Publikationen des Deutschen Archäologischen Instituts

Tivadar Vida, Daniel Winger (Volume editors), Szólád I: Das langobardenzeitliche Gräberfeld: Mensch und Umwelt

Sándor Gulyás, Tünde Törőcsik, Balázs Pál Sümegi, Pál Sümegi
Environmental history of an embayment of Lake Balaton near Szólád from the Late Glacial to the Migration Age

Römisch-Germanische Forschungen Band 76

https://doi.org/10.34780/63ea-a7g6

Herausgebende Institution / Publisher:
Deutsches Archäologisches Institut

TIVADAR VIDA / DANIEL WINGER
(HERAUSGEBER)

SZÓLÁD I

DAS LANGOBARDENZEITLICHE GRÄBERFELD: MENSCH UND UMWELT

RGK

TIVADAR VIDA / DANIEL WINGER
(HERAUSGEBER)

SZÓLÁD I

RÖMISCH-GERMANISCHE FORSCHUNGEN

BAND 76

zugleich

MONUMENTA GERMANORUM ARCHAEOLOGICA HUNGARIAE

BAND 7

RÖMISCH-GERMANISCHE KOMMISSION
DES DEUTSCHEN ARCHÄOLOGISCHEN INSTITUTS ZU FRANKFURT A. M.

INSTITUT FÜR ARCHÄOLOGISCHE WISSENSCHAFTEN DER
EÖTVÖS LORÁND UNIVERSITÄT ZU BUDAPEST

INSTITUT FÜR ARCHÄOLOGIE, GEISTWISSENSCHAFTLICHES
FORSCHUNGSZENTRUM DES EÖTVÖS LORÁND FORSCHUNGSNETZWERKES
ZU BUDAPEST

UNGARISCHES NATIONALMUSEUM ZU BUDAPEST

RÖMISCH-GERMANISCHE KOMMISSION
INSTITUT FÜR ARCHÄOLOGISCHE WISSENSCHAFTEN DER EÖTVÖS LORÁND UNIVERSITÄT
INSTITUT FÜR ARCHÄOLOGIE, GEISTWISSENSCHAFTLICHES FORSCHUNGSZENTRUM DES EÖTVÖS LORÁND FORSCHUNGSNETZWERKES
UNGARISCHES NATIONALMUSEUM

Szólád I

Das langobardenzeitliche Gräberfeld: Mensch und Umwelt

HERAUSGEGEBEN VON
TIVADAR VIDA UND DANIEL WINGER

MIT BEITRÄGEN VON
KURT W. ALT, LÁSZLÓ BARTOSIEWICZ, UTA VON FREEDEN, ERIKA GÁL, SÁNDOR GULYÁS, FERENC GYULAI, ISABELLE KOLLIG, KYRA LYUBLYANOVICS, CHRISTIAN MEYER, MARK OPELT, KÁROLY PENKSZA, ÁKOS PETŐ, DÉNES SALÁTA, TIM SCHÜLER, PÉTER SKRIBA, BALÁZS PÁL SÜMEGI, PÁL SÜMEGI, HEINRICH THIEMEYER, TÜNDE TÖRŐCSIK, TIVADAR VIDA UND DANIEL WINGER

REICHERT VERLAG • WIESBADEN • 2022

XVI, 358 Seiten mit 187 Abbildungen, 4 Diagrammen, 29 Tabellen und 73 Tafeln

Bibliographische Information der Deutschen Nationalbibliothek

Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliographie;
detaillierte bibliographische Daten sind im Internet über <http://dnb.d-nb.de> abrufbar.

ISBN: 978-3-7520-0654-4

Redaktion: Hans-Ulrich Voß, Römisch-Germanische Kommission Frankfurt a. M.
Formalredaktion: Johannes Gier, Römisch-Germanische Kommission Frankfurt a. M.
Bildredaktion: Oliver Wagner, Römisch-Germanische Kommission Frankfurt a. M.
Satz: Susanne Biegert, Bonn
Druck: Bonifatius GmbH Druck – Buch – Verlag, Paderborn
Printed in Germany
Printed on fade resistant and archival quality paper (PH 7 neutral) • tcf

Inhaltsverzeichnis

Environmental history of an embayment of Lake Balaton near Szólád from the Late Glacial to the Migration Age

By Sándor Gulyás, Tünde Törőcsik, Balázs Pál Sümegi and Pál Sümegi

INTRODUCTION

Rescue excavations implemented in 2003 along the southern shore of Lake Balaton preceding construction works of the M7 freeway yielded us a possibility to better understand the environmental history of the region. These excavations tackled the spatial distribution of archaeology to a height of 103–104 m ASL yielding numerous features as well as artefacts from the Neolithic up to the Early Middle Ages. The proximity of numerous historical embayments along the southern shoreline acting as sedimentary basins preserving geological and palaeoecological records dating back several millennia, opened up the possibility for complex geoarchaeological, environmental historical studies.

LOCATION, GEOGRAPHICAL, GEOLOGICAL, AND MODERN CLIMATIC ENDOWMENTS OF THE SITE

The sampling site is found in the centre of a former southern embayment of Lake Balaton drained by the creek of Büdös-gáti víz at a height 102 m ASL (N = 46° 48' 16.81", E = 17° 48' 59.43"), approximately 4 km to the SE from the village of Balatonöszöd along the present trajectory of the M7 freeway *(fig. 1)*. The embayment occupies a former longitudinal valley with a northwest-southeast trend surrounded by hills ranging between 120 and 300 m ASL. These are composed of Late Tertiary Lake Pannon sands and silts. Some of the slopes are covered by Pleistocene rock debris. The valley itself is filled by Quaternary lacustrine, marsh and fluvial deposits *(fig. 2)*. Slightly acidic as well as calcareous phaeozems and luvisols are present in the area harbouring woodlands, wet meadows, peatlands and grasslands along with agricultural areas[1].

The climate is Continental with strong Oceanic and Submediterranean influences seen in higher precipitation rates as well as relatively warm vegetation period. The mean annual temperature is around 11 °C, the average annual rainfall ranges between 550 and 650 mm with late-spring early summer as well as early fall peaks. In historical times, much of the embayment was in hydrological contact with the waterbody of Lake Balaton hosting a peatbog as seen on the historical map of the first austrian military survey *(fig. 1)*. As a result of the 19th century drainage measures, aimed to stabilise the modern lake level within the ranges of 104–105 m ASL to make way for the construction of the railway, the embayment was completely drained causing the complete dry-out and alteration of much of the infilling peat. Minor water bodies with an area of some square kilometres were preserved serving as water reservoirs close to the modern shoreline.

MATERIAL AND METHODS

Samples were taken from two undisturbed overlapping cores to a depth of 1.8 m using a Russian type corer. After packaging, the samples were transported to the Geoarchaeological and Palaeoecological Laboratory of the Department of Geology and Palaeontology, University of Szeged (GPL-USZ DGP) for further analysis. For our work and interpretation of the results the methodology and system of Birks and Birks was consistently adopted[2]. The core was subsampled at 2 cm increments for sedimentological,

1 Ádám et al. 1981.
2 Birks / Birks 1980.

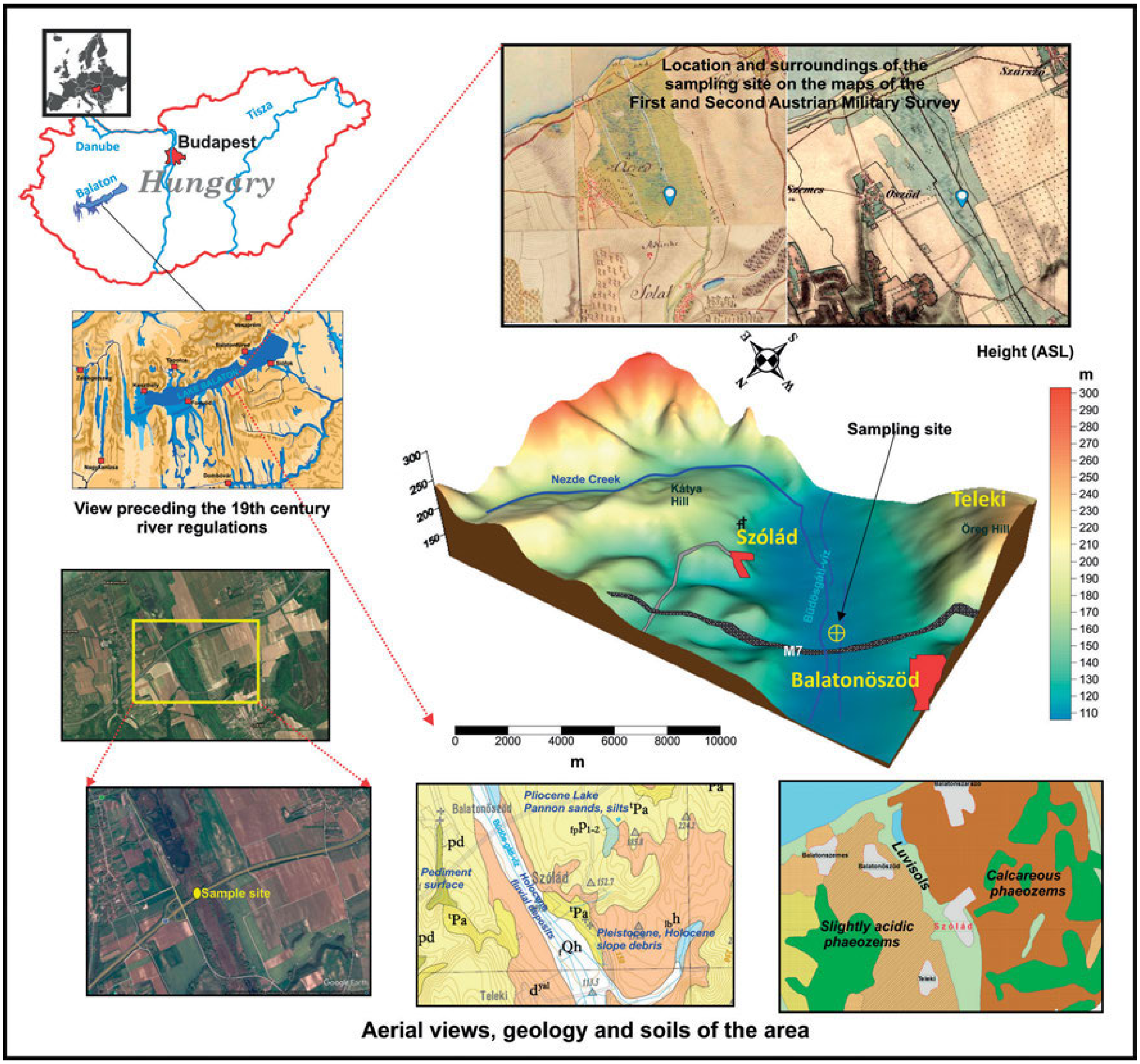

Fig. 1. Location and modern geographical and geological endowments of the study site.

geochemical and pollen analyses in accordance with the international standards[3]. Visual description of the lithology followed the internationally accepted system of Troel-Smith established for unconsolidated sediments[4]. Dry and wet colour was determined on site and at the lab using the Munsell Colour Chart. Organic and carbonate content of the samples was determined via loss on ignition following the methodology presented by Dean[5]. For the establishment of an absolute chronology three peat samples were taken at the depths of 0.2, 1 and 2 m. Two samples were submitted to bulk, while a single to AMS ^{14}C-dating. Pre-treatment followed the generally accepted procedures before graphitisation. Measurements were done in the internationally referenced AMS laboratories of Debrecen,

3 Birks / Birks 1980. – Sümegi 2003.
4 Troel-Smith 1955.
5 Dean 1974.

Hungary and Poznan, Poland. Conventional radiocarbon ages were converted to calendar ages using the software *Oxcal 4.2 online*[6] and the most recent *Intcal13* calibration curve[7]. Calibrated ages are reported as age ranges at the 2-sigma confidence level (95.4 %). For the extraction of pollen grains the method of Stockmarr was followed[8]. Lycopodium spore tablets of known concentration were added to each sample to ensure accurate pollen grain counting. Samples were studied via a phase contrast microscope under a magnification of 600–1000 times. A minimum of 500 grain counts were made to ensure the representativity of the samples for statistical evaluation. Statistical evaluation of the database and the establishment of an age-depth model was achieved using the software packages of *Statistica* and *PAST*[9]. For the determination of pollen and spore taxa the reference materials and database of the GPL-USZ DGP and the Hungarian Geological Institute were used in addition to textbooks[10]. Flue-ash concentrations were determined following the point-counting method of Clark[11]. Results of sedimentological, geochemical and palynological analyses were graphed using the Psimpoll package of Bennett[12]. Palynological zones were determined via cluster analysis using the Minkowski distance of similarity and the Ward clustering method[13]. Digital elevation models of the study area were prepared using the software package of *Surfer*. Following the detailed evaluation of the results, visual reconstructions were made for selected environmental historical periods using the graphical design programs of *Grapher* and *Coreldraw*.

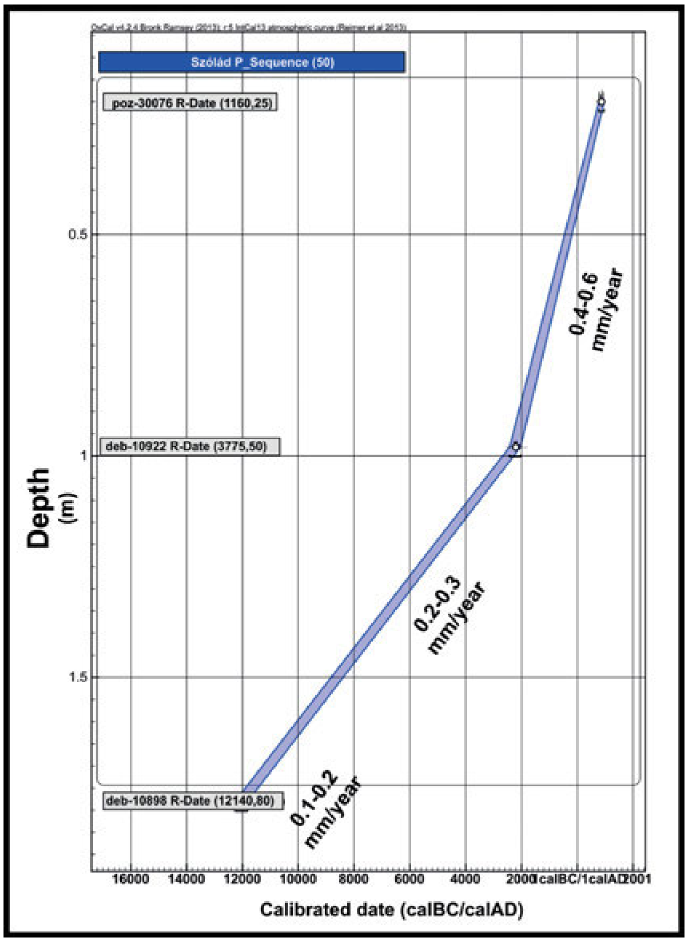

Fig. 2. Constructed age-depth model and calculated sedimentation rates.

RESULTS

Chronology

The results of ^{14}C-analyses are presented in *Table 1*. According to these and on the basis of lithological analogies, fluvial sands giving the base of the core started to accumulate in the embayment during the Late Glacial *c*. 14 000 years ago. Although the topmost part of the peat sequence must have been affected by erosion and desiccation, relatively undisturbed sediment and peat accumulation must have continued as long as the Early Middle Ages (9th century AD). On the basis of two ^{14}C-dates the uppermost 1 m of the profile spans a period from the Early Bronze Age up to today. The uppermost 45 cm of the sequence must represent the last 2000 years with *c*. 20–25 cm corresponding to the late Imperial Age and the Migration Age. However, more ^{14}C-dates lowering dating uncertainty for this period may help us further refine and constrain our chronology of this period. From about 1 m down to *c*. 1.6 m the sequence covers the remaining part of the Holocene, with *c*. 15–15 cm representing the Iron, Neolithic and Copper Ages and *c*. 20–30 cm corresponding to the Bronze Age and the Mesolithic. The lowermost *c*. 20 cm represent the Late Glacial (13 000–10 000 years ago). Sampling at 2 cm intervals yielded us a resolution of 250–300 years for the Late Glacial, *c*. 200 years for the Early and Middle Holocene. Attained resolution of the received data was around 100 years per sample from the Bronze Age to the Imperial Period. For the Imperial and Migration Ages, the best resolution was achieved with a step of *c*. 50 years.

6 Bronk Ramsey 2009.
7 Reimer et al. 2013.
8 Stockmarr 1971.
9 Hammer / Harper 2005.
10 Moore et al. 1991.
11 Clark 1981.
12 Bennett 1992.
13 Hammer / Harper 2005.

Sample depth	Sample code	Lab code	^{14}C-age (yr BP)	±1σ	2 σ calibrated age ranges (cal. BP, 95.4 %)			
					Min	Max	Mean	±1σ
0.2	SZD-1	Poz-30076	116	25	1176	986	1079	54
0.98	SZD-2	deb-10922	3775	50	4378	3981	4149	88
1.78	SZD-3	deb-10898	12 140	80	14 215	13 766	14 007	124

Tab. 1. Results of ^{14}C-analysis.

Conventional ^{14}C-ages have been calibrated using *OxCal 4.2* and the *IntCal13* calibration curve. On the basis of the received ^{14}C-ages an age-depth model was constructed and linear sedimentation rates were calculated for various lithostratigraphic units. During the Late Glacial (1.8–1.75 m) sedimentation was relatively low with an annual rate of 0.1–0.2 mm. There is a slight increase from the time of the Pleistocene / Holocene transition to a rate of 0.2–0.3 mm lasting as long as the Bronze Age (depth of 1 m). The highest accumulation rate of 0.4–0.6 mm is seen from a depth of 1 m to 0.2 m. As a result of hydrological regulation during the 19th century the topmost part must have dried out and altered.

Lithological characteristics, organic and carbonate content

The base of the core between the depths of 1.8 and 1.68 m is composed of white brown (2.5 Y 9.6), slightly bedded, fossiliferous calcareous silts with fine and very fine sand intercalations and lenses. Here the organic content was well below 2 % with a carbonate content ranging between 5–10 % *(fig. 3)*. Based on its lithological characteristics and stratigraphic position these deposits must represent a fluvial and pond sequence of the Late Glacial.

This is overlain by clays and silts of higher carbonate content to a depth of *c.* 1 m having a white brownish hue; a lacustrine sequence of a shallow pond. While there is a slight increase in the organic content to a value fluctuating around 10 %, based on the decreasing inorganic content accompanied by a gradual increase in the carbonate content two distinct stages of lake evolution could have been identified *(fig. 3)*. The first stage corresponds to the depth interval between 1.68 and 1.35 m where after a steady increase from *c.* 10 %, the carbonate content reaches a value ranging between 35–40 %. At the same time the proportion of silts and inorganic matter remains relatively high (*c.* 50 %). These deposits represent the first phase of a biotic succession of a lacustrine sequence: An oligotrophic, minerorganic lake of relatively deeper and clear waters occupying the embayment. From the depth of *c.* 1.35 m the ratio of inorganic matter undergoes a significant drop, while the carbonate content is doubled *(fig. 3)*. This transition clearly hallmarks the beginning of stage 2 in the succession. Namely, the emergence of a mesotrophic lake with clear shallow waters and carbonate-rich lacustrine mud accumulation. From about 1.04 m all the way to the surface there is a marked change in the lithology *(fig. 3)*. The organic content reaches 85 % after a rapid increase accompanied by a *c.* 50 % drop in the carbonate content between the depths of 0.95 and 0.65 m. Fine silty coarse silts of higher organic content overlain by intercalating peat and eutrophic lacustrine silts of darker hue, and high organic content indicate the transformation of the former carbonate-rich lake into an organic-rich eutrophic lacustrine system. Alternating layers of organic-rich silts, clays and peat indicate cycles of sediment accumulation characterised by alternating stages of lacustrine and marshland conditions above 0.65 m *(fig. 3)*. In this part, the organic content is reduced to values ranging between 45 and 70 % with parallelly increasing and decreasing carbonate contents. Periodic rises in the water level and the transformation of the marshland into an open eutrophic lake could have been inferred for several parts of the sequence above the referred depths. Namely, those corresponding to the Late Bronze Age (12–11th c. BC), the Early Iron Age (9–8th c. BC) with two distinct intervals. In addition, similar changes are deciphered for the Migration Age around 4–6th centuries AD and the 7–8th centuries AD.

Pollen analysis

The first zone (SZPZ-1) representing the first part of the Late Glacial was identified between 1.8 and 1.7 m *(fig. 4)*. The prevalent elements of the arboreal flora are various types of pines (Pinus) as well as birches (Betula). Nevertheless, the ratio of NAP in this interval was equally high

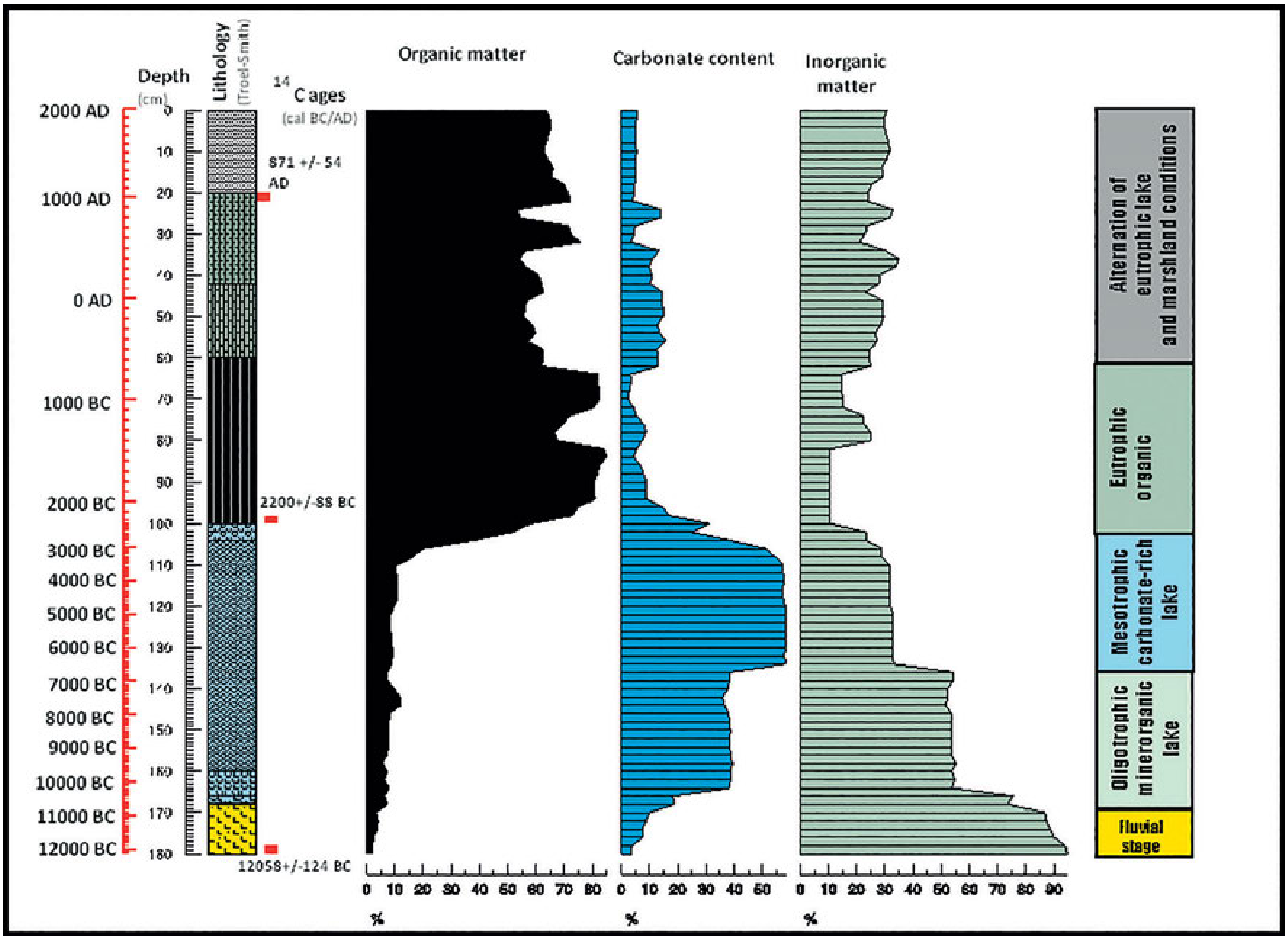

Fig. 3. Lithology, organic and carbonate content of the studied sequence.

(over 40 %) *(fig. 5)* with taxa representing various types of grasses *(Gramineae)*, artemisia *(Artemisia)*, goosefoots *(Chenopodiaceae)*. The heliophylic hazelnut is also present, most likely in the marginal areas, although in negligible proportions. Similar findings were noted in other Transdanubian sites[14]. This zone corresponds to a cold forest steppe with a dominance of Scotch pine and birches *(Pinus sylvestris – Betula)*. The presence of dwarf birch *(Betula nana)* further corroborates this view. The ratio of coniferous taxa was over 50 % with a clear dominance of Scotch pine and dwarf pines[15]. The banks of the Late Glacial pond harboured open gallery forests composed of birches and pines between 12 000–10 900 cal. BC years.

There is a marked change between the depths of 1.7–1.66 m corresponding to 10 900 and 9900 cal. BC years (SZPZ-2). The ratio of AP drops accompanied by a steady increase in NAP seen in the advance of such taxa as goosefoots and Artemisia. The only AP witnessing a rise here is that of dwarf birch. This indicates the development of a much cooler climate compared to the first part of the zone resulting in a relative opening of the vegetation. Signs of this climate change are traceable in NW Transdanubia and the foothills of the Carpathians and Alps only. Based on our results the area harboured a boreal forest steppe during the Epipalaeolithic with scattered patches of tundra as well as thermophilous taxa, where the microclimate conditions allowed *(fig. 6)*.

There is a marked increase in the AP of pines in the next zone (SZPZ-3) to a ratio over 60–70 %. The total ratio of AP was over 80 %. As a result of more favourable climatic conditions a closed boreal forest must have developed during the time representing the Pleistocene / Holocene

14 Juhász 2007.

15 Peterson / Peterson 2001.

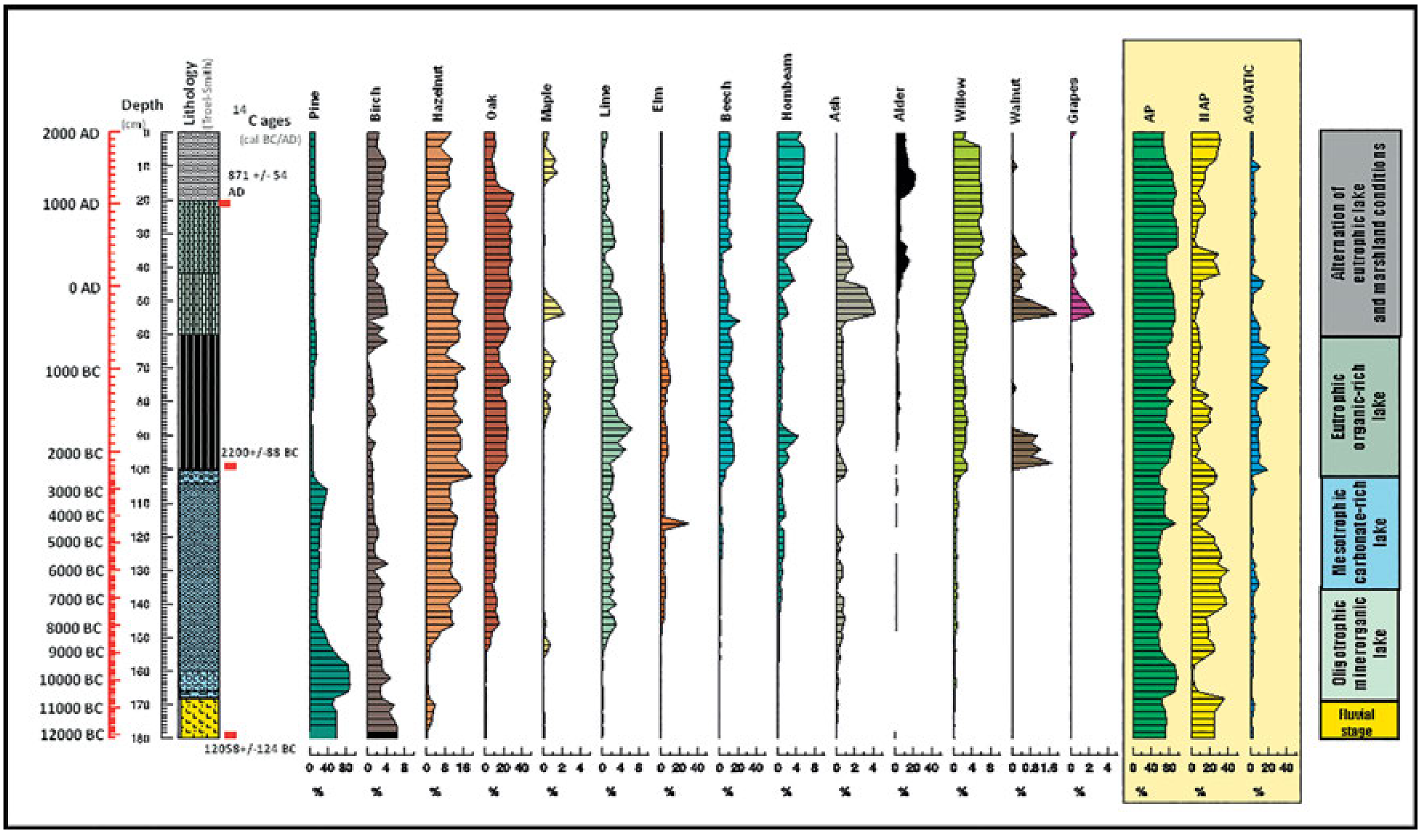

Fig. 4. Relative abundance of arboreal pollen taxa as well as the ratio of arboreal / non-arboreal and aquatic plants.

transition *(fig. 4)*. However, as the pollen composition clearly indicates this woodland must have been a mixed one harbouring numerous deciduous elements. The dominant deciduous taxa are birch and hazelnut complemented by sporadic appearances of oak, lime, elm, and ash *(fig. 7)*.

This palaeo-vegetation must have been characteristic for the opening of the Holocene between 9900 and 8900 cal. BC, representing the earliest Mesolithic. Similar conditions characterised the area of Southern Transdanubia for this interval based on palynological results[16]. This vegetation change fall roughly into the same period as in Western and Northern Europe. It must be noted though, as we indicated in subchapter 4.1 that due to the poor resolution (250–300 years / sample) determination of the accurate timing of the identified zones is not without hardships.

There is a gradual but marked decrease in pine pollen from a depth of 1.55 m upwards (8900 cal. BC years) (SZPZ-4) *(fig. 4)*. From a depth of 1.47 m (8200 cal. BC years) the ratio of pine pollen grains reaches a threshold, where the presence of local pine stands could be surely excluded. It is also the time, when our oligotrophic lake transforms into a shallow mesotrophic lake harbouring an extensive calcareous algae flora *(Chara)* and being characterised by the accumulation of calcareous muds. The emergence of this phase also hallmarks the time when the area of the embayment is first connected to the waterbody of the young Lake Balaton[17]. The development of this phase was coeval with the gradual retreat of Late Glacial / Early Holocene mixed taiga woodlands accompanied by the expansion of oak to the area *(fig. 8)*.

This type of taiga / oak woodland transition is characteristic for not only Transdanubia but the entire Carpathian Basin as well[18]. Besides oak, a higher ratio of hazelnut, elm, lime, ash, maple van be noted here *(figs 4; 8)*. According to this, the appearance of hardwood gallery forests along the lake-shore and also hardwood oak forests at a larger distance can be postulated. These conditions must have been preserved during the Neolithic and the Copper Age as well with a well-developed sub-canopy as reflected by the relatively high ratio of hazelnut pollen grains. Although the cyclical presence of weed pollen grains during this interval clearly indicates human influences in the area,

16 Juhász 2007.

17 Sümegi et al. 2008a. – Sümegi et al. 2008b. – Sümegi et al. 2009. – Sümegi et al. 2011. – Sümegi et al. 2012. – Sümegi et al. 2013.

18 Willis et al. 1997. – Sümegi et al. 2012a. – Sümegi et al. 2012b. – Sümegi et al. 2013.

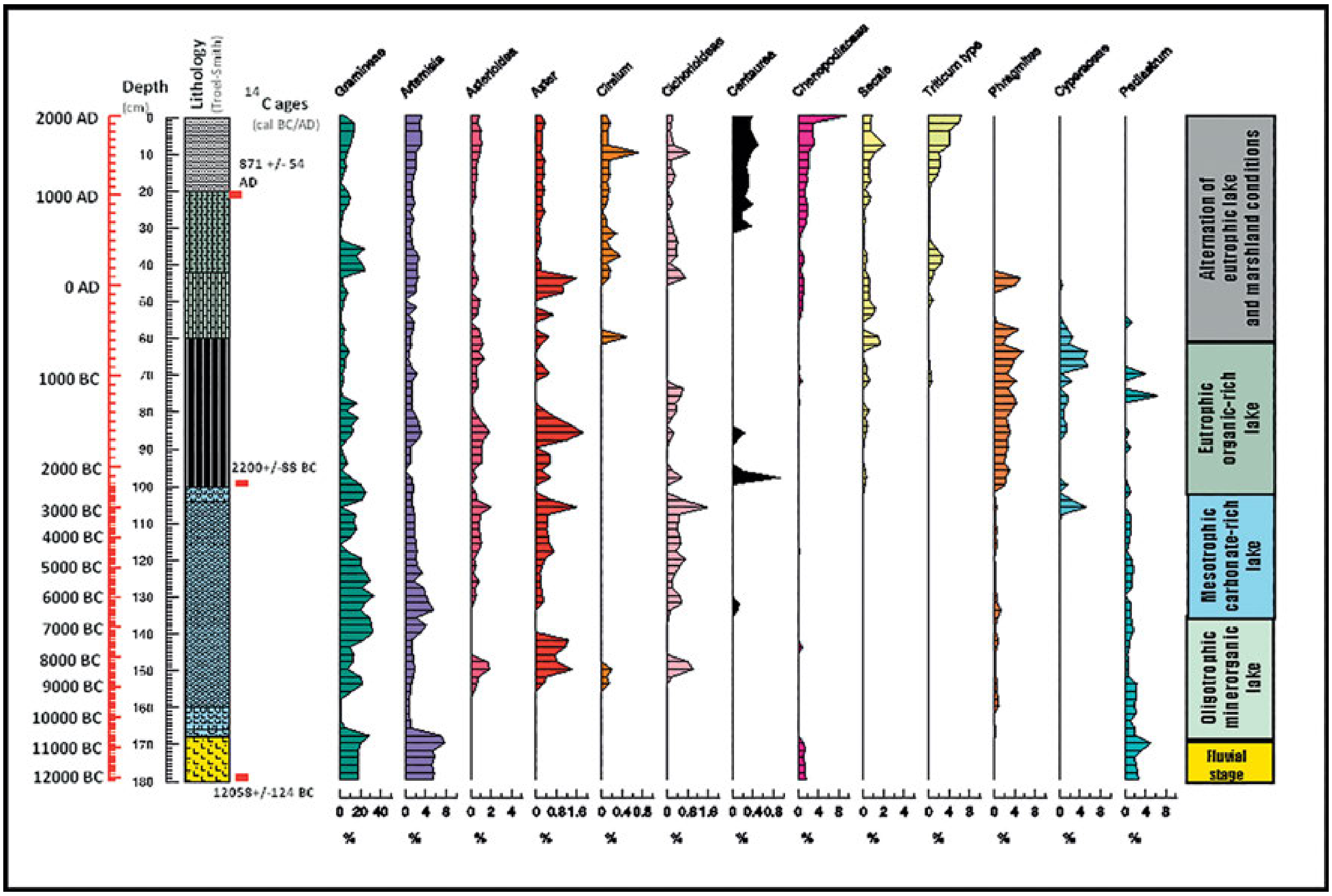

Fig. 5. Relative abundance of non-arboreal pollen taxa.

exact timing of these is not possible in the lack of absolute chronological and archaeostratigraphical data. Ages were assigned on the basis of the calculated sedimentation rates alone and will require further clarification and refinement in the future.

The most important change in the pollen composition – at the depth of *c*. 1 m – characterised by a significant increase in the pollen grains of reed and sedge (SZPZ-5) was coeval with the first appearance of peat in the sedimentary sequence hallmarking the next stage of lake evolution; the complete eutrophication of the entire embayment *(figs. 3; 5)*. According to the available ^{14}C-date from the depth of 0.98–1 m *(tab. 1; fig. 2)*, this event is dated to the Early Bronze Age (~2200 cal. BC). The former oak-dominated woodland was likewise transformed *(figs. 4; 9)* to a hornbeam / beech dominated woodland under a cooler climate. The expansion of reed, bulrush, and sedge is indicated not only by the preserved macrobotanical remains retrieved from the peat, but the NAP pollen composition as well *(fig. 5)*. A marked drop in pine pollen grains, being able to travel large distances clearly indicates that the significant vegetation cover of the embayment must have prevented the accumulation of extralocal pollen grains from this time onwards. The appearance of cereal pollen grains and an increase in weed pollens clearly indicate the presence of humans in the area and cultivated lands in the vicinity of the embayment during the Bronze Age. The dominant element of cereals was rye. For the first half of the Bronze Age plantation of walnut could also have been tackled from the pollen composition *(fig. 4)*.

In addition, grape pollen grains also turn up in the profile dated to the boundary of the Middle and Late Bronze Age (*c*. 1400 cal. BC years). This is the fourth example where traces of grape pollen could have been identified for the period of the Middle Bronze Age. Nevertheless, it must be noted that wild grape *(Vitis sylvestris)* was also present at this time in gallery forests around Lake Balaton[19].

19 Sümegi et al. 2008a. – Sümegi et al. 2008b. – Sümegi et al. 2012a. – Sümegi et al. 2012b. – Juhász 2007. – Gyulai 2002.

There is a marked decrease in the ratio of walnut in the next zone (SZPZ-6) *(fig. 4)*. This part of the profile is dated to the Late Bronze Age. Nevertheless, the constant presence of cereal and weed pollen grains *(fig. 5)* clearly indicate the continuous presence and activity of humans in the study area during this period. The significant vegetation cover in the area of the embayment was preserved during the beginning of the Iron Age. The decrease in the pollen ratio of cultivated plants indicates the disappearance of horticulture from the study area during this period. Although signs of wheat cultivation can be tackled here, the dominant cereal was rye. The woodlands preserved were characterised by a dominance of oak mixed with beech and hornbeam *(fig. 10)*. Hardwood gallery forests harbouring lime and elm must have formed along the lake forming a hydroseries dominated by hornbeam and beech towards the lakeshore under a more balanced climate.

During the second half of the Iron Age, coevally with the settlement of Celtic tribes a pollen composition indicating viticulture and horticulture of walnut developed (SZPZ-7) *(fig. 4; 5)*. These conditions must have existed till the Imperial period. What's more we may presume its presence for the entire Imperial Age. Signs of similarly well-developed horticulture for the Late Iron Age could have been inferred for several Transdanubian sites (Fenékpuszta, Sopron, Zanat, Mezőlak)[20]. Based on the observed pollen composition, a gradual transition is observed from the Late Iron Age to the Imperial Age in our area. It must be noted though that the marked increase in willow pollen grains clearly indicates the emergence of a willow marsh in the embayment. This points to the significant transformation of the terrestrial vegetation in the area probably witnessed in increased deforestation and erosion in higher areas and a higher pressure from animal husbandry and an increased population. Among cereals a dominance of rye and barley is noted *(fig. 10)*.

The last pollen zone (SZPZ-8) represents the period of the Migration Age. Here an increase in AP is noted *(fig. 4)* with the appearance of alder and birch as well hallmarking an increase in forest covered areas and restoration of former woodlands. This might be related to decreased human influences and/or climate change during the referred period *(fig. 11)*.

DISCUSSION

^{14}C-controlled detailed geoarchaeological analysis of a sedimentary core sequence taken near Szólád along the southern shore of Lake Balaton enabled us to reconstruct the palaeoenvironmental evolution of the vicinity of the site from the Late Glacial to the period of the Early Middle Ages (Migration Age). Late Glacial conditions in the area were characterised by the presence of a coniferous-birch forest-steppe complex and an oligotrophic lake having relatively deeper waters. This forest steppe was transformed into a mixed taiga harbouring deciduous elements like lime, oak, elm, ash as well as the heliophylic hazelnut towards the Pleistocene / Holocene transition and during the Early Holocene. This was the time when our oligotrophic lake was transformed into a mesotrophic lake harbouring an extensive Chara vegetation. It was also the time when hydrological connections with the waterbody of the infant Lake Balaton were established as well. Coniferous elements disappeared during the Middle Holocene giving way to a hardwood forest with a dominance of oak, presence of lime, elm, ash, maple and hazelnut, the latter forming a rich sub-canopy. These conditions were preserved through the Neolithic and Copper Ages. Signs of human influences were also traced. The first significant palaeoenvironmental change is dated to the Early Bronze Age. This hallmark the transition of our mesotrophic lake into an eutrophic lake. The oak dominated woodlands were gradually replaced by mixed deciduous woodlands harbouring beech and hornbeam besides oak. The strong presence of reed, bulrush and willow indicated the gradual paludification of the embayment. Numerous weed and cereal as well as walnut pollen grains indicate the emergence of strong agricultural and horticultural influences. Grape pollens were also detected during the Late Bronze Age, which was characteristic at other Transdanubian sites too. The Iron Age hallmarks a significant decline in the arboreal vegetation and an expansion of plant cultivation, horticulture as well as animal husbandry. In addition, our marshland gradually develops into a willow marsh towards the Late Iron Age. This transitional relatively open vegetation must have been present during the Imperial Age too indicating an increasing pressure on the landscape from a rising human population and elevated human activities. For the period of the Migration Age a restoration of woodlands can be postulated as a result of decreasing human activities and/or climatic change in the area.

20 Sümegi et al. 2004. – Sümegi et al. 2007. – Sümegi et al. 2008a. – Sümegi et al. 2008b. – Sümegi et al. 2009. – Sümegi et al. 2011b. – Sümegi et al. 2012a. – Sümegi et al. 2012b. – Sümegi et al. 2013.

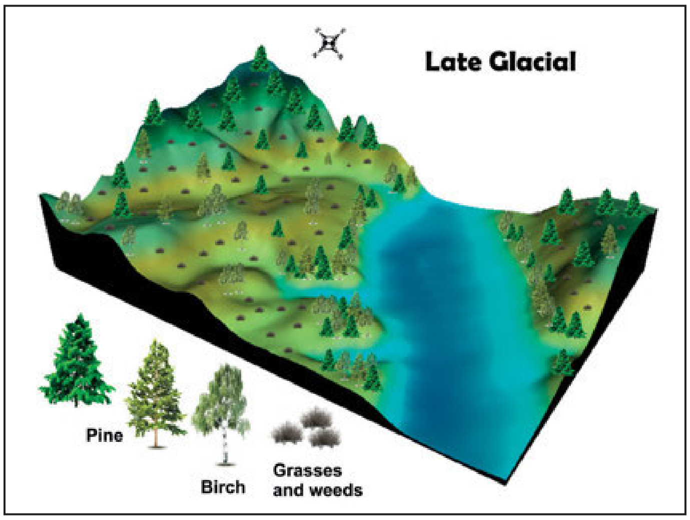

Fig. 6. Reconstructed palaeovegetation of the area during the Epipaleolithic.

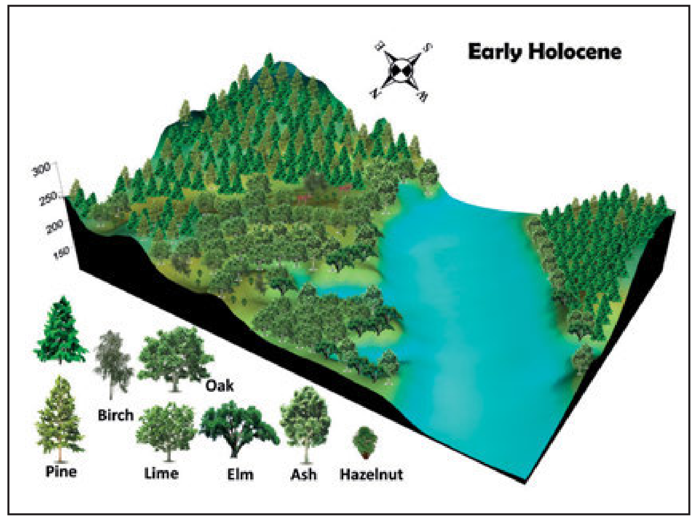

Fig. 7. Reconstructed palaeovegetation of the are for the Early Mesolithic in the area.

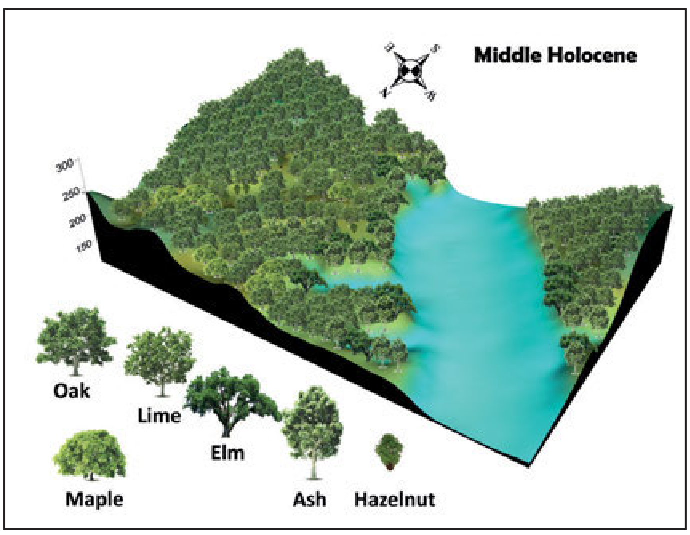

Fig. 8. Reconstructed palaeovegetation of the area for the period between the Late Mesolithic and the Bronze Age.

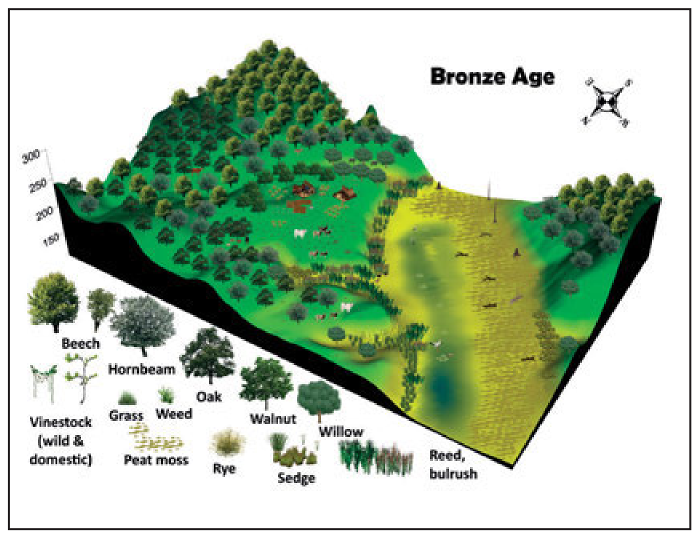

Fig. 9. Reconstructed palaeovegetation of the area for the Bronze Age.

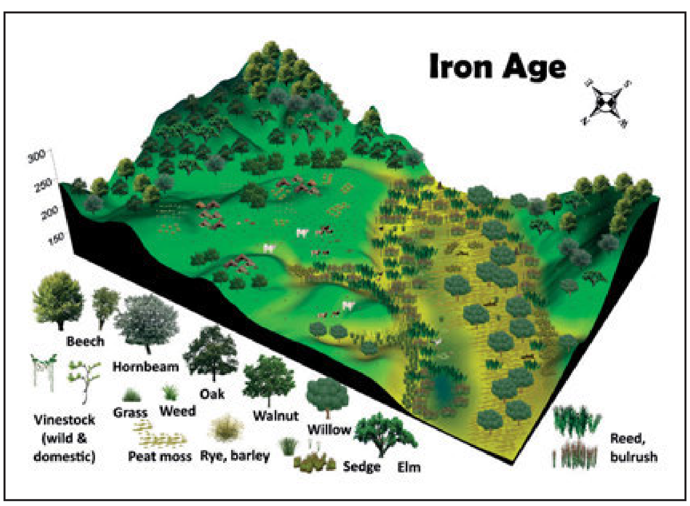

Fig. 10. Reconstructed palaeovegetation of the area for the Iron Age.

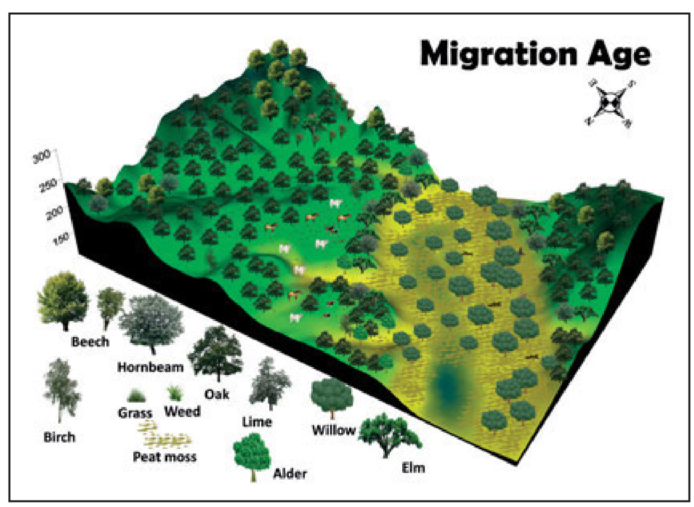

Fig. 11. Reconstructed palaeovegetation ot the area for the Migration Age (5–9th centuries AD).

ACKNOWLEDGEMENTS

Our work enjoyed support from the interim funds of the Department of Geology and Palaeontology, University of Szeged as well as the Institute of Archaeology, HAS. Additional partial funding was ensured by the OTKA Grant K 109-510.

BIBLIOGRAPHY

Ádám et al. 1981
L. Ádám / S. Marosi / J. Szilárd (eds), Magyarország tájföldrajza IV. A Dunántúli-dombság (Dél-Dunántúl) (Landscape geography of Hungary. Vol. 4. The Transdanubian Hills [South Transdanubia]) (Budapest 1981).

Bennett 1992
K. D. Bennett, PSIMPOLL. A quickBASIC program that generates PostScript page description files of pollen diagrams. INQUA Commission for the study of the Holocene. Working group on data handling methods, Newsletter 8, 1992, 11–12.

Birks / Birks 1980
H. J. B. Birks / H. H. Birks, Quaternary Paleoecology (Cambridge 1980).

Bronk Ramsey 2009
C. Bronk Ramsey, Bayesian analysis of radiocarbon dates. Radiocarbon 51, 2009, 337–360.

Dean 1974
W. E. Dean, Determination of the carbonate and organic matter in calcareous sediments and sedimentary rocks by loss on ignitions. Comparison with other methods. Journal of Sedimentary Petrology 44, 1974, 242–248.

Gyulai 2002
F. Gyulai, A Kárpát-medencei szőlő- és borkultúra régészeti növénytani emlékei. In: Z. Benyák / F. Benyák (eds), Borok és korok. Hermész kör (Budapest 2002) 101–113.

Hammer / Harper 2005
O. Hammer / D. A. T. Harper, Paleontological Data Analysis (London2005).

Juhász 2007
I. Juhász, Comparison and correlation of four pollen sequences from the Little Balaton region (Alsópáhok, Fönyed, Keszthely and Zalavár). In: Cs. Zatykó / I. Juhász / P. Sümegi (eds), Environmental Archaeology in Transdanubia. Archeolingua (Budapest 2007) 36–51.

Moore et al. 1991
P. D. Moore / J. A. Webb / M. E. Colinson, Pollen Analysis[2] (Oxford 1991).

Peterson / Peterson 2001
D. W. Peterson / D. L. Peterson, Mountain hemlock growth responds to climatic variability at annual and decadal time scales. Ecology 8, 2001, 3330–3345.

Reimer et al. 2013
P. J. Reimer / E. Bard / A. Bayliss / J. Warren Beck / P. G. Blackwell / Ch. Bronk Ramsey / P. M. Grootes / T. P. Guilderson / H. Haflidason / I. Hajdas / Ch. Hatt / T. J. Heaton / D. L. Hoffmann / A. G. Hogg / K. A. Hughen / K. F. Kaiser / B. Kromer / S. W. Manning / M. Niu / R. W. Reimer / D. A. Richards / E. M. Scott / J. R. Southon / R. A. Staff / Ch. M. Turney / J. van der Plicht, IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. Radiocarbon 55, 2013, 1869–1887.

Stockmarr 1971
J. Stockmarr, Tablets with spores used in absolute pollen analysis. Pollen Et Spores 13, 1971, 615–621.

Sümegi 2003
P. Sümegi, A régészeti geológia és a történeti ökológia alapjai (Introduction to Geoarcheology and Historical Ecology) (Szeged 2003).

Sümegi 2007
P. Sümegi, The vegetation history of the Mezőlak area. In: Cs. Zatykó / I. Juhász / P. Sümegi, (eds), Environmental Archaeology in Transdanubia. Archeolingua (Budapest 2007) 329–333.

Sümegi et al. 2004
P. Sümegi / I. Juhász / E. Bodor / S. Gulyás, Bronze Age Agricultural Impacts in the central part of the Carpathian Basin. Acts of the 14th UISPP Congress, Liege. BAR Int. Ser. 1271 (Liege 2004) 107–111.

Sümegi et al. 2008a
P. Sümegi / S. Gulyás / G. Persaits, Holocene paleoclimatic and paleohydrological changes in the Sárrét Basin, NW Hungary. Documenta Praehistorica 35, 2008, 25–31

Sümegi et al. 2008b
P. Sümegi / S. Gulyás / G. Jakab, Holocene paleoclimatic and paleohydrological changes in Lake Balaton as inferred from a complex quantitative environmental historical study of a lacustrine sequence of the Szigliget embayment. Documenta Praehistorica 35, 2008, 33–43.

Sümegi et al. 2009
P. Sümegi / T. Törőcsik / G. Jakab / S. Gulyás / P. Pomázi / P. Majkut / D. G. Páll / G. Persaits / E. Bodor, The environmental history of Fenékpuszta with a special attention to the climate and precipitation of the last 2000 years. Journal of Environmental Geography 3–4, 2009, 5–14. http://www.geo.u-szeged.hu/journal/files/articles/Sumegi-et-al_2010.pdf.

Sümegi et al. 2011a
P. Sümegi / M. Molnár / G. Jakab / G. Persaits / P. Majkut / D. G. Páll / S. Gulyás / A. J. Timothy / T. Törőcsik, Radiocarbon-dated paleoenvironmental changes on a lake and peat sediment sequence from the central part of the Great Hungarian Plains (Central Europe) during the last 25,000 years. Radiocarbon 53,1, 2011, 85–97.

Sümegi et al. 2011b
P. Sümegi / K. Náfrádi / G. Persaits / D. G. Páll / T. Törőcsik / G. Ilon, The results of environmental historical analysis of the Zanat site and its surroundings. In: J. Kvassay (ed.), The Late Urnfield Period Cemetery from Szombathely-Zanat Supplemented by an Assesment of Prehistoric and Medieval Settlement Features. Magyar Nemzeti Múzeum-NÖK (Budapest 2011) 201–355.

Sümegi et al. 2012a
P. Sümegi / G. Persaits / S. Gulyás, Woodland-grassland ecotonal shifts in environmental mosaics. Lessons learnt from the environmental history of the Carpathian Basin (Central Europe) during the Holocene and the last Ice Age based on investigation of paleobotanical and mollusk remains. In: R. W. Myster (ed.), Ecotones between Forest and Grassland (New York 2012) 13–37.

Sümegi et al. 2012b
P. Sümegi / S. Gulyás / G. Persaits / Z. Szelepcsényi, Long environmental change in the forest steppe habitat of the Great Hungarian Plains based on paleoecological data. In: J. Rakonczai / Zs. Ladányi (eds.), Review of Climate Change Research Programme at the University of Szeged (2010–2012). Institute of Geography and Geology, University of Szeged, (Szeged 2012) 7–24.

Sümegi et al. 2013
P. Sümegi / S. Gulyás / D. Molnár / Zs. Szelepcsényi, A Kárpát-medence erdőssztyepp területének negyedidőszak végi fejlődéstörténete. In: J. Rakonczai / Zs. Ladányi / E. Pál-Molnár (eds), Sokarcú klímaváltozás. Geolitera (Szeged 2013) 9–36.

Troels-Smith 1955
J. Troels-Smith, Karakterisering af lose jordater. Danmarks Geologiske Undersogelse, ser. IV,10 (Copenhagen 1955).

Willis et al. 1997
K. J. Willis / P. Sümegi / M. Braun / A. Tóth, The Late Quaternary environmental history of Bátorliget, NE Hungary. Palaeoclimatology, Palaeoecology, Palaeogeography 118, 1997, 25–47.

REFERENCES OF FIGURES

Fig. 1: Sándor Gulyás (maps: googlemaps; geological map of Hungary 1 : 500 [https://map.mbfsz.gov.hu/fdt500/]; maps of the 1st military survey [www.mapire.eu]). – *Figs. 2–11:* Sándor Gulyás.

ABSTRACT

A detailed, ^{14}C-controlled environmental historical analysis of a sedimentary core sequence taken near Szólád along the southern shore of Lake Balaton enabled us to reconstruct the paleoenvironmental evolution of the vicinity of the site from the Late Glacial period to the Early Middle Ages (Migration Age). Late Glacial conditions in the area were characterized by the presence of a coniferous-birch, forest-steppe complex and an oligotrophic lake with relatively deeper waters. Transitioning towards the Pleistocene/Holocene and during the Early Holocene, this forest steppe was transformed into a mixed taiga consisting of deciduous elements (lime, oak, elm, ash) and the heliophilic hazelnut. The oligotrophic lake was transformed into a mesotrophic lake harboring an extensive Chara vegetation, and hydrological connections with the waterbody of the infant Lake Balaton were established. Coniferous elements disappeared during the Middle Holocene giving way to a hardwood forest dominated by oak. These conditions were preserved through the Neolithic and Copper Ages. The lake was transformed into a eutrophic state during the Early Bronze Age. Oak-dominated woodlands were gradually replaced by mixed deciduous woodlands comprised of oak, beech, and hornbeam. The strong presence of reed, bulrush, and willow indicates the gradual paludification of the embayment. Numerous weed and cereal as well as walnut pollen grains indicate the emergence of strong agricultural and horticultural influences during the Early Bronze Age. Grape pollens were also detected during the Late Bronze Age, which was also characteristic at other Transdanubian sites. The Iron Age hallmarks a significant decline in the arboreal vegetation, with an expansion of plant cultivation and horticulture, as well as animal husbandry. Additionally, our marshland gradually develops into a willow marsh towards the Late Iron Age. This transitional, relatively open vegetation must have also been present during the Imperial Age, indicating an increasing pressure on the landscape from a rising human population and elevated human activities. For the period of the Migration Age, a restoration of woodlands can be postulated as a result of decreasing human activities and/or climatic change in the area.

ZUSAMMENFASSUNG

In der einstigen kleinen Bucht am Südufer des Plattensees bei Szólád wurde durch die geoarchäologische Analyse einer mit teilweiser 14C-Zeitbestimmung kontrollierten Tiefenbohrung die Entwicklungsgeschichte des Gebietes von der spätglazialen Periode bis einschließlich des Frühmittelalters aufgezeigt. Das Ufer des spätglazialen oligotrophen Sees tieferen Wassers umgab eine Waldsteppe aus Nadelhölzern und Birken. Bis zum Frühholozän entstand eine Mischtajga, in der neben den Nadelhölzern Linde, Eiche, Esche, Ulme erschienen und auch die phototropische Haselnuss. Der früher oligotrophe See nahm mesotrophen Zustand mit reicher Kalkalgenflora an, und es kam zur hydrologischen Verbindung mit dem jungen Plattensee. Bis zum mittleren Holocän entwickelte sich mit völligem Verschwinden der Nadelhölzer ein von der hartholzigen Eiche dominierter Laubwald, der vom Neolithikum bis in

die frühe Bronzezeit unverändert Bestand hatte. In der frühen Bronzezeit wurde der See eutotroph, und den früher eichendominierten Wald löste ein Laubwald gemischten Typs (Eiche, Buche, Hainbuche) ab. Das Erscheinen von Schilf, Rohrkolben und Pappel weist auf eine allmähliche Versumpfung der kleinen Bucht hin. Das Vorkommen von Unkäuter-, Getreide- und Walnusspollen in den Ablagerungen zeigen seit der frühen Bronzezeit eindeutig die Entstehung einer durch starke Gartenkultur gekennzeichneten Pflanzenzucht im Gebiet an. In den spätbronzezeitlichen Ablagerungen fanden sich auch Weinpollen ähnlich wie an vielen anderen transdanubischen milieuhistorischen Fundorten. In der Eisenzeit zeigt sich die Entstehung starken Waldeinschlags und extensiver landwirtschaftlicher Tätigkeit und die Herausbildung der Viehzucht. Das Moor wandelt sich bis zur Späteisenzeit zum Grasmoor. Die neue vorübergehend offenere Vegetation bleibt auch in römischer Zeit und deutet das Intensiverwerden der menschlichen Tätigkeit im Gebiet an. In der Völkerwanderungszeit jedoch breiten sich die Wälder weiter aus, im Zusammenhang mit geringerer menschlicher Einwirkung und/oder der Entstehung eines feuchteren, kühleren Klimas.

ÖSSZEFOGLALÁS

A Balaton déli partján Szólád mellett található egykori kis öblözetben mélyített fúrás részletes 14C időmeghatározással kontrolált geoarcheológiai elemzése révén feltártuk a terület fejlődéstörténetét a késő glaciális időszaktól a kora középkorig bezáróan. A késő glaciális mélyebb vízű oligotróf tó partját egy tűlevelűekből és nyírfából álló erdőssztyeppe vette körbe. A kora holocén időszakra egy kevert tajga alakult ki, amelyben a tűlevelűek mellett hárs, tölgy, kőris, szil és a napfénykedvelő mogyoró is megjelent. A korábbi oligotróf tavunk mezotróf állapotúvá vált, gazdag mészalga flórával és kialakult a fiatal Balatonnal való hidrológiai kapcsolat. A középső holocénre a tűlevelűek teljes eltűnésével egy keményfás tölgy dominanciájú lomboserdő fejlődött ki amely a neolitikumtól egészen a kora bronzkorig változatlan formában létezett. A kora bronzkorban a tó eutotróf állapotúvá vált és a korábbi tölgy dominanciájú erdőt felváltotta egy vegyes típusú lomboserdő (tölgy, bükk, gyertyán). A nád, gyékény és a nyár megjelenése az öblözet fokozatos mocsarasodására utal. Gyomnövények és gabona, valamint a dió pollenjének a megjelenése az üledékekben egyértelműn erőteljes kertkultúrával jellemzett növénytermesztés kialakulását jelzi a területen a kora bronzkortól. A késő bronzkori üledékekből szőlő pollenek is előkerültek hasonlóan sok más dunántúli környezettörténeti lelőhelyhez. A vaskor során erőteljes erdőirtást és extenzív mezőgazdasági tevékenység és állattenyésztés kialakulását látjuk. A láp a késő vaskorra füzes láppá alakul. Az új átmeneti nyíltabb vegetáció megmarad a római császárkor során is jelezve az emberi tevékenység intenzívebbé válását a területen. A népvándorlás korában azonban az erdők kiterjedtebbé válnak a csökkenő emberi hatás és/vagy nedvesebb, hűvösebb klíma kialakulásához köthetően.