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LATE GLACIAL AND HOLOCENE DEVELOPMENT OF THE VEGETATION IN THE LABE (ELBE) RIVER FLOOD-PLAIN (CENTRAL BOHEMIA, CZECH REPUBLIC)

EVA BŘÍZOVÁ

Czech Geological Survey, Department of Quaternary, Klárov 3/131, 118 21 Prague 1, Czech Republic;
e-mail: brizova@cgu.cz

ABSTRACT. The Labe river was an important factor in the development of the vegetation cover in central Bohemia as early as in the Late Glacial stage and particularly in the Holocene. Palynological study of the organic ox-bow lake sediments of the Labe river revealed the complexity of the notion of flood-plain from the viewpoint of vegetational history and other scientific disciplines. Samples of organic palaeomeander fills were collected for palynological analysis from test borings in the Chrást (CH, CHR), Kozly (KZ, KZL, KZY) and Stará Boleslav (SBL, SB, SBS) localities. Concurrently, samples were collected for radiocarbon dating.

KEY WORDS: Palynology, Labe river, Quaternary, Late Glacial, Holocene, Palaeomeanders, Central Bohemia, Czech Republic

INTRODUCTION

The Labe river has always been an important factor in the development of the vegetation cover in central Bohemia as early as the Late Glacial stage and but particularly in the Holocene. The events that influenced the present-day flood-plain seem to have left their impact on all the major rivers in the non-mountainous parts of Europe (Frenzel 1995). Study of the dynamism of "flood-plain" genesis is, in terms of the development of natural conditions, a complicated problem (a detailed analysis of ideas on the genesis of the Labe river flood-plain was provided by Břízová 1997c). The processes that led to the genesis of the flood-plain were influenced by climate. The historical development of the Labe river and of other major rivers may be summarized as follows (adapted after Frenzel 1995):

1) – at the turn of the Last Glacial peak (pleniglacial) and the Late Glacial stage – anastomosing rivers turned into meandering ones, the flood-plain was stabilized, abandoned channels were infilled

2) – boundary between the Glacial and the Holocene (Younger Dryas/Pre-Boreal) – decline in river energy, formation of flood-plain soils, onset of organic deposition in a quiet environment = further stabilization

3) – Middle and particularly Upper Holocene – a short period of intensive erosion at the boundary of the **Boreal/Atlantic periods 8000 years ago (c. 6000–5500 BP)**; caused: a rapid increase in precipitation towards the end of the Boreal (hydrologic change) and a probable human influence (beginning of agriculture) observed in Poland (Starkel), Hungary (Gábris), Belarus (Kalicki), in the Czech Republic, Moravia (Havlíček), all authors quoted in Frenzel (1995); Bohemia (Břízová 1997b, 1997c, 1997d – Labe river; Beneš 1995 – south Bohemia – Malše and Vl Moldow rivers)

4) – Upper Holocene **(Sub-Boreal/Older Sub-Atlantic boundary) about 2700–2500 BP** – further erosion and genesis of the base of the present-day flood-plain level observed on the Labe river (Břízová – pollen analysis SBL, CH, SBS)

5) – A.D. 400 and the early Middle Ages – colluvial erosion in the flood-plains, **A.D. 1200** – advance of mountain glaciers and continental ice sheets in the Americas and Europe, drop in average annual temperature by 1–1.5°C = arrival of floods culminating towards the end of the Middle Ages and the beginning of modern times

– changes in both the vegetation and the hydrologic river regime were influenced by increased deforestation and by the first floods

– base for the sediments forming the present-day flood-plain was created.

In view of the present state of palynological research in the Labe flood-plain, pollen analysis can provide reliable data on points 2, 3 and 4, further research may elaborate on point 5.

METHODOLOGY

Palynological research of the infilled ox-bow lakes of the Labe river, together with radiocarbon dating (for results of the ^{14}C dating – see Břízová 1997c), were con-

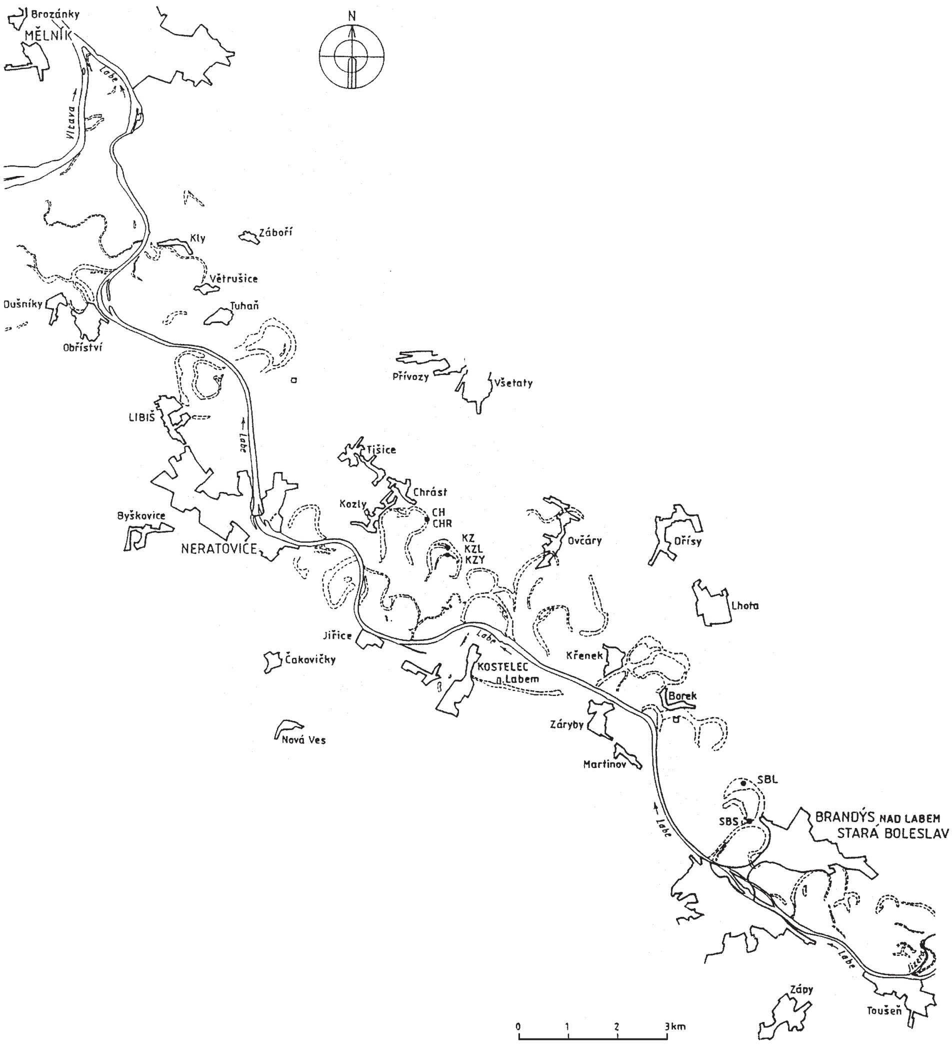

Fig. 1. Sketch map of part of the middle reaches of the Bohemian Labe channel showing the studied palaeomeanders: the higher flood-plain terrace – localities of Stará Boleslav SBL, Chrást CH, CHR, Kozly KZ, KZL, KZY; the lower flood-plain terrace – Stará Boleslav SBS. The abandoned palaeomeanders of the Labe river highlighted by geological survey (Havlíček in Dreslerová 1997) and by aerial photographs are indicated by the broken line

ducted in the localities of Chrást (CH, CHR), Kozly (KZ, KZL, KZY, radiocarbon dating only) and Stará Boleslav (SBL, SBS); Fig. 1. It was compared with earlier studies carried out in the middle reaches of the Bohemian Labe river valley (see Břízová 1994, 1995a, 1995b).

The samples were treated by the usual laboratory methods applied for the separation of Quaternary sporomorphs (Erdtman 1943, 1954, Faegri *et al.* 1964, Overbeck 1958). Stratigraphically, the sediments have been classified after Firbas (1949, 1952).

The individual levels are designated by some authors as the higher and lower flood-plain levels (RůŽičková & Zeman 1994a, 1994b, 1994c, Zeman & RůŽičková 1994, 1995). From the geological (Holásek 1991, 1992 Holásek & Zelenka 1987, 1988), palynological (Břízová 1997b, 1997d) and geomorphological points of view, it is preferable to call these levels the higher and lower flood-plain terraces (Czudek 1997).

RESULTS OF POLLEN ANALYSIS

THE HIGHER FLOOD-PLAIN TERRACE

Two palaeomeanders were analysed palynologically at this level: Chrást (CH) and Stará Boleslav (SBL), while one at Kozly (KZL) was radiocarbon dated. The best-preserved organic infill of the Chrást meander (CH) provided very important results. The infill of the ox-bow lake was two part: 2. a younger part – age IX–X, hiatus of 5000 years, 1. an older part – age I–VI.

Late Glacial (I? Older Dryas 15 000–11 800 BP **– II Alleröd** 11 800–10 700 BP).

Sedimentation started under the more favourable conditions of glacier retreat. The instability of the mostly inorganic sediments has been proved by the redeposition of Cretaceous sporomorphs and those of *Hystrix* type (reaching even into the subsequent III. phase). The individual plant assemblages were, owing to the small thickness of the analysed deposits, hardly distinguishable in detail. Vegetation was still species poor and may have consisted of thinly wooded parkland with tree taxa such as *Betula* and *Pinus*. Climatically more demanding tree taxa may also have been present. The river banks were covered by willow-dominated woodland with local formations of native grassland and herb-dominated photophilous vegetation.

Younger Dryas (**III** 10 700–10 250 BP)

Although a moderate climatic deterioration had set in, a similar depositional setting to the previous one still prevailed. *Betula* made way for *Pinus. Juniperus*, preferring a mineral substrate, also appeared. Willows (*Salix*) occurred probably in shrub form. Surprisingly high pollen values of *Corylus* were found, which can be explained by the redeposition or by the presence and survival of the taxon from more favourable times. *Quercus, Fraxinus* and *Alnus* were found sporadically. Photophil types and various forms of wetland and marsh vegetation dominated among the herb taxa. Radiocarbon data (8150 ± 290 BP: Gd – 9876, 1.55–1.57 m; 6270 ± 250 BP: Gd – 9867, 1.6–1.65 m) from the base of the profile at Chrást (CH) did not indicate the real age of the sediment but revealed an agitated sedimentation on the bottom of the river channel and probable contamination during sampling.

Pre-Boreal (**IV** 10 250–9100 BP)

The climate became warmer again. Sandy substrates were inhabited by *Betula* and *Pinus.* River banks were overgrown by *Salix*-dominated woodland and climatically more demanding tree taxa such as *Ulmus*, *Quercus* and *Fraxinus* appeared, accompanied by the first occurrences of riverside woodland. Aquatic herb vegetation also developed en masse in the form of several species of the genera *Myriophyllum*, *Nuphar* and *Potamogeton*, accompanied by an algal flora (*Mougeotia*). Shallower parts of the ox-bow lakes were occupied by *Phragmites*, *Typha latifolia*, *Sparganium/Typha angustifolia* and *Butomus*. A number of photophilous herb taxa, e.g. *Helianthemum*, and Apiaceae, Rubiaceae, Brassicaceae and the genus *Artemisia* were still present.

Boreal (**V** 9100–7700 BP)

This period was marked not only by warming but also by increased humidity of the climate (e.g. increase in pollen representation of Polypodiaceae). Larger amounts of biomass accumulated and wetland vegetation developed, contributing to the deposition of organic matter and silting up of ox-bow lakes. The flood-plain was dominated by willow woodland, *Phragmites* and from Cyperaceae genus *Carex.* The herb flora became more varied, involving some grassland types such as Lamiaceae and *Mentha,* as well as photophilous elements such as *Helianthemum,* which were still present. The silting up and growth of vegetation in the ox-bow lakes caused a decline in numbers of types requiring open water. The sandy and rocky substrates were entirely dominated by *Pinus* while the edges of the pine-dominated woodlands were overgrown by *Corylus* and *Sambucus racemosa*; *Juniperus* also occurred there. Among the other tree taxa, *Tilia, Fraxinus, Acer, Alnus, Picea* and a *Sorbus torminalis* type occurred, mostly sporadically. Pollen grains of *Picea* were also found in the preceding Pre-Boreal period (probably refugia). The base of the sediments deposited in the Boreal period were radiocarbon dated to 8630 ± 80 BP (Gd – 11 242) at 1.25–1.3 m.

Older Atlantic (**VI** 7700–6000 BP)

At the start of a climatic and vegetational peak in the analysed sediments of the ox-bow lake the Older Atlantic phase was preserved only as a remnant, possibly reflecting an event that had taken place in this area. A gradual development of forest vegetation began. *Pinus* was ousted to mineral substrates, the tree taxa of mixed and riverside woodland appeared on a larger scale: *Quercus, Ulmus* and *Fraxinus.* On the contrary, willow-dominated woodland gradually disappeared and a *Populus* type appeared sporadically. The ox-bow lake seems to have become completely silted up (increase in pollen representation curve of *Phragmites* type). The radiocarbon data of 7240 ± 80 BP (Gd – 11 239) came from a depth of 1.05–1.1 m.

HIATUS of 5000 years

The sediments of considerable parts of the older and younger Sub-Atlantic (VI, VII 6000–5100/4500 BP) and the Sub-Boreal (VIII 5100–2300 BP) periods must have been removed during some kind of erosion which occured on the Labe river.

Older Sub-Atlantic (**IX** 2800/2300 BP – A.D. 500/650/700)

The sediments deposited in this phase were analysed both at Chrást (CH) and at Stará Boleslav. The vegetational changes were influenced both by the climate and by human activity. *Pinus* was still the most pollen-represented tree taxon, being rather widespread on sandy substrates. In my opinion, the riverside woodlands were most probably located further away from the sampling sites, on the so-called lower flood-plain terrace. *Quercus* disappeared or its frequency was considerably reduced, probably due to human activity. *Fagus, Abies* and *Carpinus* began to appear. The higher pollen representation of *Picea* is explained as a possible influx from higher altitudes or, as sugested by some authors, could have been an integral part of the local assemblages (see Břízová

1994, 1995a, 1995b for more detail). Willow-dominated woodlands gradually disappeared, making way for *Alnus*. Man used the wood of some trees as timber. Pasture in the forests is evidenced by the occurrence of *Juniperus*, *Urtica* and *Rumex* while agriculture comprised the cultivation of *Fagopyrum* (perhaps redeposition) and already of Cerealia. Herb taxa indicating meadows and pastureland appeared (e.g. Asteraceae Liguliflorae and Tubuliflorae, Poaceae). The disappearance of *Phragmites* was the result of higher eutrophication of the water, but, on the contrary, types of the family Cyperaceae (mainly in Xa) were more widespread. Towards the end of the period *Alnus*-dominated woodlands also disappeared (? humans). Reduced areas covered by water still existed, being inhabited by *Potamogeton, Myriophyllum* and by algae (*Pediastrum* and *Botryococcus*). The humid microclimate of the *Alnus*– and *Picea*-dominated woodlands was reflected by the mass occurrence of spores of the family Polypodiaceae. The sediments have been radiocarbon dated to 2610 ± 70 BP (CH 2.25–2.3 m, Gd – 11238), 2180 ± 240 BP (CH 1.85–1.9 m, Gd – 10 454), 2516 127 BP (SBL 0.90–0.97 m, CU 1255/296).

Younger Sub-Atlantic (Xa – younger phase A.D. 500/650/700–1200).

Both pollen diagrams show a pronounced fall in the frequency of tree taxa, which is characteristic for large-scale deforestation of the landscape in favour of fields. *Pinus* underwent a distinct decline owing to the clearance and use of trees as timber and firewood; the same trend is visible with *Quercus,* and after its depletion *Pinus, Alnus* and *Salix* were used on a larger scale. The consequence was the spread of wetlands with a herb dominated ground flora (mainly Cyperaceae). The *Salix* and *Alnus* dominated woodlands may have been created by tree planting. *Tilia, Ulmus, Picea* and *Corylus* almost disappeared, although they were sometimes of local importance, (mainly *Picea* and *Tilia*). The expanding area of arable land (cultivation of Cerealia spp., type *Triticum,* type *Secale* and *Fagopyrum*) and more intensive cultivation methods caused the spread of nitrophilous assemblages consisting of *Sambucus nigra, Urtica* and *Rumex*, with Apiaceae and other arable indicators such as *Juniperus, Pteridium* and *Calluna vulgaris.* Forest pasture is indicated by assemblages of weed taxa with *Centaurea cyanus*, *Polygonum* t. *aviculare, P.* t. *persicaria* etc. Indicators of wetlands and stagnant waters were *Potamogeton, Myriophyllum*, Cyperaceae, *Butomus* and *Menyanthes trifoliata*. The final phase in the development of fen-peat was characterized by other microremains, e.g. *Arcella* (Rhizopoda). The definite infilling of the ox-bow lake at Chrást has been radiocarbon dated to 840 ± 60 BP (CH 0.05–0.12 m, Gd – 11262).

LOWER FLOOD-PLAIN TERRACE

The palaeomeander at Stará Boleslav (SBS) has yielded interesting results from pollen analysis. Its organic fill began to be deposited at the beginning of the Christian era (1920 ± 70 BP, SBS 2.25–2.3 m, Gd – 11 236) lasting probably until the 15th century.

Older Sub-Atlantic (IX 2800/2300 BP – A.D. 500/650/700)

Period IX was characterized by tree taxa such as *Fagus, Abies, Carpinus* and *Picea*. Here though they were only slightly represented by pollen grains which they could have been transported from more distant places.

Pinus appeared rather rarely, thriving better on the more elevated higher flood-plain terrace, in sandy and rocky places. Typical flooded riverside woodland with *Quercus, Ulmus, Tilia, Fraxinus, Acer, Populus, Alnus* and *Salix* grew at lower levels.

The shrub level with *Frangula alnus, Sorbus, Sambucus nigra, S. racemosa, Ligustrum, Viburnum*, *Cornus mas* and *C. sanguinea* was also rich in species.

Open water level was indicated by *Myriophyllum, Potamogeton, Nuphar, Nymphaea* t. *alba* and *peltata* and by algae (*Botryococcus, Mougeotia, Pediastrum).* Towards the end of IX silting up was already complete, as is documented mainly by the pollen grains of *Phragmites* and *Typha latifolia*.

The consequence of agricultural activities was the clearance of alder-dominated woodland, other tree taxa also being exploited. Crop cultivation also began to appear (1st period: at the start of deposition of organic matter at the beginning of the Christian era, 2nd: from the middle to the end of IX, 3rd: from the beginning of the 10th century crop cultivation continued until the 12th century when it became more intensive) being associated with the occurrence of arable indicators and nitrophilous assemblages (the genera *Rumex* and *Artemisia,* and the families Apiaceae, Brassicaceae, etc).

The curves of the spores of *Thelypteris palustris* and *Equisetum* rise towards the end of IX, indicating again a flood-plain assemblage.

Younger Sub-Atlantic (Xa – older phase, 6th – 13th century A.D.)

The pollen curves of tree taxa show a fall, the shrub level also gradually disappeared, the *Alnus*-dominated woodlands made way for *Salix*-dominated ones and fields; *Pinus* became more widespread. More varied weed types and indicators of human activity such as *Centaurea cyanus*, *Agrostemma githago* and plants typical for medieval settlements such as *Xanthium* cf. *strumarium*, *Bryonia alba* type, and *Echium* occurred on a larger scale. Intestinal parasites of humans and pigs such as *Ascaris* cf. *lumbricoides* and *Trichuris trichiura* also appeared, as in medieval Prague (Břízová 1997a, 1997e) and Budeč (Břízová & Bartošková 1994).

Wetland plants such as *Filipendula,* Cyperaceae*, Butomus*, *Thalictrum*, Ranunculaceae*,* the spores of Polypodiaceae, and *Thelypteris palustris* indicate swampy areas. Filling of the ox-bow lake is reflected by the mass distribution of *Phragmites* type, particularly in the second half of the period. The age of the Xa sediment is also indicated by two dating results 880 ± 70 BP (Gd – 11235) at 0.6–0.65 m and 1240 ± 80 BP (Gd – 10370) at 1.2–1.25 m.

Younger Sub-Atlantic (Xb – younger phase, 13th century – present day)

The pollen diagram shows a marked decline in tree taxa of riverside woodlands and of *Fagus, Abies, Carpinus* and of the shrub flora. On the contrary, *Pinus*-dominated woodlands developed, which is a consequence of human activity and climatic changes (possible onset of the so-called little ice age).

The herb taxa were again represented by indicators of human activity and cereals. Mainly types of Polypodiaceae and destroyers of organic matter such as Ascomycetes and lesser amounts of *Arcella* (Rhizopoda) were found among the spores.

SUMMARY OF THE RESULTS OF POLLEN ANALYSIS

Profiles for pollen analysis from the organic infills of the Labe palaeomeanders in the area between Nymburk and Mělník in the Chrást (CH, CHR), Kozly (KZ, KZL, KZY) and Stará Boleslav (SBL, SB, SBS) localities were sampled. Those that extended over the longest time interval, were evaluated in detail.

The collected samples were treated in the laboratory by the usual methods applied for the separation of Quaternary sporomorphs: maceration in HF for about 24 hours, Erdtman acetolysis (Erdtman 1943, 1954), conservation in a mixture of glycerine, ethyl alcohol and distilled water.

Samples for radiocarbon dating were collected concurrently and were treated in the laboratories in Prague (Faculty of Science, CU) and at Gliwice in Poland (Laboratorium C-14 Instytutu Fizyki Politechniki Śląskiej, Gd). The radiocarbon dating results were published in a report by the present author (Břízová 1997c).

Stratigraphic evaluation of the profiles was based on the Central European classification of Firbas (1949, 1952).

Detailed palynological evaluation and comparison with the results of radiocarbon dating revealed very complicated conditions during the silting up of the studied meanders.

Meanders in the so-called higher flood-plain terrace display infills of two types: the Chrást (CH) profile is rather complicated because one of the infills may be missing. Radiocarbon dating in the Chrást (CHR) profile indicated that the upper, younger part was absent, whereas on the contrary, the Stará Boleslav (SBL) and Kozly (KZ) profiles revealed the absence of the lower organic infill. The first, lower infill of the ox-bow lake was formed during the Late Glacial stage up to the start of the older Atlantic. The second, younger, upper infill was deposited during the episode starting at the older Sub-Atlantic and lasting until the older phase of the younger Sub-Atlantic.

The silting up of the palaeomeander in the so-called lower flood-plain terrace began in the older Sub-Atlantic (roughly at the beginning of the Christian era) and lasted until the 14th or 15th centuries A.D. (maybe even later; the uppermost 0.3 m have not been palynologically analysed owing to possible contamination by recent pollen grains).

The changes in the development of the vegetation in the sediments of the meanders can be traced from the Late Glacial stage (Alleröd) through the Pre-Boreal, Boreal, part of the older Atlantic to the older Sub-Atlantic (partially up to the younger Xb phase) until approximately the 14th or 15th centuries A.D. A considerable part of the sediments of the Atlantic (the older and particularly the younger) and the Sub-Boreal periods are missing in the studied palaeomeanders. The vegetation sequence corresponds to Central European conditions with respect to the nature of the sediment (swampy ox bow lake) and the regional setting (warmest part of the Czech Republic).

Since the study area was inhabited by man very early, the limited data avaiable indicate that from the older Atlantic period man had lived in harmony with nature, benefiting from it but not destroying it.

Human impact on the natural ecosystems began as late as the beginning of the second half of the older Sub-Atlantic. The earliest activity was the development of pasture followed by crop cultivation towards the end of the period.

Crop cultivation began at the beginning of the Christan era after the sedimentation of organic matter in the abandoned channel at Stará Boleslav SBS and devaloped with some interruptions, from the middle until towards the end of 9 at the start of the 10th century. It became more intensive in the 12th century, much earlier than was the case at higher altitudes and cooler areas of the Czech Republic (where it has been dated to have started as late as in the 13th century, A.D., locally even later).

The principal trees on the higher flood-plain terrace were mainly *Pinus,* with other taxa such as *Alnus, Quercus* and *Salix* being less frequent; on the lower flood-plain terrace *Pinus* was displaced somewhat by *Alnus, Salix* and *Quercus.*

The finds of egg-causes of the parasitic worm *Trichuris trichiura* (intestinal parasite of humans and pigs) and of *Ascaris* cf. *lumbricoides* that appear mainly in the anthropogenic sediments of medieval Prague (Břízová 1997a, 1997e) and those of the early medieval fortified settlement of Budeč (Břízová & Bartošková 1994) are worth mentioning.

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