Reconstruction of flora, soil and landscape evolution, and human impact on the Bereg Plain from late-glacial up to the present, based on palaeoecological analysis

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Introduction

The Great Hungarian Plain, called "Alföld" in Hungarian, is the biggest sedimentary basin in Europe, filled with Neogene sediment of great thickness. The geological evolution of the Pannonian basin started in the Miocene. Parallel with the uplift of the Carpathian mountain arch, the inner part of the surrounded territory began to subside. The Pannonian Sea, a subsidiary of the Tethys Sea, cut through the newly developed basin. In this basin 2000-3000 m thick marine sediments (conglomerates, sandstone, marls, clays), then 1000-2000 m thick lake sediments were deposited during the Late Tertiary. At the terminal part of Tertiary the basin bottom became land surface due to the epirogenetic rise of the Carpathians. Fluvial sedimentation started in the inner part, at about the beginning of Quaternary. As a result of fluvial activity, a 600-700 m thick sedimentary series accumulated in the deepest parts of the basin (Sümeghy, 1944, Rónai, 1985).

Rivers entering the Alföld built extensive alluvial fans in the Quaternary age (Sümeghy, 1944, Borsy et al. 1969). Of the large, sand-covered alluvial fans one evolved in the northeastern part of the Alföld (called "Nyírség") (Fig.1.). Between the sand-covered surface of the Nyírség and the volcanic mountain range, which follows the Carpathians as an inner ring, there is a lowland intersected on the surface by innumerable rivers and brooks. This lowland consists of two late Pleistocene-Holocene neotectonic catchment basins ("Szatmári-sík", "Latorca-basin") and an inter-basin region ("Tiszahát") situated in the southern part of the Carpathians (Rónai, 1985, Borsy, 1990, 1995, Borsy-Félegyházi, 1983, Borsy et al. 1989).

From the point of view of evolution, the northeastern part of the Alföld is one of the most specific regions in Hungary. It is in this part of the country that the relief conditions and the network of rivers suffered the most dramatical transformations during the last (Weichselian) glacial. All the watercourses coming from the Carpathians and North Transsylvania had a role in the evolution of the alluvial fan plain. The main river, River Tisa with its tributaries used to flow across the Nyírség alluvial fan until the beginning of the Weichselian (Fig. 2.). The Nyírség depression served as catchment for the alluvial deposits of the river rising in the NE Carpathian Mountains, until approximately 30.000 BP years ago when successive tectonic events interrupted the accumulation of alluvial sediments. Then, primarily due to tectonic causes, the river flowed into the area of the present-day "Ér-valley" (Borsy, 1995), which is situated on the border zone of the Transsylvanian Mountains and the eastern part of the Great Hungarian Plain (Fig.3).

A process of subsidence, more intense than ever before, started in the Szatmár-Bereg Plain during the Late Pleistocene (Sümeghy, 1944). As a consequence of the subsidence, a completely new network of watercourses developed, which, in the course of their erosion and deposition, transformed the sinking area into floodplains. This subsidence was, for a time, counterbalanced by the aggradational work of the river. In the middle pleniglacial period River Tisa leaving the Ér-valley meandered over the area of the Szatmár-Bereg Plain from north to south (Fig.4.).

Thus, changes of the riverbeds were frequent (Borsy, 1995, Borsy and Félegyházi, 1983) in this plain (Fig.5.). In the Szatmár-Bereg Plain the levees and river channels had an important role in sediment formation as well as in the evolution of swamps and areas with bad outlet. One of the most important peat bog areas, which is a nature protection area called "Nyíres-lake", can be found in an infilled river channel at Csaroda village in the Bereg plain.

This paper presents the results of a interdisciplinary study, whose principal aims were to examine the long-term relationship between land degradation and human activity. This paper shows the evolution of a natural environment in the Csaroda region of northeastern Hungary, using various palaeo-ecological techniques, from the late-glacial to Middle Age. In conjunction with a detailed review of regional archaeological data, these results detail for the first time the long-term relationship between different prehistoric cultures, technologies and the degradation of the northeastern Hungarian landscape.

Chronological and palaeo-ecological investigation of the sedimentological sequence of "Nyíres" lake at Csaroda

Site description

The Nyíres-lake (48° 22" N and 22° 30" E) is situated in the Tiszahát region, near the margin of the Great Hungarian Plain, approximately 11 km from the Hungarian-Ukrainian border. The Tiszahát is the northeastern region of the Great Hungarian Plain, a small region occupying cca. 500 km2 of the Carpathian Basin. This lake basin is a development of the Tisa riverbed and represents an infilled oxbow lake of clay and organic matter, overlain with fluvial sand.

The present vegetation of the Nyíres-lake consists of Sphagnum bog and stands of Betula pubescens. Inwards the peat-bog the vegetation is dominated by Eriophorum vaginatum - Menyanthes trifoliata - Vaccinium oxycoccus –Drosera rotundifolia – Comarum palustre plants mixed with Sphagnum species, whilst on the edge Dryopteridi - Alnetum association with Thelypteris palustris, and Calamagrosti - Salicetum cinereae association with Betula pubescens have developed (Simon, 1960). Scripo-Phragmitetum association with Glyceria maxima encircles the Sphagnum bog. Oak-ash-elm (Quercus robur - Fraxinus excelsior – Ulmus campestris) gallery forests are found in the levee zone, which are the highest elevations of the peat-bog areas.

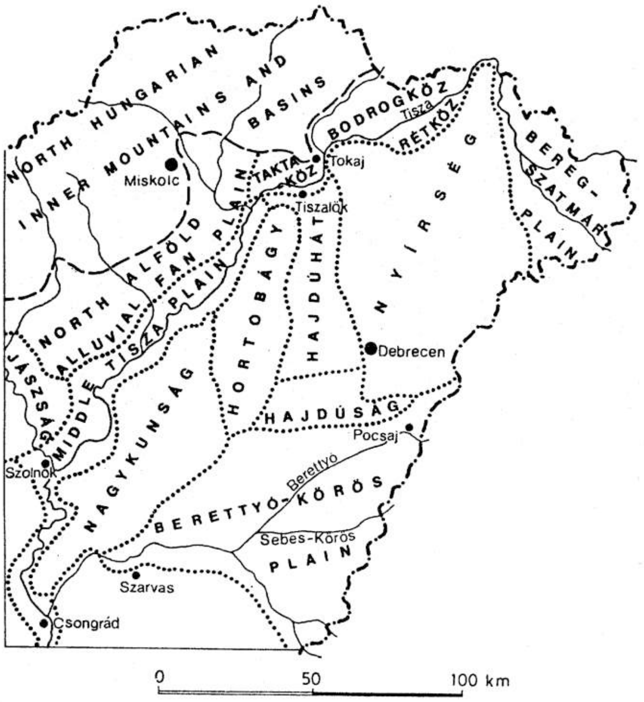


Fig.1. The geographical region within the Nyírség region of northeastern Hungary.

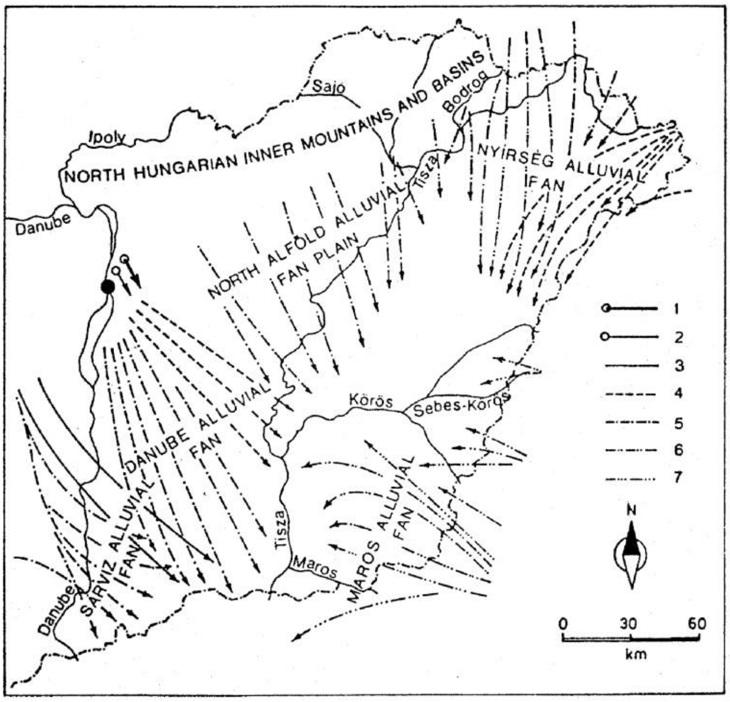


Fig.2. Tendencies of alluvial fan evolution in the Great Hungarian Plain (based on Borsy, 1995).

1. The part of Lower Pleistocen alluvial fan exposed on the surface, 2. The part of Middle Pleistocen alluvial fan exposed on the surface, 3. The alluvial fan built until the Upper Pleistocene, 4. The alluvial fan built until the begging of the Würm, 5. Alluvial fans built until the middle of the Würm, 6. The alluvial fan built until the begging of the upper periglacial period, 7. The alluvial fan built until late glacial time.

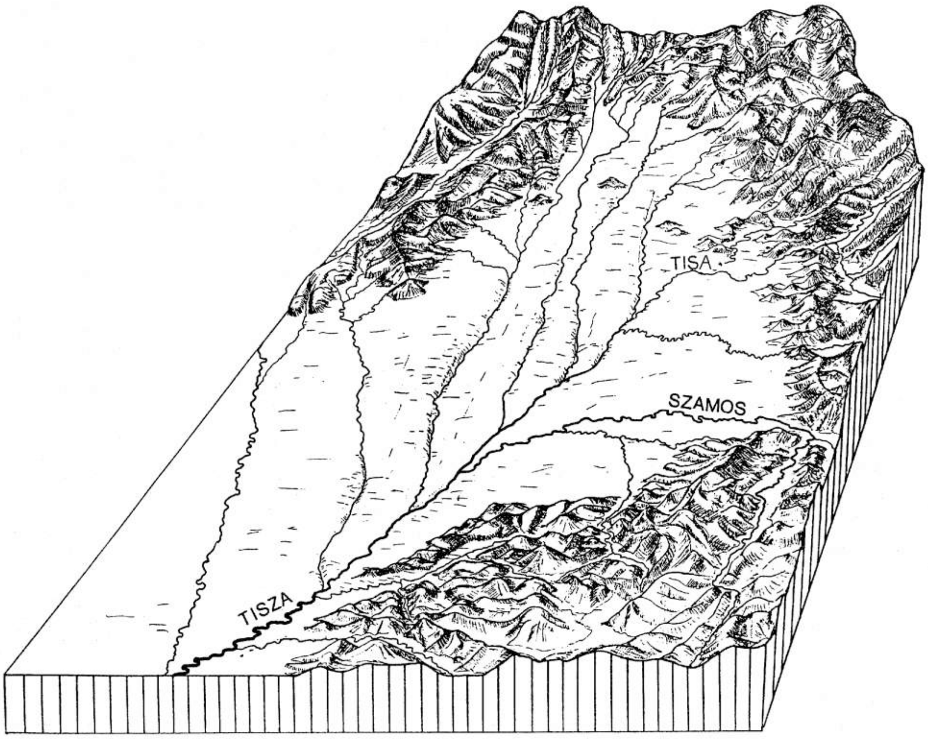


Fig.3. Network of rivers in the Early Würm (based on Borsy and Félegyházi, 1983).

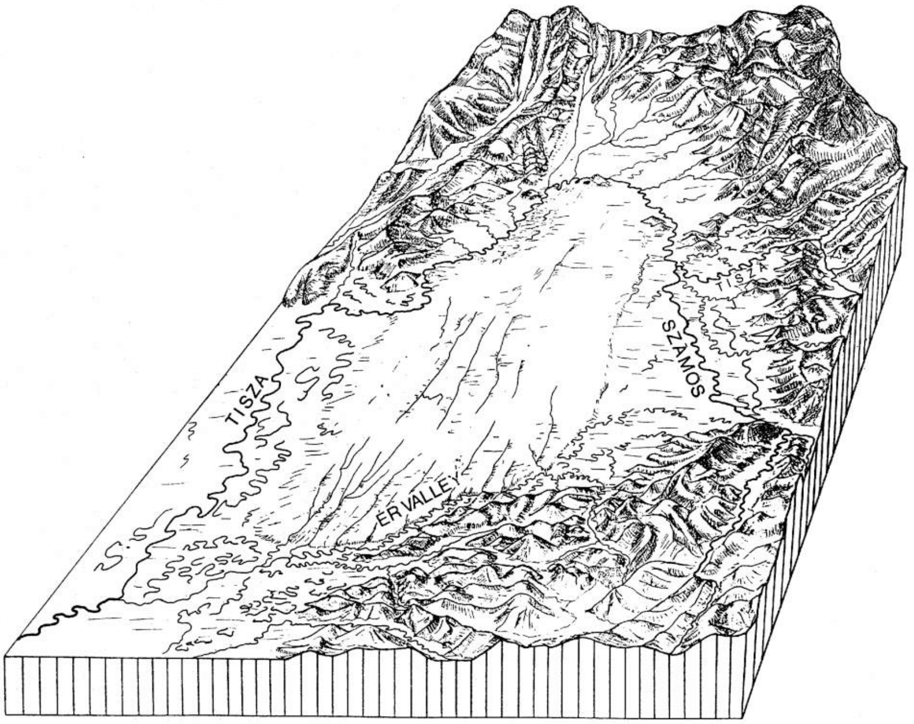


Fig.4. Network of rivers in the Upper Würm (based on Borsy and Félegyházi, 1983).

The climate in this region has a strong submontane character. This is expressed in the amount of precipitation (600-700 mm yr-1), accompanied by cooler summer and colder winter temperatures (Kakas, 1960).

Field work

Coring was carried out on a marsh in the centre of the oxbow lake (Fig.6.) on 10 January 1994, using a modified 5 cm diameter Livingstone piston corer. Core immediately was wrapped in plastic film and aluminium foil before finally being sealed in polythene sheets. The core was halved lengthways in the field. Half of the sedimentary sequence was analysed in Cambridge (UK) for pollen and AMS (Harrington, 1995), while the other half of the core in Debrecen (Hungary) for sediments, geochemistry and radiocarbon (bulk samples) dating.

Lithological analysis

Lithostratigraphic features were identified through macroscopic examination and grain-size analysis, and were described using the Troels-Smith (1955) classification.

Geochemical analysis

The core was divided into 2.5-5 cm sections. The organic and carbonate content of the core was estimated by loss-on-ignition (Dean, 1974). The inorganic weight was taken as dry weight minus organic matter and calcium carbonate weight. The elements of Na, K, Ca, Mg, Fe, Mn, Cu, Zn, S,P, Al and Cr were analysed by ICP-AES method, using a SPECTROFLAME instrument, with simultaneous and sequential measurements.

Pollen and charcoal analysis

Sediment samples of 1 cm3 were taken from the core at 4 cm intervals (starting at 150 from the top of the core) for pollen analysis, using a volumetric sampler. The lowest 13 cm represented a coarse sand layer that was not subsampled for pollen analysis. The preparation technique was a modified version of Berglund and Ralska-Jasiewiczowa's (1986) method. Two Lycopodium spore tablets of known volume (13911 spores per tablet) were added (Harrington, 1995) to all samples to give a desirable ratio for pollen to exotic spike (Maher, 1981), to enable working out pollen concentration (Bennington, 1962). A minimum count of 300 grains per sample (excluding exotics) was made in order to ensure a statistically significant sample size (Maher, 1972). Charcoal abundances were determined using the point count method (Clark, 1982).

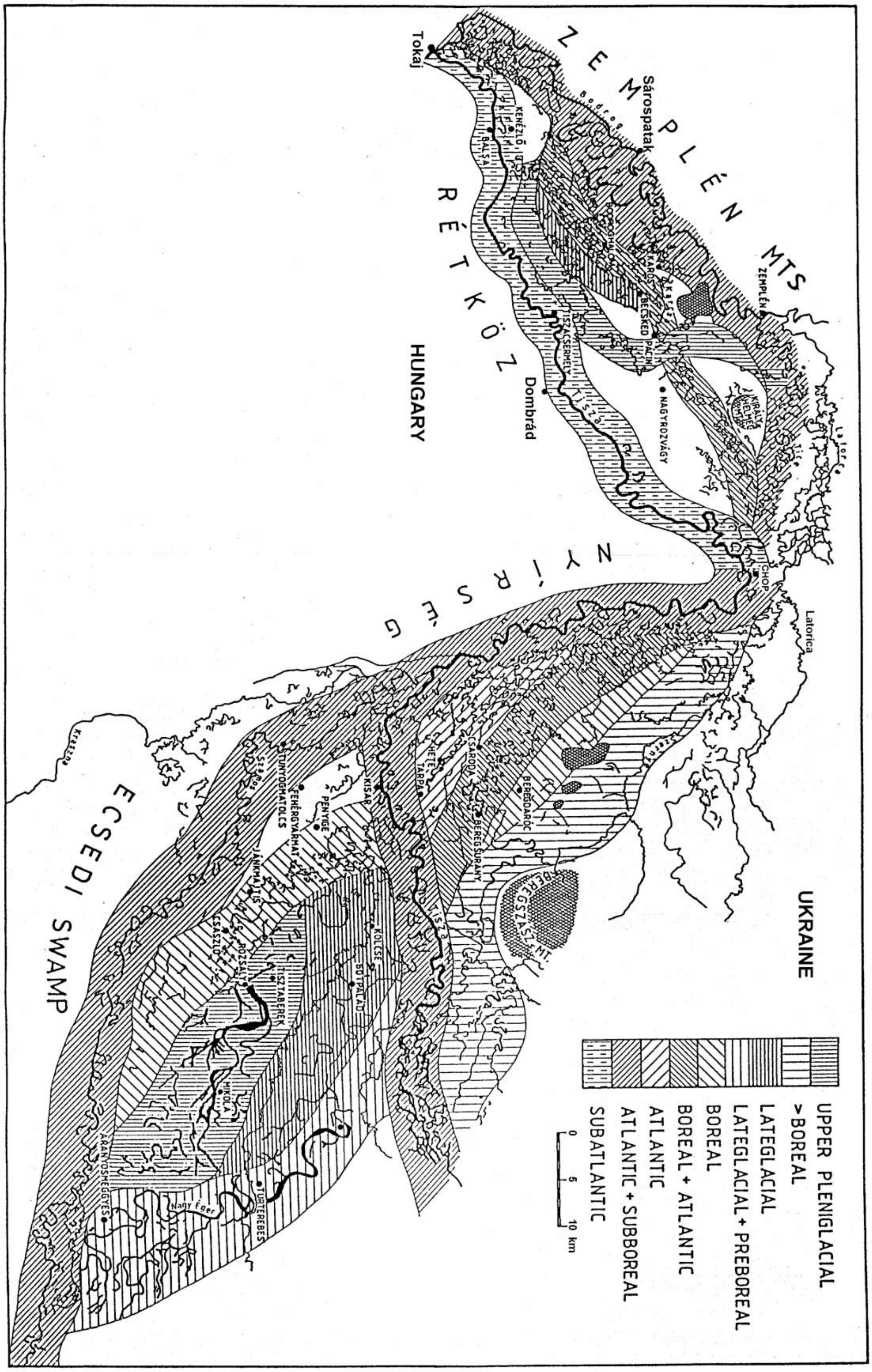


Fig.5. The age of abadoned river channels of the Tisza and Szamos in the north-eastern part of the Great Hungarian Plain (based on Borsy, 1995)

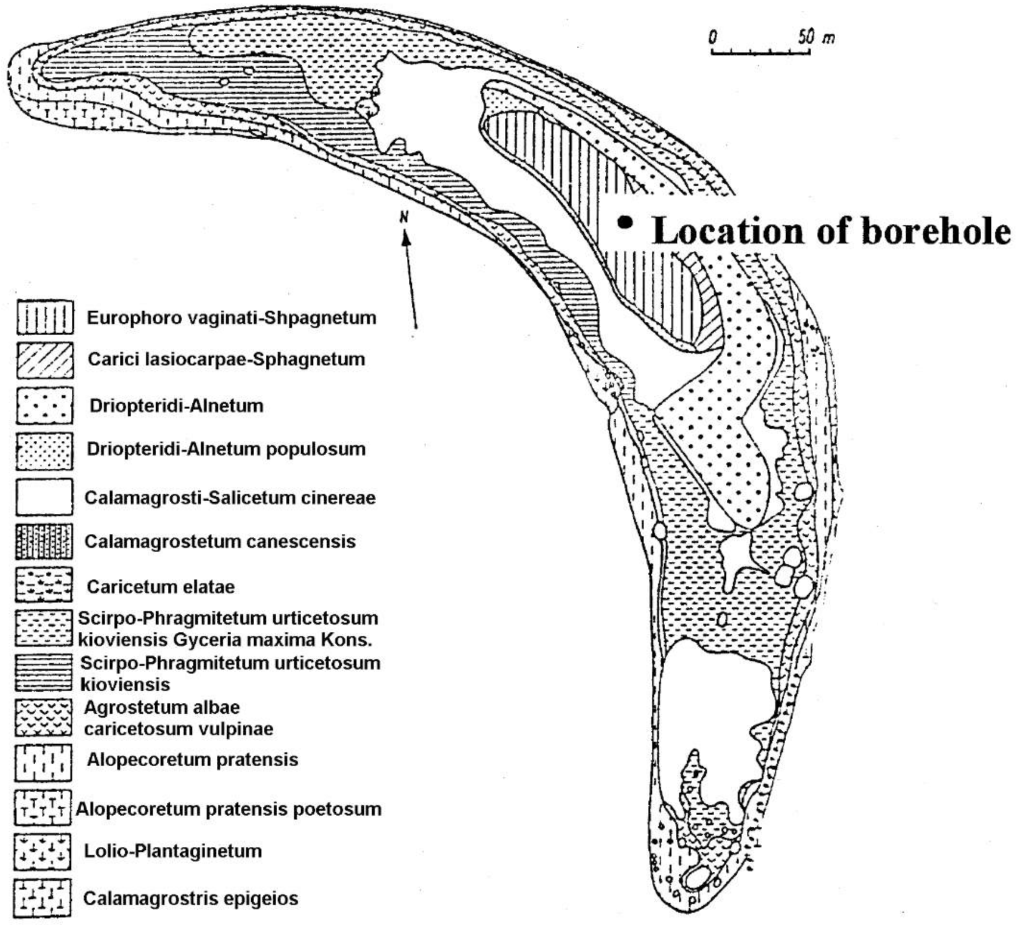


Fig.6. Location of coring site, Csaroda peat-bog.

Radiocarbon dating

Some samples were taken from core and were sent for conventional bulk radiocarbon dating to the NERC facility at East Kilbridge, but only 2 were successfully processed (between 162-158 cm and 280-278 cm). Two bulk samples were analysed for radiocarbon dating in Debrecen (between 240-245 cm and 260-265 cm). All dates are presented as calibrated BC and AD years to make them directly comparable with archaeological statements.

Geo-archaeological analysis

All the world's landscapes and ecosystems are products of natural and cultural processes. After the last glaciation, from cca. 10.000 years ago, modern climate and global environment developed but climatic variations of smaller magnitude and shorter duration have continued to evolve up to the present (Roberts, 1989). Human impact on the environment has increased progressively during the last 10 thousand years. Thus, the Holocene environment has developed under constant or periodic human effects, and some of the landscape, soil, and vegetation changes have evolved by anthropogenic impacts, therefore the regional human impact had to be reconstructed for the understanding of environmental changes.

The impact of different technologies and cultures on the landscape can be measured in a variety of ways. According to geo-archaeological hypotheses (Edwards, 1979, 1982, 1991) the charcoal, pollen, sediment and geochemical records will accord in highlighting anthropogenic effects by recording fire and erosion events, as well as changing and diversifying floristic patterns. These hypotheses are based on several assumptions e.g. that the pollen, charcoal and sedimentological, chemical signatures will respond to environmental disturbances induced by human impact. For the detection of human impact and for archaeological and geo-archaeological interpretation, a review was made of published archaeological sites covering the time period between the Mesolithic through the Late Iron Age (Roman/Barbarian Age), within a 50 km radius around the Nyíres lake at Csaroda.

Results

Lithological analysis

The core can be divided into 7 lithological units. They are described along with the results from grain-size analysis. Sediment accumulation started at about 13000 BP. The first sediment layer is 425-415 cm thick. The basal sediment is yellow-grey, non-calcareous, non-organic fine sand with coarse sand spots. The grain distribution of basal sand is typical of fluvial material, which accumulated in the water streams.

The second sediment layer is 415-395 cm thick. This sediment zone consists of grey silt with fine sand content. The grey silt contains vivianite of high dry weight value and low organic content. The base of this layer is sharply distinct from the sand below it, but there are some sandy spots and straight-crested sand ripples interbedded in the fine silty layers. This sediment layer indicates a dynamic developmental stage between lake and fluvial phases. When the fluvial phase came to its end and the lake phase started in the oxbow lake, a thick silt layer accumulated in the oxbow basin. However, the lake stage was interrupted by some flood events when inwashed sandy material accumulated in the lake basin.

The third sediment layer is of 395-368 cm. Its clay content increased gradually from base to top. The reddish brown iron-containing and bluish green vivianite-rich laminations are visible at some levels. Sediments become progressively more organic towards the top. This sediment layer indicates that the lake phase stabilised in the basin and stagnant water sediment accumulated.

The forth sediment layer is of 368-298 cm. This sediment layer consists of greenish grey, non-calcareous silt clay. Organic content is about 5 % in this layer. The amount of vivianite decreases, but some iron-rich laminations and spots can be found in the sediment.

The next sediment layer is 298-234 cm thick. This layer is inhomogeneous. There are six finely laminated and turbid clay and organic-rich sediment zones. This layer represents the highest value of carbonates in the sampled core. The laminated and turbid sediment structure indicates that a mass of eroded terrestrial material was inwashed and accumulated in the filling riverbed, thus the concentration of allogenic fraction increased.

The sixth sediment layer is 234-172 cm thick. A sharp lithological surface developed between the fifth and sixth sediment layers of Nyíres lake at Csaroda. The clay and organic content decreased, but organic components increased from the base of this sediment layer towards its top. An increase of sand content suggests that material input from floods developed in this layer.

The seventh sediment layer is of 172-150 cm. This sediment layer is characterised with high organic and clay content. The turbid sediment structure of the boundary between the 6th and 7th layers indicates that a high concentration of inwashed terrestrial sediment occurs in the lake (local catchment) basin. This peat layer with high clay and organic content developed from 172 cm up to the surface, but the part from 150 cm to the top was cut down because the layers mixed and the sediment was disturbed by postgenetic process.

Geochemical analysis

The results from geochemical and pollen analyses are plotted against depth (Fig. 7-8.). A statistical procedure was used to zone the data. All the zones are numbered from the base upwards and prefixed with following letters: NYGZ (geochemical zones), NYO-P (pollen zones).

NYGZ-1 (425-415 cm: Late-glacial)

Accumulation in the basin started in the late-glacial when a riverbed formed in the Bereg floodplain. Within the riverbed non-calcareous fine sandy coarse sand sediment was deposited with high quartz, quartzite, pyroxene and amphibole content. This sediment was predominantly inorganic and contained a high concentration of allogenic silicate minerals such as Al, K, V, Zn (Mackereth, 1966, Engstrom and Wright, 1984, Engstrom and Hansen, 1984). The arrival of these elements into the basin suggests that they represent fluvial unweathered silicate minerals. This overlying sand is considered fluviatile in origin.

NYGZ-2 (415-300 cm: Late-glacial)

The authigenic fraction shows high values of Fe and Mn and a sharply increasing Fe:Mn ratio. The similarity of the P curve to the Fe and Mn curves suggests that there is close relationship among these three elements. Such a relationship has been demonstrated to be indicative of inorganic P occurring in the sediment as an adsorbed component of amorphous iron oxide (Mackereth, 1966, Willis et al. 1997). They formed a vivianite mineral (e.g. 480-485 cm) in the sediment layer (Sümegi, 1996). The Fe, Mn content indicates that a special chemical weathering developed as a result of acidic conditions in the soil and there was an influx of these elements in large quantities. The Fe, Mn content suggest that waters at the bottom of the lake were well oxygenated and preserved these element concentrations in situ in the catchment basin (Mackereth, 1966). The iron-rich laminas probably consist of oxidised iron. On the

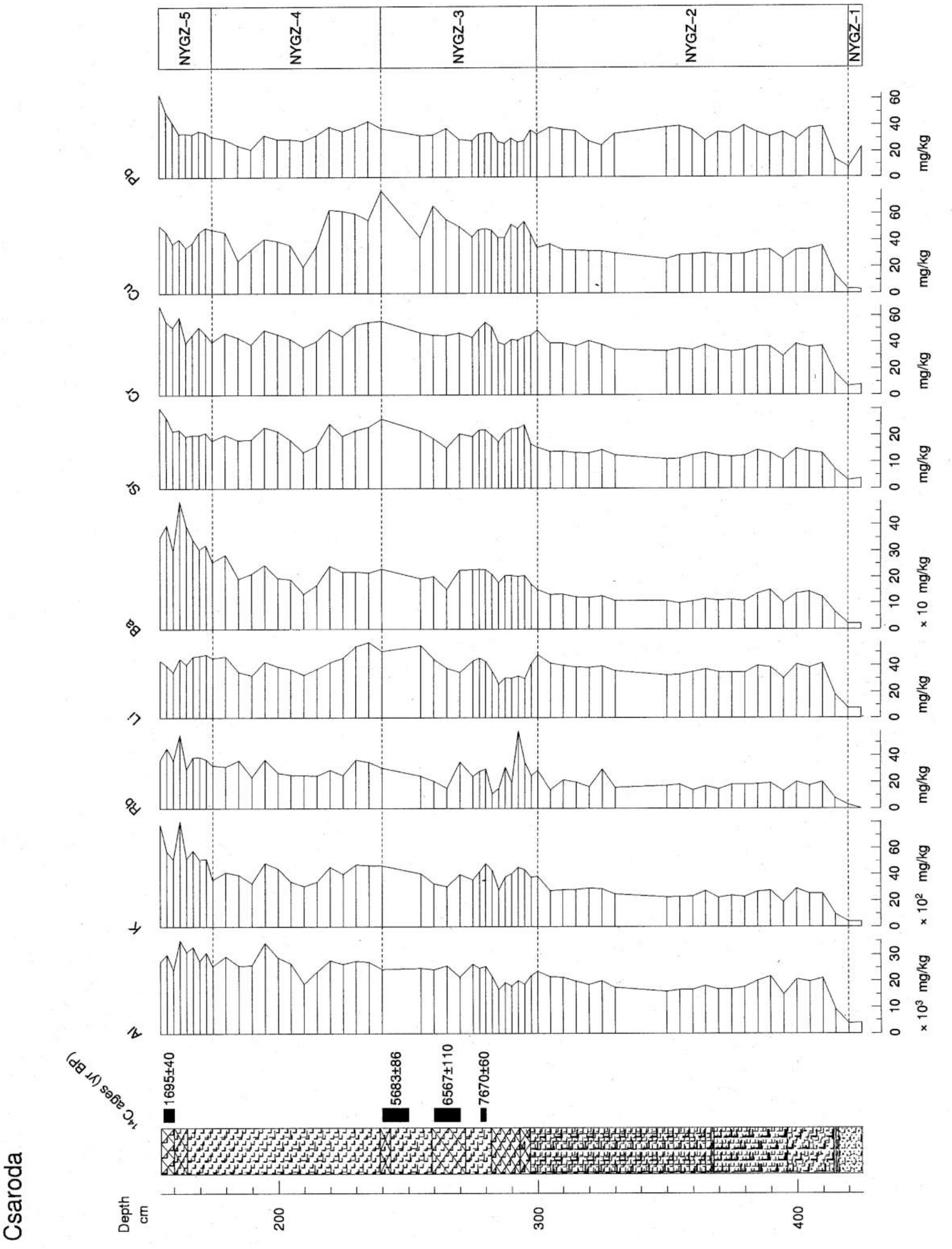


Fig.7A. Physical characteristics and elemental concentrations from the Csaroda sediment plotted against depth (based on Jakab, 1996).

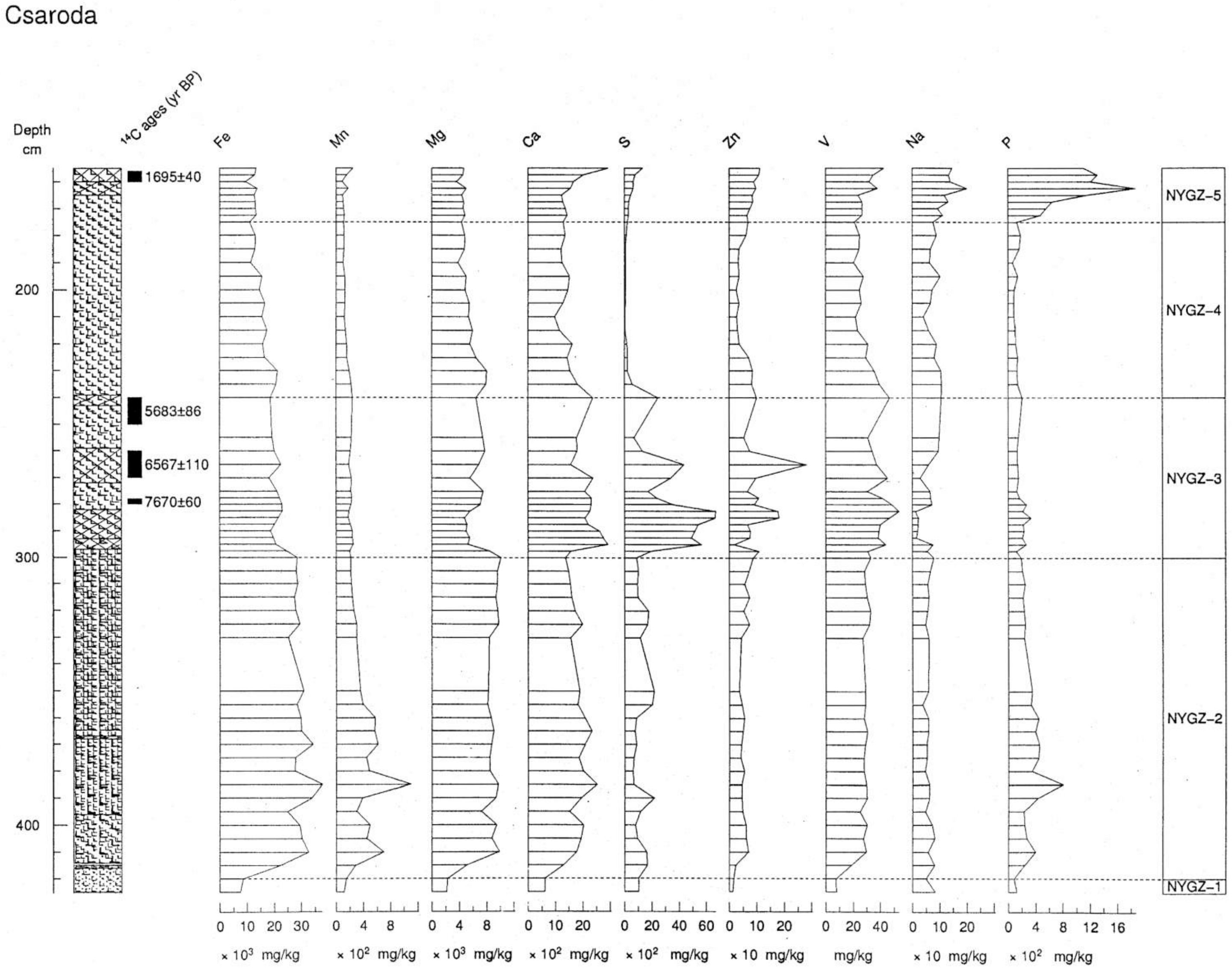


Fig.7B. Physical characteristics and elemental concentrations from the Csaroda sediment plotted against depth (based on Jakab, 1996).

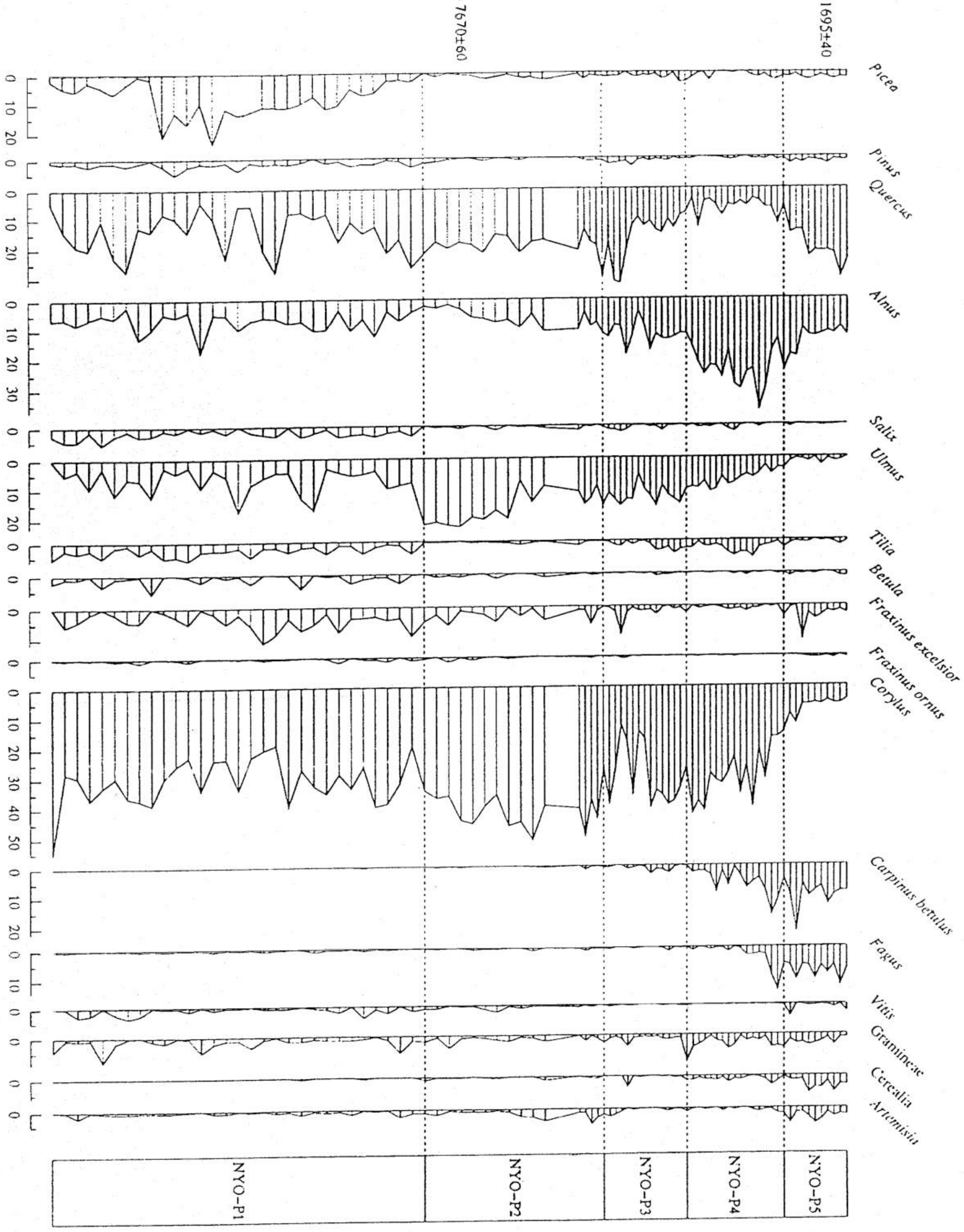


Fig.8. Percentage pollen diagram of selected taxa from Csaroda peat bog plotted against depth (based on Harrington, 1995)

other hand the low Sr:Ba ratio indicates (Qi-Zhong, 1984) that a low level of chemical weathering or a minimal surface erosion process developed around the catchment basin. These data suggest that clastic components may have entered the basin (Engstrom and Hansen, 1985). The high sand content of the sediments in the bottom layer of this zone suggests that the sediments of fluvial (flood) and stagnant waters mixed in this zone. The sand content decreased gradually parallel with increasing clay content towards the top of this zone.

NYGZ-3 (300-240 cm: cca. 9500-5000 BP)

At the late-glacial/postglacial transition all the elements representing allogenic erosion became greatly reduced as the percentage of inorganic material decreased, and there was an increase in organic content and carbonate. In the early postglacial the amount of elements associated with oxidation processes decreased. The peak of the S curve probably indicates bacterial activity and anoxic stage in the lake basin, while the higher Zn content suggests that reeds and grasses colonised and closed on the surface of the lake. Levels of calcium input prior to this increase suggest that the transformation of the vegetation continued and deciduous forest elements spread around the lake basin. This lacustrin phase differed significantly from the previous pond stage in both sediment chemistry and temperature. While the earlier Pleistocene lake environment can be characterised by sedimentation in cold water lacking Ca content and much vegetation, the early postglacial pond system can be described as being relatively rich in Ca, with carbonate content and with vegetation typical of easily warming waters. The change of chemical elements indicates that a strong erosion process around the lake and a nutrient-rich lake phase developed after the late-glacial/postglacial transition.

NYGZ-4 (240-172 cm: c. 5000-2300 BP)

The change of the sediments as of 5000 years BP possibly indicates an increased level of overland soil erosion into the catchment basin or an increased level of fluvial influence, because a number of allogenic clastic materials accumulated in the infilling riverbed. A decrease developed in the S, Zn and organic contents. This change of the chemical composition suggests that new, well-oxygenated bottom conditions formed in the basin. Probably, a mass of floodwater streamed into the basin and the water level of the lake increased. The previous early postglacial eutrophic lake stage transformed into an open watered, mesotrophic-oligotrophic lake phase. Floods could drift the mass of the silicates (sand and silt), thus clastic material became dominant in the catchment basin.

NYGZ-5 (172-150 cm: 2300-2000 BP)

The content of Zn, S, P, K elements as well as organic content increased rapidly in this layer. The increase in calcium is thought to represent throughflow from deciduous litter deposition on the one hand, and leaching Ca from the soil of the levee zone on the other. The colonised peat association absorbed the inwashed calcium the same way as with Pb, Zn, Na and Cu. The increase of P, S and organic content indicate that an eutrophic lake with less oxygenated bottom conditions then a peat bog developed in the catchment basin. These dramatic changes in the chemical composition indicate an important change in the environment of the catchment basin. According to chemical data a mass of allogenic fragments and eroded soil material accumulated in the catchment basin from 172 cm and a rapid process of eutrophication with peat formation started.

Pollen analysis

The pollen profile from Nyíres-tó extends well back into the late-glacial and presents a continuous record of vegetation dynamics around the filled riverbed until 1600 BP. With a basin diameter of approximately 200 m, the pollen catchment will be predominantly local and extralocal in origin (Jacobson and Bradshaw, 1992). Although a number of pollen grains could be deposited by streaming water in the catchment basin during flood times (Fall, 1987), because this oxbow lake was an open hydrological system which could be reached by masses of flood water from the active riverbed. According to Harrington's work (1995), the pollen percentage diagrams and the pollen concentration diagrams were zoned based on their information content (Birks and Gordon, 1985) and were assigned the prefixes NYO-P to differentiate them from the sediment zone scheme.

NYOP-1 (412-292 cm: Late-glacial – Early postglacial)

During the late-glacial (cca. 12000 BP) and up until the early postglacial (cca. 9200 BP) vegetation surrounding the Nyíres-tó basin was predominantly coniferous forest. The composition of this forest was probably similar to the present-day southern edge of the European boreal forests, with Picea, Pinus and Betula (Pastor and Mladenoff, 1992). Within the taiga forest there were other species of deciduous trees and shrubs such as Quercus, Alnus, Ulmus, Tilia, Fraxinus, Salix and Corylus. The nearest modern vegetation analogous to the composition of the pollen in this zone is the European boreal forest (Peterson, 1983, Nikolov and Helmisaari, 1992) although these forests do not contain Ulmus and Corylus. Charcoal concentration values suggest that burning was occurring during the late-glacial. This burning was probably naturally induced and in present boreal forests has been shown to be an important component of forest ecology (Payette, 1992) Probably associated with the burning, some increase in plants of the Filicales-type is shown. Generally, all arboreal taxa fluctuate throughout this zone except for Picea which peaks at 20% total pollen at 360 cm, before declining to 3% at the top of the zone (Harrington, 1995). The arboreal pollen and non arboreal pollen ratio curve shows a high degree of concordance with the concentration curve indicating particular abundance of Corylus, Ulmus, Quercus, Tilia, Fraxinus, Alnus, Betula. The presence of deciduous trees suggests that there was an important temperate refugial area for deciduous trees in this region during the last glacial.

NYOP-2 (292-232 cm: c. 9200-5000 BP)

The late-glacial/postglacial transition occurred between approximately 10.000-9200 BP. Computer simulated climatic modelling (Kutzbach and Guetter, 1986, Kutzbach et al. 1993) suggests that during this period the climate progressively became warmer. The climatic change at the late-glacial/postglacial transition resulted in some environmental changes at the Csaroda area. The percentage arboreal pollen curves in this zone are marked by high values of Corylus and Ulmus, Tilia, Quercus. Picea is present in very low quantities and Tilia, Ulmus, Corylus, Quercus taxa are virtually absent, and the pollen percentage of these species reached values at 20% (Harrington, 1995). Quercus increased in abundance to become the dominant taxon after approximately 9200 BP. The species composition of the woodland remained unchanged until approximately 7000 BP, although from cca. 8000 BP (7000 BC), there were two considerable increases in charcoal concentration and Corylus dominance. A link has often been suggested between the early increase of Corylus in the Postglacial of North and West Europe and anthropogenic activity (Smith, 1970). In particular, it has been suggested that the fire resistant shoots of Corylus enabled it to thrive in the Mesolithic (Smith, 1970), when there was deliberate landscape management using fire.

NYOP-3 (232-204 cm, c. 5000-4000 BP years)

At approximately 5000 BP the structure of the woodland transformed once again with a large reduction of the diversity of woodland, and with an increase of open ground herbaceous types, due to anthropogenic activity. This zone is marked by significant vegetation changes. Quercus rapidly declines from 30% to 10%, and reduced Fraxinus percentages and concentration are noted (Harrington, 1995). Alnus, Corylus and Ulmus all show fluctuations in percentage in this zone and concentrations of these taxa are still significantly high. Pollen concentrations decrease after 220 cm with increasing ratio of Umbelliferae, Filicales and Gramineae. The arboreal pollen and non arboreal pollen ratio generally decline throughout this zone. There was some increase in charcoal concentration, and the sediment composition changed to a brownish grey clayey layer with high inorganic content.

NYOP-4 (204-172 cm, 4000-2000 BP)

The arboreal pollen record showed an increase in Alnus, Tilia and Carpinus betulus. Junglans pollen occurred for the first time in very low quantities and Fagus rapidly increased after a charcoal peak. Corylus, Fraxinus excelsior and Ulmus all decline in concentration. An increase and consistency are noted in the Cerealia (2% dominance) and Artemisia, Gramineae curves (Harrington, 1995). Pollen concentrations are generally high but decreased after 184 cm. Charcoal concentration decreased in this pollen zone.

NYOP-5 (172-152 cm, 2000-1500 BP)

Low percentage and concentrations of Picea, Salix, Ulmus, Tilia, Corylus and Betula represent the topmost zone. The pollen dominance of Quercus, Fraxinus excelsior, Fagus and Carpinus betulus however increase, along with a consistent presence of Vitis (Harrington, 1995). Cerealia, Artemisia, Compositae, Cannabis reach their maximal abundance in this zone. A new and marked charcoal peak developed in this zone. The pollen composition, the AP:NAP ratio and an increase in grassland dominance indicate that the constant human impact developed in the environment of the analysed region. Grazing of the forest might have limited the expansion of herbaceous taxa. The increase of Cannabis pollen during this period might indicate that human communities were using the lake for rope production (Godwin, 1967). Evidence for a basin environment developing at this time is apparent in the aquatic pollen record, which indicates a change from an open water environment to a shallower water environment colonised by Typha and Nuphar.

Geo-archaeological analysis

The Mesolithic was selected as a starting point for the review because there were some archaeological evidences for the human occupation of the Csaroda region during this time (Kertész, 1996).

Age	Cultures	cal AD/BC	Archaeological findspots
Roman empire	Barbarian groups: Dacs, Celts, Vandals, Sarmatians	0-375	26
Late Iron	Celtic	300-0	31
Early Iron	Scythian	600-300	23
Early Iron	Prescythian	900-600	3
Iron / Bronze	Gáva	1250-900	32
Late Bronze	Berkesz	1450-1250	20
Middle Bronze	Füzesabony	2000-1500	15
Middle Bronze	Ottomány	2000-1500	8
Early Bronze	Nyírség	2800-2000	32
Early Bronze	Makó	2800-2000	7
Late Copper	Baden	3500-2800	22
Middle Copper	Bodrogkeresztúr	3900-3500	13
Early Copper	Tiszapolgár	4410-3760	23
Late Neolithic	Proto-tiszapolgár	4570-4270	9
Late Neolithic	Tisza-Csőszhalom-Herpály	4860-4490	5
Late Neolithic	Transitional phase of Tisza culture	5120-4710	5
Late Neolithic	Bükk-Esztár group	5260-4880	16
Middle Neolithic	Late Alföld Linear Pottery (Tiszadob)	5330-5000	11
Middle Neolithic	Alföld Linear Pottery (classical)	5330-4940	17
Early Neolithic	Körös	5950- 5400	4
Mesolithic	North Alföld Lithic Industry	Before 6000	4

Table 1. Review of the archaeological cultures, ages and numbers of inhabited sites revealed within the Carpathian Basin, inside a 50 km radius of the Csaroda region. From Mesolithic to the Dark (Migration) Age.

For an archaeological interpretation, a review was made of published archaeological sites, covering the time period from the Mesolithic through to the Roman Empire Age, within the Carpathian Basin, inside a 50 km radius around the Nyíres-tó site (Table 1). A radius of 50 km incorporates the distinctive Csaroda topographic region of fertile alluvial plain, and include some eroded volcanic hills and foothills of Carpathians.

Radiocarbon analysis

Four evenly spaced samples were taken from the core and were sent for conventional radiocarbon dating to Debrecen and East Kilbridge. The sample at 162-158 cm recorded a date of 1695 +/- 40 years BP (cca. 500 cal AD), the sample from 245-240 cm recorded a date of 5683 +/-86 years BP (4500 cal BC), the sample at 275-270 cm recorded a date of 6587 +/- 110 years BP (5400 cal BC) and the sample from 280-278 cm recorded a date of 7670 years BP (6400 cal BC). All the data are represented as calibrated BC and AD (Stuvier and Reimer, 1993) to make them directly comparable with the archaeological statements presented in this paper.

Conclusion

The lithological, geochemical and pollen profiles from Nyíres-tó extend back into the late-glacial and present a continuous record of vegetation and landscape dynamics around the basin until 1600 BP. Without any radiocarbon dating for this late-glacial sediment it is not possible to determine the age of the basal sediments although, according to earlier palaeoecological studies (Willis et al. 1995, 1997, 1998, Willis, 1997), the basal fluvial sand sediment layer may represent the transition from late-glacial (13.000-14.000 BP).

From 380 cm the coniferous pollen, especially that of Picea, increased to account for over 20% of the total pollen sum. The values of 10-20% of Picea also suggest that this taxa was one of the major components in the local vegetation (Peterson, 1983), probably present on the inside slope of the levees surrounding the oxbow lake. Modelling by Bonan (1992) suggested that soil temperatures in Picea forests with a thick forest floor and underlain with permafrost did not increase with climatic warming, unless accompanied by increses in precipitation. Spruce was an important constituent of the late-glacial north Balkan vegetation (Willis 1994) and in the eastern Carpathians (Pop, 1971).

The high value of Quercus pollen suggests that this temperate climate tree was one of the dominant taxa in the late-glacial forest around Nyíres-tó. The continuous high value of Tilia, Ulmus, Betula, Quercus, Fraxinus and Corylus with Picea pollen indicates that a mixed coniferous-hardwood forest developed in this region during the late-glacial period. The nearest modern vegetation analogous to the composition of the pollen in this zone is the European boreal forest association (Peterson, 1983, Nikolov and Helmisaari, 1992), although these forests do not contain Ulmus and Corylus (Willis et al. 1995). Thus, there is no real modern analogue for this late-glacial assemblage in Europe, only a similar recent forest type can be found in the northern part of Ukraine. A Quercus/Picea/Tilia/Ulmus/Fraxinus mixed-leaved forest with rich Corylus shrub level has been shown to have occurred around Nyíres-tó during the late-glacial time. The tree to dominate the mixed-leaved forest was Quercus, which was clearly a major component of the refugial population in this region. Nevertheless, the dominance of Tilia, Fraxinus, Ulmus suggests that the last glacial refugia of these trees developed in this region. This unusual mixture and the high amounts of Quercus, Tilia, Ulmus, Fraxinus pollen indicates that this region remained a refuge of "warm stage" deciduous tree taxa well into the most recent glacial.

According to certain pollen analytical studies (Willis et al. 1994, Tzedakis 1993, Turner-Greig, 1975) the slight and parallel fluctuation in the levels of Quercus, Tilia, Ulmus, Corylus in the sequence of Nyíres-tó before the postglacial expansion of Quercus are thought to represent late-glacial climatic oscillations. A short colder stage was represented by a slight rise in Picea values, with a parallel decrease in Quercus, Ulmus, Tilia, Corylus values between 390-340 cm. A slight decrease (10-15%) in deciduous forest elements and an associated rise (5-10 %) in Picea can represent the Younger Dryas event. Although there are no data for this event, the comparison with late-glacial vegetational changes in the pollen diagram of the nearby Bátorliget (Willis et al. 1995) leads to the conclusion that these data are representative of the Younger Dryas. However, some macrocharcoal data and lithological changes (Borsy, 1989, Borsy et al. 1981) suggest that a short and cold late-glacial climatic oscillation, which can be associated with Younger Dryas, developed in the Northeastern part of the Great Hungarian Plain.

On the other hand, it is misleading to interpret fluctuations of pollen amounts from the filling riverbed as climatic signals, since pollen diagrams may show no apparent relationship with the vegetation of a floodplain (Fall, 1987). Even the pollen found in the alluvium reflects hydrological and sedimentological influences, firstly the effect of floods or streams (Fall, 1987), since pollen types correlate significantly with sediment grain size. Consequently, the value of pollen-containing alluvium in reconstructing palaeo-vegetation and climate is limited (Fall, 1987).

The possibility of long transportation has to be ruled out for many of these types (e.g. Tilia, Ulmus, Fraxinus) because of their poor production and dispersal capabilities (Bradshaw, 1981). Therefore, persistent levels of pollen from temperate tree taxa originated from local refugial populations (Bennett et al. 1991), which were most likely located in microenvironmentally favourable areas such as south-facing slopes (Willis, 1992) and more humid ground, especially on an active flood plain.

Based on quartermalacological analyses (Sümegi-Hertelendi, 1998), the best place for refugial forest populations could be found between the foothill or sand dune and floodplain zone where warmer microclimate was accompanied with more humid microenvironment. A similar situation developed around the Nyíres-tó where a wet floodplain surrounded some small volcanic hills (e.g. Tipet hill at Barabás, Nagy hill at Tarpa). Thus, the effects of slope morphology, i. e. the altitudinal microclimatic gradients and mosaic pattern microenvironment, were favourable for the development of relict forest populations during the Pleistocene glacial times. Recent (Deli et al. 1994, 1995) and fossilic mollusc (Sümegi-Szabó, 1992) data suggest that some forest spots survived in the contamination zone of these hills and surrounding floodplains in the Pleistocene glacial phases.

Charcoal concentrations (Fig.9) indicate that fires occurred during the late-glacial (Harrington, 1995). Burning was an important component of the needle-leaved forest ecosystem, just like in present day boreal forests (Payette, 1992). Burning is thought to be related to the higher flammability levels of coniferous woodlands and

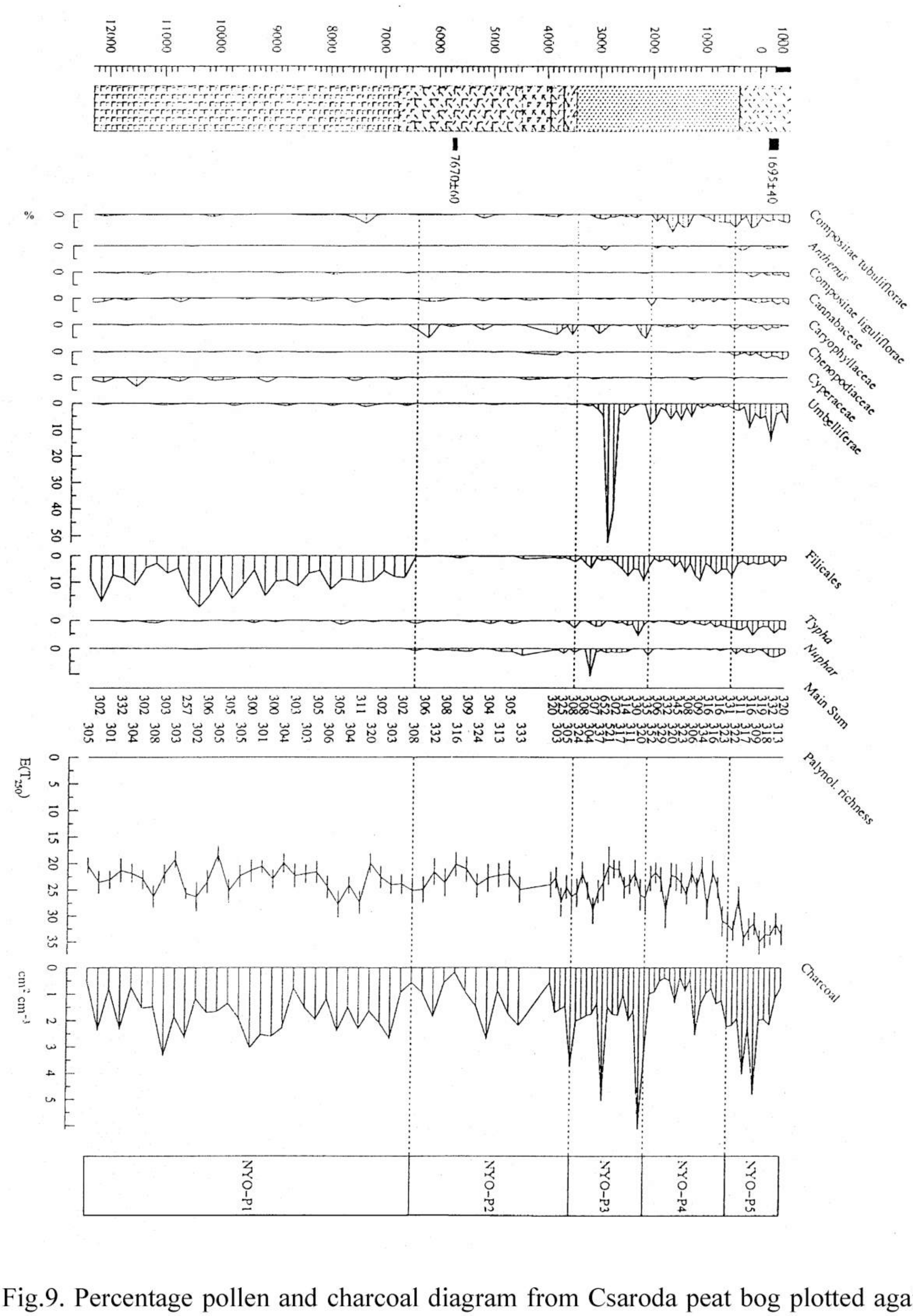


Fig.9. Percentage pollen and charcoal diagram from Csaroda peat bog plotted against depth (based on Harrington, 1995)

also to tha drier climate that was prevalent in the northeastern part of the Great Hungarian Plain during the Late Glacial (Willis et al. 1995).

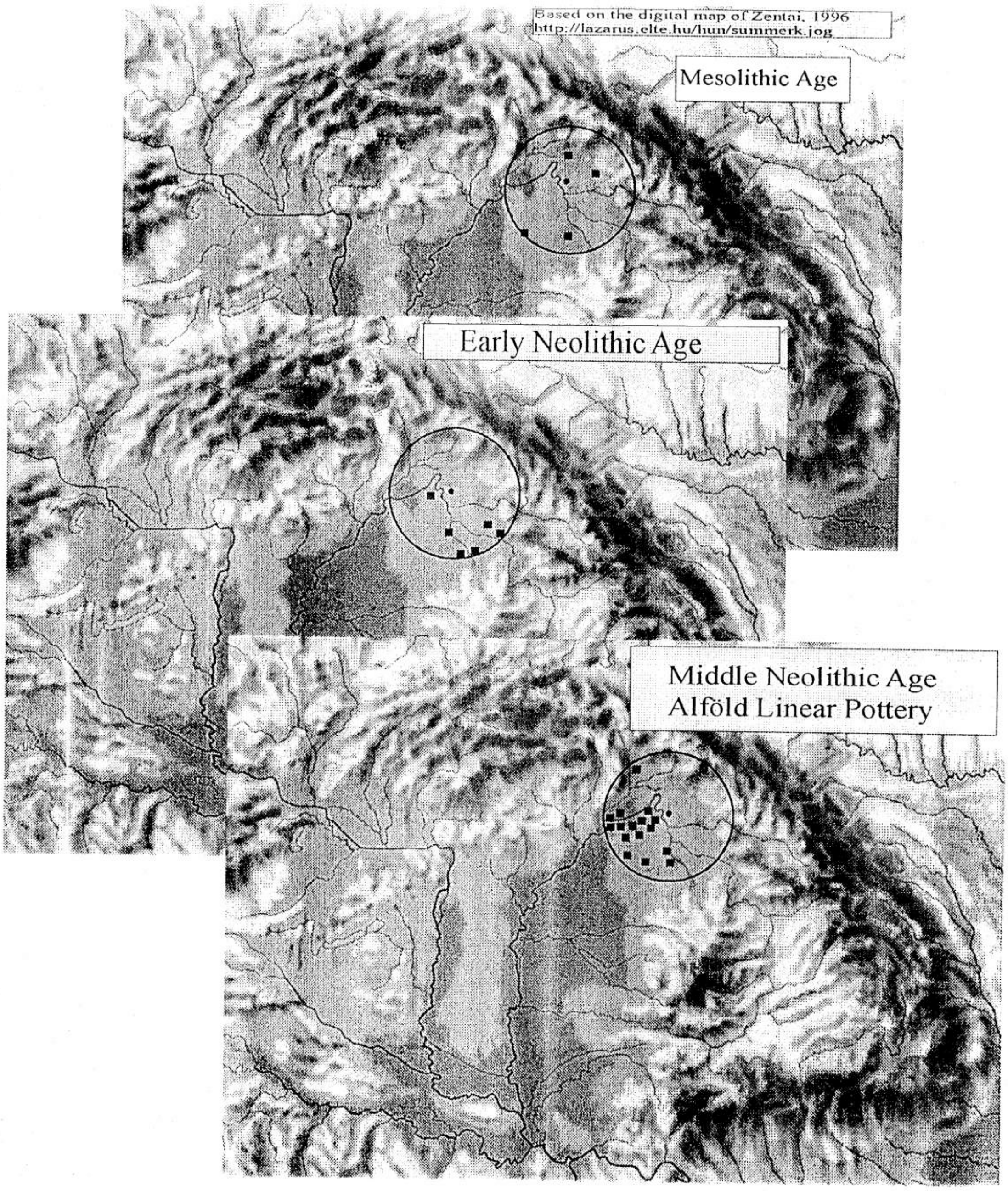
The late-glacial/postglacial transition occurred between approximately 10.000-9200 years BP. Computer simulated climatic modelling (Kutzbach-Guetter, 1986, Kutzbach et al. 1993) suggest that during this period the climate became progressively warmer. This climatic change at the late-glacial/postglacial transition resulted in a gradual transformation of Nyíres-tó at Csaroda. The Picea coniferous woods declined and mixed Quercus/Ulmus/Corylus woodland became established. The early postglacial woodland, although dominated by Quercus, was still characterised by the presence of Picea. It appears that it took more than 1000 years for this tree species to disappear from the forests, only when Quercus woodland expanded and become predominant. This woodland was composed of Quercus, Corylus, Ulmus, Tilia, Fraxinus, Alnus and accounted for over 90 % of the total pollen.

Microcharcoal records (Fig. 9.) from the late-glacial/postglacial transition suggest that burnings decreased only gradually and parallel with the decrease of Picea pollen values in the Nyíres-tó. When Picea declined and Quercus/Corylus/Ulmus/Tilia hardwood forest established, a cessation of burning occurred, since broad-leaved trees are known to be less combustible than the needle-leaved Picea (Johnson, 1992), thereby the forest became less flammable.

The change at the late-glacial/postglacial transition from coniferous to deciduous woodland is unusual in central and southern Europe, because most regions experienced a change from steppe or forest steppe to deciduous forest (Bottema, 1974, Huntley-Birks, 1982, Willis, 1992, Járainé-Komlódi, 1966). Nevertheless, this type of forest-to-forest change developed in yet another region of the northeastern part of the Carpathian basin (Willis et al. 1995, 1997).

Parallel with vegetation changes, there was an increase in the level of calcium and organic material entering the basin, from about 9000 years BP. The acid nature of the bedrock and low levels of calcium input prior to this increase suggest that, again, processes other than physical weathering are responsible for this increase. Measurements of the chemical elements in leaf litter suggest that deciduous litter has higher levels of calcium than coniferous litter (Willis et al. 1997). Thus, this increase in calcium, which is associated with the transition from mixed leaved taiga forest to deciduous forest, represents throughflow from deciduous litter depositions and the leaching of Ca from the brown earth soils (Willis et al. 1997).

According to archaeological data (Fig. 9), Mesolithic human communities existed in this region (Matskevoi, 1991, Chapman, 1994, Kertész et al. 1994) where they used the habitat for hunting-fishing-gathering, yet human role in nature was already far from passive (Roberts, 1989). Palaeo-ecological data suggest that these human populations lived in the closed forest environment in this region. This conception is very different from the view of other authors (Járainé-Komlódi, 1987: p. 38, 41, Kertész, 1996: p. 18). It seems that some archaeologists and botanists did not think about the effects of mosaic pattern environments which developed equally at macro-, regional, and micro-levels in the Carpathian basin (Sümegi, 1996, Sümegi et al. 1998).



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Mesolithic Age

Early Neolithic Age

Middle Neolithic Age
Alföld Linear Pottery

Fig.10. Archaeological findspots around the Csaroda peat bog from Mesolithic Age until Middle Neoltihic Age.

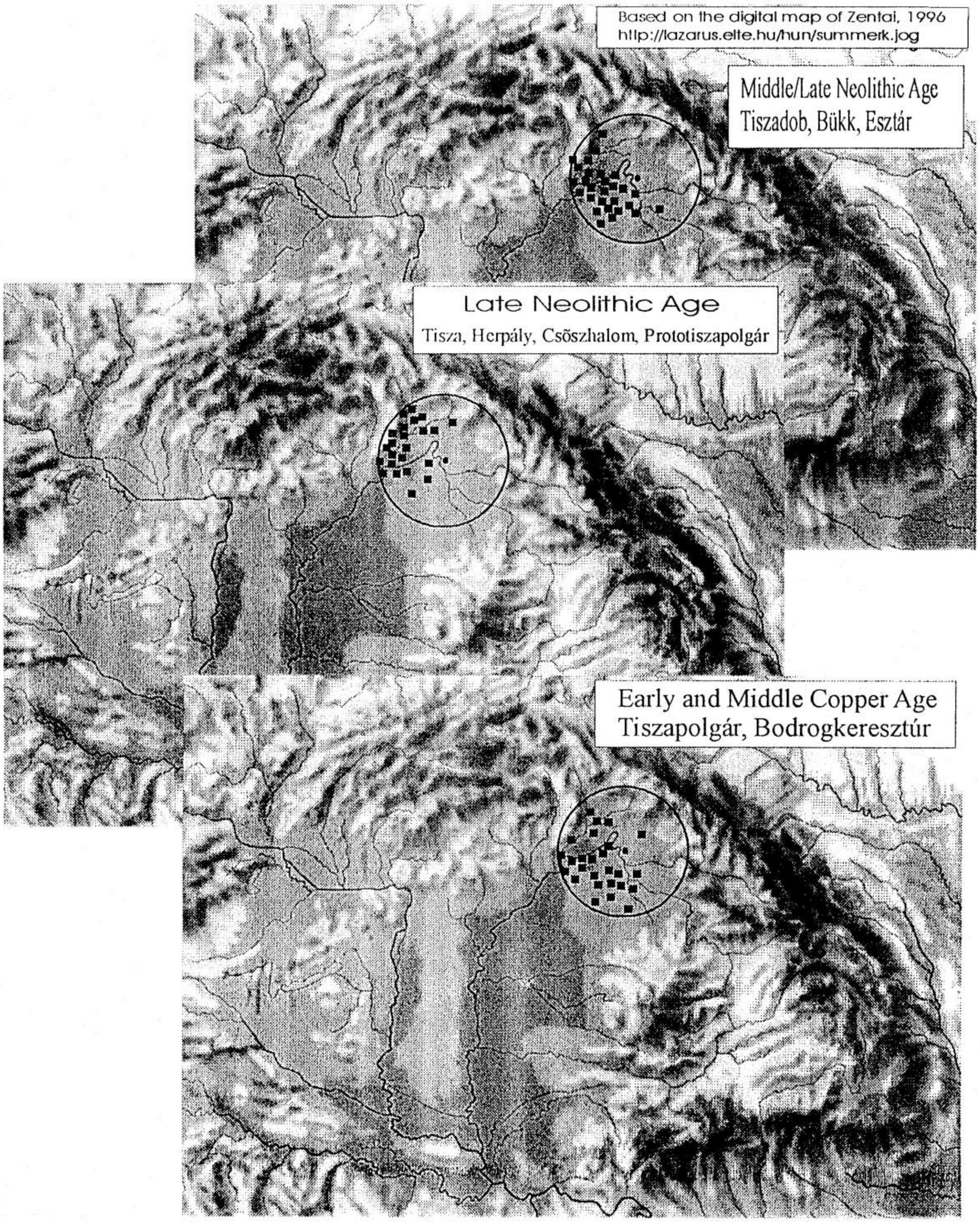
It has long been suggested that fire was an important tool of hunter-gatherers of the Mesolithic (Smith, 1970, Smith et al. 1989). In pollen and charcoal records from several Hungarian sites there is correspondance between some small peaks of hazel pollen and microcharcoal (Willis, 1997, Willis et al. 1995, 1997: Fig. 5., 1998). These data suggest that Mesolithic people may have bee responsible for bringing about the change in vegetation before 6500 cal. BC. Moreover, there is no archaeological evidence for the Neolithic occupation of the Carpathian basin before this time (Hertelendi et al. 1995, Whittle, 1996). Probably, these palaeo-ecological (Willis, 1997) and archaeological data indicate an indirect cause-effect relation in that the hunting-gathering people of the Mesolithic period used fire for changing the vegetation structure in the Carpathian basin about 7000 cal. BC.

According to Harrington's work (Harrington, 1995) there is no real charcoal evidence for human burning in the early postglacial sequence of Nyíres-tó between c. 7000 and 8000 cal. BC. However, there is an unusually high concentration of hazel pollen, which developed parallel with the decline of Picea pollen values, and a small and slight peak of charcoal concentration between 6500-7000 cal. BC. Some known localities of the Mesolithic culture are found close to the location of the analysed core sequence (Fig. 10), thus these data suggest that Mesolithic communities in this region started the transition to Neolithic agriculture and entered the substitution phase (Zvelebil and Rowley-Conwy, 1986) about 7000 cal. BC.

A considerable increase of the charcoal and hazel pollen concentration without an evidence of strong change in tree composition indicates that a new but not too strong human effect could develop in this region from cca. 5700 cal. BC. Some early Neolithic sites (Kalicz-Makkay, 1976, 1977) can be found around the analyzed sequence (Fig. 10), but it seems that early Neolithic people continued the late Mesolithic way of life. Namely, they hunted, fished and gathered and only slightly disturbed the composition of the postglacial woodland in this region. Probably, this ancient and primitive economic strategy was more useful on the acidic bedded soil surface with closed forest cover than what the real transition to Neolithic way of life could have offered. This effect is called "green corridor impact" (Sümegi-Kertész, 1998). It is possible that the land use of the Körös and then the Linear Pottery culture rooted in the Mesolithic subsistence (Chapman, 1994), thus environmental effects and palinological response would be small.

According to palaeo-ecological data this region was a background of the gathering, hunting, fishing economy during the Neolithic Age where real pasture lands or arable lands were not formed. This can be stated in spite of the fact that a number of Middle Neolithic and Late Neolithic settlements (Bóna, 1986, Kalicz-Makkay, 1977, Nagy, 1998, Raczky, 1983, Kosse, 1979, Kurucz, 1989, Kalicz, 1994) can be found within the 50 km radius of the Nyíres-tó at Csaroda (Table 1.).

The first real anthropogenic impact began to develop at the end of the Late Neolithic Age (about 4500-4600 cal. BC), for which an increase in copper values was detected. Although the gradual increase in copper amounts is independent of other geochemical signatures, the sediment structure does not indicate soil erosion or an increase of organic content in the catchment basin. Archaeological evidence suggests that extensive copper mining occurred in the Carpathian Basin from approximately 6000 years BP (Kalicz, 1982, Sherratt, 1982a, b) when various Late Neolithic and



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Middle/Late Neolithic Age
Tiszadob, Bükk, Esztár

Late Neolithic Age
Tisza, Herpály, Csőszhalom, Prototiszapolgár

Early and Middle Copper Age
Tiszapolgár, Bodrogkeresztúr

Fig.11. Archaeological findspots around the Csaroda peat bog from Late Neoltihic Age until Middle Copper Age.

Copper Age cultures (Figs. 11, 12) settled in the Csaroda region (Bognár-Kutzián, 1963, 1966, 1972, Kalicz, 1994, Kalicz-Raczky, 1984, 1987, Korek, 1989). This activity must have released Cu particles into the atmosphere, which could be carried into the basin by rainwater (Willis et al. 1995). Copper data from Nyíres-tó, together with earlier geochemical records from an other catchment basin at Bátorliget (Willis et al. 1995) suggest that copper mining and melting started in the northeastern part of Carpathian Basin in the Late Neolithic Age.

Parallel with the rise of copper contents, vegetation was still predominantly wooded but suffered disturbances by fire which caused stress in the forest (Harrington, 1995). The composition of the forest was similar to the previous woodland phase but Ulmus (elm) was gradually declining in abundance. In many areas of northwest Europe the decline of elm coincided broadly with the first signs of human activity between about 5300 and 5000 BP (Bell-Walker, 1992). Some researchers argued that elm decline was caused by the advent of the new Neolithic agricultural economy (Troels-Smith, 1960, Mitchell, 1956, Rackham, 1980, 1986), while recent ecological data suggest that a disease could be the cause of the Ulmus decline (Rackham, 1980, 1986). Thus, the exact cause of elm decrease commencing in this region in the Late Neolithic/Early Copper Age is unknown.

At approximately 3500 cal. BC the structure of the woodland transformed once again with a large reduction in the diversity of the woodland and with an increase of open ground herbaceous (e.g. Umbelliferae, Compositae) types usually associated with anthropogenic activity. Woodland instability manifests in the declines of Quercus, Ulmus, Corylus (Harrington, 1995) which may be attributable to anthropogenic disturbance (Aaby, 1986), to a form of arboriculture of building (Huttunen et al. 1992). Wood from oak and hazel, for example, are particularly processible as building material (Rackham, 1980). The general rise in Non Arbor Pollen taxa correlates with some charcoal peaks. Charcoal concentration increased to a maximum at this time suggesting that anthropogenic activity was occurring in the form of clearance by burning and exterminating natural vegetation. According to archaeological data a peak of settlement number and an occupation maximum formed around Nyíres-tó (Table 1, Figs. 11, 12) from the Late Copper Age to the Middle Bronze Age. The lack of evidence for soil erosion during this period indicates that either these activities were not occurring in the catchment basin or the nature of anthropogenic activities was such that they did not cause soil degradation. Possible forest clearance may have aimed at increasing the hunting potential on ungulates or at ensuring better possibilities for the grazing of domestic animals (Simmons, 1969). This region, firstly the backswamp areas which can be found behind the levees of the infilled river channel, may have provided vast open grounds for animal husbandry including horse breeding, from the Early Bronze Age. However, there is still no evidence for large-scale cereal cultivation or large open lands for animal keeping, as opposed to other diagrams in central and southern Europe of this time (Willis, 1994, 1996, Willis-Bennett, 1994).

From the Middle Bronze Age the composition of the woodland changed and a considerable increase of Alnus, Carpinus betulus and Fagus is detected. The expansion of these tree taxa indicate that high degree of clearing activity and human disturbance (Bjorkman-Bradshaw, 1996) started on the low floodplains (Behre, 1988, Willis, 1992). Some authors argued that the rise of these taxa can be correlated with human

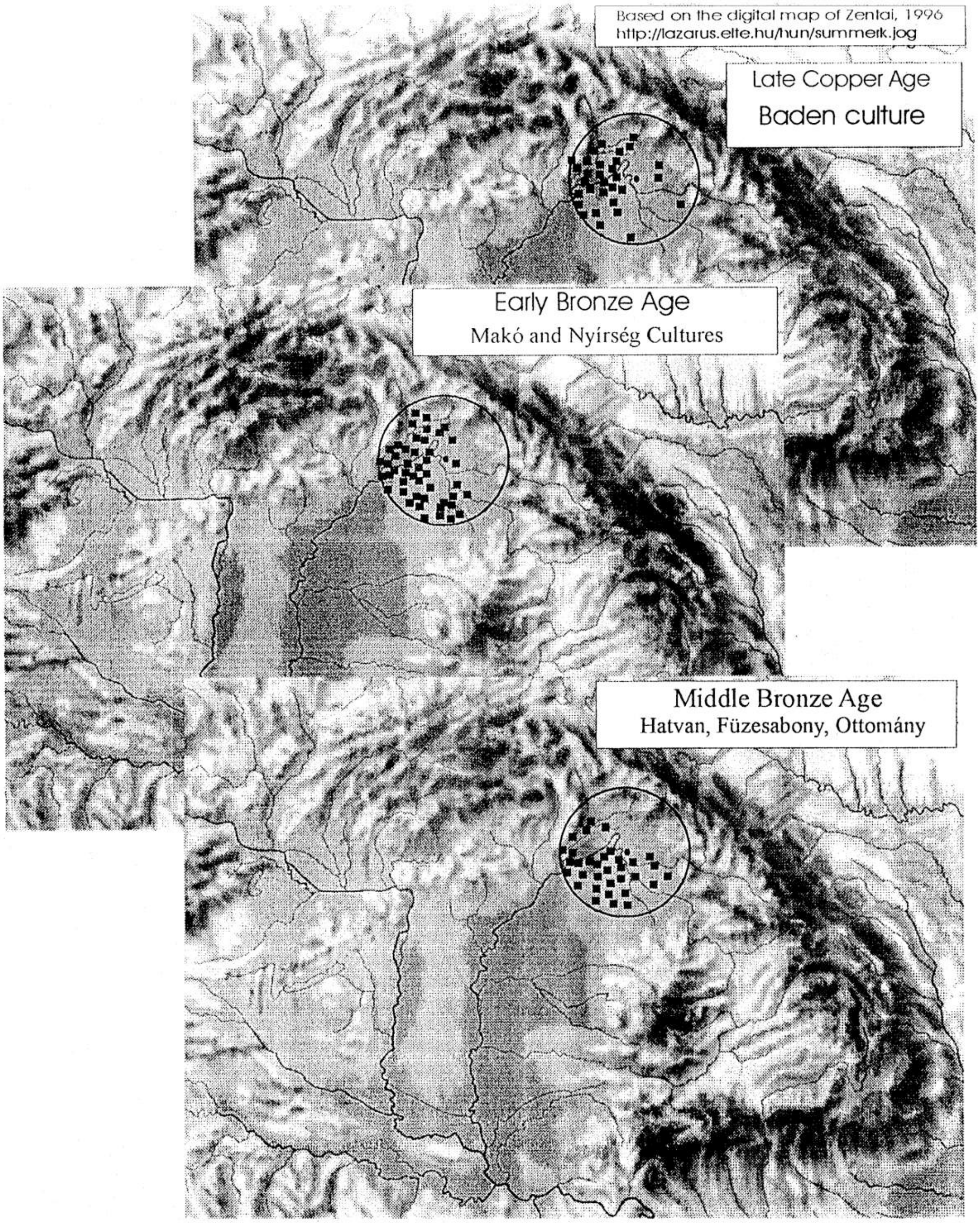

Fig.12. Fig.10. Archaeological findspots around the Csaroda peat bog from Late Copper Age until Middle Bronze Age.

impact (Tzedakis, 1993). The presence of Juglans in the pollen diagram from Middle Bronze Age clearly signifies cultivation by local human communities (Kremenetski, 1995), and it could represent the migration of this plant from the south caused by anthropogenic influence (Bottema, 1983). The final period of impact coincides with the Late Iron and Roman Ages during which time Scythian and Celtic groups then some different Barbarian groups occupied the Csaroda region (Trogmayer, 1980, Bóna, 1993). The Late Iron Age groups brought about a technical revolution in the production of high quality iron tools (Szabó, 1971). Geochemical records suggest that a threshold of irreversibility was crossed, and that soil erosion was thereafter continuous. The high increase of Cannabis (hemp) pollen during this period might indicate that Barbarian groups were using the Nyíres-tó lake for rope production (Godwin, 1967). The basin of the lake, however, was shallow and supported the growth of aquatic species such as Typha, Potamogeton, Myriophyllum and Nuphar (Harrington, 1995). Probably, one part of this lake was cleared for the procedure of hemp retting, which process unintentionally introduced large quantities of Cannabis pollen into the lake. A similar lake-clearing procedure is known to have occurred in the Roman Age on the Nagy-Mohos lake at Kelemér, which can be found 150 km to the northwest. Parallel with the increase of the hemp pollen values, charcoal concentration increased, probably indicating that a clearance of land for Cannabis cultivation started. Oak, beech, lime and elm trees also re-established, although a marked increase of grasses and open-ground herbaceous types and continuing soil erosion suggest that an unstable open landscape was developing upon human impact.

Summary

The sequence from Nyíres-tó provides an important record of environmental changes in the northeastern of Carpathian Basin from the late-glacial to times of Holocene anthropogenic disturbance.

At the beginning of the late-glacial the catchment basin of Nyíres-tó was an infilled river channel which was cut off from the riparian system. According to palinological work, pollen in the alluvium reflects hydrological and sedimentological influences, firstly the effect of floods or streams, because pollen types correlate significantly with sediment grain size. Consequently, the possibilities to use pollen-containing alluvium with special pollen taphonomy in the reconstruction of palaeo-vegetation and climate are limited.

During the late-glacial highly mixed communities (Quercus Picea/Ulmus/ Tilia/Corylus forest) were present, which have no analogue in the modern flora. The occurrence and dominance of deciduous tree populations suggest that this region, with its close proximity to the Carpathian mountain range, was an important Pleistocene refugial area for Tilia, Quercus, Ulmus and Corylus. The transition from late-glacial to postglacial took 1000-1500 years for the cold-stage forest taxa to decline gradually and the warm-period forest taxa to gain dominance. Thus, the high diversity of

Quercus/Ulmus/Corylus/Tilia/Fraxinus gallery forests and the forest-to-forest type change developed around the analysed region in the early postglacial phase.

A number of Early and Middle Neolithic sites can be found around the analyzed sequence, but according to palaeo-ecological data there are no real marks of anthropogenic disturbance, soil erosion or changes in the composition of vegetation. It is possible that the land use of the Körös and then the Linear Pottery cultures rooted in the Mesolithic subsistence, thus environmental effects and palinological response would be small.

After the Late Neolithic Age continuous but small-scale anthropogenic impact can be detected around the analysed region. During the Late Iron Age the impact upon the vegetation around the Nyíres-tó basin became intense with widespread open grounds for animal husbandry. From the beginning of the Roman Age a peak of human effects developed in this region which was used for manufacturing hemp ropes. Clearing the woodlands and burnings resulted in a reduction of woodlands, with an increase in grasses and scattered oaks. During the Roman Empire Age a Carpinus-Fagus-Quercus woodland developed around the palaeo-ecological site and the formation of the peat bog started in the basin of Nyíres-tó.

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