Journal of Env. Geogr. Vol. II. No. 3-4. (2009) pp. 5-14

THE ENVIRONMENTAL HISTORY OF FENÉKPUSZTA WITH A SPECIAL ATTENTION TO THE CLIMATE AND PRECIPITATION OF THE LAST 2000 YEARS

Sümegi, P.[1,2] –Törőcsik, T.[1] – Jakab, G.[3] – Gulyás, S.[1] - Pomázi, P.[1] - Majkut, P.[1] – Páll, G. D.[1] – Persaits, G.[1] – Bodor, E.[4]

[1]University of Szeged Department of Geology and Paleontology, H-6722 Szeged Egyetem utca 2-6,
[2]Institue of Archeology, Hungarian Academy of Sciences, H-1014 Budapest Úri utca 49,
[3]Sámuel Tessedik College of the Agriculture Szent István University, H-5540 Szarvas Szabadság út 1-3,
[4]Hungarian Geological Institute, H- 1143 Budapest Stefánia utca 14.

Abstract

This work presents the details of a multidisciplinary palaeoecological and geoarcheological study on the sedimentary sequences, including 2 undisturbed cores of the Little Balaton situated in the western part of Lake Balaton in Central Europe. The application of Quaternary palaeoecological analysis to peat and lacustrine deposits enables to identify long-term environmental changes in aquatic and terrestrial ecosystems. The principal aims were to shed light onto how former human societies and culture shaped and altered their natural environment on the one hand. Furthermore, to reconstruct the once existing environmental conditions within the framework of the natural evolution of the vegetation, soil, fauna and the catchment basin for the times preceding written historical records via the application of sedimentological, geochemical, isotope geochemical, palynological, macrobotanical, malacological and microfaunal analytical methods and approaches.

INTRODUCTION

This work presents the details of a multidisciplinary palaeoecological and geoarcheological study on the sedimentary sequences, including 2 undisturbed cores of the Little Balaton situated in the western part of Lake Balaton in Central Europe (*Fig. 1*). The application of Quaternary palaeoecological analysis to peat and lacustrine deposits enables to identify long-term environmental changes in aquatic ecosystems. The composition of aquatic plant and animal communities is largely influenced by the hydrological conditions prevailing in the basin harboring them.

The principal aims were to shed light onto how former human societies and culture shaped and altered their natural environment on the one hand. Furthermore, to reconstruct the once existing environmental conditions within the framework of the natural evolution of the vegetation, soil, fauna and the catchment basin for the times preceding written historical records via the application of sedimentological, geochemical, isotope geochemical, palynological, macrobotanical, malaco-logical and microfaunal analytical methods and approaches.

In the course of an international archaeological-research, the cooperation with the Archaeological Institution of the University of Leipzig and the Institute of Archeology Hungarian Academy of Sciences opened up the possibility to implement an environmental historical study in the western part of the Balaton region in relation to the Fenékpuszta settlement forming a part of modern Keszthely.

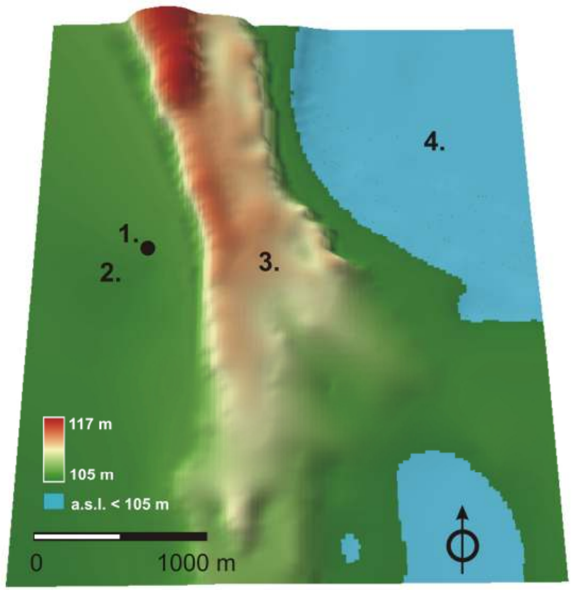

Fig. 1. 3D model of the study area with the sampling sites

The entire record goes back in time to the Pleistocene/Holocene transition, but this article mainly focuses on environmental events and conditions related to the settlement and its activities in the Migration Period. Special attention was paid to the records of the 4th-5th and the 8th centuries AD. This is justified by the fact that numerous historical interpretations published recently (Györffy – Zólyomi 1996, Rácz 2008) presented speculations about draughts and famines leading to a collapse of the local Avar Empire, based on interpretations of data from Iceland and Western Europe, but lacking regional environmental historical records from the area of the Carpathian Basin itself.

MATERIAL AND METHODS

For a complex environmental historical evaluation, the model and analytical system of Birks and Birks (1980) was adopted in our work. (*Table 1*, *Fig. 2*). To gain an overview of the subsurface geology and to highlight sites for undisturbed core retrieval about 20 probe cores were taken in the area of Fenékpuszta. This was later on complemented by two parallel cores taken by a modified Russian head corer (Sümegi 2001) yielding overlapping undisturbed core samples from the infilled lacustrine basin of the Kis-Balaton near Fenékpuszta (*Fig. 1*). After transportation to the laboratory, the cores were cut lengthwise for various analyses; the sections for palaeobotanical and geochemical analyses were stored at 4°C in accordance with the international standards. The samples submitted to lithological analyses were identical with the ones used for the palaeobotanical, macrobotanical, malacological and radiocarbon analyses. For the macroscopic description of the samples and the preparation of the lithological column the internationally accepted system of Troels-Smith (1955) was adopted. The core was divided into 1-4 cm samples. To gain information on the chronology, 13 samples of plant macrofossils were subjected to AMS (Accelerator Mass Spectrometry) radiocarbon analyses in the Radiocarbon Lab of Poznan, Poland. In order to allow comparison with other archaeological data, the raw dates were converted to calendric ages using the CALPAL calibration programme, and the most recent CALPAL-2007 HULU calibration curve. The original dates (^{14}C) are indicated as uncal BP, while the calibrated dates are indicated as cal BC.

Table 1. An overview of the methods of investigations implemented on the two undisturbed cores (N: 46º 42.621' and E: 17 º 14.048) with references describing the methods

Core	Sedimentological and geochemical analyses		Pollen and microchercoal analyses	Macrobotanical and micro-zoological analyses	Mollusc analyses	^{14}C analyses
Sümegi, 2001	Troels-Smith, 1955; Dean, 1974; Dániel, 2004		Stockmarr, 1971; Clark, 1982	Jakab-Sümegi, 2004	Sümegi, 2004	AMS method
Core name	subsamples		subsamples	subsamples	subsamples	
Valcum I. and II.	79	85	85	35	70	13

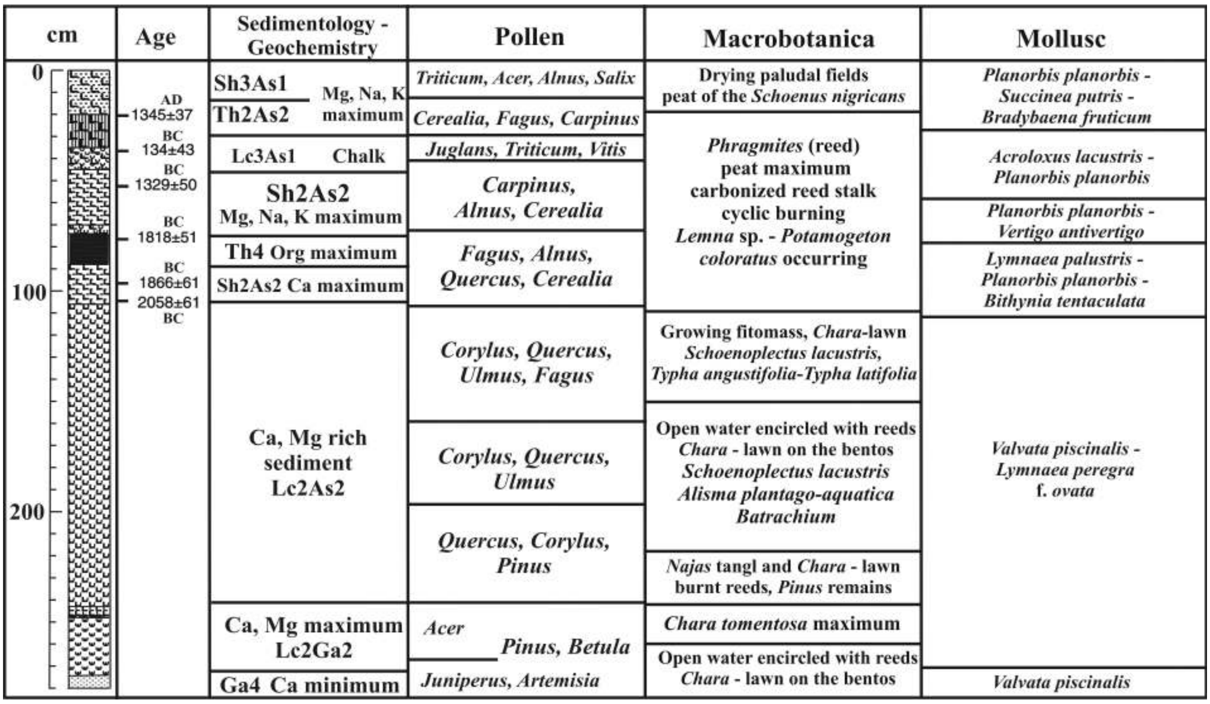

Fig. 2. Palaeoenvironmental analyses of Fenékpuszta (Kis-Balaton) cores

The organic and carbonate content of the samples were determined by Dean's (1974) LOI method. The inorganic content was further analyzed using the sequential extraction method. The so-called sequential extraction method of Dániel (2004) with a long established history in the analysis of geochemical composition of lacustrine sediments was adopted in our work. From the full procedure the step of water extraction for unseparated samples was sufficient to suit our analytical needs as it was shown by previous works (Dániel 2004), the most important palaeohydrological and palaeoecological data originates from water extraction samples. Elements of Na, K, Ca, Mg, Fe were determined using a Perkin-Elmer 100 AAS.

Sediment samples of 1 cm^3 were taken from the core at 1-4cm intervals for pollen and macrobotanical analysis using a volumetric sampler. For the extraction and description of macrofossils a modified version of the QLCMA technique (semi-quantitative quadrat and leaf-count macrofossil analysis technique) of Jakab et al. 2004 was adopted. For the extraction of pollen grains a modified version of the method of Stockmarr (1971) was adopted. A *Lycopodium* spore tablet of known volume (13911 spores per tablet) was added to all samples to give a desirable ratio for pollen to exotic spike to work out pollen concentrations. A minimum count of 500 grains per sample (excluding exotics) was made in order to ensure a statistically significant sample size. Charcoal abundances were determinated using the point count method (Clark 1982).

Mollusc shells were collected from 2 to 4 cm thick subsamples taken at regular intervals throughout the core. Following the palaeoecological classifications of Sümegi (2004), the aquatic malacofauna was divided into two groups: species demanding steady water inundantion (ditch group) and species tolerant to periodic water supply (slum group). Terrestrial fauna was grouped as follows: water bank (hygrophilous), mesophilous, xerophilous, cold-resistant, intermediate, thermophilous, open habitat preferring, ecoton habitat preferring and woodland habitat preferring species. Malacological record was also classified according to the recent geographical distribution of the species, following Sümegi (2001) and on the basis of palaeoclimatological indicator roles. Results from all analyses are plotted against depth using the PSIMPOLL programme (Bennett 1992).

THE STUDY SITE

Lake Balaton is the largest lake in Central Europe, with a modern open water area of 593 km^2. The lake basin has a maximum length of 77 km, and a width of 8-14 km with a mean water depth of only 3-4 m. The area of the Little Balaton is located west of the modern open water system in a separate neotectonic catchment basin forming an extensive marshland today. Based on historical maps of the first and second Austrian Military Survey the area of the Little Balaton used to be a part of the larger unregulated lake system in historical times preceding the 19^{th} century regulations.

The neotectonic basin of the Little Balaton is located between the peninsula of Fenékpuszta, the Zalavár geological ridge and Somogy Hills. The Zalavár ridge and the neck of the Fenékpuszta peninsula are composed of Pannonian and Pliocene deposits overlain by Late Pleistocene loess. The area of the referred catchment basin is about 50 km^2. Our samples were taken in a small embayment located on the northern part of the catchment basin known as the Fenékpuszta Embayment. This area was infilled as a result of natural vegetation succession of peatlands during the Holocene.

This region lies on the boundary of the moderately cool–moderately wet (Köppens Cf) and the moderately cool–moderately dry climatic zones (Köppens BS). The mean annual temperature is 9.8 ºC. The mean temperature of the growth season is around 15.5-16 ºC. The rate of annual precipitation is around 700 mm, 440 mm of which falls during the growth season. The climatic conditions of the region are favorable for forestry primarily. Nevertheless, these endowments enable the cultivation of less heat demanding species.

The region is part of the *Saladiense* regarding vegetation geography; the most common forest associations are oak-hornbeam forests (*Querco robori-Carpinetum*), sessile oak-hornbeam forests (*Querco petraeae-Carpinetum*), oak-ash-elm gallery woods (Querco-Ulmetum), and willow-poplar gallery woods (*Salicetum albae-fragilis*). The natural shrub level is dominated by white cinquefoil (*Potentilla alba*), vetches (*Vicia cassubica*, *V. oroboides*), large red deadnettle (*Lamium orvala*), cyclamen (*Cyclamen purpurascens*), prostrate rock-rose (*Fumana procumbens*), fescues (*Festuca vaginata*, *F. rupicola*).

Higher ridges are predominantly covered by brown forest soils (accounting for about two-thirds of the area), hosting arables, vineyards and hornbeam-oak forests in about even proportions. The soils of the catchment basin areas are hydromphic covered with gallery woods, meadows and pastures. The region is characterized by a flora typical for the Preillyricum between the Illyricum phytogeographical province of the western Balkans and the Pannonian region covering most of modern-day Hungary. Numerous Illyric*,* Submediterranean and Alpine floral elements thrive in the undergrowth of oak forests. Large stands of alder trees (*Alnus glutinosa)* dot the wet meadows with a constantly high water table. The open areas around the mires are utilised as arables and pastures.

ARCHAEOLOGY OF FENÉKPUSZTA

The area is characterised by a mix of cultures from an archaeological point of view. As shown by the archaeological data, the area was continually inhabited from the second half of the Neolithic. It is by no means accidental as the Fenékpuszta Isthmus, just like the Máriaasszony Island in Vörs belonging to the southern part of Lake Balaton, was the most important crosspoints of Lake

Balaton between the pointbars of Balatonberény which could have existed as early as the Antiquity (Sági 1968, Müller 1987). The area was populated during the Neolithic (M. Virág 1996) Copper and Bronze Ages by representatives of various cultural groups (see Bondár 1996, Horváth 1996). The area was also inhabited in the Iron Age by members of the Halstatt culture of the early Iron Age as well as the Celts in the late Iron Age.

The Celts managed to survive in the area at the time of the beginning of the Roman conquest in the 1st century AD (Müller 1996). The Romans appearing in this area in the Imperial Age thus settled in a highly modified so-called cultural rather than natural landscape. Based on archaeological data, a fortress was built where the roads running from Aquile to Aquincum and to Sirmium and Augusta Treverorum traversing diagonally Transdanubia met. The size of the fortress is astonishing with 44 round towers ranging 377 x 358 m fortress square meters. The building was constructed of ca. 87 000 m^3 stones. The walls were 2.6 m thick and 10 m high with possibly 4 gates. Traces of 22 edifices have turned-up so far which adjusted to the by-pass joining the north-southern gates. Out of these rise the more than 1000m^2 big horreum and the building of the Early Christian basilica.

Based on the size and the edifices of the forests, a significant population engaged in advanced farming must have inhabited the area of Fenékpuszta in the Imperial Age. According to the archaeological and historical data gathered until now, the fortress was destroyed by Ostrogoths in October 455 AD. After its reconstruction, the fortress might have been the seat of Thiudimer, the Eastern-Gothic king, as the cemetery of the eastern Gothic people migrating to the East-Roman Empire was excavated just south of the fortress (Straub 2002). The ownership of the examined area is problematic in the following half century. There was an assumption that it belonged to Odoaker, the Italian king then the Suebians of the Danube spread their authority up to this region. According to another concept, a part of the leaving eastern Goths stayed and could have owned the fortress then the Lombards extended their authority over this area. Following the pullout of the Lombards in 568, the previous population could have lived on in Fenékpuszta, though they might have added new folk elements to their existed ones as more changes can be examined in the archaeological material.

Namely, parts of the jewellery, following the Avar conquest after 568, have no local antecedents and the new funerary practices and objects were in sharp contrast with the poor funerary adornments dated before 568. Parallel with this event, an Early Christian basilica was erected with three apses. Similar type of construction works were recorded only in Northern Italy and in the Balkans for the same period. The leaders of the area established their cemetery near the horreum after the second half of the 6th century.

The cemeteries, which were not looted, were started to be used around 568 and funerals took place here up to 630. At present, 460 graves are known from this period in the locality of Keszthely-Fenékpuszta. Most of the new findings are related to the Avars. In spite of this fact, we cannot take the factual Avar population's presence into account as probably a mixture of local population could have been formed here who paid tax to the Avars. However, the standpoint of researchers about the consistency of population is diverse. According to Károly Sági, the population of the fortress consisted of late antique and western Germanic population. László Barkóczi referred to the burying rituals with stones as a custom of the local survival population. István Bóna assumes the presence of a Byzantine or Lombard ruling class with Byzantine elements.

There are also theories of Alamans and Franks escaping to be under the Avars' authority. Moreover, the research has lately started to take the elements of Romanised Christians into account escaping from the southern part of Noricum and Pannonia. The research named this mixed ethnical group as the Keszthely culture. The ruling class and the followers of Keszthely culture disappeared after the siege of the fortress in 630, though burying sparsely happened in the commonality cemetery until the end of the 7th century A.D.

Following the decline and fall of the Avar Empire, the Karoling Age (Szőke 1996) came in the life of Fenékpuszta which existed as long as the Hungarian conquest and the occupation of the area in Transdanubia, so for a century or so. Based on the one hand on medieval archaeological findings, the medieval church and cemetery of Pusztaszentegyház as well as on on its dated bell originated from 1509, it was the place of a medieval village called Fenék (= Bottom). This settlement has been noted first in 1347 and last in 1594 (Vándor 1996). At this time the fortress might not have been used and by the end of the Turkish Empire, the area had become deserted.

In the 18th century, the population moved to Keszthely. The land, together with Fenékpuszta, was bought by the Festetics family in 1739. In the times came, they influenced the image of the area and established horse-breeder premises, carpenter and ship building plants. They have probably used the stones of the Roman fortress too, although the walls of it are also marked on an Austrian military map made in 1782 (Timár et al. 2006). At the same time, on the maps made in 1792 and in 1805, the fortress is not marked anymore. According to this, the total demolition of it might have happened between 1782 and 1792, so at the end of the 18th century.

RESULTS

Based on the collective evaluation of biotic and abiotic records a fairly complete history of the geological and environmental evolution of the area could have been drawn.

Fluvial sands giving the bedrock of our cores must have formed about 11 kys ago, at the end of the Pleistocene (Sümegi et al. 2008). This level is characterised by the presence of *Valvata piscinalis*, a moving-water gastropod as well as the smallest calcium and magnesium content and the most essential inorganic material content. The observed minima of water soluble elements seems to be congruent with the picture drawn from the evaluation of other records; i.e. the deposition of fluvial sediments and non-weathered silicates to the incipient neotectonic basin. This incipient catchment basin must have been fringed by pine woodland with stands of birch and reed.

The fluvial deposits are overlain by a slightly layered, pink lacustrine layer with highly varying carbonate content and spots of volcanic ash. This horizon marks the evolution of a larger lake system within the forming catchment basin as also marked by a maximum of Ca and Mg in the deposits among water soluble elements. The inferred 3 m deep, mesotrophic lake rich in carbonate must have existed in the area from the beginning of the early Holocene until the end of early Bronze Age (20^{th}-21^{st} century BC). The retrieved lacustrine deposits yielded a significant amount of stonewort algae as well as parts of floating read grass and shells of *Lymnaea peregra* f. ovate and *Valvata piscinalis* marking the presence of a well-lit, deep, calcareous lake in the area for the referred period.

The former coniferous woodland was replaced by a deciduous woodland dominated by oak, elm and hazel during the referred period as seen from the pollen record. Macrobotanical remains talk about the emergence of a wide belt of reeds, bulrushes and sedges on the shore before the gallery woodland.

From a depth of 106 cm up to the surface, representing the periods of the early Bronze Age to the Middle Ages a general decrease in the water level is inferred compared to the previous stage of the lake. Nevertheless, three distinct periods or cycles could have been identified when the continuous deposition of organic materials in a marshland setting halted and was exchanged by lacustrine sedimentation within the framework of an eutrophic lake (*Fig. 2*). This stage marked the end of the open lake system, and although these periodic water level rises significantly influenced the deposition of calcareous lacustrine muds into the basin, conditions like in the modern open lake system of Balaton never returned to the area afterwards.

Cycle 1. after the formation of an Early Bronze Age peat layer, in the period corresponding to the end of the early Bronze Age, beginning of the middle Bronze Age (beginning of the 19^{th} century BC), a dynamic but short rise of the water level occurred in the examined area based on the macrobotanical and malacological findings leading to the formation of a shallow eutrophic lake in the basin (*Table 2*). At the end of the same period, and in the second part of the middle Bronze Age peat deposition resumed leading to the formation of floating marsh and a closed peat layer at this part of Kis-Balaton. Then in the late Bronze Age, due to a rise of the water level, the peat formation halted again resulting in the deposition of a thin layer of lacustrine marls over the previous peat sequence.

Cycle 2: following the late Bronze Age, in the early Iron Age, a subsequent peat deposition could have been inferred (between the 8^{th} and 2^{nd} century BC) followed by another rise in the water level and the formation of another short shallow lacustrine phase. The high correlation between the observed concentrations of water soluble Mg, Na, K and the accumulated peat horizons is by no means surprising, as these elements tend to accumulate in aquatic plants. Around the end of the late Bronze Age, beginning of the Iron Age, besides the remains of plants and molluscs preferring a lacustrine environment, a drop in the amount of the referred elements could have been observed marking a phase of inundation (between 66-62 cm), followed by another stage of peat deposition between the depth of 62-48 cm. In the Iron Age, between the 8^{th} and 2^{nd} century B.C., a more pronounced inundation of the basin could have been inferred from a dynamic decrease of water soluble elements. Conversely, at the beginning of the Imperial Age, peat formation was dominant as seen from a gradual increase in Mg, Na and K in the deposits.

Cycle 3: following the deposition of lacustrine marls in the Late Iron Age another peat formation started from the Imperial Age. The Imperial Age also marked the end of these natural cycles of lake-marshland stages and conditions characteristic of a marshland seem to have stabilized for the forthcoming periods in the area. The speed of sediment accumulation also decreased probably because a part of the surficial peat deposits suffered incipient pedogenesis. From the shift observable in the geochemistry a short period of inundation could have been inferred at the end of the Imperial Age and at the beginning of the Migration Period. This might have been the outcome of a general increase in precipitation on the one hand. But this is not the only factor we must take into account while finding an explanation to the short rise in the water table within the catchment basin. As shown by written records Romans have devised a drainpipe system in the 3rd century AD, with which the level of Lake Balaton was kept artificially low. The rise in the water level at the time of the Migration Period, could be attributed to the fact that these drainpipes constructed by the Romans might have been clogged in the lack of general cleaning and maintenance. Nevertheless, the inferred rise in the water table in our area is congruent with the transformations observed in a more distant catchment basin of Nagybárkány located in the NE part of Hungary as well for the same period (*Fig. 3*). Here a general increase in the precipitation as inferred from pollen data and a rise in the water table could have been postulated (Jakab – Sümegi 2005). Similar changes were

Table 2. Results of radiocarbon analysis

cm	BP	+/-	cal BP	+/-	cal BC/AD	+/-	Lab code
20-21	610	30	605	37	1345 AD	37	Poz-20847
22-23	1050	30	966	23	984 AD	23	Poz-20915
25-26	1235	30	1175	61	775 AD	61	Poz-20840
29-30	1355	30	1290	13	660 AD	13	Poz-20888
30-31	1400	30	1318	18	632 AD	18	Poz-20838
31-32	1480	30	1366	16	584 AD	26	Poz-28408
34-35	1875	30	1813	48	137 AD	48	Poz-21486
36-37	2110	30	2084	43	134 BC	43	Poz-20889
40-41	2750	30	2840	35	890 BC	35	Poz-28407
52-53	3050	35	3279	50	1329 BC	50	Poz-20848
76-77	3485	35	3768	61	1818 BC	51	Poz-20849
96-97	3540	35	3816	61	1866 BC	61	Poz-20850
104-105	3670	35	4008	61	2058 BC	61	Poz-20890

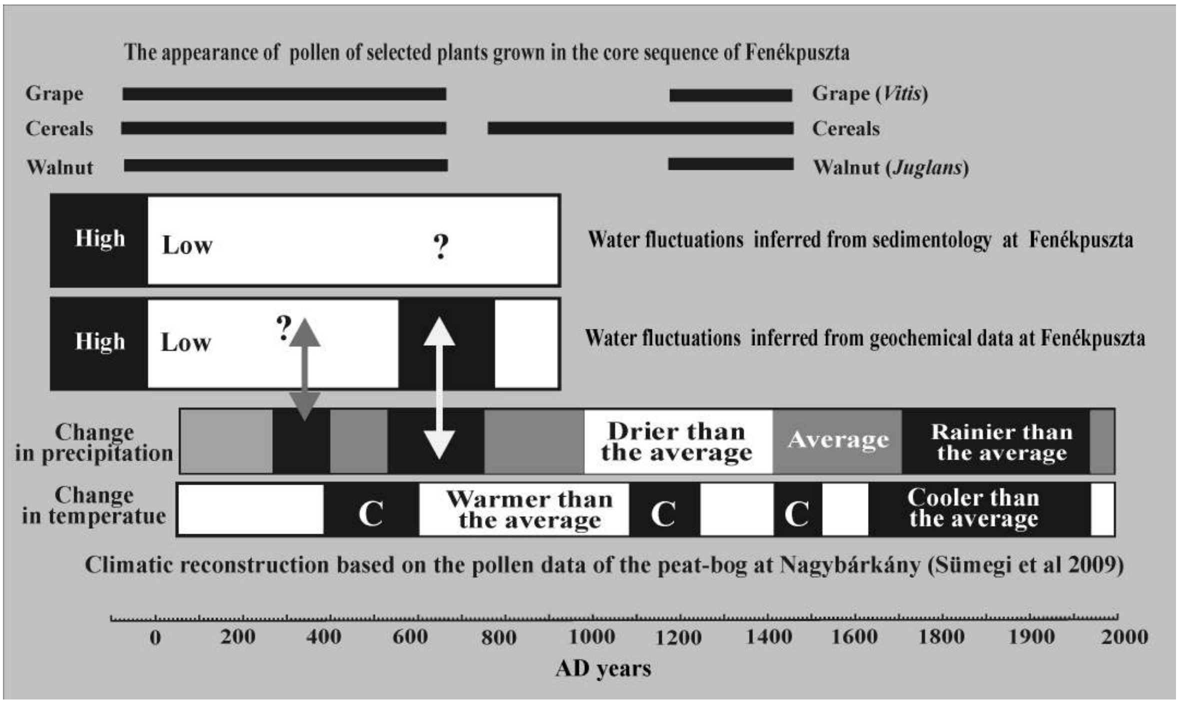

Fig. 3. Comparison of the Fenékpuszta and Nagybárkány (see Sümegi et al. 2009) investigations

observable on the core section corresponding to the Imperial Age from a nearby lacustrine-marshland system at Lake Baláta (Jakab – Sümegi 2007) in the south western part of Transdanubia, which enjoys similar climatic endowments as the site of Fenékpuszta. Many historians put forth numerous postulations about long-lasting draughts and severe consequences on the population of the Carpathian Basin for the period of Great Migrations (Györffy – Zólyomi 1996, Rácz 2008). Some of them went as far as stating that the main push factor for migration of Eastern European tribes was the general aridity of the climate resulting in long-lasting draughts. The cornerstone of these statements was the observed low water level of the Caspian Lake during the referred period followed by a subsequent inundation of the coastal harbors (Györffy – Zólyomi 1996, Rácz 2008). The inferred paleoclimatological reconstructions of these authors raise significant problems from several points and are challenged by modern paleoecological data:

1./ Fluctuations in the water table of the Caspian Lake are not related to fluctuations in the precipitation to the Eurasian steppes forest steppe areas because the drainage of this lake system is located in the highland region of the Caucasus and Central Asia on the one hand, as well as the taiga belt on the north (Rodionov 1994). Thus making inferences about the precipitation of the steppes based on fluctuations of the water level of the Caspian Sea is not accurate.

2./ The majority of the harbours, inundated later on from the end of the Antiquity and the early Migration Period, are located in a tectonically highly active area in the northern part of the Caspian Sea. Plus, at the edge of the Volga delta. Consequently, we have two geological forces working in the referred area which might have resulted in an inundation of the coastal areas and harbours independently of fluctuations in precipitation (Aladin – Plotnikov 2000). The continuous sinking of the northern bed of the Caspian Lake (inland sea) is of striking importance here (Degens – Paluska 1979). Although this process causes annually only a few millimetres of change, within hundreds of years it might have lead to even a one meter rise of the water level in the coastal areas. The other force is related to the sediment carrying capacity of the River Volga leading to a rapid infilling of the accommodation space in the coastal areas, which again might be a cause of water level increase there.

3./ According to the data retrieved by geologists, climatologists and geographers (Mayev et al. 1983) working in the area, the water level of the Caspian Sea was extremely high at the end of the Antiquity and the beginning of the Migration Period, because the water balance of this inland sea is influenced by not only the precipitation coming through the rivers which is a significant factor, but also the temperatures around the inland sea (Klige – Myagkov 1992). According to the data we have at hand, the development of a cooler phase in the Central-Asian area can be inferred at the beginning of the Migration Period. So it is not surprising that a quite high water level was reconstructed for the Caspian Lake in this period which is in sharp contrast with the statement given by the referred Hungarian historians. At the same time, the data prove that in the course of the past 2000 years, quite significant changes have happened in the water level of the Caspian Lake. But these changes had connections primarily to the development of temperature and only secondly to the precipitation coming through the rivers (Budyko et al. 1988).

Thus water level changes in the referred lake system are related to fluctuations in the precipitation of Central Asia, the Caucasian highlands and the Eurasian taiga belt, as well as the temperature fluctuations of Central Asia. Thus the climatic and demographic models made by historians for the area of Central Europe for the period of Great Migrations seem to be in sharp contrast with the paleoecological information for the area of the Caspian Sea and those of the Carpathian Basin as well and as such need adverse correction.

Returning to the environmental history of Keszthely-Fenékpuszta in Kis-Balaton, the beginning of the Migration Period, which was characterized by a rise in the water level with highly ambiguous causes, was followed by another dynamic increase in the water soluble elements of Mg, Na, K marking peat formation. Peat formation initiating during the Imperial Age continued during the Migration Period as well. Nevertheless pedogenesis was also observable in these peat horizons. Thus from the period of the Imperial Age and the subsequent period of Great Migrations the emergence of a stable marshland could have been inferred for the northern parts of the Fenékpuszta Isthmus. These conditions survived until the closure of the Middle Ages in this part of the Kis-Balaton. This peat formation might have been continuous from the time of the Great Migrations. But the element content of the near-surface layers could have been dynamically modified by hydromorphic soil formation which took place in the Middle Ages. This hampered the reconstruction of water level fluctuations in the area from the end of the Migration Period onwards.

Besides precipitation, various forms of agricultural activities could have been captured in our record as well. Based on the pollen content a widespread cultivation of corn and extensive animal husbandry could have been inferred for the area of the Fenékpuszta Isthmus from the Middle Bronze Age. Yet, the most powerful human influences are related to the Imperial Age. From the end of the Iron Age the proportion of open-area loving plants, weeds, Gramineae, Artemisia increased significantly, together with numerous plants marking intensive horticulture such as *Juglans, Vitis*. As for the pollen results, cultivation of *Juglans*, *Vitis* and *Triticum* survived until the 7th century AD based on radiocarbon dates. On the basis of this, we can conclude that agricultural activities with sub-Mediterranean characteristics of cereal production and horticulture developed at the end of the Iron Age and the beginning of the Imperial Age in this region. Communities having proper production experiences and engaged in the referred form of agriculture populated the study area until the second half of the 7th century after the Migration Period (*Figs. 2, 3*).

The pollen of *Juglans* and *Vitis* vanished from the section while the pollen of cerealia, though in a subordinate ration, but survived from the second half of the 7th century. According to this, an extremely dynamic change in the economy of the examined area can be assumed. The referred communities, having farming experiences with Submediterranean characteristics, and establishing quite dynamic environmental changes as well as farming records in the Imperial Age and operating a well developed farming system at the end of the late Iron Age, might have been driven out of the examined area. Based on radiocarbon data these transformations must have taken place between 604 and 673 AD (95% probability).

SUMMARY OF FINDINGS

Based on the collective evaluation of biotic and abiotic records a fairly complete history of the geological and environmental evolution of the area could have been drawn (*Table 2*). In the first phase at about 10-11 kya, a neo-tectonic basin developed giving the foundation of the emerging lacustrine system. The infilling of this catchment basin initiated even at this stage leading to the deposition of fluvial sands. The juvenile lake was surrounded by a coniferous woodland with stands of birch on the shores and an extensive reed belt. At around 10 ky BC a mesotrophic lake emerged and the gallery forest fringing the lake and dominated by pine, birch and hazel were replaced by woodlands dominated by hazel, elm and oak. The rate of silting-up was generally low during this period enabling the preservation of lacustrine conditions for a long time. The infilling of the basin was more rapid during the second half of the Neolithic as well as the Copper Age. This was the period when pollen taxa marking plant cultivation, stock farming first appeared in our catchment basin, and fluctuations in the concentrations refer to the emergence of increased agricultural activities in the surroundings of the Fenékpuszta Isthmus from this time onwards.

Lacustrine conditions were preserved till the beginning of the Bronze Age yet pronounced transformations in the surrounding vegetation could have been inferred attributable to human activities. Based on the long preservation of lacustrine conditions we may assume that the subsidence of the basin and the development of the general accommodation space must have kept pace with the rate of deposition for about 7000 years. This system and the fragile equilibrium was broken as a consequence of intensive human activities from the Neolithic onwards. As a result of these events, three major cycles could have been identified in the area in the form of alternating marshland and lacustrine conditions from the Middle Bronze Age to the Middle Ages. The alternating shifts among these stages are related to the natural succession of the marshland and resulted in distinct periods of lowstand and highstand in the basin. The first lowstand is observable at the end of the early Bronze Age and at the beginning of the middle Bronze Age, followed by a significant rise in the water level during the middle Bronze Age. The second cycle evolved during the late Bronze Age and Iron Age also characterized by successive lowstand and highstand conditions. The third cycle is connected to the period of the late Iron Age and Imperial Age. This third cycle is of outstanding importance in understanding the environmental history of the period of Great Migrations.

In this third cycle peat formation seem to have stabilized following an eutrophic lacustrine stage creating a stable marshland which survived from the Imperial Age through the Migration Period up to the Middle Ages. Besides peat formation, soil formation also took place in equilibrium creating marshland hydromorphic soils.

At the end of the late Iron Age and the beginning of the Imperial Era one of the most essential agricultural economies evolved, a Submediterranean type of crop cultivation and horticulture of wine and walnut. This form of agriculture appeared around 0 AD lasted until the 7th century AD in the area. Thus Roman type Submediterranean agricultural activities must have characterized the area during the Migration Period as well.

From the 7th century AD onwards there is a marked change in the pollen record, implying the abandonment of this former Submediterranean type of agriculture and the establishment of agricultural activities based on mainly stock farming during the 8-9th centuries AD. Data indicating resumed horticultural activities and crop cultivation could be inferred from the 10-11th centuries onwards in the area.

TEMPERATURE AND PRECIPITATION CONDITIONS OF THE LAST 2000 YEARS

As it can be seen on the climate reconstructions prepared on the basis of paleoecological data (*Fig. 3*), the first 400 years following the birth of Christ was characterized by temperatures above the average values for the past 2000 years. Then in the 5th and 6th centuries a pronounced cooling could have been inferred, which was followed by a warmer period again with temperatures higher than the average for about 500 years in the Carpathian Basin. Fluctuations in precipitation for the same period are characterized by much higher amplitudes than those inferred for the temperature. In the first 200 years precipitation was around the average of the past two millennia. The 3rd and 4th centuries AD are characterized by higher precipitation values with rates returning to near average in the 5th century. Another period of higher precipitation follows spanning the interval from the 6th to the 8th centuries.

If we compare these findings with records of grape, walnut and cereal production characterizing a Submediterranean type agricultural economies in the area (*Fig. 3*), it can be clearly observed that the presence or absence of these plants in layers from the Middle Ages and the Migration Period is independent of climatic fluctuations and are largely related to the production experiences of the referred societies. Water level fluctuations inferred from sedimentological and geochemical proxies talk about a different story (*Fig. 3*) According to sedimentological results, a highstand characterizing the Iron Age was followed by a continuous lowstand. The geochemical data is somewhat congruent with this picture with some minor differences. The Iron Age highstand is clearly observable in both records, but the general lowstand following was interrupted by a short phase of highstand between the 5th and 7th centuries AD in accordance with higher inferred precipitation rates.

According to our findings, lake level fluctuations inferred for the area of the Kis-Balaton can be correlated with those of the Alpine lakes (Magny 2003), while the evolution of the temperature record seems to be correlated with the fluctuations (Holzhauser et al. 2005) of Alpine glaciers. To sum up in one sentence, the climatic and environmental evolution of our site seems to follow that observed in the Eastern Alps for the past 2000 years. Thus making inferences about the climate of this region based on data from Central Asia is by no means accurate.

Acknowledgements

This research was financed by the project managed by Orsolya Tamáska Heinrich, for which the authors are greatly indebted.

References

Aladin N. B. – Plotnikov I. S. 2000. The Danger of Large-scale Ecological Catastrophy in the Caspian (The Comparative Analysis of Causes and Effects of Ecological Crises in the Aral and Caspian). *The Caspian Bulletin* 4: 112-126

Bakay K. – Kalicz N. – Sági K. 1966. Magyarország régészeti topográfia 1. Veszprém megye régészeti topográfiája. A keszthelyi és tapolcai járás. Budapest: Akadémiai Kiadó. 221 p.

Bennett K. D. 1992. PSIMPOLL - A quickBasic program that generates PostScript page description of pollen diagrams. INQUA Commission for the study of the Holocene: working group on data handling methods. *Newsletter* 8: 11-12

Birks H. J. J. – Birks H. H. 1980. Quaternary Palaeoecology. London: Edward Arnold Press. 289 p.

Bondár M. 1996. Késő rézkor. Kora bronzkor. In: Költő L. – Vándor L. (eds.) Évezredek üzenete a láp világából. Kaposvár-Zalaegerszeg: Somogy és Zala Megyei Múzeumok Igazgatóságai. 34-41, 44-47

Budyko M. I. – Yefimova N. A. – Lobanov V. V. 1988. The Level of the Caspian in Future. *Meteorology and Hydrology* 5: 86-94

Clark R. L. 1982. Point count estimation of charcoal in pollen preparations and thin sections in sediments. *Pollen et Spore* 24: 523-535

Dániel P. 2004. Methods of the five-step extraction-digestion method. In: Sümegi P. – Gulyás S. (eds.): The geohistory of Bátorliget Marshland. Budapest: Archaeolingua Press. 53-56

Degens E. T. – Paluska A. 1979. Tectonic and climatic pulses recorded in Quaternary sediments of the Caspian–Black Sea region. *Sedimentary Geology* 23: 149-163

Györffy Gy. – Zólyomi B. 1996. A Kárpát-medence és Etelköz képe egy évezreddel ezelőtt. *Magyar Tudomány* 41/8: 899-918

Holzhauser H. – Magny M. – Zumbuhl H. J. 2005. Glacier and lake-level variations in west-central Europe over the last 3500 years. *Holocene* 15/6: 789-801

Horváth L. 1996. Késő bronzkor. Kora vaskor. Késő vaskor. In: Költő L. – Vándor L. (eds.) Évezredek üzenete a láp világából. Kaposvár-Zalaegerszeg: Somogy és Zala Megyei Múzeumok Igazgatóságai. 57-66, 71-77

Jakab G. – Sümegi P. 2004. A lágyszárú növények tőzegben található maradványainak határozója mikroszkópikus bélyegek alapján. *Kitaibelia* 9: 93-129

Jakab G. – Sümegi P. 2005. The evolution of Nádas-tó at Nagybárkány in the light of the macrofossil finds. In: Gál, E.-Juhász, I. – Sümegi, P. (eds.) Environmental Archaeology in North-Eastern Hungary. Varia Archaeologica Hungarica 19. Budapest: MTA Régészeti Intézet. 67-77

Jakab G. – Sümegi P. 2007. The vegetation history of Balátató. In: Zatykó Cs. – Juhász I. – Sümegi P. (eds.) Environmental Archaeology in Transdanubia (Hungary). Varia Archaeologica Hungarica 20. Budapest: MTA Régészeti Intézet. 334-336

Klige R. G. – Myagkov M. S. 1992. Changes in the water regime of the Caspian Sea. *GeoJournal* 27: 299-307

Magny M. 2004. Holocene climatic variability as reflected by mid-European lake-level fluctuations, and its probable impact on prehistoric human settlements. *Quaternary International* 113/1: 65-79

Mayev E. G. – Maeva S. A. – Nikolaev S. D. 1983. New Data on the Holocene History of the Aral Sea. The Paleography of the Caspian and Aral Seas in Cainozoic Era. Part 2. Moscow: Nauka. 133-144

Müller R. 1987. Megjegyzések Fenékpuszta történetéhez. *Zalai Múzeum* 1: 105-116

Müller R. 1996. Római kor. Hunok, germánok. Keszthely kultúra. In: Költő L. – Vándor L. (eds.) Évezredek üzenete a láp világából. Kaposvár-Zalaegerszeg: Somogy és Zala Megyei Múzeumok Igazgatóságai. 79-84, 85-92, 93-97.

Rácz L. 2008. Magyarország környezettörténete az újkorig. Budapest, MTA Történeti Intézete. 261 p.

Rodionov N. S. 1994. Global and regional climate interaction: the Caspian Sea experience. Water Science and Technology Library 11. Dordrecht: Kluwer Academic Publishers. 241 p.

Sági K. 1968. A Balaton szerepe Fenékpuszta, Keszthely és Zalavár IV-IX. századi történetének alakulásában. *Antik Tanulmányok* 10: 15-46

Sümegi P. 2000. Negyedidőszaki paleoökológia szerepe a magyarországi lápok vizsgálatában. In: Szurdoki E. (ed.) Tőzegmohás élőhelyek Magyarországon: kutatás, kezelés, védelem. Miskolc: CEEWEB Munkacsoport. 13-26

Sümegi P. 2001. A negyedidőszak földtanának és őskörnyezettanának alapjai. Szeged: JATEPress. 262 p.

Sümegi P. 2004. The Mollusc analysis. In: Sümegi P. – Gulyás S. (eds.) The geohistory of Bátorliget Marshland. Budapest: Archaeolingua Press. 62

Sümegi P. – Gulyás S. – Jakab G. 2008. 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: 33-43

Sümegi P. – Jakab G. – Majkut P. – Törőcsik T. – Zatykó Cs. 2009. Middle Age paleoecological and paleoclimatological reconstruction in the Carpathian Basin. *Időjárás* 113: 265-298

Stockmarr J. 1971. Tables with spores used in absolute pollen analysis. *Pollen et Spores* 13: 615-621

Straub P. 2002. 5. századi tömegsírok Keszthely – Fenékpusztán. *Studia Archeologica* 8: 177-200

Szőke B. M. 1996. Avar kor vége. Karoling kor. In: Költő L. – Vándor L. (ed.) Évezredek üzenete a láp világából. Kaposvár-Zalaegerszeg. 104-106, 115-122

Timár G. – Molnár G. – Székely B. – Biszak S. – Varga J. – Jankó A. 2006. Digitized maps of the Habsburg Empire. The map sheets of the second military survey and their georeferenced version. Budapest: Arcanum. 59

Troels-Smith J. 1955. Karakterisering af lose jordater. *Danmarks Geolosika Undersogelse* 3: 39-73

Vándor L. 1996. Királyi hadiút mentén. Honfoglalás és Árpád-kor. Törökkor. In: Költő L. – Vándor L. (eds.) Évezredek üzenete a láp világából. Kaposvár-Zalaegerszeg. 135-153

M. Virág Zs. 1996. Újkőkor (neolitikum) és korai rézkor. In: Költő L. – Vándor L. (eds.) Évezredek üzenete a láp világából. Kaposvár-Zalaegerszeg: Somogy és Zala Megyei Múzeumok Igazgatóságai. 22-33