	.	.	.	.	.	.	o	.	.	.	.	.	.	.	+	+	.	.
Fumaria officinalis	.	.	.	.	.	.	.	.	.	.	.	.	.	o	.	.	.	.
cf. *Galeopsis tetrahit*	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Geranium molle/collumbinum	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Glaucium corniculatum	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.
Herniaria glabra	.	.	.	.	.	.	.	.	o	.	.	.	.	.	.	.	.	.
Hypericum perforatum	.	.	.	.	.	.	.	.	+	o	.	.	.	.	.	.	.	.
Juncus sp.	.	.	+	.	.	.	o	.	.	.	.	.	.	.	.	.	.	.
Lamium cf. *amplexicaule*	.	.	.	.	.	.	.	.	.	.	.	.	o	+	.	.	.	.
Lapsana communis	.	.	.	.	.	.	.	.	.	.	.	.	o	+	.	.	.	.
Lemna minor/gibba	o	+	.	o	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Leontodon autumnalis	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.

Table 4 continued

Ecological groups	1		2			3	4					5	6	7	8			9
Syntaxa	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
Leucanthemum vulgare agg.	.	.	.	.	.	.	.	o	.	.	.	.	.	.	.	.	.	.
Lychnis flos-cuculi	.	.	.	.	.	.	o	.	.	.	.	.	.	.	.	.	.	.
Lycopus europaeus	.	.	.	o	o	+	.	.	.	.	.	.	.	.	.	+	.	.
cf. *Myosoton aquaticum*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
Myriophyllum cf. *verticillatum*	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Myriophyllum spicatum	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Neslia paniculata	.	.	.	.	.	.	.	.	.	.	.	.	.	o	.	.	.	.
Papaver cf. rhoeas	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Persicaria hydropiper	.	.	.	.	.	o	.	.	.	.	.	.	.	.	.	.	.	.
Persicaria lapathifolia agg.	.	.	+	.	.	+	.	.	.	.	.	.	+	+	.	.	.	.
Persicaria maculosa	.	.	.	.	.	.	.	.	.	.	.	.	.	o	.	.	.	.
Picris cf. *hieracioides*	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Polycnemum arvense	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.
Polygonum aviculare agg.	.	.	.	.	.	.	.	.	.	.	.	o	+	+	.	.	.	.
Potamogeton cf. *natans*	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potamogeton crispus	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Potentilla anserina	.	.	.	.	.	.	.	.	.	.	.	o	.	.	.	.	.	.
Prunella vulgaris	.	.	.	.	.	.	o	.	.	.	.	.	.	.	.	.	.	.
Ranunculus acris	.	.	.	.	.	.	o	+	.	.	+	.	.	.	.	.	.	.
Ranunculus repens	.	.	.	.	.	+	o	.	.	.	.	+	+	.	+	+	.	.
Ranunculus sceleratus	.	.	o	.	.	o	.	.	.	.	.	.	.	.	.	.	.	.
Rorippa palustris	.	.	o	.	.	o	.	.	.	.	.	.	.	.	.	.	.	.
Rubus idaeus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	o	+
Rumex cf. *crispus*	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Rumex cf. *obtusifolius*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.
Sambucus ebulus	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.	.
Scirpus sylvaticus	.	.	.	.	.	.	o	.	.	.	.	.	.	.	.	+	.	.
Scleranthus anuus	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.
Setaria cf. *viridis*	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Setaria pumila	.	.	.	.	.	.	.	.	.	.	.	.	o	.	.	.	.	.
Silene cf. *viscaria*	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	o
Solanum dulcamara	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	o	.	.
cf. *Sparganium erectum*	.	.	.	o	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Stachys cf. *annua*	.	.	.	.	.	.	.	.	.	.	.	.	.	o	.	.	.	.
Stellaria graminea	.	.	.	.	.	.	.	o	.	.	.	.	.	.	.	.	.	.
Stellaria media agg.	.	.	.	.	.	.	.	.	.	.	.	.	o	+	.	.	.	.
Taraxacum officinale agg.	.	.	.	.	.	.	+	.	.	.	.	+	+	+	.	.	.	.
cf. *Thalictrum flavum*	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Thlaspi arvense	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.
cf. *Typha latifolia*	.	.	.	o	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Urtica dioica	.	.	.	+	+	.	.	.	.	.	.	.	.	.	+	+	o	+
Urtica urens	.	.	.	.	.	.	.	.	.	.	.	.	o	.	.	.	.	.

Table 4 continued

Ecological groups	1		2			3	4					5	6	7	8			9
Syntaxa	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
Vaccaria hispanica	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.
Valerianella dentata	.	.	.	.	.	.	.	.	.	.	.	.	.	o	.	.	.	.
Zannichellia palustris	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Ecological groups and the syntaxa relating to the various groups

1 Aquatic vegetation. A, Lemnetea; B, Potametea

2 Hygrophilous herbaceous vegetation. C, Eleocharion ovatae; D, Phragmition communis; E, Oenanthion aquaticae

3 Ruderalised hygrophilous habitats. F, Bidention tripartitae

4 Grassland vegetation (meadows, pastures and dry grasslands). G, Calthion; H, Arrhenatherion; I, Plantagini-Festucion ovinae; J, Festuco-Brometea; K, Violion caninae

5 Trampled habitats. L, Plantaginetea majoris

6 Annual vegetation of ruderalised sites. M, Chenopodietea (Fumario-Euphorbion, Spergulo-Oxalidion, Panico-Setarion)

7 Crop weeds. N, Secalietea (Caucalidion lappulae, Sherardion, Veronico politae-Taraxacion, Aphanion)

8 Hygrophilous woodland vegetation. O, Salicion triandrae; P, Alnion glutinosae; Q, Alnion incanae

9 Trees. R, Querco-Fagetea

+ Taxon occurs in the group

o Taxon has its main occurrence in the group

x Taxon is considered to have occurred in the group in the past

R. acetosa type and *S. sylvaticus*. The class Molinio-Arrhenatheretea (Calthion) could be identified according to the diagnostic species. Also *S. graminaea*—the species with a wide ecological valence from dry to wet meadows was among the list of grassland species.

Both the macro-remains and pollen of this group showed a decreasing tendency in the profile. Many of them were also found in the backwater in Mala Strana (Kozáková & Pokorný, 2007; Čulíková, 2010), as well as in the drainage ditch of the Old Town defence system (Beneš et al., 2002), and in the Prague Castle (Kozáková & Boháčová, 2008). Moreover, the following taxa were also found in other archaeological sites in Mediaeval Prague: *Caltha palustris*, *Lychnis flos-cuculi*, *Ranunculus*, *S. sylvaticus, S. graminaea* and *Cirsium*. It is thus possible to conclude that meadows were probably quite widespread in Prague suburbs (mostly around the river and its tributaries) and the material of the meadows (hay) was also manipulated in households (or it could have been transported by animals and deposited in cesspits in the form of dung).

Dry grasslands

The occurrence of some rare pollen types (e.g. *Lychnis viscaria* type, *Anthericum* type, *Saxifraga oppositifolia* type, *Thesium* type, *Aster tripolium* type, *Helianthemum*, *Lithospermum arvense*, *Medicago lupulina* type, *Echium* type, *Teucrium* type and *Verbascum* type) in the pollen spectrum would imply that xerophilous grasslands probably developed in the close vicinity of the investigated water reservoir. The area of Prague has many places where biotopes mainly belonging to the class Festuco-Brometea could occur. These habitats were probably used as pastures in the past. The presence of grazing indicators (e.g. pollen of Poaceae, *P. lanceolata*, *C. vulgaris*, *J. montana* type; and charcoal from *Juniperus*) in the pollen spectrum would support such a scenario (Behre, 1981). Those habitats with remaining dry grassland vegetation within Prague are nowadays generally under the status of nature reserves (Dostálek & Frantík, 2008). We could suppose that such habitats were more common within the area before the New Town of Prague was established.

Annual vegetation of ruderalised sites

The following species of ruderal vegetation were found: cf. *Capsella bursa-pastoris*, *Chenopodium album* aggr., *C. hybridum*, *C. polyspermum*, *Echinochloa crus-galli*, *E. helioscopia*, *Lapsana communis*, *P. aviculare* aggr., *Setaria pumila*, *Stellaria media* aggr., and *T. arvense*. The present-day class Chenopodietea (Fumario-Euphorbion and Panico-Setarion) could be identified according to the diagnostic species.

This group of vegetation shows an increasing tendency, culminating in the upper half of the profile. It corresponds with the pollen curve of trampled vegetation indicators, and this trend is at the same time opposite to the trend of semi-natural types of vegetation mentioned above. When comparing with other sites, the macro-remains of these species are nearly ubiquitous both in archaeological sites and in natural sediments, so this vegetation probably grew inside the town and around the villages, as well as along watercourses. In contrast, perennial ruderals were very scarce on this site. Nevertheless, their particular occurrence in the Old Prague trade centre Ungelt (Opravil, 1986) indicates the different environment in the urban and trade centre of that time.

Weeds

The following weeds were found: *Anagallis arvensis*, *Aethusa cynapium*, *Agrostemma githago*, *A. arvensis*, *Aphanes arvensis*, *A. serpyllifolia* aggr., *Bupleurum rotundifolium*, cf. *Capsella bursa-pastoris* (Brassicaceae), *C. cyanus*, *Chenopodium album* aggr., *E. helioscopia*, *Fallopia convolvulus*, *F. officinalis*, *Glaucium corniculatum*, *Lapsana communis*, *Lithospermum arvense*, *Microrrhinum minus*, *Neslia paniculata*, *Papaver* cf. *rhoeas*, *P. lanceolata*, *P. major*, *P. arvense*, *P. aviculare* aggr., *Rumex crispus/obtusifolius*, *S. annuus*, *Stachys* cf. *annua*, *Stellaria media* aggr., *T. arvense* and *V. dentata*. The present-day class Secalietea (Caucalidion lappulae, Sherardion, Aphanion and Veronico politae-Taraxacion) could be identified according to the diagnostic species. However, some of these weedy species are no longer present in present-day fields, although they were very frequent in Mediaeval fields (i.e. *Agrostemma githago*, *Glaucium corniculatum*, *Bupleurum rotundifolium* and *P. arvense*).

Both the number of species and quantity of weeds increased in time (both pollen and macro-remains), along with the pollen of cereals. Many of these weed species are ubiquitous in archaeological sites (*Aethusa cynapium*, *Anagallis arvensis*, *A. arvensis*, *A. serpyllifolia*, *C. cyanus*, *F. officinalis*, *Lithospermum arvense*, *Neslia paniculata*, *Fallopia convolvulus*, *S. annuus* and *V. dentata*). The possible explanation is that they frequently entered settlements along with the field products brought in. Nevertheless, some weedy species often found in cesspits were not encountered on this site (e.g. *Caucalis platycarpos*, *Galium spurium*, *Lithospermum arvense*, *Adonis aestivalis* and *Sinapis arvensis*). On the other hand, some weedy species were almost only found here (e.g. *A. cotula*, *Vaccaria hispanica* and *S. annuus*) though some of them were also encountered at Mala Strana.

Environmental changes

Terrestrial vegetation

During the period between the end of tenth to approximately the middle of fourteenth century, rather extensive changes of plant species composition took place in the region of Prague. The changes observed at the investigated site clearly correspond with the general trends in landscape management reconstructed by Kozáková et al. (2009). According to this reconstruction, a fine mosaic of habitats existed in Prague before the end of twelfth century. Subsequently, the environmental diversity decreased considerably during the following centuries. This trend was explained as a result of increasing ruderalization and intensification of the land use.

In the site investigated, the field indicators (both cereals and field weeds) increased over time (Fig. 4), whereas the proportion of broad-leaf trees and shrubs decreased (Fig. 5). This trend in the pollen spectra could be interpreted as a manifestation of the gradual enlargement of land under the plough. At the same time, the proportion of ruderal plants increased continually both in the pollen and macro-remains spectra. The trend in grassland indicators is much less clear; however, this type of vegetation seems to decrease slightly with time. A gradual decline in the semi-natural hygrophilous vegetation was accompanied by an opposite tendency in trampled vegetation (*P. aviculare* and *R. acetosella*). This trend, along with the distinct increase of landscape ruderalisation, seems to indicate the gradual intensification of human

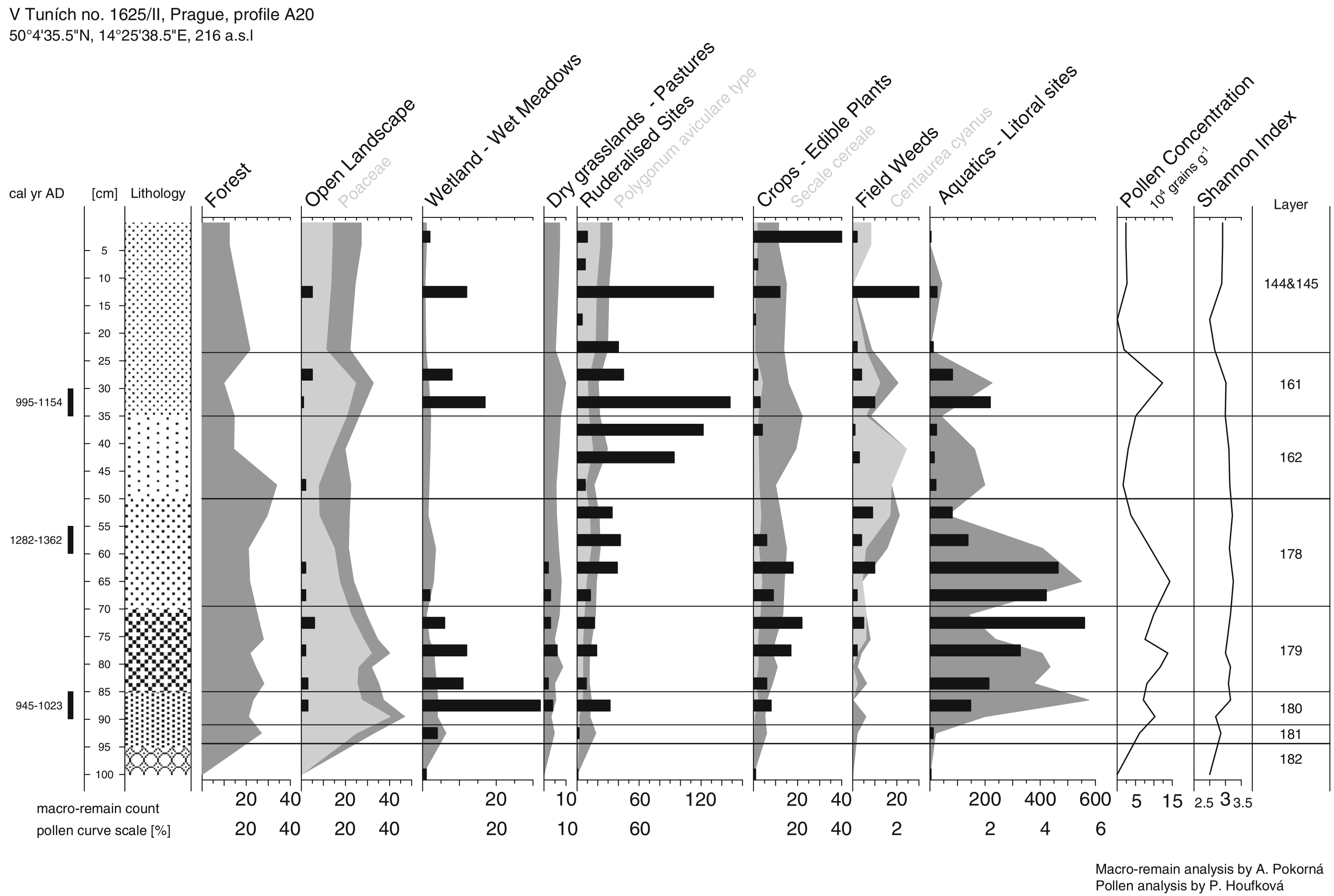

Fig. 4 Trends in development of vegetation units (as recorded in the A20 profile) expressed by both sums of macro-remains (*histograms*) and percentage of pollen within the total pollen spectrum (*curves*). *Dark grey curves* represent total percentage of pollen types assigned to individual vegetation units; whereas the *light grey area* within the curve represent the proportion of selected pollen type within the unit. Total number of determined pollen types is expressed by the Shannon index (dimensionless quantity). The depth from the surface (*y axis*) is expressed in cm. Calibrated radiocarbon dates (cal yr AD) are plotted along the *y axis*

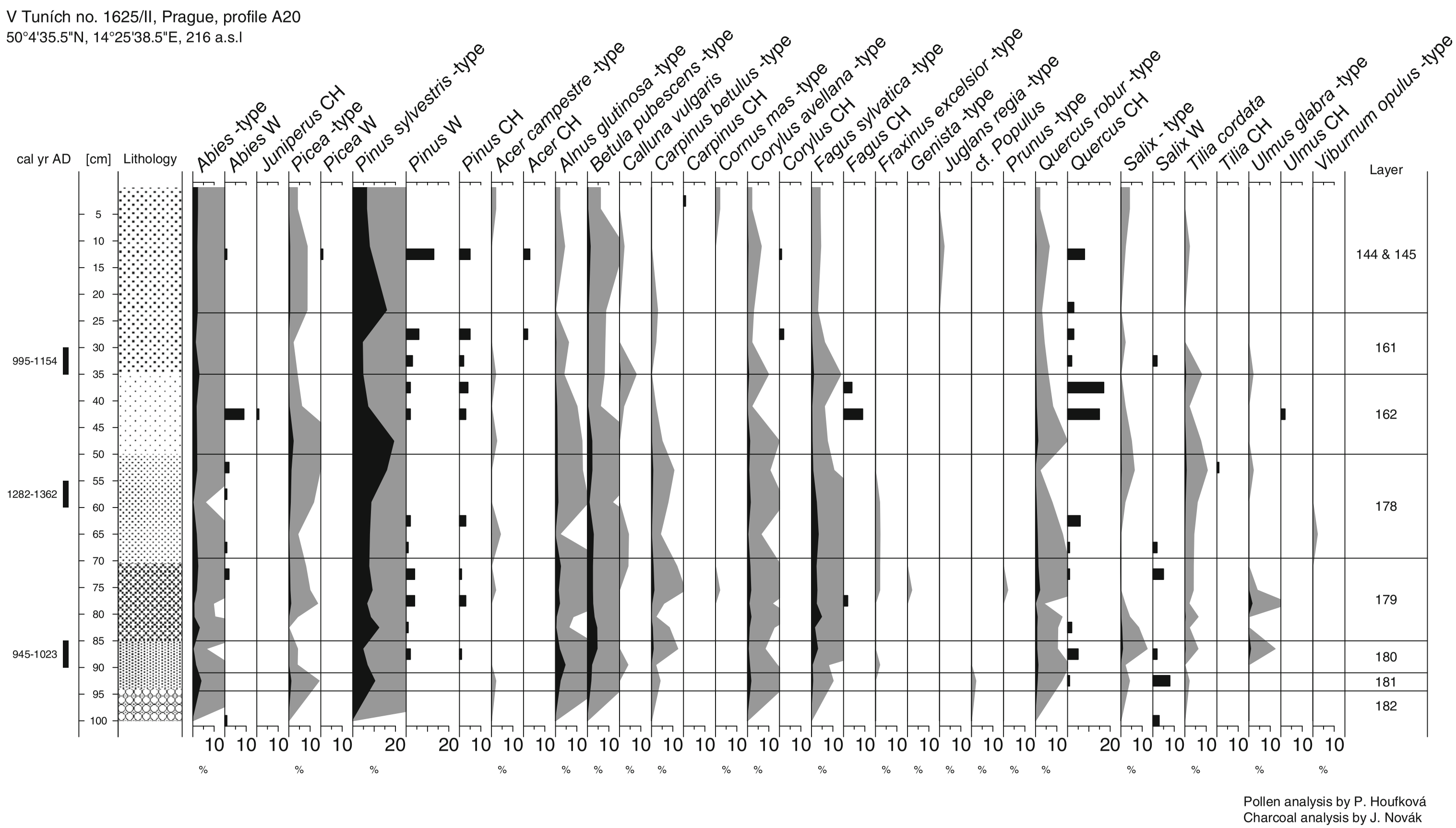

Fig. 5 Occurrence of woody plants in the A20 profile. Mixed diagram of both pollen (percentage within the total pollen spectrum expressed by curves, *grey areas* depict the same values exaggerated tenfold) and charcoal/wood (count of pieces expressed by histograms). The depth from the surface (*y axis*) is expressed in cm. Calibrated radiocarbon dates (cal yr AD) are plotted along the *y axis*

activity around the water pool. A similar intensification of anthropogenic influence is clearly visible in the development of the aquatic environment of the pool, which has been documented thoroughly.

The area of Prague belongs to the Bohemian Thermophytic region, the Prague Basin subunit of the phytogeographical region called The Prague Plateau (Skalický, 1997). The potential vegetation of this site is Hercynian oak-hornbeam forest (Carpinion), acidophilous oak forest (Genisto germanicae-Quercion) and ash-alder alluvial forest (Alnenion glutinoso-incanae) (Moravec et al., 1991; Neuhäuslová, 1998). According to the results of pollen, wood and charcoal analyses, all of these types of forest vegetation were probably present in the vicinity of the study site. An analogous species composition has been recorded from other Prague Mediaeval sites (Beneš et al., 2002; Kozáková & Pokorný, 2007; Kozáková et al., 2009; Novák et al., 2012). The results originating from both charcoal and wood analyses revealed a lower number of species than the pollen analysis. Some rare shrub species (e.g. *Viburnum opulus* type, *C. mas* type and *Juglans regia* type) were recorded only through the pollen analysis. Such differences between the pollen and the charcoal/wood analyses reflect the various source areas. The species composition of charcoal fragments reflects the

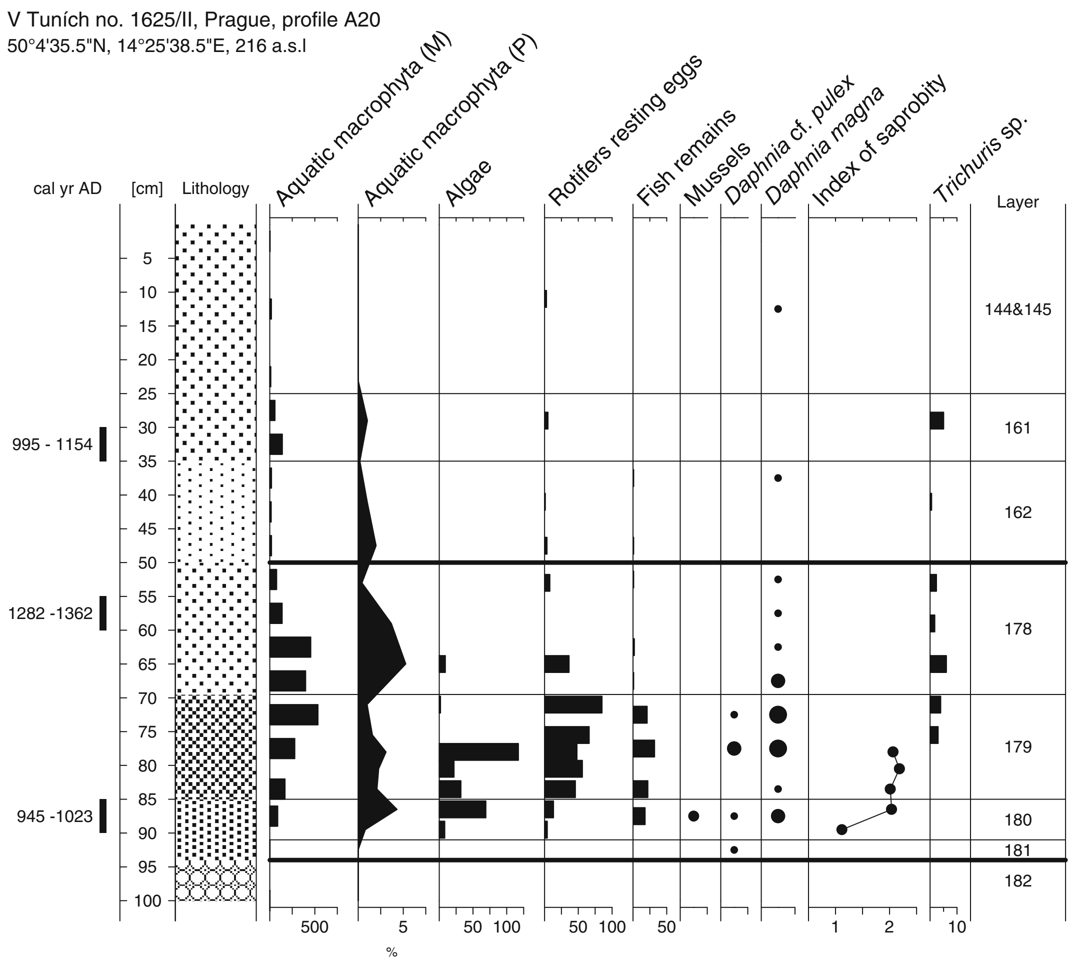

Fig. 6 Quantification of proxy data indicating the aquatic environment (as recorded in the A20 profile). The depth from the surface (*y axis*) is expressed in cm. Calibrated radiocarbon dates (cal yr AD) are plotted along the *y axis*. The count of macro-remains (macrophyta, algae, resting eggs of rotifers, *Trichuris* eggs as well as fish remains) is expressed in pieces (*x axis*). Aquatic macrophyta are represtnted by both sum of macro-remains (M) and percentage of pollen (P). Estimated abundance of mussels and *Daphnia* are plotted as *black dots*; the size of dots (small, medium and big) corresponds to the estimated quantification. The level of aquatic pollution is expressed by index of saprobity (dimensionless quantity) calculated according to diatom spectrum

use of firewood originating in close proximity of the site (Théry-Parisot et al., 2010; Novák et al., 2012). In contrast, the species composition of wood often reflects local vegetation cover, e.g. willow branches, or selectively collected construction material (fir and spruce).

Aquatic environment

Using a series of various methods, it was possible to make a detailed reconstruction of the aquatic environment of the site and its gradual changes. The changes of water quality were documented by a series of organisms: water macrophytes (*C. demersum*, *Lemna minor/gibbaI, M. spicatum*, *Potamogeton*, *Sparganium* and *Z. pallustris*), green algae (*Pediastrum simplex*, *T. minimum* and *Scenedesmus*), cladocera (ephipia of *D. magna* and *D.* cf. *pulex*), fish (Cyprinidae: *T. tinca*, *L. cephalus*, *A. alburnus, R. rutilus* and Perciformes), rotifers and diatoms of various species. On the grounds of the diatom composition, an index of saprobity was calculated—which could be used as a measure of water quality (Fig. 6).

According to the index of saprobity (1.2), the base of the profile (layers 181 and 182) was the result of sedimentation in considerably oligosaprobic conditions. The index of saprobity then gradually increased, exceeding 2 within layer 179, followed by the absolute disappearance of diatoms in layer 178. The rapid and almost synchronous decrease of green algae, diatoms and fishes in layer 178 implies that it was probably the response of aquatic organisms to some changes in the environment. The water was obviously greatly shaded by a thick layer of both *L. gibba/minor* and *P. natans*. This could explain the decrease of green algae but not also the decrease of diatoms occurring in early spring and late autumn, when summer shadowing by floating plants should be irrelevant. Alternatively, the high content of dissolved nutrients, which was probably connected with anoxia, could have been a major culprit causing the disappearance of both diatoms and fishes. Pollution of the water by organic waste (e.g. excrement) could be the principal reason for the rapid decrease in water quality. This interpretation is supported by appearance of the intestinal parasite *Trichuris* (not the human one) eggs shortly before the diatoms disappeared. Other waste indicators found in these two layers were as follows: seed of cucumber, seed of grape, pig bone and several pieces of ceramics.

According to the environmental demands of the fish (Table 2), the aquatic environment of the pond was probably rather diversified—the determined fish species occur both in *lotic* (i.e. flowing) and stagnant water (e.g. ponds and pools with muddy substrates). Tench and chub tolerate a lower amount of oxygen dissolved in water and prefer sites overgrown by vegetation. Species of the order Perciformes could occur in various types of water pools (e.g. lagoons, lakes of all types, or slow to medium flowing watercourses).

As opposed to the lower half of the profile, the intrerpretation of the upper part is much less clear. We assume that the layers 180, 179 and 178 definitely represent sedimentation in water reservoir. On the other hand, the overlying sediments (layers 162, 161, 145 and 144) are characterised by a rapid decrease in the number of remains of aquatic organisms. This could be due to a deterioration of preservation conditions. Besides, the psammitic (fine sandstone) character of the sediment of these layers implies an increased influx of material, which could be connected to an increased risk of contamination. Moreover, the possibility of the redeposition of an older material (the ^{14}C date within the layer 161, see above) should be taken into consideration.

There are two possible explanations of this phenomenon. One of the possibilities is that the material of the layer 161 is the result of redeposition of older sediment, perhaps connected to subsequent increase of building activity at the site. In that case all the materials from the upper part of the profile would be heavily contaminated. Alternatively, the older material encountered in the layer 161 could have been washed away from another location and later settled on the investigated site, similarly to the sandy sediments of the layers 162, 145 and 144—which are probably the result of an outwash from some higher positions of the drainage area. In that case the assemblages of biofacts encountered in the upper part of the profile would represent a mixture of material of both local and regional origin. Nevertheless, we suppose that the second scenario is more probable because of continuous succession of anthropogenic indicators in both macro-remains and pollen spectra. On the other hand, it is not possible to determine whether the water reservoir merely changed its character after the middle of fourteenth century or it disappeared and only a wet place with seasonal water influx remained.

Origin and function of the pond

Origin

The existence of the water reservoir is obviously related to the strong springs rising on the boundary between the permeable gravel of the Vinohrady riverine terrace and the underlying impermeable clay and bedrock (Zavřel, unpublished reports). The groundwater emerging from the base of this terrace also probably flowed inside the permeable layers of the secondary transported sands, afterwards seeping out onto the surface. In addition to that, the water from the terrace could also have flowed above the surface creating occasional small watercourses. For all these reasons the site and its near surroundings had been characterised for a long time by a high level of groundwater (Zavřel, 2009, unpublished report) and numerous wetlands and springheads (for more details to the hydrology of the New Town of Prague, see Zavřel (2006)).

The most probable explanation of the pond origin is that this naturally wet place was dammed artificially. However, this could not be proved definitively, as the supposed dam position lies outside the excavation area. Nevertheless, a 50-m section of a brook was found in the close vicinity of the investigated area (Fig. 2) (Kašpar, 2003). There could be two possible interpretations of the mutual relationship between these two features (the pond and the brook): According to the slope direction, either the brook flowed out of the pond, or the brook had no connection with the pond (in which case the pond would probably be very small).

Function

Knowledge of carp breeding and fishpond dam construction came to the Czech lands from West Europe (Makowiecki, 2001), probably with monks from Germany. Before this time, the so-called 'vivaria piscium', i.e. artificial water pools (stews, 'stavy') used for storage of captured fishes (Čítek et al., 1998), were constructed here, probably already since the eightth to ninth centuries (Andreska, 1987). Their existence in Moravia near Olomouc has been supported by a document from 1078 (Hurt, 1960). The oldest reference concerning a fishpond in Bohemia is a mention in the Chronica Bohemorum, in the part relating to the foundation of the Sázava monastery (Kosmas, 2011) in the 11th century. In 1227, the king Ottokar II of Bohemia authorized the construction of fishponds. In the fourteenth century, fish farming was already an important economic activity in the Czech lands. Since the first half of the fourteenth century, small ponds were built in the middle of each village, serving both for fish farming, and as fire water reservoirs (Čítek et al., 1998).

According to the fish species composition and the dating of the sediments, we could assume that the pond could have served for the retention of water and/or storing of fish, but not for fish breeding. During the earlier phases of the pond's existence, the water was clean enough for drinking; however, it was later heavily contaminated by organic material. Still, it could have served as a water reservoir for various handicrafts, as, for example, brickmaking, pottery, ironworking or leather processing.

The further history of the pond remains unclear. The uppermost layers of the sedimentary sequence had been destroyed during the construction of the basement. However, the existence of three ponds belonging to a farmstead nearby was documented even in 1428 (Tomek, 1892). According to historical maps from 1791 (Herget's plan) and from 1816 (Jüttner's plan), this part of the New Town of Prague remained undeveloped (at least not built on) and the ground concerned was a part of some open areas or garden plots.

Conclusions

The results of this study allow the following conclusions:

1. According to the results of the environmental analyses, the material of the lower part of the profile is definitely a result of sedimentation on the bottom of a water reservoir. The duration of the water body was estimated for the period from the end of tenth century to approximately half of fourteenth century according to radiocarbon dating. Several species of freshwater fishes were determined according to bones/scales, but no remains of carp were found. Therefore, we can conclude that this was probably a kind of water reservoir containing fishes; however, it was not a typical fishpond intended for carp farming.

2. The origin of the water reservoir was connected with rich water springs having their source on the slope of the riverine terrace. The pond itself was probably constructed artificially, or alternatively a shallow natural pool could have been deepened and extended. Nevertheless, because the extent of the investigation area was too small, any remains of the dam structure were not documented.
3. The water quality was estimated according to proxy data. We assume that the water was originally relatively clean and the base of the profile was the result of sedimentation in considerably oligosaprobic conditions. However, increasing degree of organic pollution was documented in subsequent layers, caused probably by human influence (occasional waste disposal and defecation of domestic animals).
4. The character of the surrounding vegetation was reconstructed according to both pollen and macro-remains data. Originally, the water body was surrounded by vegetation of semi-natural character (i.e. hygrophilous herbaceous vegetation directly on the banks as well as wet meadows, pastures and willow shrubs in the proximity). Later, gradual changes in the surrounding environment were documented. Increasing ruderalisation and intensification of human impact in closer proximity were manifested by indicators of trampled vegetation and nitrophilous plant species. Additionally, increasing proportion of cereals and decreasing proportion of trees in the pollen diagram indicated the significant changes taking place on the landscape level.

Acknowledgment This research was supported by the project GACR 13-11193S and 'PAPAVER - Centre for Human and Plant Studies in Europe and Northern Africa in the Postglacial Period', reg. No. CZ.1.07/2.3.00/20.0289 and co-financed by the European Social Fund and the state budget of the Czech Republic. We are grateful to Dr. Helena Svobodová-Svitavská for help with ambiguous pollen determinations and to Dr. Miloslav Devetter for valuable comments on rotifers eggs determination. We wish to thank Anna Svatušková for help during the excavation and Steve Ridgill for making improvements to our English.

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