Climatic versus human modification of the Late Quaternary vegetation in Eastern Hungary

Doktori (PhD) értekezés tézisei

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Debrecen, 2002.

1. Introduction and aims

The history of vegetation during the Ice Age and since the last glacial period, the Weichselian, has occupied Hungarian researchers for almost a century. In eastern Hungary the first pollen analyses were done by *B. Zólyomi, Z-né. Borsy, G. Csinády, E. Vozáry* and *M. Járai-Komlódi*. They mainly analysed Late Glacial and Holocene oxbow lake sediments. Apart from the studies of *Járai-Komlódi*, most pollen analytical work was connected to research projects the primary purpose of which was the elucidation of geomorphological problems such as the Weichselian channel migration of the Tisza. Therefore, the pollen diagrams emerged from these studies were usually of low resolution, consequently the interpretation of the vegetation changes missed a spatial consideration of the plant community changes and the inter-site comparison of the sequences along absolute timescales. Moreover, the weakness of these studies lies in the use of an arboreal pollen (AP) sum, the ignorance of non-arboreal pollen types and the general acceptance of the Central-European scheme for the subdivision of the Holocene.

In contrast with the earlier pollen diagrams, *Félegyházi's* lowland and North Hungarian mountain profiles were often supplied with radiocarbon dates, moreover she paid special attention to the identification of non-arboreal pollen types and the various algae that often accompanied the pollen grains on the microscope slides. As a result of an Anglo-Hungarian research project in the last couple of years, several multidisciplinary analyses were carried out in the Great Hungarian Plain and North Hungarian Mountains by *K. J. Willis, R. Andrews, G. J. Harrington* and *A. R. Gardner.* The pollen diagrams that resulted from these investigations have relatively high-resolution necessary for the identification of short-term vegetation changes, and in most cases the chronology is based on serial radiocarbon age determinations. These studies were initiative in the selection of sites for the present study; moreover, we aimed to obtain data comparable with these radiocarbon-dated, high-resolution diagrams. The principal idea was that in the near future local pollen assemblage zones be used to establish regional pollen zones for the various biogeographical units of the Carpathian basin.

The area originally selected for investigation in this thesis was delineated on the basis of some recent biogeographical observations. According to these, the distribution area of several Sub-Mediterranean species characterised by Pontic and Balkan area-centres shows a northern extension along the piedmont of the Eastern Carpathians (Figure 1) and along the major rivers of the eastern Great Hungarian Plain including the Romanian territories. The northern limit of this zone can be identified in Ukraine, in the vicinity of Munkács. *Tilia tomentosa* reaches its northern distribution limit in this area (Figure 1). In the malacoufauna, the pontic species, *Pomatias rivulare*, extends as far north as Bátorliget, whereas the distribution of a typical Sub-Mediterranean forest association, Quercetum frainetto (xerotermic oak forest), forms a tongue in the southern part of the area (Figure 1).

This area has a unique and especially diverse climate: the continentality of the lowland is attenuated by orographic precipitation, whereas the geomorphological diversity with Karst Mountains, river valleys and volcanic hills provides a range of habitats from dry and warm to cold and humid micro- and mesoclimates. The piedmont and adjacent lowland areas have a dual character that must also have existed during the climatic deterioration of the last glacial period (Weichselian). Therefore, it is conceivable that the warm temperate flora survived in micro- and mesoclimatic oases, e.g. on the south-facing slopes, during the glacial period, whereas the cold and humid places must have rescued some elements of the cold tolerant boreal flora in the Holocene (e.g. *Ligularia sibirica*, *Iris hungarica*). Furthermore, the actual biogeographical observations led scientists to propose a migration route along the piedmonts and adjacent lowland areas that could have played a particular role in the Late Glacial and early Holocene northward expansion of the warm temperate flora and fauna.

These ideas, though supported by weighty biogeographical arguments, have not yet been evaluated by palaeoecological data. Therefore, our aim was to collect sedimentary sequences along a SE-NW transect in this region (Figure 1) and address these question through the pollen analysis of Upper Pleniglacial, Late Glacial and Holocene deposits. It was obvious that in three years and in scope of a PhD research budget one cannot analyse the great number of cores necessary for the demonstration of the time-transgressive spread of warm temperate trees in this area; however, we hoped that the analysis of a smaller region, namely the northern part of the transect, will contribute valuable data to the Upper Pleniglacial, Late Glacial and Holocene vegetation development of the Carpathian basin that can be later expanded by moving south along this transect.

Five sites were selected: one peat bog: **Nagymohos** , and three oxbow lakes in various stage of infillment: **Fehér-tó, Sarló-hát oxbow, P-I palaeochannel** and **Báb-tava** (Figure 1).

In the light of the above theoretical considerations this research focused on the following aspects:

1. Re-investigate and re-evaluate the Upper Pleniglacial and Holocene regional vegetation history of north-east Hungary using a number of techniques and approaches not available earlier for Hungarian palynologists.
2. Increase the resolution of the pollen records by using 2-8 cm sub-sampling of the sediment cores.
3. Determine local pollen assemblage zones at each site using consistent and reproducible numerical zonation techniques and use PCA for the inter-site comparison of the pollen spectra.
4. Examine the wetland successions by means of physical, microfossil and plant macrofossil analyses.

5. Reconstruct natural and human-induced fire histories by means of micro-charcoal analysis.
6. Estimate floristic richness from the palynological richness of the sediment samples and relate Holocene dynamics of estimated floristic richness to disturbance from fires and other human impacts.
7. Use pollen concentrations and influxes to estimate quantitative changes in the arboreal populations.
8. On the basis of points 2-7 interpret at higher temporal and spatial resolution the vegetation development for each pollen assemblage zone delineated.
9. Finally, examine the time-transgressive spread of beech (*Fagus sylvatica*) and hornbeam (*Carpinus betulus*) during the Holocene along the eastern migration route.

2. Methods

The majority of the cores was obtained using a 5-cm diameter modified Russian corer. To avoid disturbance at the core tops, overlapping cores, 0.5-1m apart were taken and adjusted using sediment stratigraphy. The uppermost sediment of Fehér-tó was sampled using a modified Livingstone corer with a chamber of 100-cm length and 10-cm diameter. All cores were extruded in the field and wrapped in plastic film and aluminium foil before transporting to the laboratory, whereupon they were stored at +2°C to prevent desiccation and growth of microorganisms. Cores were described in the laboratory. The descriptions consisted of a trivial part and a characterisation following the system developed by *Troels-Smith*.

For the determination of sediment organic and carbonate content loss on ignition was used at 550 and 900°C. The weight-loss-on-ignition was calculated as percent of dry weight and converted to percentage inorganic and carbonate content by subtracting LOI values from 100.

Grain size composition was determined in the Fehér-tó (FT-I) and P-I palaeochannel (P-I) cores. Coarse material (> 63 mm) was removed and fractionated by wet sieving. The frequency of fractions finer than 63 mm was generated using the hydrometric method of *Papfalvy*.

Humification measurements were only made on the peat samples of Nagymohos peat bog. 1 cm^3 sub-samples taken at 4 cm intervals from the peat core were treated using the colorimetric method of *Aaby & Tauber*.

Chemical elements were analysed in the Nagymohos (NM-II) core. The principal aim of geochemical analysis has been to provide a record of past soil erosion within the catchments.

Dried samples from Nagymohos taken at every 4-cm were digested with 65% nitric-acid and 25% hydrogen-peroxide using a modified technique of *Bengtsson & Enell*.

To study lake-productivity in the shallow lake phases of Nagymohos, we extracted pigments in 100 ml 90% acetone from 1 cm^3 sub-samples taken at 29 levels.

Chlorophyll derivatives (CD) were measured as the absorbance of raw acetone extract at 666 nm.

Conventional radiocarbon dating was performed on bulk samples by the Nuclear Research Centre of the Hungarian Academy of Sciences, Debrecen. The minerogenic oxbow sediments of Báb-tava, P-I palaeochannel and Sarló-hát could not be dated using conventional techniques, therefore an acid-solution treatment was deployed that is widely used in the radiocarbon dating of fossil soils.

Among the cores examined in scope of this study a great variety of sediments prevailed that required different pollen concentration techniques to be used. Apart from the standard chemical process of *Berglund & Ralska-Jasiewiczowa* that is a solution technique resulting in the removal of the organic matrix and mineral particles of the sediment, density separation, fine sieving combined with bleeching were applied for the clayey oxbow sediments of Fehér-tó and Sarló-hát to attain a better concentration of pollen on the microscope slides.

Slides were analysed using Nikon and Zeiss Laboval 4 light microscopes fitted with x10 and x15 magnification oculars and x20, x40, x100 objectives. Algae, ascospores, mycelium and fruit-bodies of fungi, rhizopods and other fossils were identified using the descriptions and illustrations of Van Geel.

The basis for calculation in the percentage pollen diagrams is, for all terrestrial taxa, this pollen sum. Aquatic pollen and Pteridophyta spore percentages (A) were calculated using the formula A/(M+A).

Quantification of microscopic charred particles on the pollen slides was performed using the point count estimation method of *Clark*. By this method, the surface area of charcoal per unit volume of sediment (x cm^2cm^{-3}) could be calculated.

Numerical and multivariate analyses were performed using PSIMPOLL 2.27 and 3.00 (*Bennett*), Statistica 5.1 and Nucosa 1.05 (*Tóthmérész*).

Rarefaction analysis was used to estimate E(Tn), the number of terrestrial pollen and spore taxa in n grains at each sample, as a measure of temporal changes in palynological diversity, termed palynological richness by *Birks & Line*.

Ordination techniques were used to identify the major gradients both in the terrestrial and wetland pollen data. From NM-II, BT-I, SH-II and P-I the most abundant pollen and wetland microfossil types were selected and used for the chord distance calculation.

3. New results and establishments

3.1. Methodological improvements

3.1.1. For the laboratory preparation of minerogenic oxbow-lake deposits I have developed a technique that is a special combination of already known chemical and physical treatments: micro-sieving is combined with bleaching. Using this method a better concentration of pollen grains was achieved, since the lignose fine organic fraction of the sediment was efficiently removed (see Chapters 3.9. and 4.3.).

3.1.2. I have first applied in Hungary the comprehensive and detailed analysis of non-polliniferous microfossils in peat deposits (e.g. Rhyzopoda, Meliolaceae, Chironomidae, *Gelasinospora sp.*, *Microthyrium sp.*, *Tilletia sphagni*, *Helicoon sp.*, *Callidina angusticollis* (Rotatoria), Zygnemataceae, Chlorophyceae) using the descriptions and illustrations of Van Geel. Taking into account the ecological indicator value of these taxa, a more exact palaeoenvironmental characterisation of the wetland successions was achieved.

3.2. Results in pollen taphonomy

3.2.1. I have attempted to throw light on the principles of pollen deposition in the oxbow lakes of Eastern Hungary. By drawing up a general model, I applied correlation analysis on the grain-size and pollen frequency data and demonstrated that during floods the water-born component of the sediment increases. On the other hand, I failed to demonstrate that during floods differential settling driven by different size and terminal velocity of the pollen grains takes place. What seemed more likely from these data was the different overall pollen load of the floodwater that settled uniformly. The main feature of the pollen load is the higher representation of floodplain pollen types.
In my opinion, this can be explained by the characteristics of floodwater flows from the active channel to the oxbows. Lateral floodflows spread across the entire floodplain carrying slackwater to the abandoned channels. On the way, however, the water flushes the wetland vegetation re-suspending pollen from the surface that will later settle in the meanders as the current velocity decreases.

3.2.2. I have found close connection between grain-size distribution and total pollen concentration (TPC) in the examined oxbow-lake sediments. In the Upper Weichselian sequence of Fehér-tó, higher sand frequencies were coupled with high TPCs pointing to long-distance pollen transport, probably from the upstream catchment of the river. Higher resolution analysis of the P-I meander completed these findings by that the steepest decrease of the sediment accumulation rate was found in the final stage of the high flood-frequency periods and this has coincided with peak TPCs.

3.2.3. In the horseshoe-shaped Late Glacial and Holocene meanders, total pollen concentrations gradually increased from the bottom to the core top. Using this regularity I inferred a common mechanism in the sediment accumulation of the lowland oxbows of the Great Hungarian Plain (Báb-tava, Sarló-hát). Therefore, modelling of the sediment accumulation can be achieved if large number of radiocarbon dates becomes available.

3.3. Stratigraphical results

3.3.1. Comparative analysis of the Upper Pleniglacial pollen sequences revealed cyclic changes in the vegetation cover of Eastern Hungary with a periodicity of ~2000 years between *ca.* 25000 and 14600 cal. yr. BP. I have distinguished three milder phases with higher vegetation cover (EH-1: ? – ~ 24500; EH-3: ~ 22700–21400; EH-5: ~19500–18500 cal. yr. BP) and three colder phases when cold continental steppe and tundra-steppe expanded. These oscillations were correlated with the Heinrich 1 and 2 and Dansgaard-Oeschger 2 climatic oscillations of the deep-sea and Greenland ice cores, and also with the Upper Pleniglacial microinterstadial – stadial fauna phases of the loess-mollusc analyses.

3.3.2. Comparative analysis of the Holocene pollen sequences from the NE Great Hungarian Plain (GHP) revealed five distinctive vegetation phases that however were not regarded as regional pollen zones in Cushing's concept. I have correlated these phases with the Holocene vegetation zones of Járai-Komlódi and partly reinforced her establishments concerning the Holocene vegetation development of the NE GHP. On the other hand, using radiocarbon measurements I have elucidated the chronological framework of the Holocene vegetation phases and improved Járai-Komlódi's interpretation of the Holocene vegetation development. According to this, in the early Holocene, up to *ca.* 10200 cal. yr. BP, the NE GHP was covered by boreo-nemoral forest steppes. In the canopy, deciduous trees dominated. Between *ca.* 10200 and 5400 cal. yr. BP, warm temperate mixed-oak forest elements spread, but the regional vegetation remained open forest steppe, only in the Bereg-plain did closed forests develop. Hazel (*Corylus avellana*) was abundant through this phase. Between about 5400 and 3700 cal. yr. BP the share of hornbeam (*Carpinus betulus*) and later beech (*Fagus sylvatica*) gradually increased at the expense of hazel and elm (probably *Ulmus campestris* and *U. laevis*). Between 3700 and 2000 cal. yr. BP beech and hornbeam became the major constituents of the canopy besides oak (probably *Quercus petraea*, *Q. robur*, *Q. cerris* and *Q. pubescens*). The frequency of beech and hornbeam in the forest could have attained 40-45% in the Bereg Plain. Apart from the increasing human disturbance the density of the forest stands was the highest in this phase. In the Middle Tisza Region forest stands showed the same increase in the canopy, however, differed markedly from the Bereg Plain in that the naturally treeless areas of the early and middle Holocene have not become forested in this phase.

The recent potential vegetation of the NE GHP was formed about 2000 cal. yr. BP, when beech and hornbeam withdrew from the forests and oak attained dominance again in the zonal vegetation. In the Bereg Plain beech and hornbeam survived up to present. Human disturbance has become decisive in the vegetation changes since *ca.* 2000 cal. yr. BP.

3.3.3. On the basis of my pollen analyses, the climatic optimum of the Holocene was between *ca.* 7350 and 6750 cal. yr. BP in NE Hungary. In this period, oak (*Quercus spp.*) species spread at the expense of hazel (*Corylus avellana*). I have explained the advantage of oak with an increase in the length of the growing season and the attenuation of the early spring and late autumn temperature extremes. In addition, moisture availability (a) could have also increased.

3.4. Palaeoenvironmental results

3.4.1. I have pointed out by the palaeoecological investigation of the Upper Pleniglacial peat and shallow lake deposits of Nagymohos that in the southern mire basin about 25300 cal. yr. BP a stone pine (*Pinus cembra*) fen-wood was formed. The closest analogue to this can be found in Western Siberia today. The understorey was made up of brown mosses (identified by Gusztáv Jakab) and boreal wetland herbs (*Carex nigra***, *Carex rostrata***, *Eriophorum sp.*, *Potentilla palustris*, *Polygonum bistorta*, *Filipendula ulmaria*). According to the microcharcoal analysis, this fen-wood was burnt down about 24000 cal. yr. BP. Subsequently, between *ca.* 23200 and 21000 cal. yr. BP the southern basin of Nagymohos turned into a shallow lake as a result of paludification. The marginal area of the lake was covered by poor fen hollow and hummock associations. At the same time, pines (*Pinus cembra*, *Pinus sylvestris*) withdrew from the surrounding slopes, and an expansion of cold continental steppes, arctic-alpine meadows and talus slope associations commenced (characteristic species of the latter two were *Soldanella sp.*, *Polemonium coeruleum*, *Saxifragaceae*, *Sedum sp.*, *Androsace sp.*). Among the arboreal species only juniper (*Juniperus sp.*) and larch (*Larix sp.*) advanced. The species composition of the LGM flora most resembled the transitional zone between the present day boreal forest and forest tundra zone of NE Europe and Western Siberia.
** seeds

3.4.2. By comparing the Holocene hydrosere and terrestrial vegetation development of Nagymohos, I have pointed out that the wetland succession from shallow lake to poor *Sphagnum*-fen via an eutrophic fen phase was interrupted two occasions: between *ca.* 7250-7000 and 6700-6500 cal. yr. BP. In both cases, the mire water table and nutrient level increased temporarily. On the basis of palynological, peat humification, geochemical and organic content data these changes were brought about by human induced soil erosions, i.e. selective tree felling entailed an increase in surface run-off and so the water level increased.

3.4.3. The oxbow lake, Báb-tava, was cut-off from the active channel about 7760 cal. yr. BP. A distinctive feature of the terrestrial vegetation development of the area was the permanence of high hazel (*Corylus avellana*) abundances. This has came to halt only about 3700 cal. yr. BP when hornbeam (*Carpinus betulus*) and beech (*Fagus sylvatica*) invaded the forests. Between *ca.* 6800 and 6250 cal. yr. BP, spruce (*Picea abies*) occurred and increased temporarily in the forest indicating short-term deteriorations of 200-300 years.

3.4.4. The Sarló-hát oxbow lake was formed by neck cut-off about 17100 cal. yr. BP. The pollen analysis of the Holocene part of the sequence revealed that the southern part of Takataköz and the Borsod floodplain were covered by warm continental forest steppes throughout the Holocene. The highest forest cover was attained in the middle Holocene (about 70-75%). In the herbaceous flora characteristic species of the high stalk wet meadows and continental steppes of the Euro-Siberian forest steppe zone prevailed (e.g. *Artemisia spp.*, *Cirsium spp.*, *Aster*-type, *Anthemis*-type, *Ranunculus spp.*, *Peucedanum spp.*) on the basis of which I concluded that that some edaphically or hydrologically constrained areas supported natural meadows throughout the Holocene. Hazel (*Corylus avellana*) started to spread at *ca.* 9600 cal. yr. BP and only withdrew from the forests about 3400 cal. yr. BP.

3.4.5. In collaboration with English and French colleagues, the pollen sequences were subjected to palaeoclimate reconstruction using Guiot's transfer function method. I have pointed out that in Eastern Hungary the mean temperature of the coldest month (MTCO) showed remarkable fluctuation between *ca.* 25000 and 15000 cal. yr. BP. I found three milder-winter periods, around 25000 cal. yr. BP and between *ca.* 20500-20000 and *ca.* 19000-18500 cal. yr. BP. Winter mean temperatures were 6 to 10 ^{O}C lower than today. The winter and summer mean temperature anomalies showed minima and maxima at different times. Mean temperature of the warmest month (MTWA) showed the highest negative anomaly around 21500 cal. yr. BP; temperatures were about 7.5 ^{O}C lower than today. As far as the anomalies, the SE GHP showed markedly higher anomalies for each climatic parameter than the Putnok Hills in North Hungary, although the absolute values were lower in the latter area.

3.4.6. The Holocene climate was investigated in the NE GHP. I have put the emphasis on the bioclimatic parameters such as GDD5, a, AET/PET, P-PET. Growing degree-day sums above 5 ^{O}C (GDD5) were about 700-400 ^{O}C lower than today up to 9000-8500 cal. yr. BP in the NE GHP; between *ca.* 8000 and 3500 cal. yr. BP GDD5 values were in average 100 ^{O}C higher, but with a remarkable fluctuation (the anomaly was the highest in the Bereg Plain: 400 ^{O}C). Between *ca.* 3500 and 1500 cal. yr. BP GDD5 was lower than today.
In the middle Holocene MTWA was in average 0.5-1 ^{O}C higher, but we got negative anomalies as well.
The most humid period of the Holocene was between 3000 and 1000 cal. yr.

BP in NE Hungary. Moisture availability indices (a) were the lowest between *ca.* 8500 and 8300 cal. yr. BP on the basis of which I inferred a *ca.* 200 years draught period.

3.5. Human impact

3.5.1. According to my pollen analyses, arable farming first occurred in the southern part of the investigated area (NE Hunagry) and younger dates were obtained in the Bereg Plain and Putnok Hills. All radiocarbon dates fell between 7900 and 7100 cal. yr. BP that corresponds to the Neolithic in Hungary. In particular, *ca.* 7900 cal. yr. BP (Sarló-hát) and 7800 cal. yr. BP (Nagymohos) indicate that in the analysed regions cereal cultivation started almost coincidentally with the prevalence of the earliest Neolithic cultures.

3.5.2. The first remarkable soil erosion coupled with grazing and/or forest burning occurred in the Late Neolithic around Sarló-hát and Nagymohos (*ca.* 7000-6800 cal. yr. BP), whereas the soils and the forests remained relatively undisturbed until the Middle Copper Age (*ca.* 6000 cal. yr. BP) around Báb-tava.

3.5.3. Permanent decline in the forest cover commenced in the Middle Bronze Age (*ca.* 370 cal. yr. BP) as the earliest in the Bereg Plain. This decline delayed *ca.* 700 years in the Taktaköz and only occurred in the Early Iron Age. From these dates the forests have never returned to natural state: due to selective felling and forest burning species composition altered permanently.

4. Publications and conference presentations

4.1. Papers in journals and proceeding volumes

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