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HOLOCENE VEGETATION HISTORY AND HUMAN ACTIVITY IN THE KIS-BALATON AREA, WESTERN HUNGARY

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Two cores, dated by 23 radiocarbon data were investigated by pollen analysis and multivariate mathematical methods together with the settlement history of the area to determine the Holocene vegetation history and the human influence in the prehistoric times in the ancient bay of Lake Balaton. The first occurrence of anthropogenic indicators, pollen of *Triticum* and *Triticum monococcum-Hordeum* type, was detectable in the middle of the 6th millennium, in the Early Neolithic Period. From this time until the top of the sequence, the presence and the value of cereals were in correspondence with the settlement history. Pollen of weeds were irrelevant as anthropogenic indicators. Forest clearance takes place only after 3000 BC.

Key words: Holocene vegetation history, human influence, Lake Balaton, pollen analysis, western Hungary

INTRODUCTION

In palynological science the study of human influence over the plant cover has a long history. From the 1930s Franz Firbas worked out methods, with which the human disturbance was investigable (FIRBAS 1937), then in 1941 and 1949 J. Iversen in his publications pointed out the vegetation changes caused by the prehistoric tribes as a matter of fact (IVERSEN 1941, 1949). In his classical papers anthropogenic indicator taxa, mainly pollen of ruderals were determined. In the second half of the 20th century the interdiscipline cooperation between palynology and historical sciences has had a great impetus. About 40 years after Iversen's work, in the 1980s, Karl-Ernst Behre made a contribution by collecting and summarising existing knowledge about the anthropogenic activity (BEHRE 1981, 1986, 1988). However, their works are valid only to the territory of Europe north of the Alps. The Carpathian Basin has its own history; this area has always had an important and unique role in the development of the Holocene vegetation, prehistory and the archaeology of Central Europe. The study of human influence in Hungary started early. B. Zólyomi already in 1930 drew a parallel between the development of Holocene vegetation and the historical-archaeological periods (ZÓLYOMI 1931). A few years later he verified that the changes of forest components in the upper part of pollen profiles was caused by human disturbance (ZÓLYOMI 1936). In his classical work (ZÓLYOMI 1952) he described the vegetational development of the

surroundings of Lake Balaton and in some cases he identified traces of human influence.

Mankind's influence on the plant cover appears in three important areas: 1) crop cultivation, 2) animal husbandry, and 3) the technical use of natural resources.

1) By cultivating land and disturbing the natural plant cover new doors are opened for the spreading of weeds. 2) Animal husbandry opens way for spreading nitrophilous taxa, and by cutting young branches and leaves for stock-breading the pollen production of some trees could decline. 3) Perhaps the most irreversible changes in vegetation are caused by the technical use of natural resources. Cutting of huge amounts of mature trees for building fortresses and towns in the late prehistoric and in historic times, and the excessive use of wood resources for mining and for metallurgy since the Iron Age during the entire Middle Ages, of course together with the wide availability of arable land, the agriculture has made a very significant impact on the vegetation.

At the end of the last century, assisted by extensive archaeological excavations, and with the development of absolute dating and palynological methods several complex investigations were carried out to detect this process (BERGLUND 1991).

To investigate this development in Hungary we intended to find an adequate region and it was the area of the ancient bay of Lake Balaton, the so-called Kis-Balaton marsh area (Fig. 1). Our hopes were nourished, because the history of this



Fig. 1. Map of the investigated area.

area is well-known thanks to the systematic archaeological investigations, the sediment is suitable for absolute, ^{14}C dating and the peat deposited in the ancient bay has, more or less, preserved the pollen precipitation of the Holocene.

Geomorphology of the area

The marsh areas of the Kis-Balaton and Zala valley comprise three basins. The largest of them, about 32 km long and 3 km wide in average is the middle, the main basin, which is cut into two parts by the river Zala. The western side-basin is the real valley of the river Zala, of which an 18 km long section is peat deposit and is closed to the main basin south of the village of Zalavár by a narrow headland. The eastern side-basin is the smallest, being a 8 km long narrow valley along the Marót valley channel and is closed to the main basin at the village of Főnyed.

After 1946 a 100 m density core network was established in the main basin, which was widened after 1951 into the western side-basin. About twenty years later a more precise frequency (50 m) network was set up in the area (DÖMSÖDI 1977). The sampling sites were selected according these maps.

Prehistoric settlement history

The area of the lower Zala valley and the Kis-Balaton have been investigated archaeologically by systematic and rescue excavations since 1979, so the reconstruction of the settlement history from the beginning of the Neolithic until the Middle Ages is at our disposal (KÖLTŐ and VÁNDOR 1996).

The area is settled since the very beginning of the Neolithic Period, the earliest archaeological site is Vörs-Máriaasszony island from the Starčevo culture, dated to the first half of the 6th millennium (KALICZ *et al.* 1998). Based on the archaeological data from other regions, the small, short-living settlements are characteristic to this culture (KALICZ 1988). The remains of cereals, crop of *Triticum* sp. and imprints in the pottery and daubing from our site (Berzsényi, B., *pers. com.*) and imprint of *Triticum dicoccon* Schrank from the nearby locality of Kéthely are unambiguous evidence of the ancient crop cultivation in the investigated area (FÜZES 1989).

According to KÖLTŐ and VÁNDOR (1996) the Middle Neolithic Period (2nd part of the 6th millennium), the Transdanubian Linearband Ceramic (LBC) is represented by several localities in the area. The settlements occur mainly in the lower areas of the islands and on the shores. In the middle period of the culture the settle-

ments are grouped in the surroundings of the town of Keszthely, or further south, at Balatonhídvég.

Towards the end of the Middle Neolithic Period the number of localities decreases, and the settlement intensity apparently becomes smaller in the Kis-Balaton area.

In the Late Neolithic, during the period I–II of Lengyel culture (4900–4500/4400 BC) numerous localities occur again. Most of the settlements are small, but densely cover the area in a network fashion, the more significant of them settled at the important points of strategic and commercial junctions. The crossing point at Balatonhídvég was used by the settlers as well as probably the crossing possibility at Fenékpuszta.

In the Early Copper Age (4500/4400–4000 BC) the area is sparsely settled, but the crossing point at Hídvég appears to be prominently important, shown by the big fortress system excavated here.

During the Middle Copper Age (4000–3600/3500) the number of localities increases in the region, in some places, as in the case of Zalavár-Basasziget, the presence of long-lasting settlement is evident. Large numbers of grinding stones, storage pottery were excavated, referring to the importance of crop cultivation.

At around the middle of the 4th millennium, at the beginning of the Late Copper Age the material culture has begun to be unified in the Carpathian Basin, the Baden Culture countermarks the last 300 years of this millennium. The settlements are single layered, short lived and cover the dry areas in a dense network.

The settlements of the Early Bronze Age (2700/2500–1900/1800 BC) are insufficiently known, these usually cover large areas; since the density of population was low, probably only a few families lived in one particular area for a longer period of time. The sculptures of animals (sheep, cows and pigs), characteristic of this period, are evidence of the importance of animal husbandry; the storage pits, granary pottery and antler hoes are the same as those of the crop cultivation.

In the Middle Bronze Age (1900/1800–1400/1300 BC) the villages are of varying size, and the network is more dense in the southern part of the basin. From the localities stays, fish-scale, mussel and mollusc remains were excavated in a large amounts, and several storage pits refer to continuous and important crop cultivation.

In the Metal Ages the human impact changes qualitatively, since there was a growing need for material goods, the growing population needed more food and expanded arable lands; the use of new and larger areas was made easier with metal tools and weapons.

MATERIALS AND METHODS

Sampling: The sampling was made by a Russian peat corer which resulted 500 mm long sequences. They were stored at 4 °C until the laboratory work begun. Subsamples were taken with 5 cm interval, or if it seemed necessary, according to the changes of the sediment.

Laboratory methods: The laboratory process was based on the generally accepted acetolysis method for the Holocene peat samples (BERGLUND and RALSKA-JASIEWICZOWA 1986). In case of higher inorganic content it was completed with the density separation technique elucidated by ZÓLYOMI (1952). For calculating the pollen concentration of the samples *Lycopodium* tablets were used according STOCKMARR (1971).

Technical and pollen morphological description: The nomenclature of the families and genera follows SIMON (2000); in case of the names of pollen groups the taxon list of the European Pollen Database was used. The pollen grains were identified by using the keys of FAEGRI and IVERSEN (1989), MOORE *et al.* (1991) and the atlases of REILLE (1992, 1995). In some cases special descriptions of pollen and other microfossil types were used (ANDERSEN 1979, BEUG 1961, KEDVES 1982, KOMÁREK and JANKOVSKÁ 2001). To identify highly problematic grains (*i.e.* corroded, degraded or broken forms) the reference pollen collection of the W. Szafer Palaeobotanical Institute of the Polish Academy of Sciences in Cracow was consulted.

Pollen dispersal: The problematics of the short and/or long distance transport of pollen grains are well-known, and have been thoroughly investigated since decades. Having wide experience in this regard and the identification of pollen source are very important for the interpretation of a pollen diagram. Based on the studies of H. Tauber (TAUBER 1965, 1967, 1977), S. Th. Andersen (ANDERSEN 1970) and JACOBSON and BRADSHAW (1981) nowadays we have concrete, measured data for the pollen distribution from the emissive plant. In a closed forest most of the pollen precipitates in a 20–30 m distance, while in an open land, as our study area was, a regional pollen rain (from a 10 km radius) is expected (BERGLUND 1986). Of course, it is necessary to carefully follow the anthropogenic indicators, and take into account that a large portion of herbs and the cereals (except for rye) are insect-pollinated, and the flying ability of their pollen is rather poor. If we identify such pollen types we may conclude that the pollen source is nearby.

Mathematical methods, computer analysis: Calculation of pollen percentages, plotting pollen diagrams and the multivariate analyses (principal component analysis, rarefaction analysis, age-depths calibration) were performed using PolPal software (WALANUS and NALEPKA 1999, NALEPKA and WALANUS 2003).

Pollen count and determination of local pollen zones: For the better statistical calculation we aspired to calculate the proposed thousand pollen in each samples (BERGLUND and RALSKA-JASIEWICZOWA 1986). To reach this number sometimes counting of 4–5 slides was necessary. The values of each taxa were calculated as the percentages of the sum of trees and shrubs (arboreal, AP) and herbs (non arboreal, NAP) pollen. The pollen of aquatics and the spores of Filicales, as plants with local significance, were excluded from the total pollen sum, their percentage values, however, were related against the sum of AP+NAP. The local pollen zones were determined according to the changes of the main terrestrial taxa (BIRKS and GORDON 1985). The pollen diagrams are represented in two ways, according to depth and according to age. The first is helpful in the investigation of the development of the geomorphology and the hydrological history of the area, while the second one makes it possible to compare the pollen diagrams of different sequences and the coordination of the archaeological periods and pollen data.

Principal component analysis: Holocene pollen diagrams showing the vegetation and land use history have many taxa and many samples. The PCA analyses display clearly the variation observable in raw data and draw attention to some data not readily apparent thus it is recommended to anal-

yse the data with this multivariate technique as well (TURNER 1986). In our case the PCA analyses reflected only the main vegetational changes.

Palynological richness: The reconstruction of temporal changes in diversity from pollen assemblages is potentially important not only in the palaeoecological studies, but in the investigation of human impact, because community diversity may, in part, result from historical processes (BIRKS and LINE 1992).

Dating: The absolute dating of the cores was made in the Laboratory of Environmental Studies, Institute of Nuclear Research of the Hungarian Academy of Sciences using radiocarbon method. The ^{14}C measures were carried out from the same samples as the pollen analyses to eliminate the possible crawling errors. The calibration of the conventional radiocarbon data was calculated by the Calib Rev 4.4.2 program (STUIVER and BRAZIUNAS 1993, STUIVER *et al.* 1998*a*, *b*).

RESULTS

Keszthely-Úsztatómajor

The studied region is situated in the system of the mire areas of the ancient bays of Lake Balaton in the middle part of the Kis-Balaton and Zala valley swamp-basin, north of the Zala river (lat.: 46°45'46"N; long.: 17°13'30"E). Geomorphologically the mire plain dominates the area, a subtle difference of level – 105–107 m a.s.l – is characteristic. Two small islands rise from the plain, the Sziget (120 m a.s.l) and the Cibere hill. Our sampling point is in the plain, between the Hévíz and Úsztatómajor channel. Preliminary results were published previously (MEDZIHRADSZKY 2001*a*, SZÁNTÓ and MEDZIHRADSZKY 2004).

Radiocarbon data

Eleven datings were made from the whole depth of the profile in approximately equal sequences. Among them the samples deb–5085 and deb–5088 provided incorrect and reversed data, they were omitted from the interpolation of the pollen curve (Table 1).

Sedimentation

The total depth of the profile is 580 cm and it is entirely a peat deposit. In the Holocene, about the upper 480 cm peat with coarse remains is characteristic. The peat was formed according to the ancient water level from *Cladium mariscus*, *Eupatorium cannabinum* and *Schoenoplectus lacustris* (Table 2).

Table 1. Radiocarbon data of Keszthely-Úsztatómajor.

lab.code	depth/cm	conv. radiocarbon age (BP)	calibrated radiocarbon age (BC)
deb–5036	90–100	3730±58	2295–1949
deb–5038	135–150	4073±67	2783–2468
deb–5083	190–200	5559±74	4546–4314
deb–5082	240–250	7154±70	6113–5871
deb–5061	290–300	8021±107	7190–6643
deb–5044	340–350	8864±161	8305–7583
deb–5085	390–400	10657±128	11052–10341
deb–5088	415–430	10239±158	10695–9384
deb–5059	470–485	9574±142	9255–8553
deb–5086	540–550	10380±155	10911–9687
deb–5060	570–580	10835±170	11238–10617

The sedimentation rate in the Holocene period of the profile is 20 yr/cm in average; between 7500 and 2000 BC it is 23 yr/cm, while between 2000–1700 BC the sedimentation is faster, 7 yr/cm deposition speed is observed (Fig. 2).

Palynological study

For the investigation of anthropogenic influences, according to the archaeological data, the upper 480 cm of the profile was analysed and four local pollen assemblage zones (LPAZ) were determined (Figs 3–4).

Table 2. Lithology of Keszthely-Úsztatómajor.

Depth	Description of the sediment
0–50 cm	soft black soil
50–90 cm	peat with a lot of inorganic material
90–225 cm	brown peat with coarse debris
225–270 cm	mixed peat with coarse plant remains
270–300 cm	peat with very loose structure
300–360 cm	dark brown peat with coarse plant remains
360–400 cm	peat with fine grey sand and calciferous precipitation
400–480 cm	dark brown peat with coarse plant remains

LPAZ I. 480–280 cm (10300–8000 conv. ^{14}C BP; 10150–6700 cal ^{14}C BC): In this zone *Pinus* dominates, its value is 30–40%. *Betula* reaches 15%. During this zone constantly occur the pollen grains of *Quercus* and *Ulmus*. Among herbs the family of Poaceae shows the highest, 30% value. Considerable is the presence of *Artemisia*. The value of Filicales is low. The area appears to have been more or less opened, without closed forest. The reed-grass vegetation is sparse, with only sporadically occurring pollen grains of *Myriophyllum* and *Nymphaea*. In the shore area the dominance of the bulrush vegetation (*Typha* and *Sparganium* sp.) is evident. Based on the ratio of the broad-leaved trees this phase was divided into three subzones.

LPAZ Ia. 480–365 cm. Low values represent *Quercus* and *Ulmus*, the curve of *Betula* reaches its highest value.

LPAZ Ib. 365–320 cm. *Quercus* and *Ulmus* multiply, *Betula* decreases. The curve of *Corylus* increases. The forests begin closing, while the values of Poaceae decrease. *Nymphaea* increases in the water.

LPAZ Ic. 320–280 cm. At 15% *Quercus* and *Ulmus* become stable, while *Corylus* reaches the first peak. Further decrease of Poaceae is observed.

LPAZ II. 280–210 cm (8000–5700 conv. ^{14}C BP; 6700–4900 cal ^{14}C BC): Among the main characteristic features of this zone are the high value of *Quercus* (about 30%), the first significant occurrence and peak of *Fagus* without *Carpinus*,

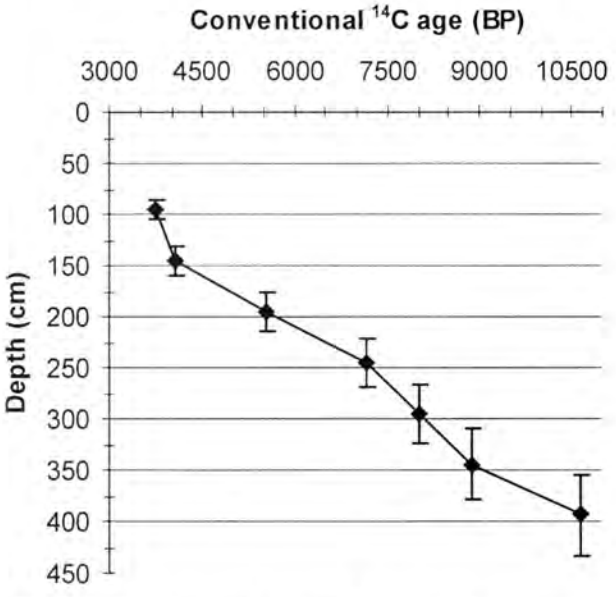


Fig. 2. Sediment accumulation rate, Keszthely-Úsztatómajor.

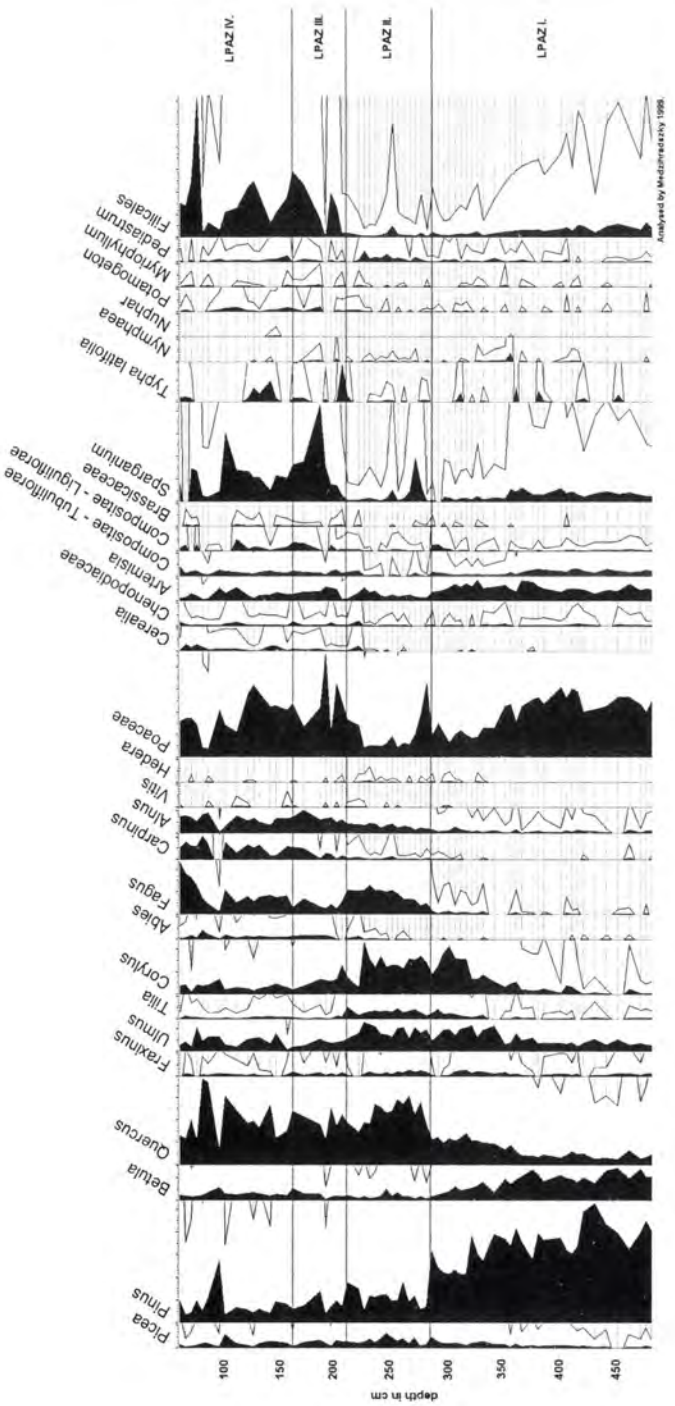


Fig. 3. Pollen diagram against depth. Holocene sequence of Keszthely-Úsztatómajor. 100% = AP+NAP. The rate of the exaggeration is 10×.

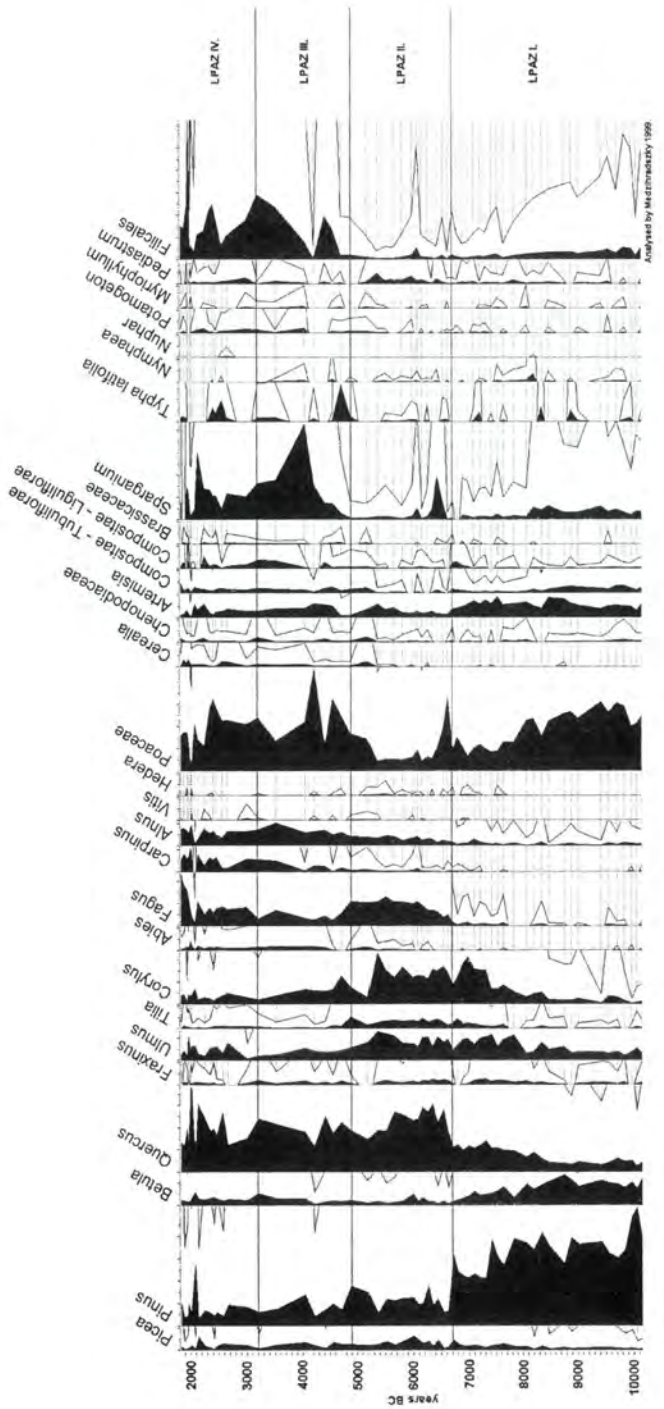


Fig. 4. Pollen diagram against calibrated radiocarbon age BC. Holocene sequence of Keszthely-Úsztatómajor. 100% = AP+NAP. The rate of the exaggeration is 10x.

the constantly high percentage of *Corylus* and the decreasing curve of Poaceae. Only in this zone is relatively high the value of *Tilia* with about 3–4%. The amount of *Ulmus* is considerable. This is the period of the closing forests. The reed-grass vegetation is poor, the occurrence of *Nymphaea* and *Myriophyllum* is sporadic, but the first *Pediastrum* peak is apparent. The zone may be divided into two subzones.

LPAZ IIa. 280–220 cm. *Quercus* and *Ulmus* reach the highest value, the *Fagus* curve drops, and the presence of *Corylus* is stable (10%). Herbs are present in a very small amount, *Artemisia* has a low value, and the Compositae-Tubuliflorae and C. Liguliflorae pollen groups occur only in few cases.

LPAZ IIb. 220–210 cm. The separation of this short period well corresponds with the decreasing value of *Quercus* and *Corylus*, and the beginning of emergence of Poaceae. In this subzone we observe for the first time the occurrence of the pollen type of cereals.

LPAZ III. 210–160 cm (5700–4500 conv. ^{14}C BP; 4900–3200 cal ^{14}C BC): In this zone the value of *Quercus* decreases to 20% and that of *Ulmus* to 4–5% the value of *Ulmus*. *Tilia* basically disappears. The values of *Fagus* also decrease, while *Carpinus* occurs increasingly. The number of the pollen grains of Poaceae increases, with significant presence of *Artemisia*. The forests open, while the herbs increase. The spores of Filicales occur in great amounts, often even the sporangium is visible. Suddenly the *Sparganium-Typha* sp. curve increases, the reed-grasses multiply but *Pediastrum* decreases. The zone was divided into two subzones.

LPAZ IIIa. 210–185 cm. Peaks of Poaceae and cereals are apparent.

LPAZ IIIb. 185–160 cm. Along with a moderate increasing of *Fagus* the curve of *Carpinus* also increases. The Poaceae values decrease. Constant but low value is detectable in the cereal group.

LPAZ IV. 160–60 cm (4500–3400 conv. ^{14}C BP; 3200–1700 cal ^{14}C BC): In this zone the values of *Quercus* vary between 20–40%, while *Ulmus*, *Fagus* and *Carpinus* increase. The ratio of Poaceae is high, and further emerge the herbs. The presence of cereals is constant. In the aquatic environment the bulrush vegetation is significant. The zone was divided into three subzones.

LPAZ IVa. 160–110 cm. At steadily high Poaceae value, 10% presence of *Fagus* and a small peak of *Ulmus* is characteristic of the period.

LPAZ IVb. 110–80 cm. Suddenly a rise in the value of *Pinus* is observed, along with a small increase of *Betula*. *Quercus* reaches its highest, 40% value. The changes in the ratio of trees are not interpretable by the changes of climatic conditions.

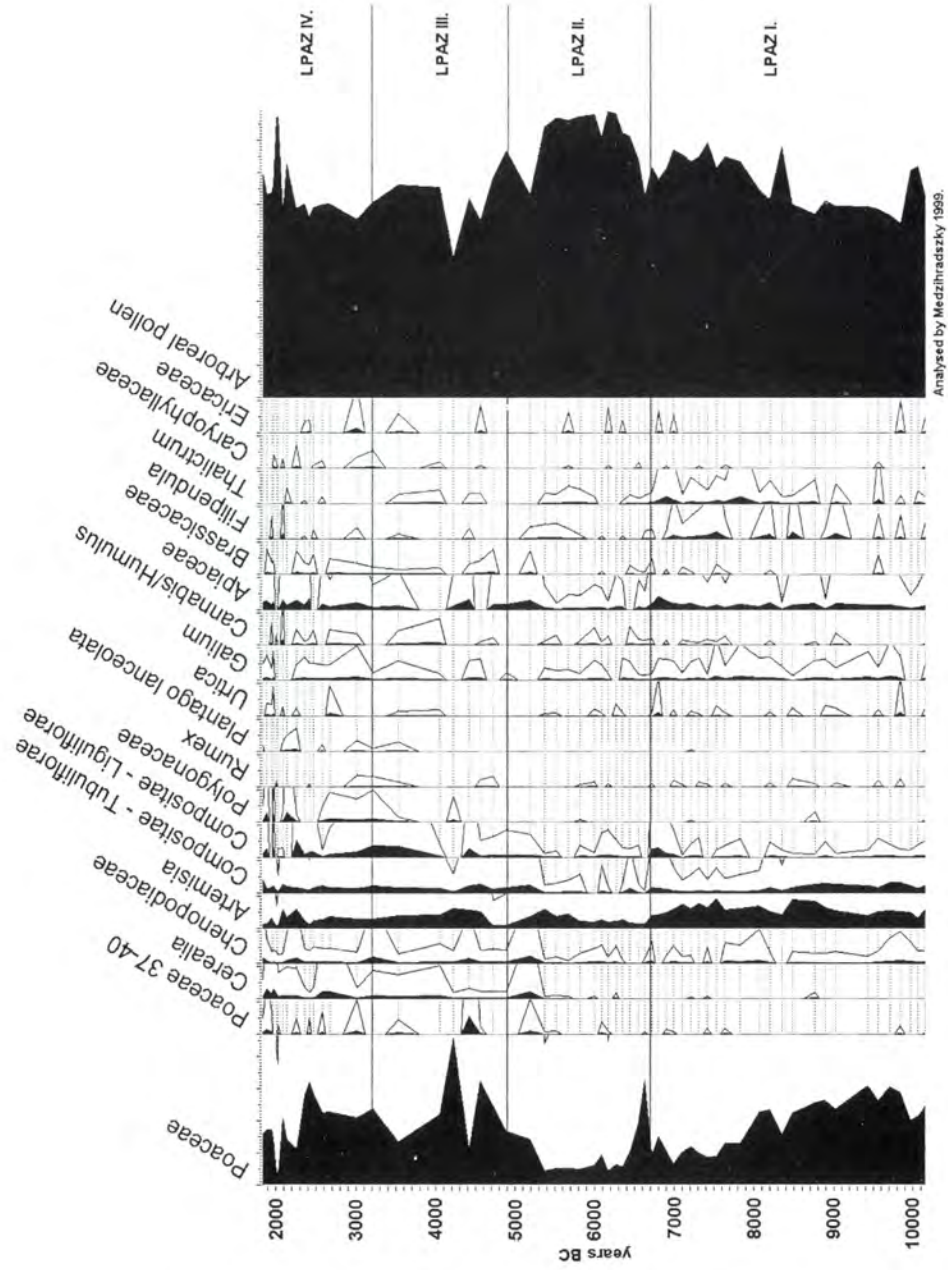


Fig. 5. Pollen diagram of the herbs against calibrated radiocarbon age BC. Holocene sequence of Keszthely-Úsztatómajor. The rate of the exaggeration is 10×.

LPAZ IVc. 80–60 cm. The separation of this short period is based on the sudden rise of *Fagus* curve and the decrease of *Quercus*. High, about 3% of the value of cereals and we observe an extremely high number of the spores of Filicales.

Anthropogenic signs

In order to investigate the taxa and palynological phenomena connected to the human presence we had to make a special diagram where pollen of non-arboreal plants is separately and more detailed figured. To compare the ratio of indicator taxa related to the overall changes in the vegetation the curve of arboreal pollen is closed. All curves are related to the total pollen count, AP+NAP as 100% (Fig. 5).

The primary indicator taxa, the cereals, occur constantly in the LPAZ IIb. This subzone was dated by calibrated ^{14}C to 5500–4900 BC, which implies the middle part of the Neolithic. The peak of Poaceae with pollen grains bigger than 40 μm, the *Triticum* group (except *Triticum monococcum*), occurs at a depth of 220 cm, and the *Triticum monococcum-Hordeum* group (37–40 μm) is also observed in this layer.

The earliest settlements in the source area of pollen rain could be dated to the period of the Transdanubien LBC, to the 2nd half of the 6th millennium. As stated by some references, in the agriculture of LBC the animal husbandry and the slash and burn method was applied (VIRÁG 1996, H. SIMON 2003). In our area of investigation we could not find a clear evidence of this, but maybe the small decrease of *Quercus*, the strong decrease of *Ulmus*, the emerging of Poaceae and Chenopodiaceae with a peak of *Artemisia* indicate, in part, human disturbance.

From the beginning of the Late Neolithic (4900 BC) until the top of the profile at 1650 BC (Middle Bronze Age) the curve of the cereals is continuous. The continuous presence of Chenopodiaceae and *Artemisia*, the occurrence of *Plantago lanceolata* also refers to human disturbance.

These results are supported by mathematical methods, the palynological richness diagram refers to anthropogenic signs by increasing values in the LPAZ III and in the first part of the LPAZ IV, but the PCA analysis only shows a very sharp climatic change at 280 cm depth, that is about 6700 BC (Fig. 6).

Főnyed

The study area is situated south of the river Zala, in the middle part of the swamp basin of the Kis-Balaton, in 104 and 104.5 m above sea level, from which the islands rise about 1 to 7 m (lat.: 46°38'22"N; long.: 17°14'40"E). The sampling point is west from the village of Főnyed, between the railway and the Cölömpös-

channel. The area is covered with 30–50 cm water. Although the settlement history of the area is characterised by the archaeological localities south of the crossing point at Balatonhídvég, the source of pollen precipitation could be originated from a larger area, because of the openness of the basin from north and because of the direction of the prevailing wind. Some pollen transport by water flow is also possible. Preliminary and somewhat simplified results were published earlier (MEDZIHRADSZKY 2001*b*, SZÁNTÓ and MEDZIHRADSZKY 2004).

Radiocarbon data

The upper 230 cm of the sediment contained enough organic material for radiocarbon dating. From this profile 12 measures were made, the sample deb–7720 has shown reversed data, maybe because of pollution. For the dating of the part of the profile below 230 cm we used extrapolation based on previously acquired data and the similarity of the pollen curve of Keszthely-Úsztatómajor (Table 3).

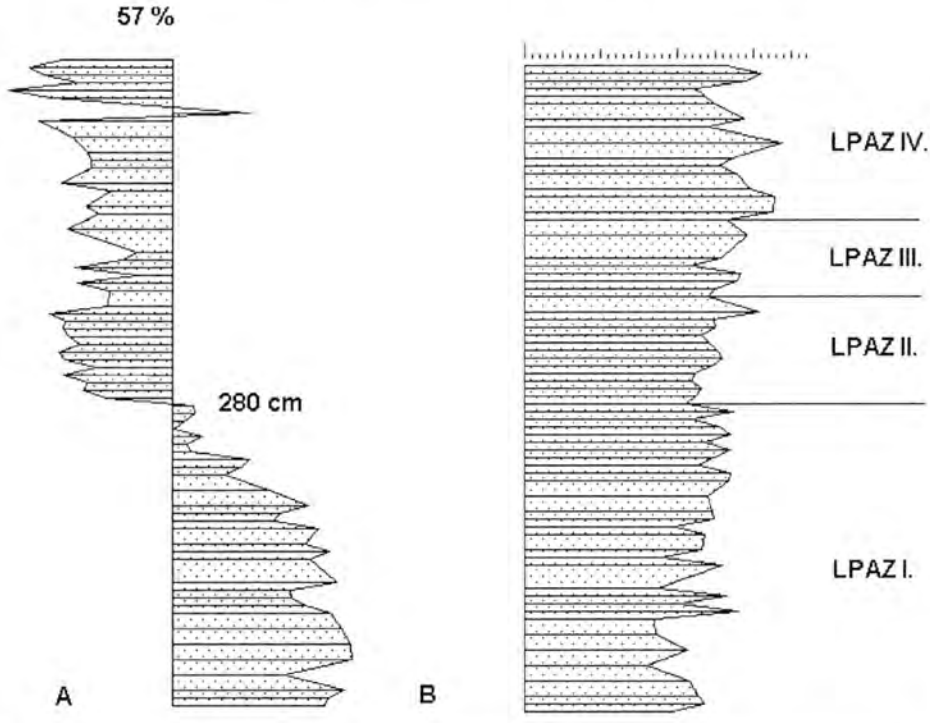


Fig. 6. First principal component (a) and rarefaction analysis (b) of the Holocene sequence of Keszthely-Úsztatómajor.

Table 3. Radiocarbon data of Főnyed.

lab.code	depth/cm	conv. radiocarbon age (BP)	calibrated radiocarbon age (BC)
deb-7711	0–20	3030±55	1410–1115
deb-7909	30–50	4085±60	2768–2485
deb-7717	50–60	4530±55	3375–3051
deb-7925	60–70	5010±60	3939–3684
deb-7718	70–80	5475±70	4466–4161
deb-7833	80–100	5980±65	5012–4730
deb-7720	100–110	4890±55	3786–3614
deb-7928	155–165	5955±75	5022–4678
deb-7725	180–190	6080±55	5102–4818
deb-7929	195–205	7010±160	6193–5635
deb-7937	205–210	7030±95	5991–5818
deb-7727	220–230	7275±70	6242–6004

Sedimentation

The coring area was covered with 50 cm deep water, the depth data were calculated below of this water, from the top of the soil (Table 4.)

The sedimentation rate was constant between 4900 and 1300 BC, about 43 yr/cm. Around 4,900 BC a 70 cm thick sediment was developed very rapidly during a period of few years. The feature of the sediment refers to a flood, a sort of in-

Table 4. Lithology of Főnyed.

Depth	Description of the sediment
0–30 cm	soft black soil with molluscs, roots and stems remains
30–107 cm	mixed peat wit mollusc debris, sandy layer between 55–57 cm
107–158 cm	bright calciferous mud
158–170 cm	muddy layer with rich organic content
170–180 cm	fibrous peat
180–232 cm	blackish brown peat
232–280 cm	sandy layer
280–480 cm	calciferous mud

flow of a huge amount of fresh water. Between 4800–5900 the rate is similar to the upper part of the profile, below it the speed of sedimentation was higher, 10 yr/cm (Fig. 7).

Palynological study

For the investigation of the anthropogenic impact the upper 340 cm of the profile was analysed and four local pollen assemblage zones (LPAZ) were determined (Figs 8–9).

LPAZ I. 340–240 cm (*ca* 11350–7900 conv. ^{14}C BP; *ca* 10200–6900 cal ^{14}C BC): The high percentage of *Pinus* (50%) and a constant presence of *Picea* are characteristic for this zone. Among the deciduous trees *Betula* reaches a relatively high value, 12–15%. Slow rise of *Quercus* is shown and few pollen grains of *Fagus* are detectable. The value of Poaceae is 15% in average, and Brassicaceae, probably *Cardamine* show peak values. From the aquatics, the bulrush vegetation is significant with *Typha latifolia*. The reed-grass vegetation, *Myriophyllum verticillatum*, *Potamogeton* sp., *Nymphaea*, and *Pediastrum* refer to open surface of water. The zone was divided into two subzones (LPAZ Ia. 340–275 cm and LPAZ Ib. 275–240 cm). The division of the subzones was based on the decrease of *Betula* and increase of *Quercus*, *Ulmus* and *Corylus*.

LPAZ II. 240–95 cm (7900–6000 conv. ^{14}C BP; 6900–4900 cal ^{14}C BC): The decrease of conifers and the increase of deciduous forests mark this era. In some

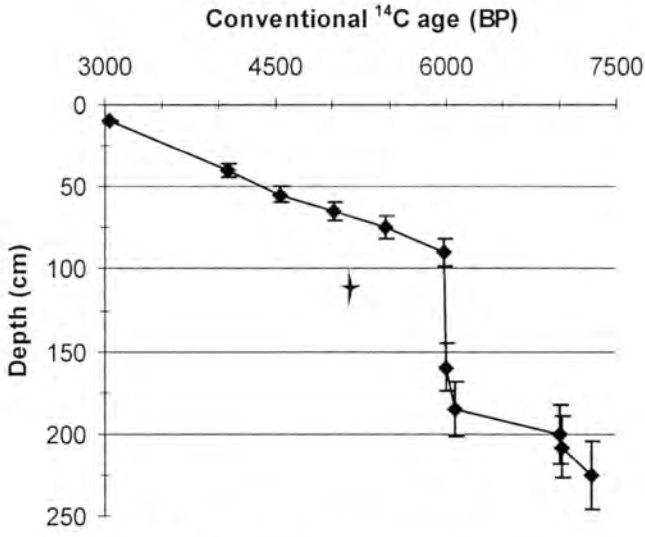


Fig. 7. Sediment accumulation rate, Főnyed.

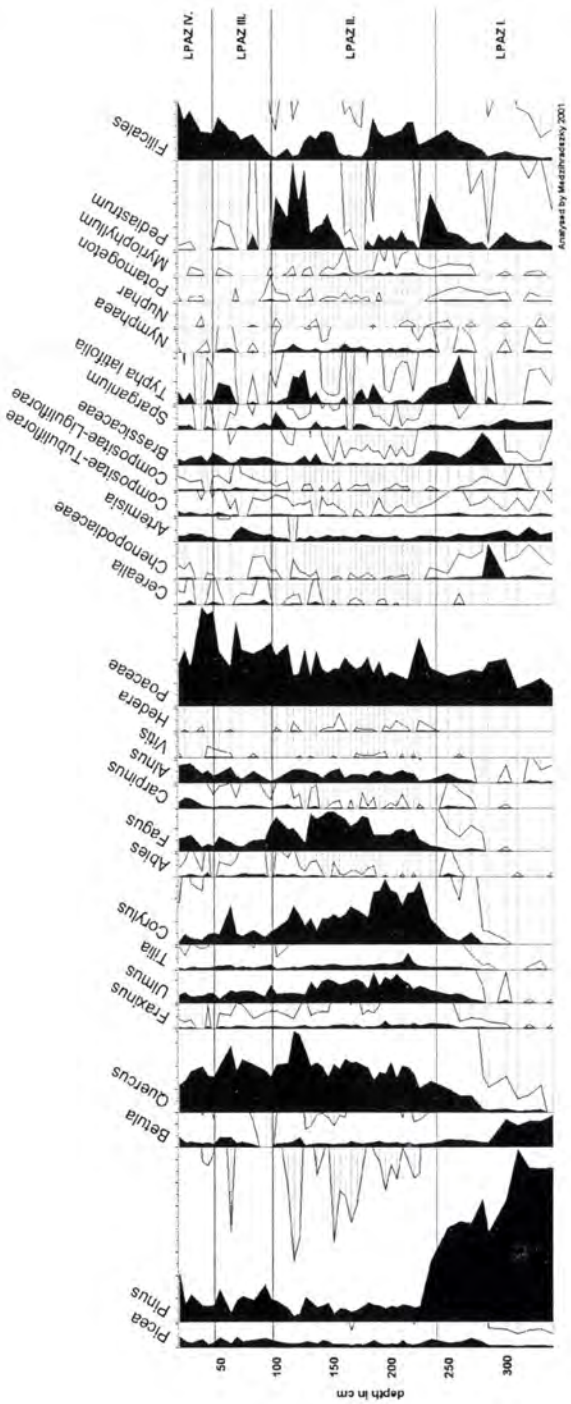


Fig. 8. Pollen diagram against depth. Holocene sequence of Főnyed. 100% = AP+NAP. The rate of the exaggeration is 10×.

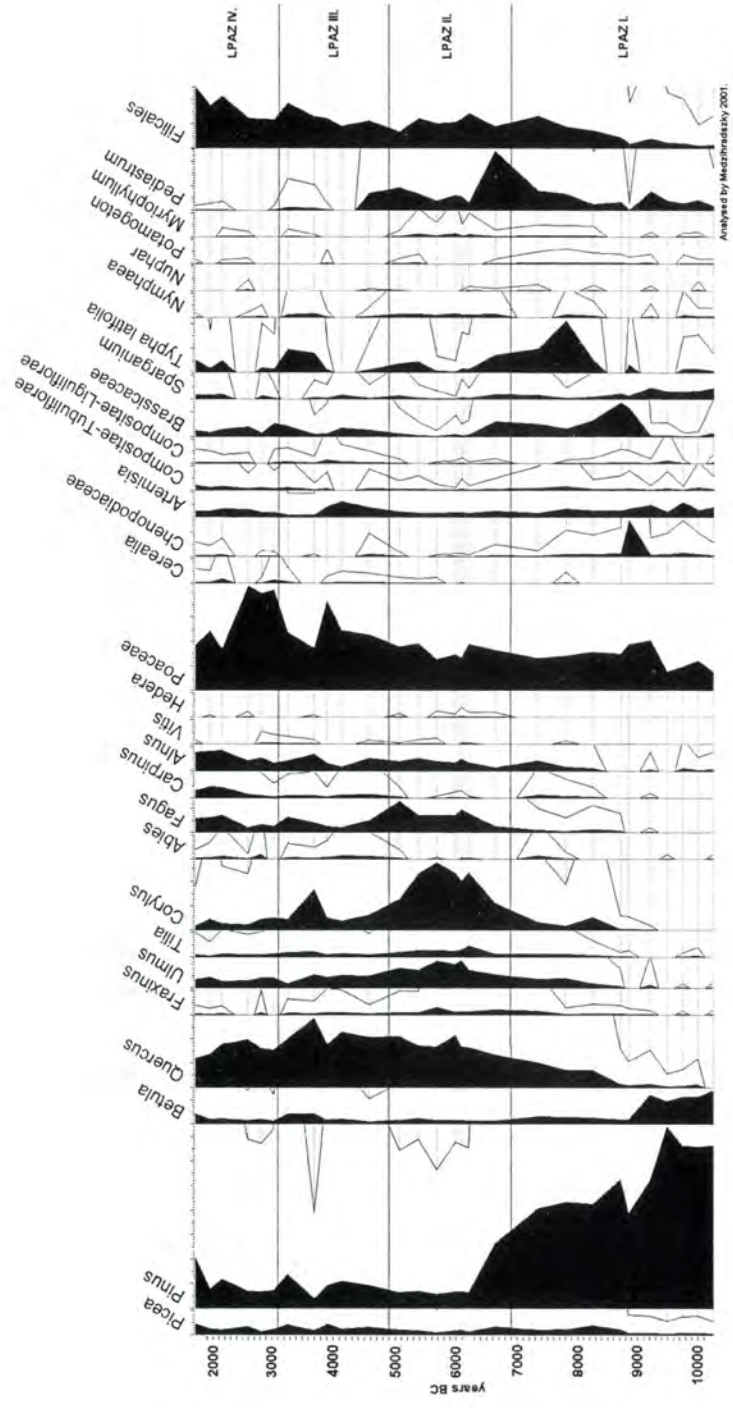


Fig. 9. Pollen diagram against calibrated radiocarbon age BC. Holocene sequence of Fónyed. 100% = AP+NAP. The rate of the exaggeration is 10×.

levels *Quercus* reaches 30% value, otherwise 20% in average. *Ulmus* is about at 10%, *Fagus* is somewhat below 20%. *Corylus* has a peak at 25%. Among the herbaceous plants the value of Poaceae is 20% in average and only 1–2% of this falls within the *Phragmites* type. Cyperaceae and Brassicaceae families decrease, and very low is the value of both subfamilies of Compositae. Among the aquatic plants the presence of *Nymphaea* and *Myriophyllum-Potamogeton* reed grass is significant. Very high is the value of *Pediastrum*. Cereals do appear in this zone for the first time. The zone was divided into two parts.

LPAZ IIa. 240–180 cm. The value of *Fagus* increases (up to 10%), and *Corylus* shows its highest percentage (25%). The only peak of *Tilia* occurs in this subzone with 10%. A general decrease of herbs is detectable. The upper border of the subzone was drawn mainly because of the sudden change in the sedimentation.

LPAZ IIb. 180–95 cm. *Fagus* further increases up to 20%, while *Corylus* decreases rapidly. The Poaceae curve is stable at about 20%. Between 130 and 115 cm a very high *Pediastrum* peak occurs.

LPAZ III. 95–50 cm (6000–4600 conv. ^{14}C BP; 4900–3100 cal ^{14}C BC): A moderate increase of *Pinus* and a small decrease of *Quercus* characterise the zone. The value of *Fagus* decreases as well as *Carpinus*, and although the latter is greatly reduced, it is constantly present. Poaceae are very significant again and the Cyperaceae also increase. The growing presence of *Artemisia* and Compositae could be related to forest clearance.

From anthropogenic point of view the zone could be divided into two parts (LPAZ IIIa. 95–65 cm and LPAZ IIIb. 65–50 cm). In the IIIb subzone, compared to the IIIa, a small *Betula*, *Corylus* and *Quercus* peak and an apparent decline of Poaceae and *Artemisia* is observed. The cereals are missing.

LPAZ IV. 50–0 cm (4600–3000 conv. ^{14}C BP; 3100–1500 cal ^{14}C BC): *Quercus* decreases, but *Fagus* increases together with *Carpinus*. Poaceae reaches the highest value, 40%. The values of other herbs also increase.

Anthropogenic signs

The anthropogenic taxa and phenomena were analysed in a special diagram, according to Keszthely-Úsztatómajor (Fig. 10).

Pollen of the cereals occur at 215 cm, 205 cm, 195 and 190 cm depth. This is discontinuous but the consistency could refer to the Starčevo culture (Early Neolithic, middle of the 6th millennium). From a depth of 165–60 cm (about 4900–4400 BC), among the Poaceae pollen types, *Triticum monococcum-Hordeum* group (37–40 μm) and *Triticum* group (> 40 μm) occur constantly, which is evidence of significant crop cultivation during the Late Neolithic. From this age

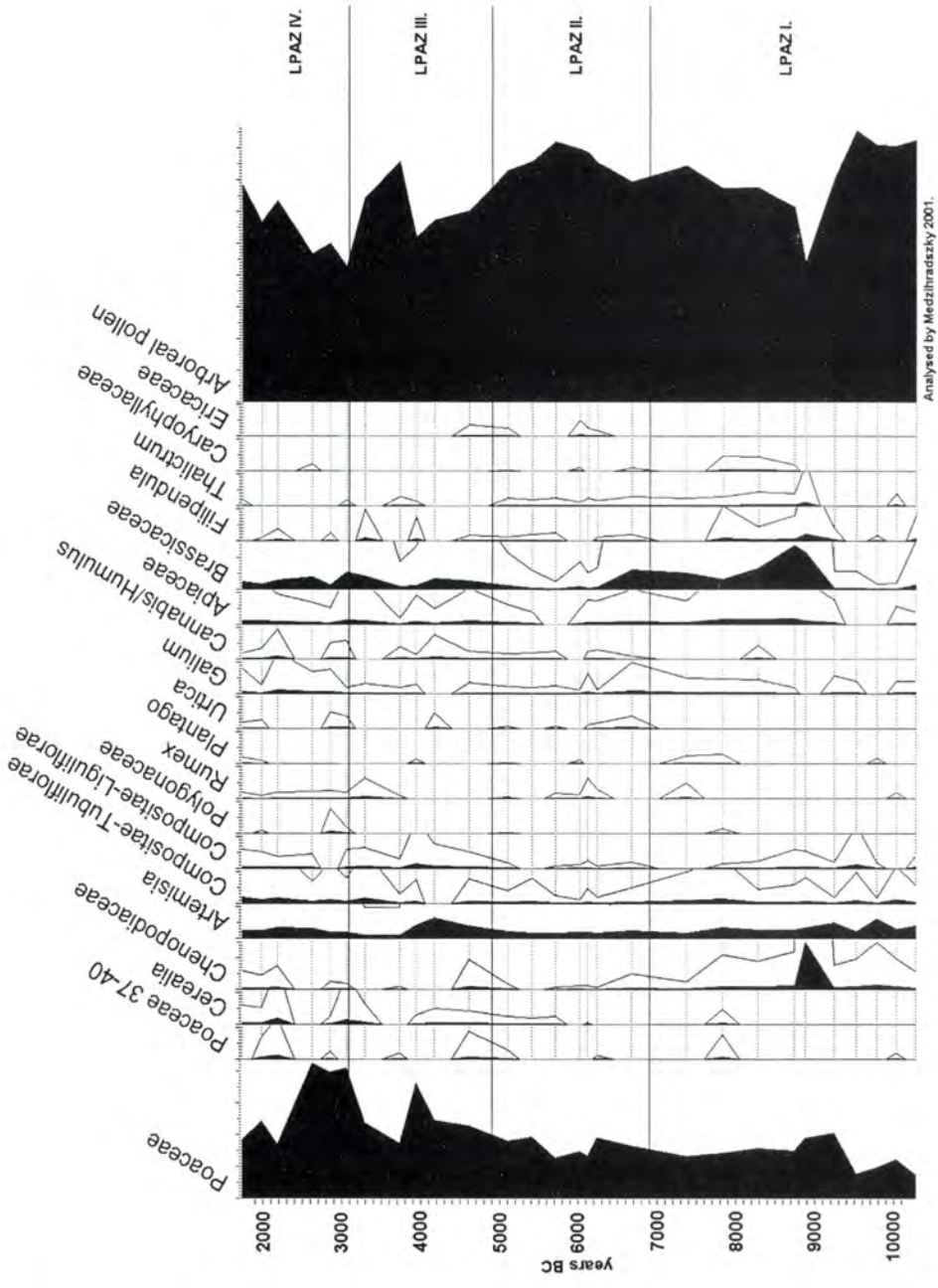


Fig. 10. Pollen diagram of the herbs against calibrated radiocarbon age BC. Holocene sequence of Főnyed. The rate of the exaggeration is 10×.

several settlements of the Lengyel culture have been excavated. During this period small peaks of secondary indicator taxa, *Artemisia*, Chenopodiaceae, *Plantago lanceolata* and Compositae are visible.

The surroundings of the coring point appear to be unsettled in the Late Copper Age (2nd half of the 4th millennium), only one locality with sporadic fragments of pottery is known. In the pollen diagram the lack of cereals and small increase of trees is observed.

In the LPAZ IV, during the Early and Middle Bronze Age cereals and ruderals (*Artemisia*, Chenopodiaceae) are present. The forests are opened.

The palynological diversity increases at the end of the LPAZ II and at the beginning of LPAZ III, later in the LPAZ IV, which corresponds with the settlement intensity. The PCA analysis shows a very well marked change at 250–234 cm, about 6,900 BC (Fig. 11).

DISCUSSION

Our pollen profiles represent the Holocene vegetation history of the Kis-Balaton area from its beginning until the middle of the 2nd millennium. Between

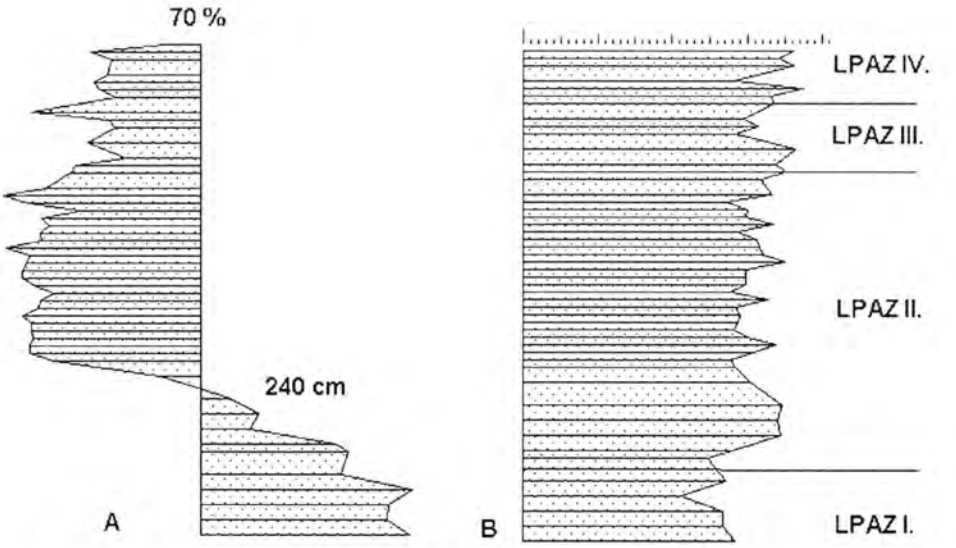


Fig. 11. First principal component (a) and rarefaction analysis (b) of the Holocene sequence of Főnyed.

10500/10300 BC and 6900/6700 BC *Pinus* and *Betula* are characteristic, but the broad-leaved trees, *Quercus*, *Ulmus*, *Fraxinus* and *Tilia* occur as well. From 6900/6700 BC until 4900 BC, during the Early and Middle Neolithic the deciduous trees are dominant; closed forests covered the surroundings and the islands of the ancient bay. 4900–3200/3100 BC is the time of the first significant settlement network (Late Neolithic and Copper Age), whose traces, the occurrence of cereals are detectable in the pollen diagrams. From 3200/3100 BC to the top of the sequences, about to the middle of the 2nd millennium (end of the Copper Age, Early and Middle Bronze Age), along with the primary indicator taxa, the cereals, another human impact, the decrease of trees and increase of the herbs is evident. However, ruderals as anthropogenic markers are not significantly present and the woodland appears to have been untouched for most of this period of time although there were repeated declines and recoveries of the principal tree taxa. No significant change in the pollen ratio of the trees and shrubs and herbs was observed during the prehistoric times in the region of Lake Kis-Balaton. However, the role of plant cultivation may have been limited for the ancient inhabitants of the Kis-Balaton area compared to other areas in Hungary, due to the limited amount of available land suitable for agriculture and the presence of the lake.

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