“per sylvam et per lacus nimios”

The Medieval and Ottoman Period in Southern Transdanubia, Southwest Hungary: the Contribution of the Natural Sciences

Institute of Archaeology
Research Centre for the Humanities
Hungarian Academy of Sciences

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In memoriam Zsuzsa Miklós

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Research Centre for the Humanities
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"STUDIES ON SETTLEMENT ARCHAEOLOGY AND ENVIRONMENTAL HISTORY IN SOUTHERN TRANSDANUBIA, 1300–1700": AN INTERDISCIPLINARY RESEARCH PROJECT IN A NUTSHELL

"… *per sylvam et per lacus nimios* …" ("across a forest and a multitude of lakes") is how a pilgrim travelling to the Holy Land in the eleventh century described his crossing across the Drava River.[1] Reading the Ottoman-period travelogues written some six hundred years later, in 1664,[2] it seems that the Drava region had changed little: it was still extensively covered with woodland and marshland. The goal of our research project was the exploration of this landscape, its changes, and the impact of the region's communities on this land, set in a broader Transdanubian context.

Supported by the Hungarian Scientific Research Fund (OTKA Grant K 72231), our project entitled "Studies on Settlement Archaeology and Environmental History in Southern Transdanubia, 1300–1700" was completed in 2013. During its course, particular issues concerning environmental history, settlement patterns, cultural history, and material culture linked to castles and their surrounding areas were explored, using a number of different research methods.[3]

The choice of the study area was prompted by various considerations. One was that earlier findings made at different sites in southern Transdanubia (Hungary) by researchers taking part in the project inspired the broadening of the investigations, both thematically and geographically. At the same time, the Drava district, selected for further studies within the region, offered very favorable opportunities for new research. As a border area, the Drava district was relatively undisturbed by intensive construction work, and had lacked

1 "*Dehinc per sylvam et per lacus nimios atque trans flumen per navigium ad villam, ubi est habundantia panis, usque ad unam civitatem non longe hinc positam, quae vocatur Dordomest in aliis quatuor diebus*." ("From here, across a forest and a multitude of lakes and then by sailing across a river [they arrived] to a village, which has abundant supply of bread, then during another four days [they went] to a town not too far from here, which is called Dordomest.") Johann Georg von Eckhart: Corpus hostoricum medii aevi: sive scriptores res in orbe universo praecipue in Germania a temporibus maxime Caroli M. Imperatoris Usque ad Finem seculi P. Chr. n. XV. gestas enarrantes. Vol. 2. Lipsiae, 1723. 1345. For more about the source, see Györffy, Gy.: *István király és műve* [King Stephen and his work]. Budapest: Gondolat, 1977, 299–300.

2 Evliya Çelebi: "we travelled through forests on sandy soil for six hours": *Evlia Cselebi török világutazó magyarországi utazásai 1660–1664* [The journey of Evliya Çelebi, the Turkish traveler, through Hungary, 1660–1664]. Translated: Karácson, I. Foreword, comments, and revision of notes: Fodor, P. Budapest: Gondolat, 1985^2, 552; Pál Esterházy: "the entire day was spent by wading through marshland": *Esterházy Pál: Mars Hungaricus.* Translated: Iványi, E. Ed.: Hausner, G. Zrínyi-könyvtár III. Budapest: Zrínyi Kiadó, 1989, 140.

3 The participants of the project were Zsuzsa Miklós (†) (*castellum* at Őcsény and aerial archaeology), Csilla Zatykó (environmental and landscape archaeology at Berzence and its broader area), Gyöngyi Kovács and her colleagues (Ottoman-Turkish castle at Barcs), Márton Rózsás (castle and other investigations at Barcs and its broader area), Attila J. Tóth (underwater archaeology), László Bartosiewicz and Erika Gál (archaeozoology), Pál Sümegi and his colleagues (environmental history), István Viczián (geomorphology), Attila Kreiter and Péter Pánczél (petrographical analysis of ceramics), and Katalin T. Biró (lithic artifacts).

Figure 1. Map of the study area showing the sites investigated during the project (map by Sándor Ősi)

archaeological exploration. It was, therefore, a place where new directions for research could be formulated.

Intensive work – partly based on earlier research – took place at sites in Tolna and Somogy counties. Part of the project was the assessment of the assemblages from the excavations conducted at the medieval *castellum* at Őcsény (Tolna County) and at the Ottoman-Turkish palisaded castle at Barcs (Somogy County). In both cases, the archaeozoological finds were evaluated too, and the immediate and broader area of each fortification were investigated. Occupied from the thirteenth to the early sixteenth century, the structure at Őcsény was the first medieval *castellum* in Hungary to be excavated fully. The Ottoman-Turkish palisaded castle at Barcs, a newly built fortification that was part of the Ottoman Empire's system of border castles along the Drava River from 1567 until 1664, protected the area around Szigetvár. Regarding the architectural characteristics of Hungary's smaller Ottoman-Turkish palisaded castles and the lives of those stationed in these strongholds, the investigations at Barcs yielded very important data. Key information on the medieval settlements in the neighborhood of Barcs, as well as on the area's little-known medieval ceramics, was acquired by studying and assessing the material collected during surface surveys.

Although the medieval history of Berzence (Somogy County) could not be separated from the history of the castle standing on the outskirts of the settlement, archaeological and natural scientific research performed there yielded new findings, primarily with regard to medieval settlement patterns, the environment, and land usage.

As part of the project, traditional archaeological work such as the study and the assessment of finds was performed, and, additionally, surface surveys were conducted, as was fieldwork for the investigation of the medieval environment remains. The research work was complemented with aerial and underwater archaeological prospection as well.

Regarding the Drava region, the first aerial photography reconnaissance for archaeological purposes was performed in this project. The aim was not only to explore castles and settlements as archaeological sites, but to document the changes in them as well, and also – by photographing marshy areas and watercourses now partly filled in and ploughed up – to show alterations in their immediate surroundings and in the wider environment. Some of the underwater archaeology work was connected to the research project for Barcs and its surroundings. The surveying of the remains of the Ottoman-Turkish pontoon bridge at Drávatamási, an underwater site of Europe's largest log pontoon, was part of the project too, although some of this work was done independently of the project as part of an international collaboration.

In addition, as a new research avenue, geomorphological analysis and core samplings for reconstructing environmental history were performed. Supplemented by an analysis of the archaeozoological finds, the results of these examinations contributed to the reconstruction of the environment. By determining the composition of artifacts, the goal of the natural scientific studies was to identify the network of links between the different regions, settlements, and castles, both locally and in a broader sense also.

During the research work, attempts were made to adjust the investigations, methods, and sources used to the nature and the scale of the different locations, and to the principal questions of the project. In the case of Barcs Castle, where we could rely on the evidence provided by the ceramic and animal bone material recovered in the course of the excavations to a high degree, greater emphasis was placed on the archaeozoological and petrographical evaluation; in addition, aerial archaeological prospection and environmental history analyses were also performed. Regarding the wider area of the manorial estate of Berzence Castle, bearing in mind the microregional scale, the basis for the archaeological research was provided by the findings of the surface surveys and of the region's geomorphological analysis. In the case of Berzence, the data from two documents describing in detail the division of landed property could also be utilized, as could the findings of the geological borings when reconstructing the history of the settlement and of the local environment.

Although earthenware, bones, and soil samples were used, the focus of our research was always on human beings and their activities. Answers were sought as to how people lived in the given territories in the eventful period between 1300 and 1700, during which, from the second half of the sixteenth century onwards, the Ottomans controlled the region. The aim was to uncover the kinds of settlements they lived in, the kinds of artifacts they used, the kinds of food they ate, and the kind of environment they lived in, as well as the kinds of responses they gave to the environmental challenges they faced. Also examined was the evidence for descent, religion, cultural identity, lifestyle, forms of activity, farming, handicrafts, and trade.

The use of the available historical, archaeological, and natural scientific evidence along with a wide array of research methodologies contributed in a creative way to a better understanding not only of the region's inhabitants and their environment, but also of the environmental components of different historical periods (climate, vegetation, riverbeds, forests, stock of game, etc.), land usage, farming, and lifestyle. Of course, the investigations could not extend to every detail, but the many strands could be interwoven to form a broad tapestry. Often pioneering in nature, research on environmental history and the natural scientific analyses yielded new data of the kind that will undoubtedly serve as the basis for further research.

The present volume offers a summary of the environmental history and the findings of the natural scientific analyses of this interdisciplinary research project. The archaeological findings of the program, parts of which have already been published in preliminary reports,[4] will appear in a subsequent volume.

Gyöngyi Kovács and Csilla Zatykó

4 Cf., for example, the studies by Gyöngyi Kovács and Márton Rózsás, Csilla Zatykó, Zsuzsa Miklós, and Attila J. Tóth in *A középkor és a kora újkor régészete Magyarországon / Archaeology of the Middles Ages and the Early Modern Period in Hungary* I–II. Eds.: Benkő, E. – Kovács, Gy. Budapest: MTA Régészeti Intézete, 2010. See also Kovács, Gy. – Bartosiewicz, L. – Éder, K. – Gál, E. – Miklós, Zs. – Rózsás, M. – Tóth, J. A. – Zatykó, Cs.: Medieval and Ottoman-period (14th–17th c.) archaeology in the Drava River region, Hungary. Results of an interdisciplinary project. *Acta Archaeologica Academiae Scientiarum Hungaricae* 65 (2014) 155–168.

Environmental History and Geomorphology

THE ENVIRONMENTAL HISTORY OF SOUTHERN TRANSDANUBIA DURING THE MEDIEVAL AND THE OTTOMAN PERIOD IN THE LIGHT OF PALAEOECOLOGICAL AND GEOARCHAEOLOGICAL RESEARCH

Pál Sümegi, Dávid Molnár, Katalin Náfrádi, Dávid Gergely Páll, Gergő Persaits, Szilvia Sávai and Tünde Törőcsik

INTRODUCTION

Southern Transdanubia was an important, densely populated region in Hungary during the medieval period. In the sixteenth and seventeenth centuries, the area became particularly prominent owing to its role as a military buffer zone between the Habsburg Monarchy and the Ottoman Empire. This region, specifically the Drava region, was practically a blank spot in terms of archaeological research, as it has been a border area since the twentieth century.

In addition to historical and archaeological studies, the investigation of past environments and environmental conditions as well as of how human activities were adapted to environmental conditions are equally important.

The environmental history research described here was part of a complex interdisciplinary research project, "Studies on Settlement Archaeology and Environmental History in Southern Transdanubia, 1300–1700", funded by a grant from the Hungarian National Scientific Research Fund (OTKA Grant K 72231), that was conducted in fundamentally important areas and sites. Together with the archaeologists, we selected sedimentary basins presenting medieval geological layers for palaeoecological analysis in the area of Őcsény, Decs, Barcs, and Szenta-Berzence.

As a result of the joint field surveys and core samplings, the following sites were investigated through undisturbed cores. Our first site was the fort at Őcsény. Unfortunately, only recent sediments were found here, and therefore another core was extracted from the Batta Channel (today: Báta vize [Báta Stream]) near the destroyed market town of Ete, lying close to Decs-Ete. Our next sampling location was an abandoned riverbed in Lankóci-erdő [Lankóci forest] located between Csurgó, Gyékényes, and Berzence. An additional core was taken for palaeobotanical analysis from a filled-up riverbed not far from the Ottoman fort of Barcs. Over fifty samples were collected for sedimentological, geochemical, pollen, and macrobotanical analyses at each site.

We could separate and examine the geological layers representing the medieval, Ottoman periods, and the Early Modern Age. The vegetation, human impact, erosion, and filling-up processes of these chronological horizons were reconstructed. This is the first complex analysis of the environmental history of the Ottoman period in Hungary. This study is unique in Central and South-East Europe, and its findings are currently only comparable with the results of dendrochronological studies.

METHODS

Sedimentary basins as a source of environmental history models

The focus of our environmental history studies was on exploring the development of anthropogenic (pits, wells, ditches, postholes, and graves) and natural (oxbow lakes)

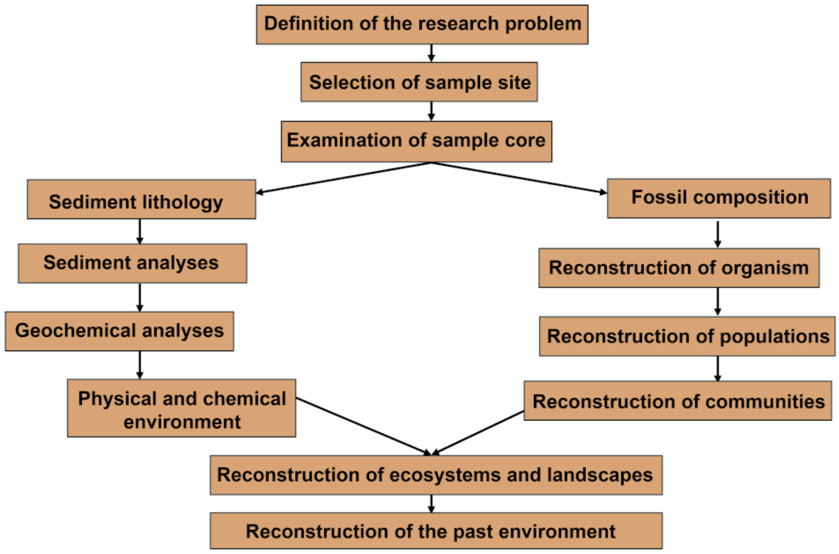

Figure 1. Methods of Quaternary palaeoecological studies
(after Birks – Birks 1980)

sedimentary systems and their broader area. In order to explore various sedimentary basin systems, we first have to understand the mechanism of sediment accumulation and of how different fossil remains are embedded. Specifically, the reconstruction of local deposition environments and small-sized sedimentary basins plays an important role in Quaternary palaeoecological, geoarchaeological, and environmental history research. The examination of the micro- and macrofossils deposited in sediments is of aid in reconstructing the vegetation, the soil, the fauna evolution, and the anthropogenic impact on a local and regional level. One of the most accurate Quaternary palaeoecological reconstruction models demonstrating past environmental changes was developed regarding the relationship between lakes and the water catchment system. The model is based on the concept that lakes, bogs, and swamps as well as their catchment areas are determined by the geomorphological and geological characteristics of the water catchment area, its natural watershed, and boundaries.

Sediments from the catchment area, erosion material from soils and slopes, dust and pollen carried by the wind from long distances can be illuviated into the sedimentary basin where they accumulate. Organisms living in the sedimentary basin or in lakes also accumulate and can create sediments. Thus, as a result of erosion and transportation processes, diverse material accumulates in the sedimentary system and provides information about past environmental changes *(Fig. 1).*

Naturally, material arriving from various distances (allochthonous) or deposited locally (autochthonous) indicate different palaeoenvironmental changes, and represent environmental factors located at various distances from the sedimentary basin. Therefore, even though the palaeoenvironmental data are derived from the sediments of a specific sampling location (profile, core), the accumulated sediments and fossils provide information on the environmental changes and processes that took place in the entire sedimentary basin.

Regarding certain materials accumulated in the sedimentary basin (for example dust and pollen carried by the wind), the caption area of a lake, bog, or swamp is not the same as the catchment area. The dust and pollen carried by the wind usually depends on the general air circulation and wind direction. The accumulation of sediments eroded by surface areal erosion depends on the relief, the vegetation cover, and the intensity and distribution of precipitation. The plants and mollusks living in a lake system are determined by chemical and physical factors (the equilibrium or shift of decomposing [oxidative-reductive] processes, temperature, soluble O_2 content, light transmission, water movement, and the quantity and quality of organic and inorganic material).

The accumulation of materials of diverse origin indicates that the sedimentary basin represents the changes of both the water catchment and the caption area. At the same time, the accumulation of sediment layers in a lake, bog, or marshy system is a time-dependent event, and therefore it captures not only the events that occurred in the catchment area, but also provides chronological information about the position of the sedimentary basin and the layers.

Sediments deposited as a result of erosion, transportation, and accumulation together with sedimentary basins provide data about the spatial as well as the chronological changes of past environments. Radiocarbon and other dating methods of sediments provide information about the sedimentation rate and the speed of erosion and accumulation in the catchment area.

The combination of these investigations with palaeobotanical analyses offer data regarding vegetation changes. Furthermore, we can gain an even more accurate picture of the former environment of the sedimentary basin if the investigations are expanded to include sedimentological, geochemical, and malacological material.[1] The chronological resolution of the sedimentary sequence and the embedding sediment (matrix) is determined by factors creating layer disturbances such as wind, streams, and mixing movements. Additionally, the activity and intensity of organisms such as deposit feeders and (in)benthos animals can cause disturbances in layers.

If our goal is to analyze micro-scaled environmental changes (several acres), we need to choose smaller, closed sedimentary systems that carry information about local changes only. One good example of a small-sized local sedimentary basin is the oxbow lake in the northern part of the Little Balaton region.

The sediment in which fossils are embedded also offers significant information about the lacustrine sedimentary basin and the evolution of the catchment area. A more accurate reconstruction of the former environment is possible by the sedimentological and geochemical analysis of the unidentified fine-sorted organic material and the fine-grained inorganic material. Based on the geochemical analysis of lake, bog, and marsh sediments, the first environmental reconstructions of sedimentary basin's catchment area were carried out by John Mackereth, a British researcher.[2] According to his hypothesis, the inorganic material content determined by the loss on ignition method and the sodium and potassium content obtained during the chemical process are related to the erosion of the lake's catchment area. He noted that if the catchment area of the sedimentary basin is covered by vegetation, its surface is stable, the bedrock is deeply weathered, and covered by soil. Consequently, as a result of water drop erosion and areal water flow, mostly ions and colloids dissolved in downfiltrating waters are carried into the sedimentary basin and the erosion of unweathered silicate grains is minimal.[3]

As nutrients (e.g. potassium and sodium) end up in the sedimentary basin, algae proliferate, which leads to the accumulation of fine-grained, organic material-rich detritus lacustrine sediments. If the surface of the catchment area becomes instable due to the decline of the vegetation cover caused by natural (forest fire) or anthropogenic factors, erosion can also destroy the soil layer of the catchment area and the weathered part of the bedrock,

1 Birks – Birks 1980.
2 Mackereth 1966.
3 Mackereth 1966.

called regolith. In this way, silicate grains weathered to a different degree and unweathered silicate grains accumulate in the sedimentary basin.

John Mackereth mainly studied oligotrophic lakes, where the amount of organic material in the lake was relatively low and the greater part of the organic material originated from the soil of the catchment area. In our view, the processes reconstructed by him and the models proposed by him can be applied to a limited extent only in the case of the sedimentary sequences in southern Transdanubia because different mesotrophic and eutrophic lake sediments accumulated during the Holocene in the area of the sampling locations.[4]

The geological, isotopic geochemical, and geochemical analyses of sediments in Transdanubia, and the comparative chemical composition analysis of the embedded fossils – mollusk shells – are suitable for checking the palaeoenvironmental reconstruction made on the basis of fossils. Sedimentological and geochemical investigations can be employed to reconstruct former vegetation changes and pedological changes as a result of anthropogenic impact; however, we cannot automatically draw conclusions regarding past changes in the soil system merely by looking at the chemical composition of the sediments that accumulated in the sedimentary basin.[5] The reason for this is that it is difficult to determine the origin of the grains carried into the lake because the autochthonous components are mixed with the deposited material, which are undissolvable in limnic environments and carried either by precipitation, leaching, or wind. At the same time, the chemical composition of the sediment can also be modified by syngenetic or postgenetic diagenetic processes.

Analysis of geomorphological methods and historical maps

Decs-Ete, one of the study areas *(Fig. 2)*, is located on a Pleistocene lag surface in the Tolna Sárköz microregion. The assumed port of Barcs was explored by extracting cores from the former riverbed by the medieval fort. At Lankóci-erdő by Berzence, a filled-up stream bed was explored in a stream alluvium that was active during the medieval period, located in a depression that covered several square kilometers. The Barcs and Berzence sites are both located in an intensive neotectonic depression in the Middle Drava region.

The evolution of the microregion can be studied from the close of the Pliocene/onset of the Quaternary, as the topographical conditions that form the morphological basis of the microregion classification had evolved by that time. The morphological analyses are based on cores and elevation models, while the morphometric analysis was performed on contour maps. At the same time, because it is crucial in geomorphology to determine uniform and approximately identical surfaces, we used a 1 m resolution shaded elevation model, which shows the slope angle and the surface curvature model according to slope direction. Based on the results of these analyses, we reconstructed the runoff conditions and hydrography of the investigated locations.

In terms of historical maps, we are quite fortunate because the study area even appears on Ptolemy's map from the second century AD that was copied in the medieval period. We could consult several maps from antiquity to the Modern Age recording conditions prior to the river regulations for the characterization and historical analysis of the area *(Fig. 3).*

4 Sümegi 2004.
5 Engström – Wright 1984.

Figure 2. The location of the study sites on a Google Earth image

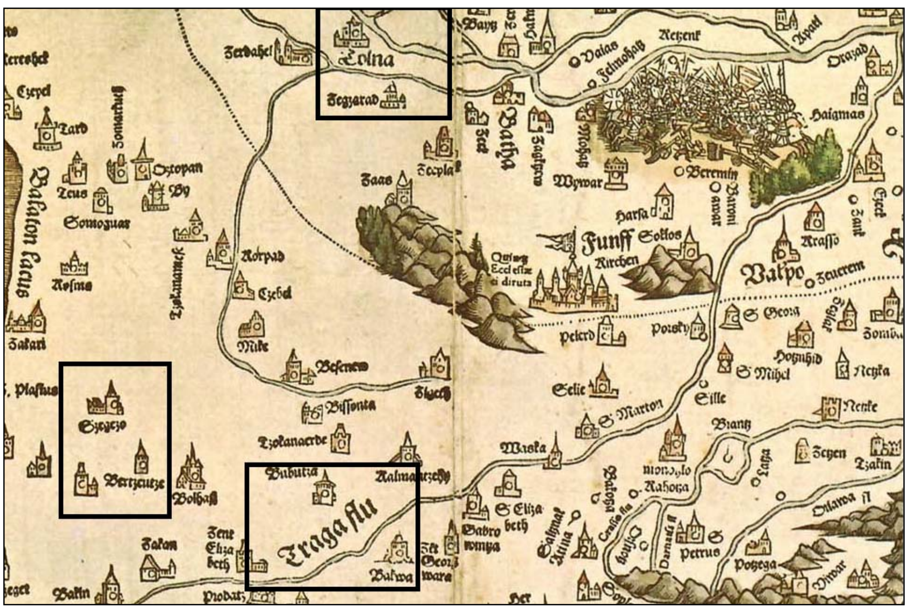

Figure 3. The study sites (black rectangles) on Lazarus secretarius' historical map from 1528 (after Tímár et al. 2008a)

Pollen extraction and pollen analysis

The *Lycopodium* spore tablet method was used for determining pollen concentrations.[6] Since this method is not widely used in Hungary, we present a brief description of the method. Each tablet contains a known number of acetolysed *Lycopodium* spores. It is very important that the tablet is mixed with the sample during the first step of pollen extraction, since the

6 Stockmarr 1971.

possible pollen loss that might take place during the extraction is in a one-to-one relationship with the amount of *Lycopodium* spore loss and it leads to a constant ratio of the marker spore and the fossil pollen grains.[7]

The pollen counts were conducted in the usual way, the only difference being that we recorded the number of the *Lycopodium* spores as well. Since the starting amount of the marker spore is known, we can easily calculate the total pollen concentration, the ash concentration, and the concentrations of each pollen taxon. The advantage of the method compared to other absolute extraction methods is that it is not necessary to analyze the entire area of the cover slip. In knowledge of the sedimentation rate, we can calculate the pollen influx per taxon (pollen grain/cm^2/year).

The pollen-rich organic material was mounted on a glass slide bonded in silicone oil. During pollen analysis, at least 300 terrestrial pollen grains were counted in order to have statistically significant results. If fewer than 100 pollen grains were counted, the sample was considered sterile and the observed species were recorded.

An optical microscope was used for the pollen identification with magnification of 600–1000x. The identification of pollen and spores was performed using the pollen reference materials of the Department of Geology and Palaeontology, University of Szeged, and of the Geological Institute of Hungary, as well as standard reference books.[8]

Microcharcoal concentration was determined according to the point-count method of Robin L. Clark.[9] The results are presented as cm^2/cm^3 in the pollen diagram. The model and analytical system of Harry John B. Birks and Hilary H. Birks[10] was used for the complex palaeoecological evaluation and the PSIMPOLL program[11] for plotting the analytical results.

Macrobotanical analysis

We conducted the macrobotanical analysis on organic-rich layers. A modified version of the QLCMA technique (semi-quantitative quadrat and leaf-count macrofossil analysis technique)[12] was used for the description of the macrofossils. Organic material occurring in peat and organic-rich lake sediments can be divided into two main groups. On the one hand, there are materials that can be identified with lower ranked taxa (specific peat components), while in the case of non-specific peat components, an identification is not possible.

In the case of specific peat components, the identification can be made at the species level. These are very important in the reconstruction of the accumulation environment and can contribute to the reconstruction of past plant associations. The most important specific peat components are seeds, fruits, reproductive organs, mosses, rhizome-epidermis (*Carex* species), leaf epidermis, other tissues and organs (trichoma, tracheids etc.), remains of insects, and ostracoda shells. For the identification of soft plant tissues, we used the reference book by Gusztáv Jakab and Pál Sümegi.[13]

Since the organic material content of several samples was relatively low, larger amounts of samples were used. 5–10 cm^3 samples were taken at 4 cm intervals and concentrations were calculated based on the sample volumes. The amount of peat components was 1 cm^3,

7 Berglund – Ralska-Jasiewiczowa 1986.
8 Moore et al. 1991; Reille 1992; Beug 2004.
9 Clark 1982.
10 Birks – Birks 1980.
11 Bennett 1992.
12 Jakab et al. 2004; Jakab – Sümegi 2004.
13 Jakab – Sümegi 2004.

while the amount of seeds was 8 cm^3. Samples were sieved through a 300 mm-diameter sieve.

To obtain concentrations for the macrofossil components, a known amount of marker grains (0.5 g poppy seeds, *ca*. 960 pieces) was added to the sample. In a Petri dish, the total number of poppy seeds and the fossil remains were counted in ten 10 × 10 mm quadrats using a stereomicroscope.

Rhizomes such as mosses can be identified only by using a light microscope. Thus, 100 pieces of monocotyledons were selected and wet dissections were prepared, allowing us to obtain the percentage values of identified and undifferentiated monocotyledons.

Macrobotanical concentrations were obtained as follows:

$$\text{Macrofossil concentration} = \frac{\text{counted macrofossil (average)} \times 960 \text{ (total poppy seed)}}{\text{counted poppy seed (average)} \times \text{volume of the sample (cm}^3\text{)}}$$

RESULTS

Environmental history of the medieval market town of Decs-Ete

One unique aspect of the study site is that we could determine the eighteenth-century location of the riverbed from the comparative analysis of Google Earth images and the map of the First Military Ordnance Survey of Austria-Hungary *(Figs 4–7).* The map of the First Military Ordnance Survey clearly shows that the Batta Stream was an accompanying stream that flowed from a higher-lying relief; it was not an actively developing riverbed and only floodwater flowed in its channel after the Pleistocene. Accordingly, Holocene sediments accumulated in the channel of the Batta Stream and the palaeobotanical material embedded in its sediment was suitable for the reconstruction of local environmental factors, including the medieval landscape history.

On the basis of the core, the filled-up, drained, and ploughed Batta Stream had probably developed in the Upper Pleistocene and is a 35,000-year-old riverbed. A significantly thick, silt-rich Pleistocene sediment accumulated in the riverbed; however, taking into account that a roughly 1.5 m thick sediment layer accumulated during 25,000 years, the sedimentation rate is regarded as low (0.06 mm/year).

The bed of the Batta Stream may have been a tributary of the Danube River in the branched river system of the Upper Pleistocene in view of the riverbed development, the sediment type, and the sedimentation rate. Silt-rich oxbow lake sediments accumulated at a very low rate in the Pleistocene environment. As a result of weathering at the end of the Pleistocene (during the Late Glacial), an oxbow lake sediment accumulated with increasing organic material and clay content. Average and not well-preserved pollen grains occurred in the sediment; nevertheless, the pollen material was suitable for palaeobotanical analysis and for the reconstruction of the former environment and the human impacts on the vegetation during prehistory, the Roman Age, the Migration period, and the medieval period. The sediment sequence of the undisturbed core extracted from the Batta riverbed lying north of the medieval settlement of Decs-Ete is shown in *Table 1,* while the results of the radiocarbon analysis are presented in *Table 2.*

Our findings set the development of the study site in an entirely new perspective. Based on previous geological data, the Sárköz region is located in the Mecsek zone, in the northern part of the Tisza (Tisia) Unit, which is the western zone of the Tisza-Dacia Unit. The Lower Carboniferous Mórágy Granite Formation can be found in the western part of the region,

Table 1. The sediment sequence of Core 1 in the Batta palaeochannel on the northern side of Decs-Ete

GPS coordinate	*Depth (cm)*	*Troels-Smith category*	*Lithostratigraphy*
46° 16′ 46.19 N 18° 42′ 22.40 E	0–15	Sh2As2	Blackish-brown hydromorph soil, level A.
	15–30	Sh1As3	Dark brown hydromorph soil, level B.
	30–50	Dg1Ga1As2	Yellowish-brown laminated lake silt with inwashed soil, charcoal, and burnt daub from the abandoned settlement layer, between the 18th–20th centuries.
	50–55	As4	Laminated oxbow lake sediment without human impact. This layer was formed after the abandonment of the medieval village.
	55–75	Dg1Sh1As2	Laminated organic material-rich oxbow lake silt (pelite) with charcoal; high microcharcoal content. A medieval village level with strong human impact.
	75–105	As4	Grayish-green laminated silt deposited in a mesotrophic oxbow lake. Minimal human impact.
	105–180	As2Ag2	Greenish-yellow Pleistocene oxbow lake, silt-rich sediment with limonite spots, limonite laminas, and minimal weathered material content.
	180–220	Ga1Ag3	Grayish-green Pleistocene oxbow lake sediment with flaser structure.
	220–240	Ga2Ag2	Dark-grey cross-bedded sandy silt, Pleistocene stream sediment layer.

Table 2. Radiocarbon dates for the medieval level in the core sequence of the Batta palaeochannel at Decs-Ete

Depth (cm)	*Uncal BP year*	*Cal BP year*	*Cal AD year*	*Code*
55–56	444 ±21	492±56	1441±15	D-AMS 005122

and its 18 × 11 km surface outcrops in the Mórágy Block. The migmatitic granite rock was formed as a result of ultrametamorphism during the Variscian orogenesis. The granite can be found east of Mórágy in the vicinity of Bátaszék, on the northern side of the Lajvér Stream, under younger formations. The granite-migmatite series pass through to the eastern side of the Tisza Unit to the Great Hungarian Plain, where it was identified in cores.

South of Szekszárd, the granite block is bordered by the Mecsekalja zone in a southwest to northeast direction. The blocks to the north of this zone are in a deeper position than those that are south of the Mecsekalja zone. This is supported by the cores, as granite can be found at a depth of 885 m at Szekszárd and at 112 m at Bátaszék. In the basement of the Sárköz region, in the vicinity of Sárpilis, the granite block protrudes, as it appears at a depth of 86 m.

This geological situation had an effect on the evolution of the Quaternary river system in this region. In the southern Sárköz region, on the outskirts of the village of Báta, Middle Triassic (Anisian) bluish-gray Muschelkalk shifted to the granite block. According to drillings, the minimal thickness of the rock is over 200 m in the vicinity of the village; however, the drillings did not reach the bedrock of the formation. The limestone probably sank and rose together with the granite block, and today it lies no more than a few meters underneath the surface *(Fig. 8)*. During the Holocene, this rock unit blocked the Danube River (later Sárvíz) towards the south and forced the river to shift in an eastern direction. In the entire

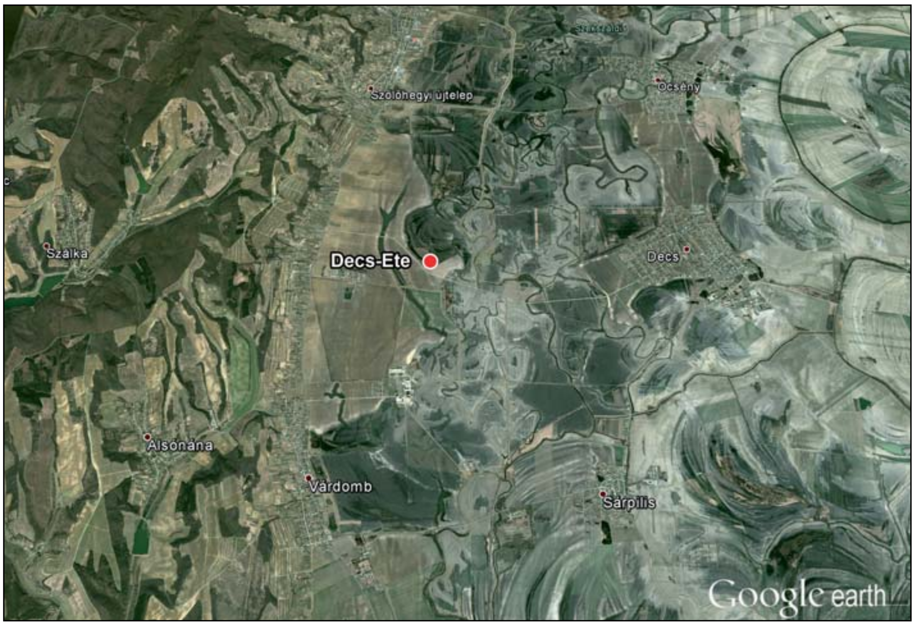

Figure 4. The coring location in the Batta Channel on the northern outskirts of the Decs-Ete settlement on a Google Earth image, March 2006

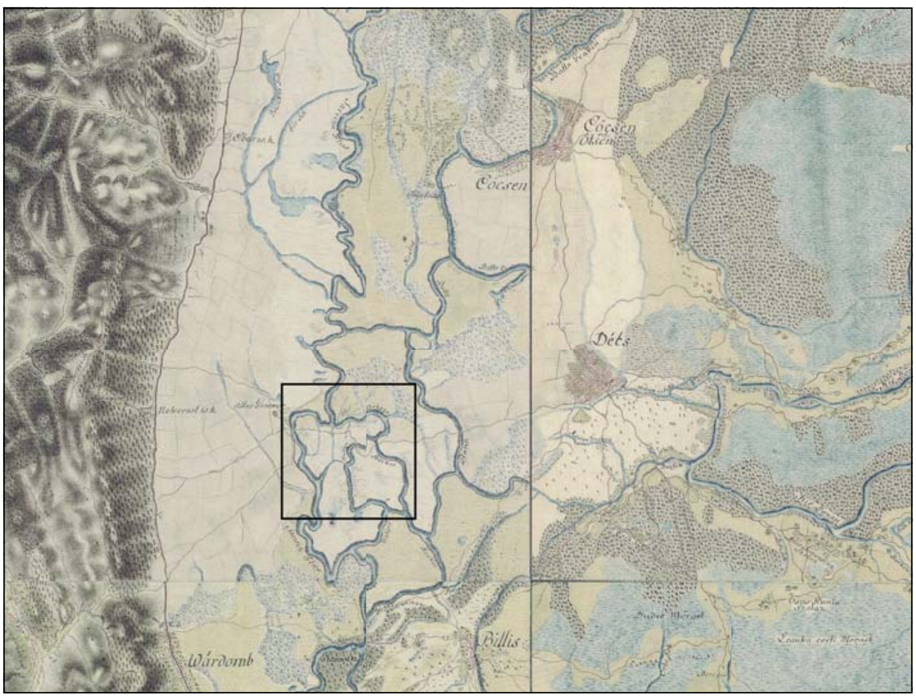

Figure 5. The coring location in the Batta Channel on the northern outskirts of the Decs-Ete settlement on the map of the First Military Ordnance Survey of Austria-Hungary from 1782

Sárköz region, Pannonian layers were deposited on the Carboniferous granite and Triassic limestone. There are no Pannonian formations in the Sárköz region; however, they can often be found on hillsides, in valleys, and in road cuts in the Szekszárd Hills. Thus, the entire surface of the Sárköz region is covered by Quaternary sediments that were deposited with

Figure 6. The coring location in the Batta Channel on the northern outskirts of the Decs-Ete settlement on a Google Earth image, March 2006

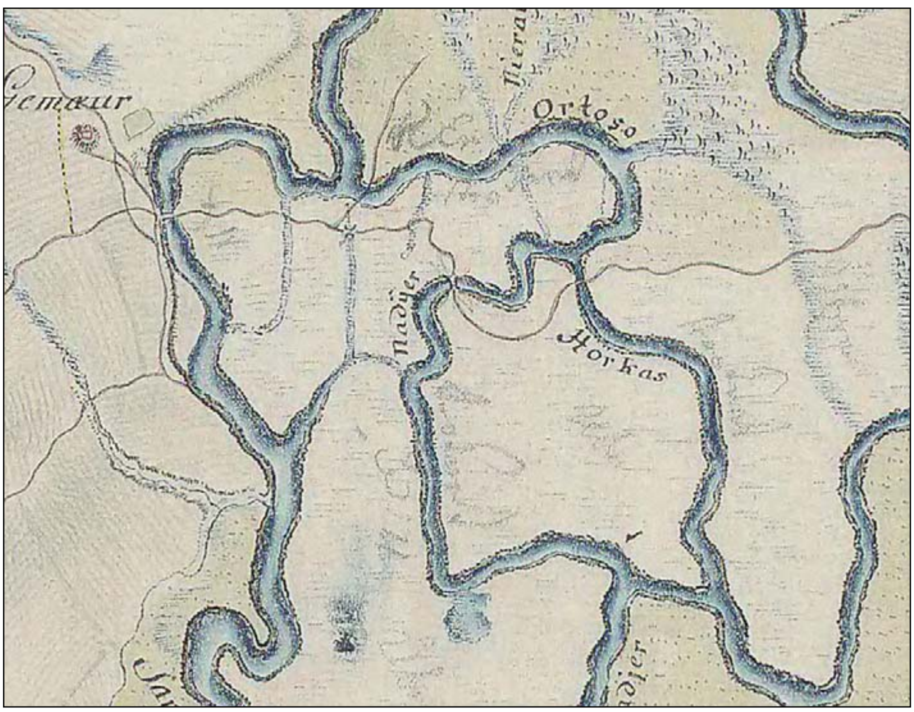

Figure 7. The coring location in the Batta Channel on the northern outskirts of the Decs-Ete settlement on the map of the First Military Ordnance Survey of Austria-Hungary from 1782

diverse bedding and accumulated to a thickness of about 40–60 m depending on the degree of subsidence, the quality of the deposited sediment, and the variability of morphological conditions. Quaternary sediments thicken in a west to east direction *(Fig. 14)*.

On Pannonian formations, the alluvial sediments of rivers flowing from the direction of Transdanubia were deposited, while from the Upper Pleistocene onward, the floodplain material of the Danube River accumulated. From the Middle Wurmian onward, the Danube River accumulated upward fining riverine sediments in the longitudinal depression between Kalocsa and Mohács. The thickness of the Pleistocene riverine sediments is 20–40 m. It predominantly consists of medium- to coarse-grained and unclassified sand *(Figs 8–9)*. Grains are moderately or little rounded and worn. Gravel intercalations are frequent; they are mostly made up of quartz, quartzite, flint, and limestone, and calcareous concretions also occur in some location. Thin, chalky, and sandy-clay brook intercalations also appear infrequently. Similar sediments can be found to a depth of several hundred meters in old Danube deposits in the Danube-Tisza Interfluve.

In the Sárköz region, just as in other parts of Transdanubia, considerable loess formation took place during the Pleistocene. 40 to 60 m thick loess layers with loam zones accumulated on the western hillside of our study area. Infusion loess was formed in the wet areas of the Danube Valley. It is predominantly an alluvial formation and is sometimes mixed with clay. Its thickness is 3 × 5 m and covers surfaces above the floodplain.

The village of Decs lies on an infusion loess-covered lag surface of this type, as does the village of Ete that was deserted during the Ottoman period. It was previously assumed that the sediments of these flood-free, flat reliefs (called *göröndök* by the locals) were formed in the earlier stages of the Holocene and they were considered to be washed and redeposited loess material. On the one hand, the relative height of these terraces, compared to the low stand of the Danube, is 9–11 m; on the other hand, our studies have proven that these terraces are accompanied by Pleistocene riverbeds, indicating that their formation preceded the Holocene. As we can see in *Figure 6*, Őcsény, Decs (and Ete), and Sárpilis are located on the highest relief (*görönd*), where the Pleistocene loess is overlain by sand in some places. Sand movement is clearly connected to the neotectonic incision of the Danube River's channel and to the late Pleistocene transformation of the fluvial environment prior to the Holocene.

As a result of the warmer and wetter climate at the onset of the Holocene, the water level of the Danube River rose and the river split into several branches; its meanders lay across the entire Sárköz region. The dominance of the Danube River in the area came to an end in the wake of the river regulations in the 1880s, when large meanders were cut off, marshy and swampy areas were drained, and the river was constrained between embankments. Today, Gemenc Forest is located on the floodplain on the Danube side of the embankment. Although the current mechanism of the river in the Sárköz region is not of the lower reaches type, the area is still characterized by the filling up of the floodplain. The reason for this special filling up is that Danube River transports a small amount of traction sediment, while fine-grained suspended sediment deriving from bank erosion is deposited on the floodplain. The outer side of the embankment is now cultivated almost everywhere despite the fact that it is dotted with smaller and larger depressions that are filled with water during rainy periods or meltwater during spring around the former Pleistocene oxbow lakes (called *gyűrök* in Hungarian). Originally, they were several meters deep riverbeds. Our sampling location was one of these filled-up and ploughed off former oxbow lakes, a *gyűr*.

At the beginning of the Holocene, the braided riverbeds of Danube River formed extremely distinctive landforms, which were recognized and recorded by Count Luigi Fernando Marsigli, who sailed along the Danube during his river exploration and mapping work after the Ottoman period, and published in his work in 1726 *(Fig. 10)*.[14] His map, offering the first detailed depiction of the Sárköz region, shows that the Sárvíz runs at the western boundary

14 Marsigli 1726.

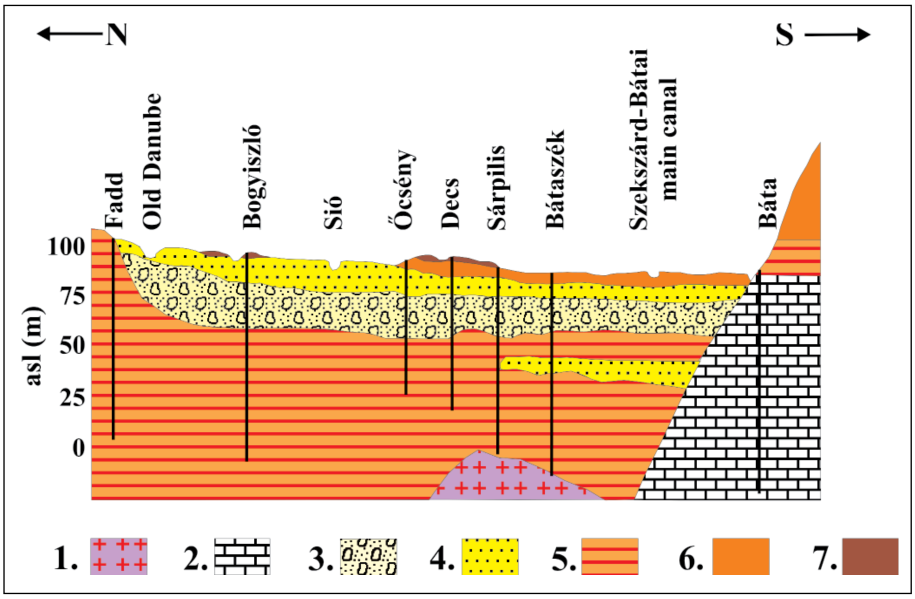

Figure 8. The north-south geological cross-section of the Sárköz region (after Sümeghy 1953)
1: granite, 2: limestone, 3: gravelly sand, 4: sand, 5: clay, 6: loess, 7: wind-blown sand

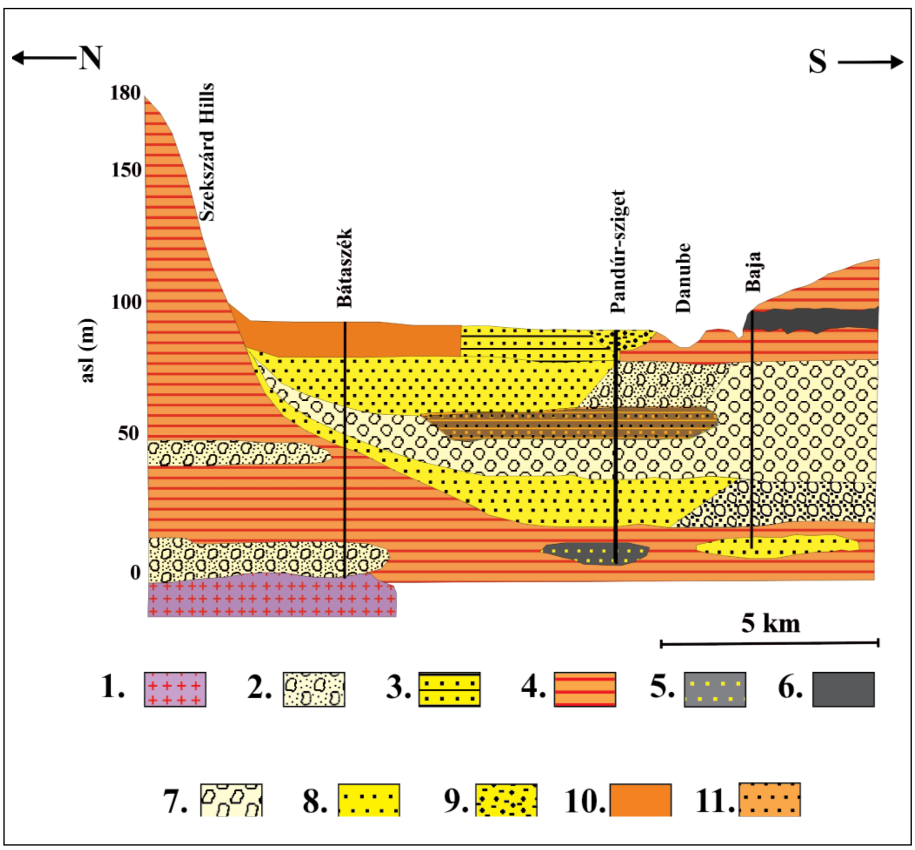

Figure 9. The west-east geological cross-section of the Sárköz region (after Sümeghy 1953)
1: granite, 2: gravelly sand, 3: clayey sand, 4: clay, 5: sandy silt, 6: silt, 7: gravel, 8: sand, 9: silty sand, 10: loess, 11: sandy silt

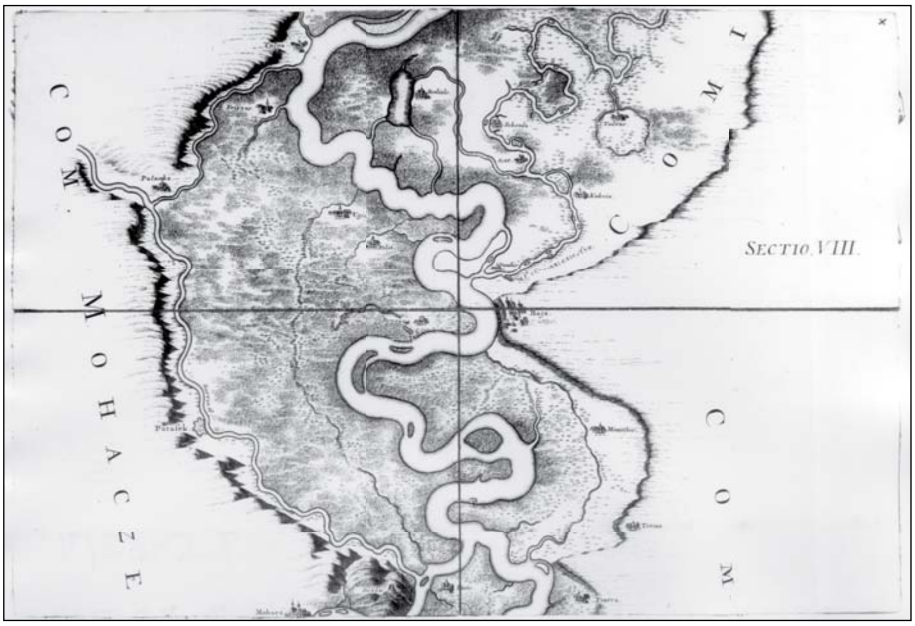

Figure 10. Section VIII of Count Luigi Fernando Marsigli's Danube map, showing the Decs-Ete area and the Tolna Sárköz region (after Marsigli 1726)

of our study area at the foothill and flowed into the Danube at Báta. According to Marsigli, the Sárköz region was a swampy area criss-crossed by smaller streams, including the Ráros-Pösze-patak that flows through the Sárköz region and now functions as the Szekszárd-Báta main channel. The course of Danube River prior to the regulations can be clearly made out on the map, as can the larger meanders that have survived in the form of oxbow lakes. There are a few *fok*s (water outlet/inlet/canal) around the settlements as well.

The significance of this dendritic channel system formed during different geological ages is outstanding because the flood-free islands and peninsula-like areas suitable for human settlement and subsistence were surrounded by oxbow lakes, channels that drained floodwaters, and active riverbeds. Therefore, food-producing economies, floodplain economies, and non-food-producing subsistence strategies (fishing, hunting, and gathering) could all be pursued until the Modern Age and the time of river regulations.

The results of the palaeobotanical analysis

56 pollen taxa were identified *(Fig. 11)* in the sedimentary sequence that had accumulated from the end of the Pleistocene to the Modern Age. This taxon number corresponds to deposits characterized by an average or slightly weaker than average pollen taphonomy, meaning that we had probably found about one-half or two-thirds of the former vegetation that was suitable for fossilization. Samples for pollen analysis were taken at 1 cm intervals for the medieval level, and at 5 and 10 cm intervals for the other parts of the profile *(Fig. 12)*. We identified five local pollen zones on the basis of the statistical cluster analysis of the full pollen profile *(Fig. 13)*, i.e., five local, very similar vegetation development phases and their transition zones could be distinguished *(Table 3)*.

To test the results of the cluster analysis and the local pollen zones, we performed a Principal Component Analysis (PCA) for the pollen samples and pollen taxa. The PCA method indicated six local pollen zones, i.e., six vegetation development phases, but it can

Table 3. Pollen zones and local vegetation changes as reflected by the core sequence at Decs-Ete

Depth (cm)	*Age*	*Pollen zone with local vegetation changes*
30–0	Modern Age	Decs-Ete pollen zone 7: New agricultural system is established.
50–30	Ottoman period	Decs-Ete pollen zone 6b: The medieval agro-ecosystem was destroyed, partial forest and landscape regeneration started.
55–50	Ottoman period	Decs-Ete pollen zone 6a: Abandonment of the Hungarian medieval village.
76–55	Medieval period 55–56 cm: 1441±15 cal AD years	Decs-Ete pollen zone 5: Landscape with mosaic vegetation patterning; the medieval agricultural system was formed. Presence of cultivated fields, pasturelands, meadows, and sedge-covered oxbow lakeside. Weed-rich patches around the settlement.
1.2–0.8	Late Holocene	Decs-Ete pollen zone 4: *Fagus* and *Carpinus* in the gallery forest. A system of cultivated fields and pastureland was created in the gallery forest zone – strong human impact during the Roman Age and Prehistory.
1.6–1.2	Early Holocene	Decs-Ete pollen zone 3: *Quercus-Fraxinus-Ulmus-Tilia* hardwood gallery forests on the low floodplain and Convallario-Quercetum forest existed on the high floodplain.
1.8–1.6	Pleistocene–Holocene transition	Decs-Ete pollen zone 2: Mixed-leaved taiga forest with *Pinus sylvestris*, *Quercus*, *Ulmus*, *Tilia* and *Corylus*. *Carex*, *Typha* and *Phragmites* covered the lakeside zones and meadow spots.
2.2–1.8	Late Glacial	Decs-Ete pollen zone 1: Mixed-leaved gallery taiga forest with *Pinus sylvestris* and *Betula*. A forest steppe on the high floodplain with *Artemisia*, Gramineae, *Carex* and *Pinus sylvestris* stands.

also be seen that some samples are characterized by a transitional composition between individual vegetation development phases or groups. As a result of the PCA method, not only can samples of diverse pollen composition be identified, but plant taxa that cause differences can be determined as well *(Fig. 14)*.

The riverine sand bedrock between 2.4 and 2.2 m was devoid of pollen: pollen material was not found in this level of the profile. Accordingly, the first local pollen zone developed between 2.2 and 1.8 m. The results of the pollen analysis per local pollen zones are as follows.

Decs-Ete pollen zone 1 (2.2–1.8 m)

The dominant part of the pollen material, essentially reflecting the former local and extralocal vegetation composition, was pine pollen *(Fig. 15)*. The dominance value of *Pinus*, primarily *Pinus sylvestris* (Scots pine), reached and exceeded 55%, being as high as 70% in some samples. As a result, *Pinus sylvestris* was clearly a dominant forest component in this pollen horizon. On the basis of our pollen database for Hungary, this pollen composition in Transdanubia had developed between 15,000 and 9000 cal BP. This Scots pine-dominated local pollen zone corresponds to the end of the Pleistocene, the transitional level between the Pleistocene and the Holocene, and the beginning of the Holocene.

Besides Scots pine pollen, birch (*Betula*), alder (*Alnus*), and willow (*Salix*) appeared among the arboreal taxa with lower values. Aside from arboreal species, aquatic plants

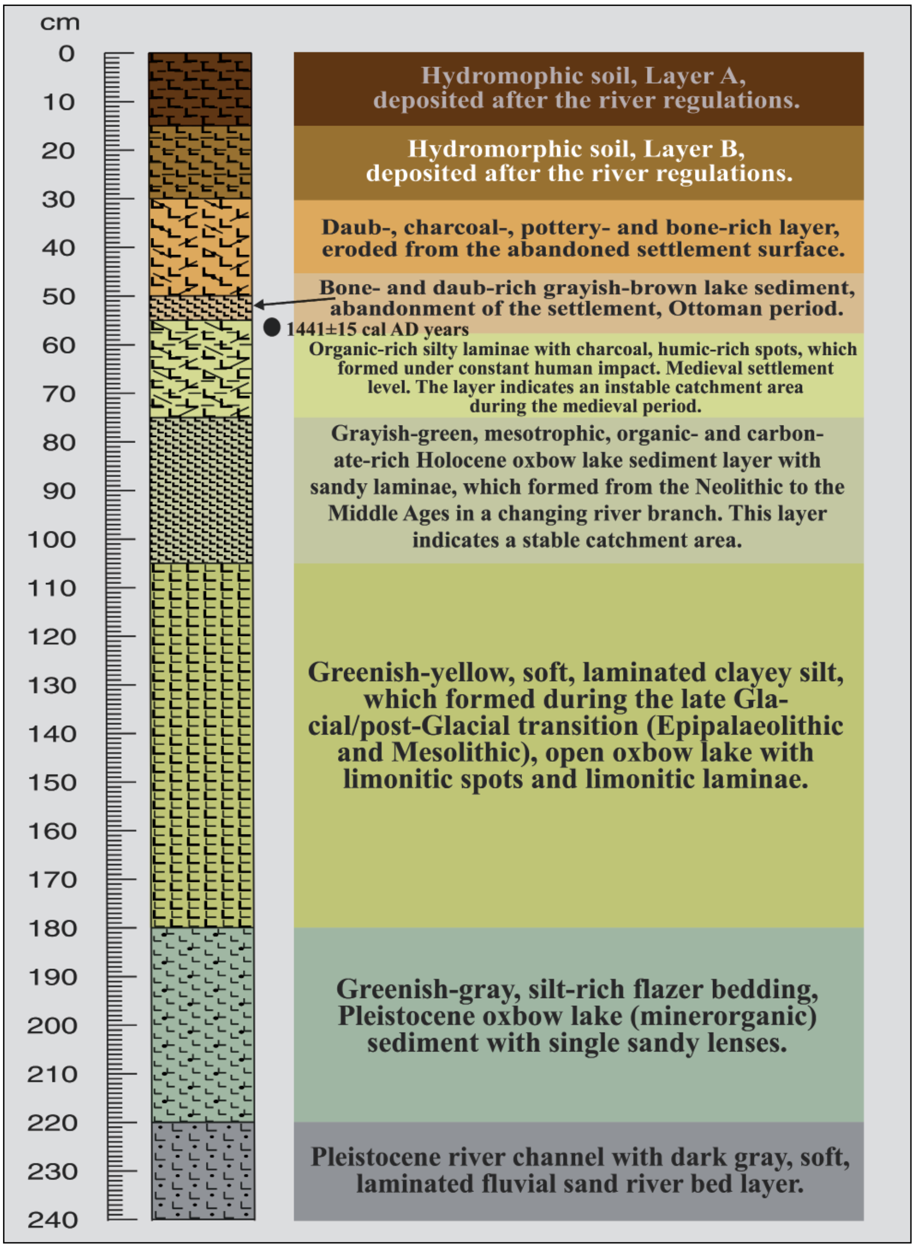

Figure 11. Lithological description of the undisturbed core sequence for pollen and palaeobotanical analyses from Decs-Ete

were represented in a significant proportion, and the values of grasses (Gramineae), sedges (Cyperaceae), mugwort (*Artemisia*), and goosefoot (Chenopodiaceae) were prominent as well *(Fig. 20)*. On the basis of this pollen composition, a birch-pine-dominated taiga forest interrupted by patches of *Artemisia* and grasses can be reconstructed. From an archaeological perspective, this level of the profile corresponds to the Epipalaeolithic and the beginning of the Mesolithic. Bulrush (*Typha*) and reed (*Phragmites*) pollen remains appeared in the upper part of this level, indicating a milder climate and the beginning of the climatic conditions of the Holocene.

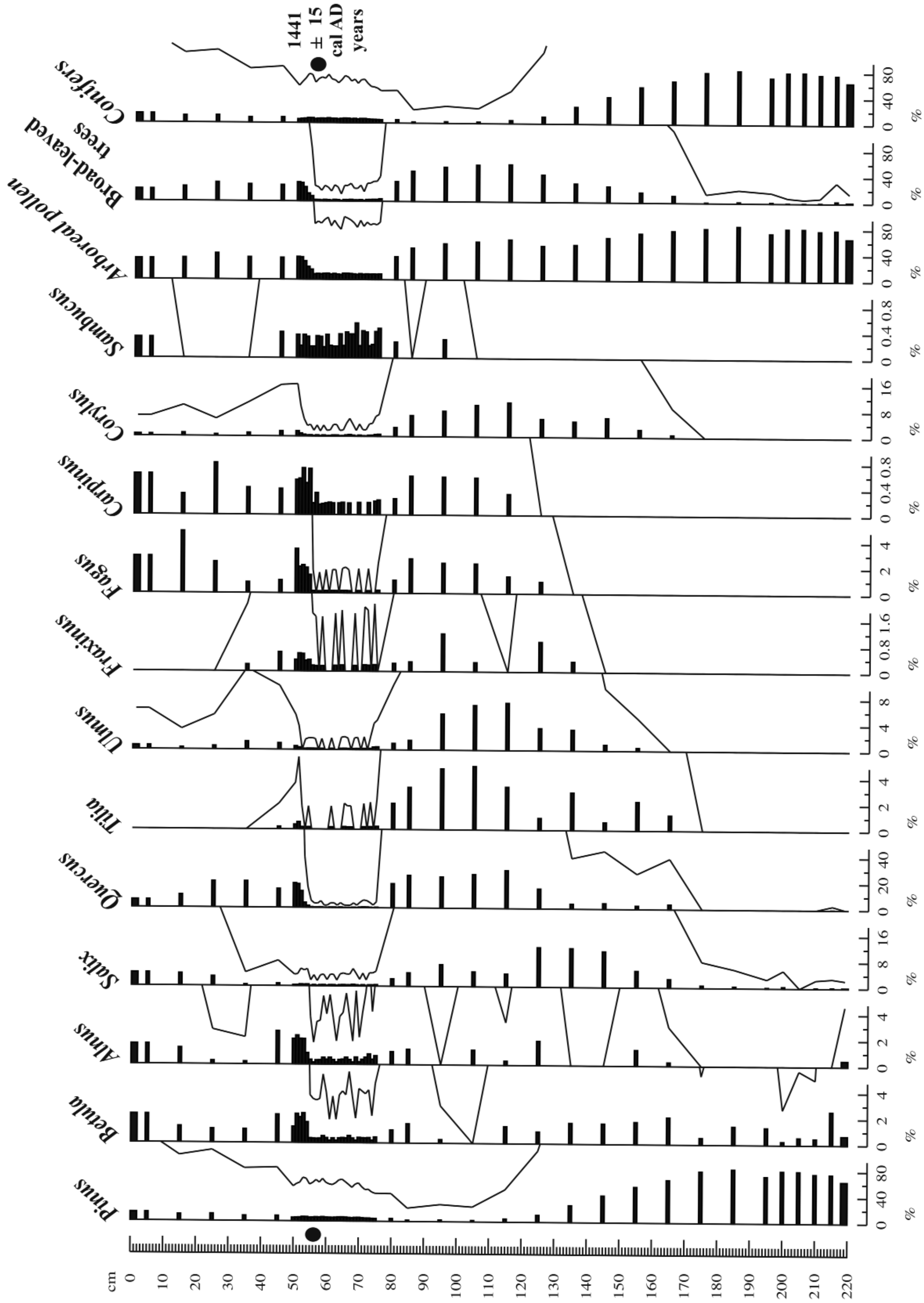

Figure 12. Pollen profile of the undisturbed core sequence from Decs-Ete (arboreal pollen)

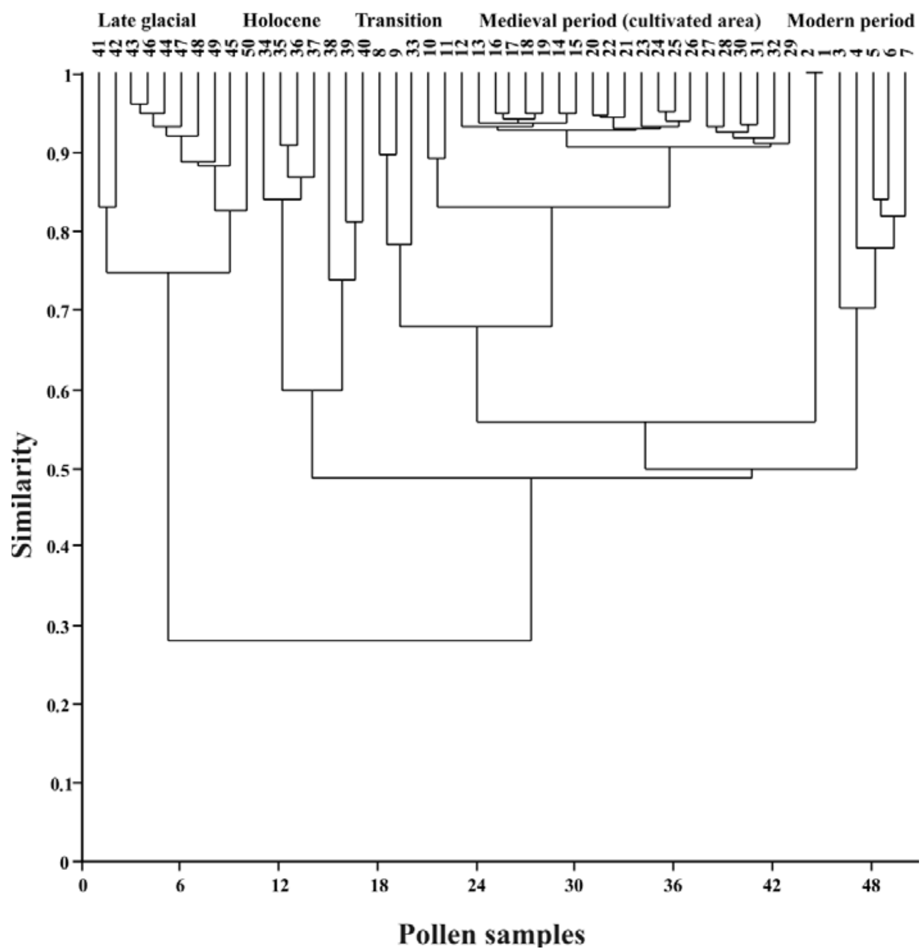

Figure 13. Cluster analysis of the pollen assemblages showing vegetation development phases and local pollen zones from the undisturbed core sequence at Decs-Ete

In order to understand the spatial development of the natural vegetation and the climate conditions during the Pleistocene and the Holocene, we need to have an understanding of the vegetation development of the study area, which in turn depends on geomorphological and groundwater conditions, the so-called hydroseries of the study site *(Fig. 16)*. In addition, we must be familiar with recent climatic conditions as well as with the differences and their scale compared to the studied chronological horizons.

The following zonation can be observed in the floodplain along rivers *(Fig. 16)*: willow shrubs (*Salicetum triandrae, S. purpureae*) thrived along the Danube River and the abandoned channels in the lowest and permanently flooded areas. At present, willow-poplar gallery forests (softwood gallery forest; Salicetum albae-fragilis), oak-ash-elm gallery forests (hardwood gallery forest; Querco-Ulmetum hungaricum) with poplar trees (Querco-Ulmetum populetosum) dominate the slightly higher relief and areas that are flooded during shorter periods of time, while the highest areas are occupied by patches of Lily-of-the-valley-oak forests (Convallario-Quercetum danubiale). In lowland areas, ploughland and planted poplar forests have replaced the natural vegetation.

The average value of climate-weather conditions (temperature, sunshine duration, and precipitation) is usually higher in the region's southern part than in its northern part. The mean annual temperature in the southern part is 10.8°C that exceeds the country-wide average.

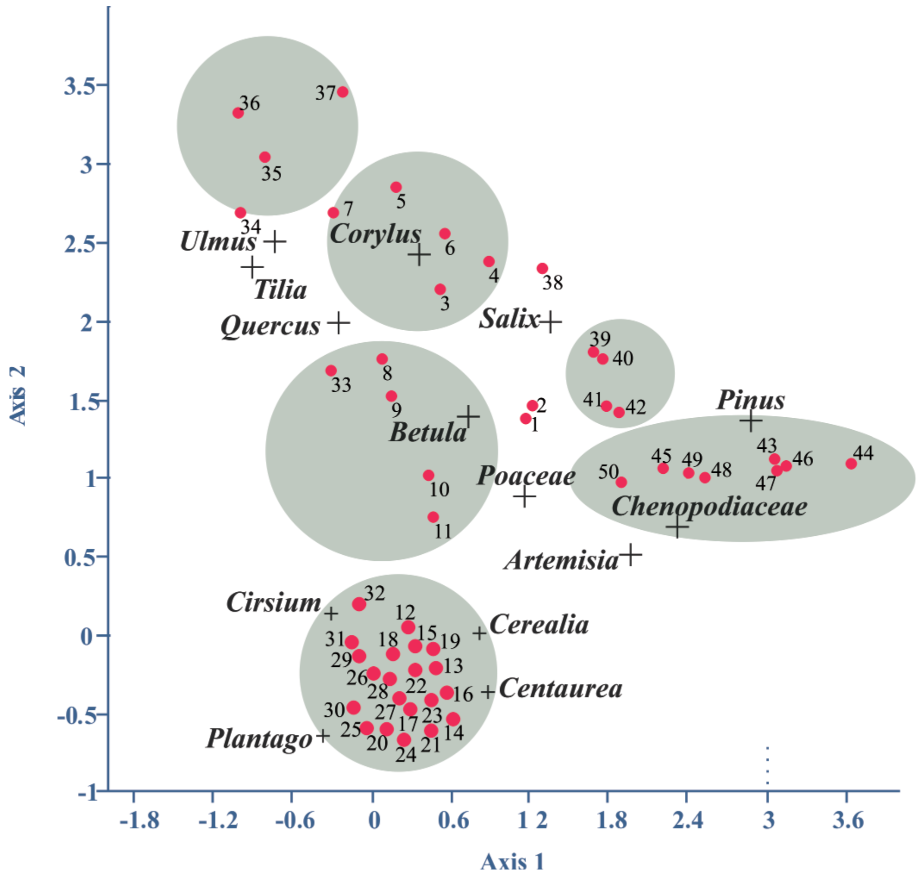

Figure 14. PCA of pollen assemblages showing vegetation development phases and local pollen zones from the undisturbed core sequence at Decs-Ete

However, the mean annual temperature range reveals more about the climate of an area than the mean annual temperature, which is calculated by the difference between the hottest and coldest month's mean temperature. In the Tolna Sárköz region (or, to be more precise, at the climate station in Bátaszék), this value is 22–23°C, which is lower than that of the Great Hungarian Plain, which exceeds 24.5°C. This indicates that the continental climate effect declines compared to the Great Hungarian Plain. Sunshine duration exceeds 2100 hours per year, making it one of the regions with the highest sunshine duration in Hungary. Mean annual precipitation is slightly higher than 650 mm. The main wind direction is northwesterly and southerly.

Figure 17 shows the Walter-Lieth climate diagram of the Tolna Sárköz region (the climate station in Bátaszék). The left vertical axis indicates the temperature values in °C, while the right axis indicates the precipitation values in mm. The horizontal axis shows the twelve months with numbers. The figure reveals that the precipitation curve is above the temperature line all year long and the monthly precipitation is less than 100 mm in every month.

According to the Walter-Lieth diagram, this indicates a humid climate; the area between the two curves is marked by vertical hatching *(Fig. 17)*. The red dashed curve is the precipitation value reduced by its one-third value. Drought periods are marked in the diagram where the red curve runs under the temperature curve. In the Tolna Sárköz region, this lasts from the end of July until the end of August.

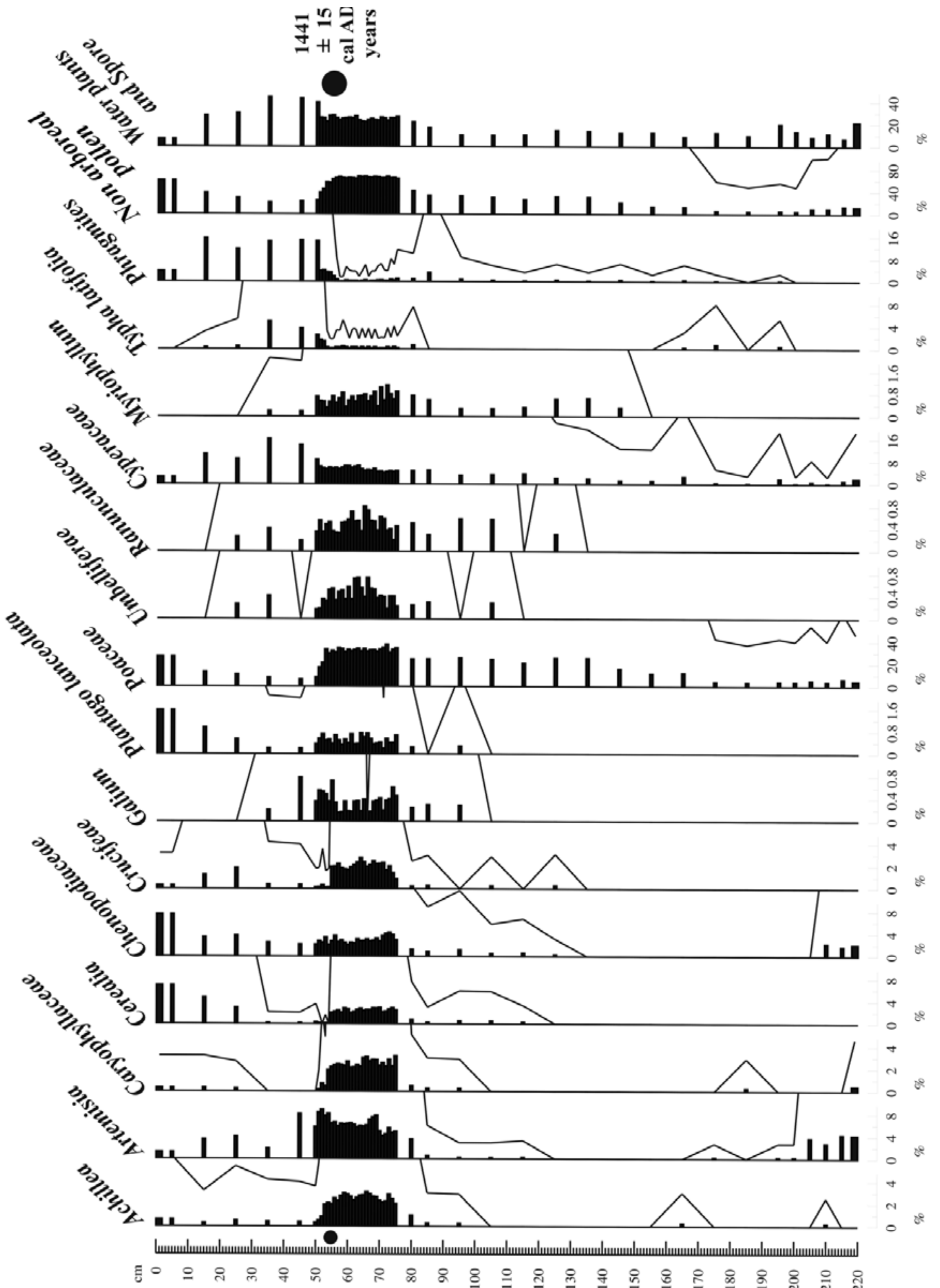

Figure 15. Pollen profile of the undisturbed core sequence at Decs-Ete (non-arboreal pollen)

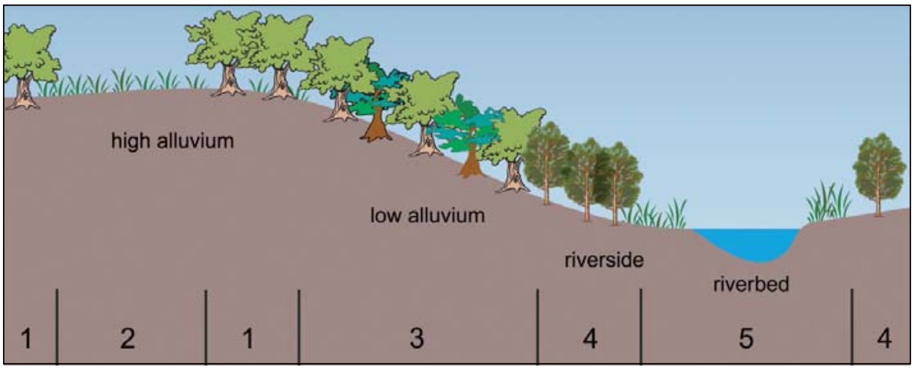

Figure 16. Plant communities according to geomorphological and hydrological conditions (hydroseries) in the study area between the high bluff and the riverside
1: *Caricetum eleata*, 2: Convallario- Quercetum, 3: *Quercus-Fraxinus-Ulmus* hardwood gallery forest with *Populus* trees, 4: *Salix-Populus* softwood gallery forest, 5: *Salicion triandrae*, 6: water-covered riverbed

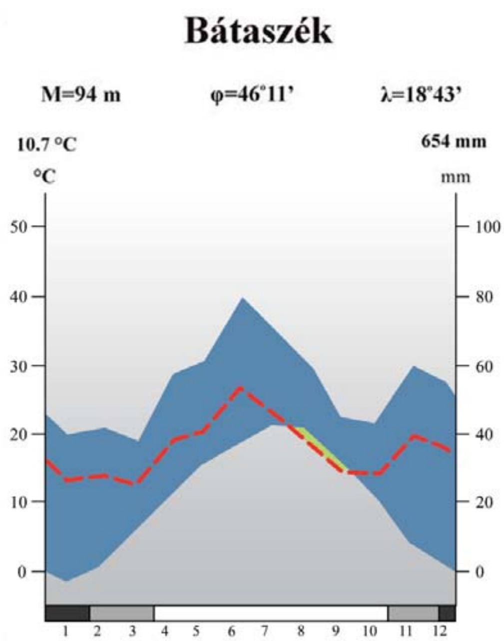

Figure 17. Walter-Lieth climatic diagram of Bátaszék

In the horizontal axis, dark colors indicate chilly months that last from roughly mid-December until mid-January in the Decs area. During this period, the mean temperature is less than 0˚C. In winter, according to many years of average, the soil is covered by snow for 33–35 days; its maximum thickness is 23–25 cm. The frost period is indicated by the hatched area in the figure and it lasts from mid-February to early April or from late October to mid-December. During the growing season, the temperature does not fall below the freezing point, and the mean temperature is 17.0–17.3˚C between April 1 and September 30.

Accordingly, the climate and vegetation is significantly different from the current one *(Fig. 16)* from the end of the Pleistocene to the onset of the Holocene, corresponding to the archaeological horizons of the Epipalaeolithic and Mesolithic. *Pinus sylvestris* dominated the gallery forests of the Tolna Sárköz region, and the pine forest was mixed with birch, willow, and alder trees in the deepest points of the floodplain *(Fig. 18)*. The gallery forest opened up towards the higher-lying areas of the floodplain and was interspersed with wetter, drier cold steppe patches, resembling a forested steppe to some extent. On the waterfront, cold-tolerant *herba fruticiformis* plant communities and tussock sedge developed.

Decs-Ete pollen zone 2 (1.8–1.6 m) and Decs–Ete pollen zone 3 (1.6–1.2 m)

At the beginning of the Holocene, the hydroseries that dominated at the close of the Pleistocene was quickly transformed (pollen zone 2, transitional horizon between pine and deciduous forests). Based on the pollen record, deciduous trees and shrubs, especially

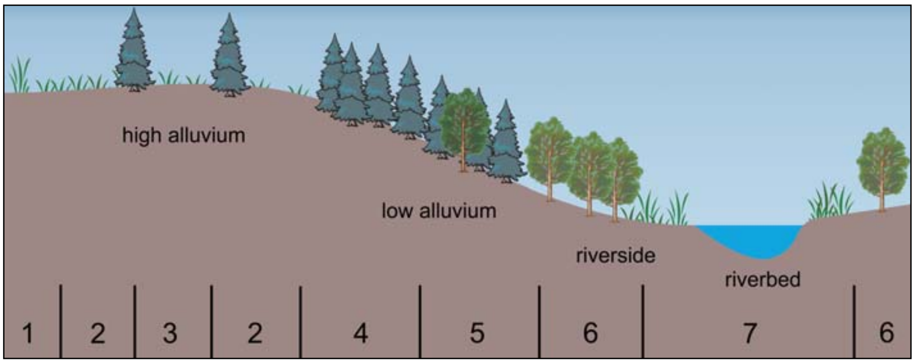

Figure 18. Plant communities according to geomorphological and hydrological conditions (hydroseries) in the study area between the high bluff and the riverside during the Pleistocene (Pleistocene hydroseries)
1: Cold steppe with tundra taxon, 2: cold steppe with conifers, 3: conifer-dominated Boreal forest-steppe, 4: *Pinus sylvestris*-dominated gallery forest, 5: *Pinus-Betula* gallery forest, 6: *Betula-Alnus-Salix* gallery forest, 7: water-covered riverbed with sedge, tall sedge, and tundra elements in the riverside zone

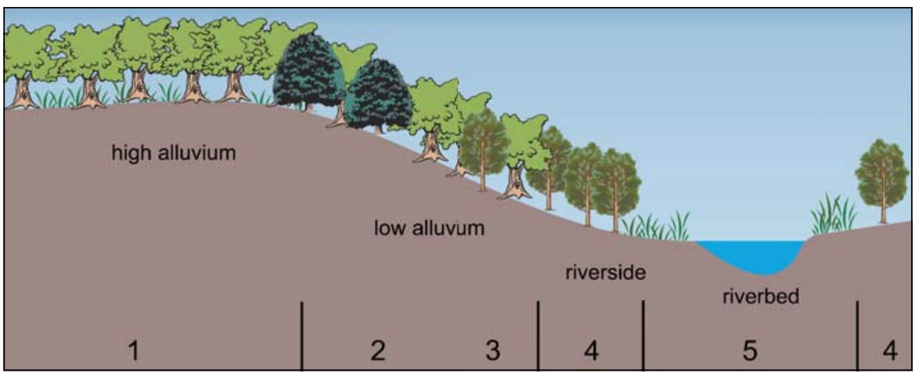

Figure 19. Plant communities according to geomorphological and hydrological conditions (hydroseries) in the study area between the high bluff and the riverside during the Early Holocene (Early Holocene hydroseries)
1: closed Convallario-Quercetum, 2: *Tilia-Ulmus-Quercus-Fraxinus-Corylus* hardwood gallery forest, 3: hardwood and softwood mixed gallery forest, 4: *Salix-Populus*-dominated softwood gallery forest, 5: Typhetum, Phragmitetum, and Caricetum vegetation zones in the riverside

oak- (*Quercus*), elm- (*Ulmus*), ash- (*Fraxinus*), lime- (*Tilia*), and hazelnut- (*Corylus*) dominated gallery forests evolved in the lower-lying floodplain areas *(Fig. 19)*. In the higher floodplain areas, oak-dominated closed forests (with Lily-of-the-valley) emerged.

On the waterfront, the number of cold-tolerant elements declined; an alder-, willow-, and poplar- (*Populus*) dominated softwood gallery forest developed, and reed, sedge, and bulrush zones expanded along the direct riversides, oxbow lakes, and living channels. This closed deciduous forest vegetation dominated the Danube alluvial plain during the early Holocene in the second part of the Mesolithic and at the beginning of the Neolithic.

Decs-Ete pollen zone 4 (1.2–0.8 m, late Holocene)
The vegetation changed at the end of the Neolithic and during the Copper Age, as indicated by the appearance of beech (*Fagus*) and hornbeam (*Carpinus*). Aside from the appearance of beech and hornbeam, significant human impacts occurred during this milder climatic period. Oak forests in the higher floodplain areas were cleared over large areas during the archaeological horizon of the Lengyel culture (Late Neolithic). Pasturelands, meadows, cultivated fields and settlement areas were established in the cleared areas in the second half of the Neolithic and at the beginning of the Copper Age. This pollen zone spans the Bronze Age and the Iron Age, and probably the Roman Age as well.

Decs-Ete pollen zone 5 (0.8–0.5 m, medieval period)
In the more recent period of the Holocene that spans the entire medieval period as well, the vegetation changed significantly. This is supported by radiocarbon dates measured on organic material from between 55 and 56 cm in the profile, which corresponds to 1426–1466 cal AD years according to the Calib700 (IntCal 13) program.[15]

The vegetation change can be quite clearly attributed to human impact since the amount of cereals (Cerealia), especially the ratio of wheat pollen, rose sharply in this horizon. In addition, weed pollen that indicate cultivated fields, settlements, roads, and meadows, such as thistle (*Cirsium*), mugwort, goosefoot, plantain (*Plantago*), centaury (*Centaurea*), milfoil (*Achillea*), and bedstraw (*Galium*) dominated, which is a clear indication of the presence of settlements and cultivated land in the study area.

Compared to the prehistoric vegetation changes, the vegetation transformation was almost all-embracing in the medieval period. Forests were totally cleared around the riverbed, and the lack of aquatic and waterside spores and pollen indicates that the waterfront vegetation (reed, bulrush) was trampled and burnt, and as a result, sedge vegetation spread on the waterside *(Fig. 20).* The vegetation transformation probably extended to the entire broader area of Ete and probably to the outskirts of both Őcsény and Decs during this period. It seems likely that the original forest vegetation was restricted to the higher elevations of the Tolna

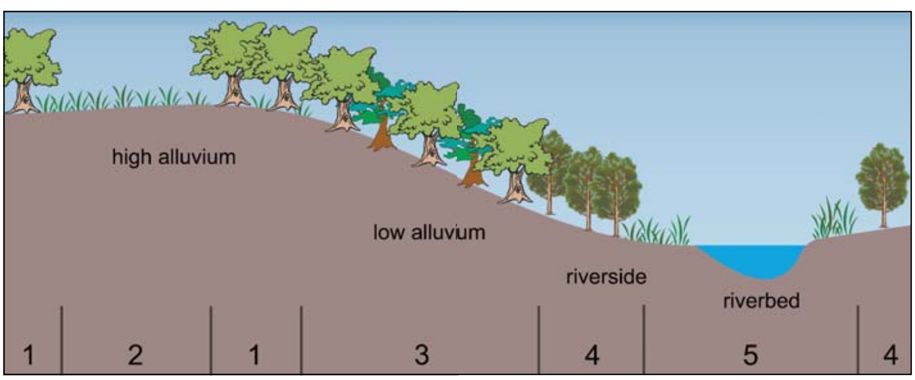

Figure 20. Plant communities according to geomorphological and hydrological conditions (hydroseries) in the study area between the high bluff and the riverside during the Middle Holocene (Middle Holocene hydroseries)
1: closed Convallario-Quercetum, 2: cut-off area of oak forests, 3: hardwood and softwood gallery forest with *Carpinus* and *Fagus*, 4: *Salix-Populus*-dominated softwood gallery forest, 5: Typhetum, Phragmitetum, and Caricetum vegetation zones in the riverside

15 Reimer et al. 2013.

Hills and the lower-lying floodplain areas of the Danube alluvium, where it expanded to a few square kilometers around the riverbed. The data suggest that the ploughland gradually extended to the entire area of the island-like higher floodplain during the medieval period.

The significant proportion of crucifer (Cruciferae) pollen is remarkable because its ratio is so high that the presence of vegetable gardens can be inferred. The increase of parrot's-feather (*Myriophyllum aquaticum*) pollen reflects a change in the aquatic environment as the riverbed eutrophicated and became covered by vegetation. The higher amount of toxic buttercup (Ranunculaceae) indicates trampling in the waterside area (perhaps a reflection of the watering of animals) and the presence of pasture meadows. As a result, the medieval environment was characterized by settlements, trampled areas, watering places, cultivated fields, pastures, and meadows.

Decs-Ete pollen zone 6a and 6b (0.5–0.3 m, Ottoman period–Early Modern Age)

The ratio of weeds, shrubs, and arboreal species indicating abandoned cultivated fields began to increase gradually in and above the few centimeters thick, grayish-brown lacustrine layer that contained burnt daub, ceramic fragments, and charcoal. Human impact decreased drastically in this level of the profile. The number of cereal pollen dropped and on the testimony of the pollen composition, the area of cultivated fields declined, abandoned lands ran wild, and reforestation began.

Presumably, this pollen composition reflects the abandonment of settlements and the collapse of the agrarian ecosystem during the Ottoman period. Since the environmental change was not induced by climate change, we may assume that the population farming the lands decreased.

Decs-Ete pollen zone 7 (0.3 towards the surface, Modern Age, eighteenth–twentieth centuries)

In the latest level of the profile, pollen indicating cultivated fields, meadows, and pastures reappeared alongside the growing proportion of weeds, reflecting the increasing scale of agricultural production after the Ottoman period. However, the village was not resettled; the pollen composition typical of medieval settlements developed due to the expansion of cereal cultivation and animal husbandry from the eighteenth century onward.

ENVIRONMENTAL HISTORY RESEARCH IN THE DRAVA VALLEY

Introduction

Besides the Sárköz region, the Drava Valley was the other study area of the research project. The Drava River rises in Italy between Dobbiaco (Toblach) and San Candido (Innichen) at 1228 m above sea level and enters the Danube River in Croatia at Aljmas at 83 m above sea level. During its 695 km long course, the Drava River passes through five countries (Italy, Austria, Slovenia, Croatia, and Hungary). The catchment area of the river is 40,000 km^2, and its average discharge is around 600 m^3/s. Its largest tributary is the Mura River. The Drava River reaches Hungary at river kilometer 237 (Drava-Mura estuary) and leaves Hungary towards Croatia at river kilometer 70.2.

The study sites (Barcs, Ottoman palisaded fort, and Berzence, Lankóci-erdő) are located in a midreach river valley, in the Middle Drava Valley microregion that extends over 300 km^2 and has a length of 60–70 km. Similarly to other river valleys, the extent of floodplains

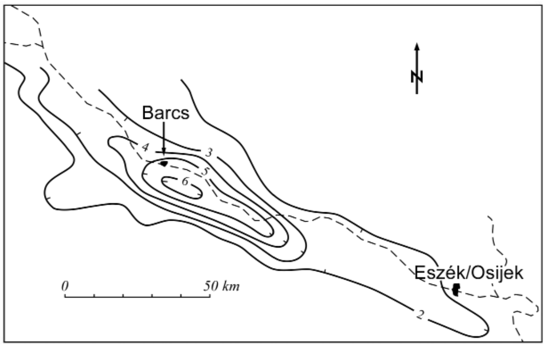

Figure 21. The depth of the Tertiary basin in the Drava trench. Isolines (2, 3, 4, 5, 6) indicate the depth of every thousand meters

on the alluvial plain of the Drava River and its landforms are strongly correlated with the genetics of the valley. In the Carpathian Basin the Drava River started to evolve during the Middle Miocene, i.e., approximately 16 million years ago. During the Middle Miocene, the channel section north of Barcs, while during the Upper Miocene, the channel section south of Barcs began to subside *(Fig. 21)*. As a result of the million years' long subsidence, a northwest to southeast oriented extremely deep, so-called structural trench was formed. The direction of this trench is identical to the main flow direction of the Drava River, and it is likely that it basically determined the evolution and course changes of the Drava River from the time of its formation. The ancient crystalline rocks of the base of the Carpathian Basin lie 2000–5000 m deep in this trench. The deepest partial basin, lying 5000 m deep, evolved in the area of Barcs *(Fig. 21)*. On the testimony of the geological data, the most intensive subsidence occurred during the final stage of the Miocene, during the Pannonian and Pliocene periods, approximately 7–3 million years ago. The Drava River appeared in this trench after the last marine transgression of the Carpathian Basin. During the last 2.6 million years, i.e., during the Quaternary, the southeast runoff direction of the Drava River has not changed. New structural, so-called neotectonic movements, basin subsidences occurred in the longitudinal section of Hungary during the Holocene, during the last 12,000 years *(Fig. 22)*.

The largest basin developed in the southern foreland of the Ormánság, while another neotectonic partial basin was formed to its east, extending to the mouth of Danube River towards Eszék (Osijek, Croatia), at a distance of 50–60 km from the partial basin at Ormánság *(Fig. 23)*.

Both the Drava major structural trench and the neotectonic basins (Ormánság, Eszék) are linked to the tectonic fault of the Drava Valley, the Drava lineament. Geophysical investigations indicated that the tectonic line and the associated strong seismicity were related to the convergence of the Adriatic microplate and the Southern Alps as well as to the pressure of the ALCAPA (Alps-Carpathians-Pannonian) unit.

Although the impact of neotectonic movements on archaeological periods may seem insignificant in general, in the Drava Valley it determined riverbed shifts and conversions, the detachment of meanders and their filling up as well as the development of the high bluffs to such an extent that it essentially determined settlement patterns and the system of navigable waterways in the medieval period. Geological and geophysical studies have shown that the Quaternary uplift in the border of the Pelso unit formed typical morphological and genetic differences at the northern edge of the Drava Valley. Here, the river alluvium and terrace sediments are contacted by tens of kilometers long slightly curved scarps with the older Pleistocene aeolian sediments and the Pannonian formations. This scarp played a decisive role in the study areas at Berzence and Barcs.

Thus, we can assume that the right-hand strike-slip faults with vertical components along the Drava River appear as listric faults that separate the subsiding and uplifting areas from each other. Due to this fault, the riverbed of the Drava River could shift even without a climate change or silting following deforestation. The neotectonic movements and the ensuing rapid riverbed displacements could cause major difficulties for the communities

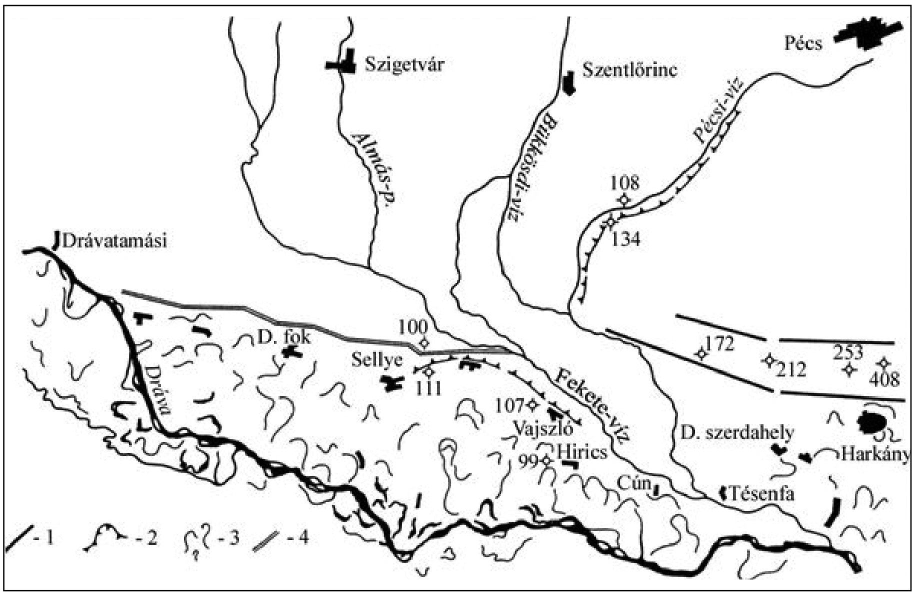

Figure 22. Quaternary neotectonic sub-basin in the foreground of the Ormánság region
1: tectonic line, 2: high bluff, 3: oxbow lakes, 4: hydroregulation canals

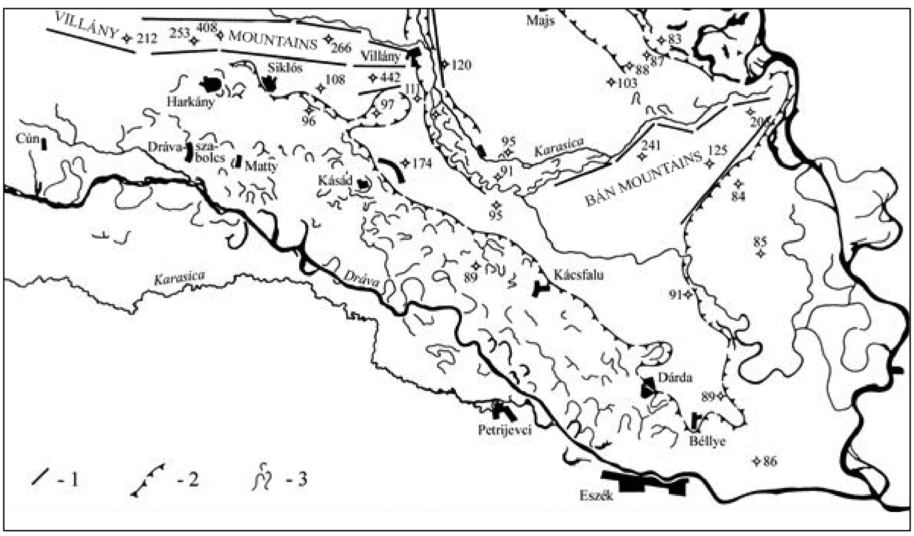

Figure 23. Holocene neotectonic sub-basin between the settlements of Drávatamási and Eszék/Osijek
1: tectonic line, 2: high bluff, 3: oxbow lakes

that had settled along the river if the active riverbed used as a commercial and military waterway shifted, if the riverbed was abandoned or became silted, and if the high bluffs, ideal areas for settlements, were eroded *(Fig. 24).* During the reconstruction and evaluation of the hydrological and vegetation changes of the Drava Valley, we had to take into account these cyclic neotectonic processes as well.

As part of the floodplain system, the high floodplain, lies farthest from the main riverbed, and the highest area is sometimes only 1–2 m higher than the low floodplain. Its surface was rarely flooded prior to the river regulations, while the lower-lying floodplain was inundated by almost every flood. The higher-lying floodplain was presumably formed at the

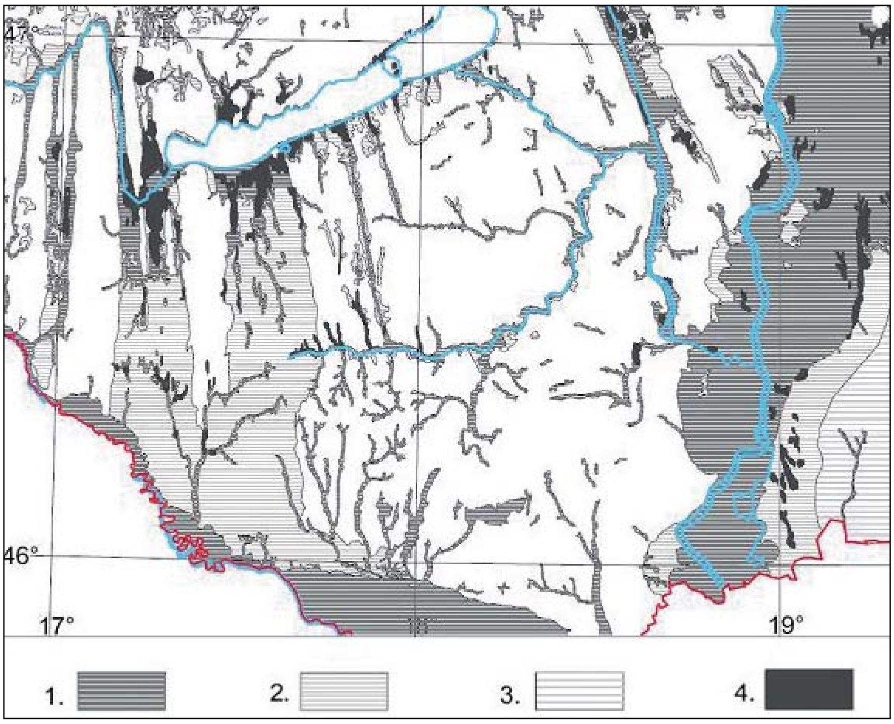

Figure 24. Neotectonic indicator sediments in Transdanubia
(after Síkhegyi 2008)
1: Holocene sediment accumulations, 2: Pleistocene terrace sediments,
3: older Pleistocene terraces, 4: Holocene lake, peat, and marsh sediments

beginning of the Holocene, although, on the basis of the geological mapping, it is assumed that the formation of the higher-lying floodplain areas began already at the end of the Pleistocene. The lower-lying floodplain area continues to develop. Natural abandoned oxbow lakes (meanders) and backwaters that were formed in the first half of the Holocene can be found on the higher-lying floodplain. However, these are extremely indistinct in the field and usually are only a few decimeter deep undrained hollows.

Approaching the main riverbed, the lower floodplain often has a sharp relief edge, where meanders and oxbow lakes that formed during the last 6–8000 years are present. These are more developed hollows, as their depth reaches 2 m in many cases. Very often, water-preferring vegetation appears in these depressions. Occasionally, we also found that the closer an area lies to the recent main riverbed, the more characteristic its landforms.

Environmental history analysis of the abandoned riverbed at the Ottoman palisaded fort in Barcs

The branch of the Drava River flowing by the Ottoman palisaded fort at Barcs was an active river channel, on which even a port was built according to the written sources. The river was navigable and suitable for mooring, flowing as it did beneath the high bluff at Barcs, as can be seen on the map of the First Military Ordnance Survey of Austria-Hungary from 1782 *(Fig. 25)*, on the map of the Second Military Ordnance Survey of Austria-Hungary from 1869 *(Fig. 26)*, and on the Hungarian Military Map from 1941 (*Fig. 27)*. At the same time, the maps also reveal that the riverbed was channeled and drained gradually. As a result, the upper part of the profile corresponding to the seventeenth and nineteenth centuries was not suitable for pollen analysis. In 1782, the ordnance survey recorded the unregulated, but filled-up condition of the riverbed, consequently living water probably only entered it in time of floods from the end of the sixteenth century. The riverbed appears on the map of the Second Military Ordnance Survey (1869), as does the line of the first drainage channel that was dug in the nineteenth century along the centerline of the sixteenth-century active riverbed. Moreover, it can be clearly seen that a major meander on the eastern outskirts of Barcs, marked as active riverbed on the map, was cut off during river regulations. Thus, the riverbeds that were still active in the sixteenth and seventeenth centuries became part of the drained floodplain as a result of natural and anthropogenic processes.

Figure 25. The town of Barcs and the floodplain of the Drava River on the map of the First Military Ordnance Survey of Austria-Hungary from 1782 (after Jankó et al. 2005)

At the same time, it also became clear that the eastern branch was not active in the sixteenth century. Therefore, our investigations focused on the western, filled-up riverbed beneath the high bluff. In addition, the military map from 1941 shows that a railway line and railway station was built in the Barcstelep industrial area (sawmill and timber processing), and a major part of the area was filled up in the process. It must also be noted that the railway embankment of Barcs–Nagyatád ran along the river shore.

During the construction of the railway and the factory, the area was fundamentally transformed; however, the western and the northern part of the riverbed beneath the high bluff, which was active in the sixteenth century, and the former Ottoman fort remained untouched *(Figs 27–28)*. Finally, the upper part of the finer-grained sediment that accumulated in the riverbed during the past 300 years dried out as a result of drainage. Other parts of the riverbed were drained and filled up, and intensive construction activity (building of sports

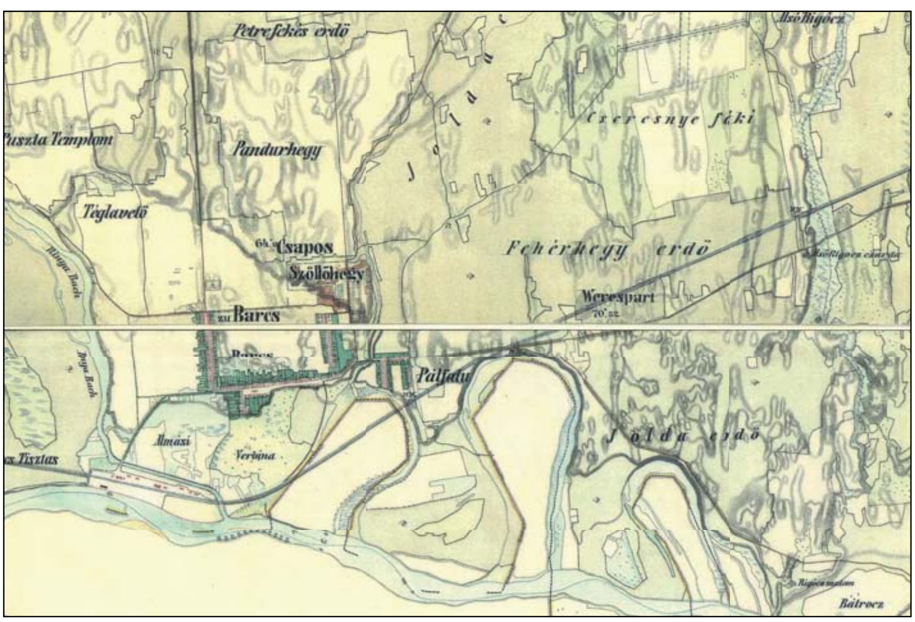

Figure 26. The town of Barcs and the floodplain of the Drava River on the map of the Second Military Ordnance Survey of Austria-Hungary from 1869 (after Timár et al. 2011)

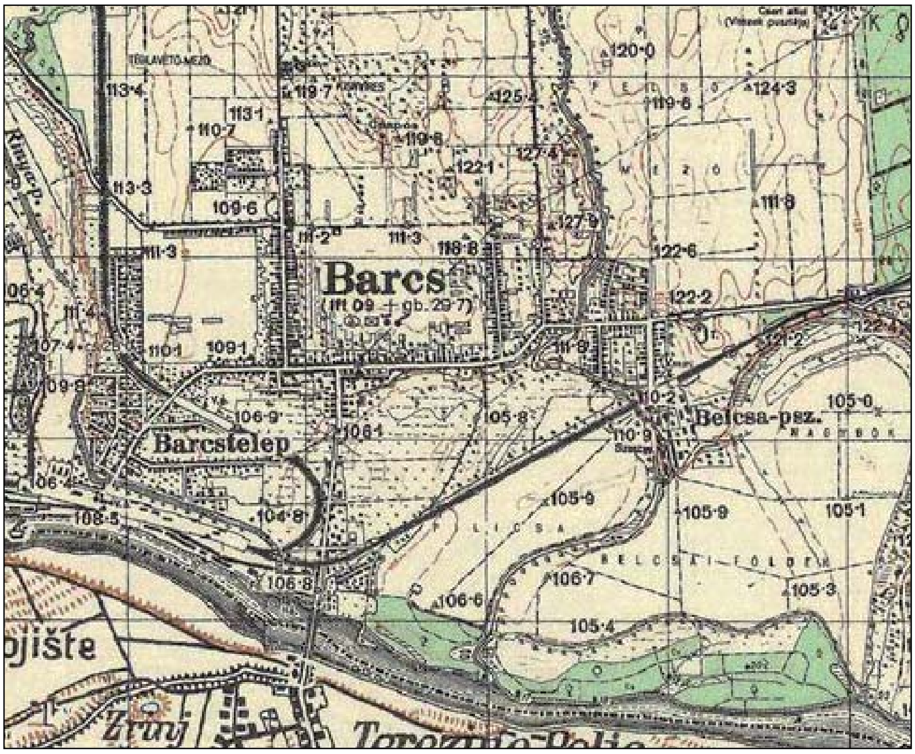

Figure 27. The town of Barcs and the floodplain of the Drava River on the Hungarian military map from 1941 (after Tímár et al. 2008b)

Figure 28. The town of Barcs and the floodplain of the Drava River with the coring location on a Google Earth image, August 2007

fields and dirt tracks, asphalting of roads, erection of concrete and stone fences, tree planting, and park design) made the investigation of the former riverbed impossible. The only meander suitable for analysis can be found in the school vegetable garden at the demolished wall of

Figure 29. The town of Barcs on the eroded high bluff and the floodplain of the Drava River with the coring locations (red circles) in the filled-up riverbed by the fortress on a 3D Google Earth image

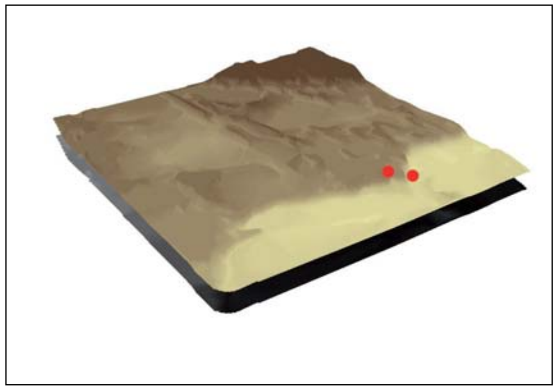

Figure 30. The town of Barcs on the eroded high bluff and the floodplain of the Drava River with the coring locations (red circles) in the filled-up riverbed by the fortress on a 3D model

the former fort *(Fig. 28)*. This is also confirmed by the 3D models *(Figs 29–30)*, as a double meander is located at the foot of the former fortress, whose curve correlates well with the direction of the riverbed that had been filling up according to the eighteenth-century map. In the 3D models, we can clearly make out the loess and wind-blown sand-covered high bluff at Barcs that developed as a result of erosion at the edge of the Drava alluvium. The coring locations *(Fig. 30)* in the moat and at the foot of the fortress on the high bluff are shown on the digital elevation model.

The location of the Barcs fort on the high bluff and the sampling location in the Drava riverbed at the foot of the fortress (or the high bluff) can be clearly seen on the map prepared by the geometric combination of the Second Military Ordnance Survey and Google Earth images *(Fig. 31)*. The distance between the moat and the sampling location is approximately 65 m, with a difference of about 5 m between the levels of the two.

A very simple filling up sequence was noted in the profile of the core *(Fig. 32, Table 4)*. In the bedrock level, a dark gray, slightly cross-bedded riverine sand was identified between 280 and 160 cm, which can be linked to an active riverbed. On the testimony of the organic material content, the riverine sand accumulated before 1556±45 years until the sixteenth century between 155 and 160 cm *(Table 5)*.

At a depth of 160–155 cm (at the beginning of the seventeenth century, in 1601 at the latest), a significant change occurred in the profile. The amount of fluvial sand decreased considerably and could be found only in intercalated lenses and bands. An organic material-rich, brownish-gray, flaser bedded (sand lenses and bands) clayey silt sediment was deposited. This is a typical sediment in oxbow lake environments that periodically received sandy sediments through floodwater during the most significant floods.

The radiocarbon dates indicate that sediment accumulation was remarkably rapid. The sedimentation rate was 4 mm/year between 160 and 80 cm, it accumulated during 200 years, between the seventeenth and eighteenth centuries. A comparable sediment accumulation rate can be principally noted in boggy lakes and floating mats; the sedimentological data would suggest that the paludification of the oxbow lake that was detached in the seventeenth century was very rapid. The paludification of oxbow lakes and the appearance of floating mats is a very fast process. Over 40–50% of the surface of a much more extensive Tisza riverbed today known as Malom-tó [Malom Lake] at Tiszadob that was artificially detached

Figure 31. The town of Barcs on the eroded high bluff, the floodplain of the Drava River, and the location of the filled-up riverbeds by the fort on the combined georeferenced map of the Second Military Ordnance Survey of Austria-Hungary from 1869 and a Google Earth image, with the location of the coring site (white circle)

Table 4. Lithological description of the core sequence from the one-time Drava riverbed by the palisaded fort at Barcs, a channel that was active during the Ottoman period

GPS coordinate	*Depth (cm)*	*Troels-Smith category*	*Lihtostratigraphy*
45° 57′ 27.52 N 17° 27′ 56.91 E	0–15	Sh2As2	Blackish-brown hydromorph soil, level A.
	15–30	Sh1As3	Dark brown hydromorph soil, level B.
	30–120	As4	Yellowish-brown dry clayey silt.
	120–160	Ga1As3	Oxbow lake sediment, free of human impact, accumulated after the abandonment of the village during the Ottoman period.
	160–280	Ga4	Dark gray, slightly laminated sandy silt, former river deposit.

Table 5. Radiocarbon data (2 σ: 74.5 %) of the undisturbed core sequence from the filled-up Drava riverbed by the palisade fort at Barcs

Depth (cm)	*Uncal BP years*	*Cal BP years*	*Cal AD years*	*Code*
155–156	325±15	394±45	1556±45	D-AMS 005118

in 1847 was covered by a floating mat by the mid-twentieth century, a body of water that is six times larger than the studied Drava riverbed.

In the light of the above, it can be assumed that after becoming detached from the active riverbed in the seventeenth century, the Drava riverbed became paludified within 30–40 years. The detachment of the riverbed was not necessarily induced by climate change or anthropogenic impact (erosion and silting up as a result of deforestation) since the neotectonic processes and tectonic activity (the speed up of neotectonic subsidence) described in the above could generate the shift of the active riverbed and the paludification of the evolved oxbow lake rapidly.

Overlying the yellowish-brown organic material-rich sediment were two layers (A and B) of a hydromorph soil that developed after the river regulations in the nineteenth and twentieth centuries. The lithostratigraphy indicates a classic filling-up series from the riverine sandy layers of the bedrock through the finer-grained oxbow lake sediments to the hydromorph soil that evolved on the top of the series. The hydromorph polyhedral structured soil is small-grained due to cultivation and has a significant organic material content, which may be the result of anthropogenic soil transformation due to intensive fertilization and cultivation.

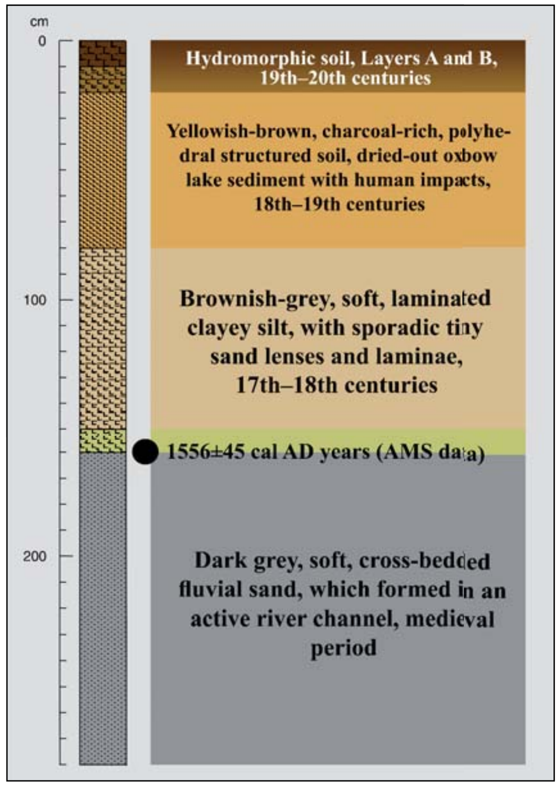

Figure 32. Lithological description of the undisturbed core sequence for palynological and palaeobotanical analyses in the infilled Drava riverbed by the palisaded fort at Barcs

The upper 160 cm of the profile at Barcs was used for palaeobotanical analysis: the same procedure was followed in the pollen analysis *(Fig. 33)* of 50 samples as at Decs-Ete. On the basis of the statistical analysis (cluster analysis and PCA), four pollen horizons were distinguished *(Figs 33–35)*. These pollen zones reflect local pollen levels and vegetation changes from extralocal to regional scales rather than the typical changes of classic pollen zones (developing as a result of climate change). On the basis of radiocarbon data, the pollen composition changes of the past 400 years could be reconstructed in 5 to 10 years/sample intervals starting from 1550–1570.

Barcs, filled-up riverbed by the palisaded fort, pollen zone 1 (160–148 cm)

The first pollen zone could be identified in the flaser bedding horizon between 160 and 148 cm, which still contained a relatively large quantity of riverine sand *(Table 6)*. The most significant pollen material was Scots pine (between 40–50%) that has air sacks. Despite the high dominance values of pine, it was not a local vegetation element in the Drava alluvium, either in the sixteenth century, or at the turn of the sixteenth and seventeenth centuries. An unusual pollen taphonomical situation caused this special pollen composition: an open oxbow lake that was connected to the active channel by flood waters functioned as a pollen trap *(Fig. 36)*. In the case of rivers flowing from the high mountain region, pine pollen with air sacks floated in the water towards the alluvium and accumulated in the oxbow lakes that were connected with living waters periodically, during floods, and had not become wholly isolated. The riverbed at Barcs may have been a similar oxbow lake in the late sixteenth century–early seventeenth century, explaining this special pollen accumulation and pollen composition that is mainly characteristic in the mountain and highland regions.

Table 6. Pollen zones and local vegetation changes as reflected by the core sequence from the former Drava riverbed by the palisade fort at Barcs

Depth (cm)	*Age*	*Pollen zones and local vegetation changes*
82–0	19th–20th centuries	Barcs pollen zone 4: Local gardens, strong human impact, regional cultivated fields and pasturelands. The number of aquatic and marshy plants decline; filled-up oxbow lake; agricultural cultivation began on the dried-out surface of the oxbow lake.
114–82	18th century	Barcs pollen zone 3: A weed-rich area evolved around the settlement and the destroyed Ottoman fort. *Sambucus* pollen dominance increased; the settlement was abandoned, but cereals and *Zea mays* pollen were present continuously. Marshland plants thrived in the oxbow lakeside zone.
148–114	17th century	Barcs pollen zone 2: Water plants: *Myriophyllum* and *Nuphar*, and marshland plants such as *Carex*, *Typha*, and *Phragmites*, Pteridophyta pollen and spore content increased. A floating mat evolved on the surface of the oxbow lake, the filling up intensified.
160–148	16th century 1556±45 cal AD years	Barcs pollen zone 1: Inwashed pollen content and special pollen taphonomy in an open oxbow lake system; strong regional effect in pollen content. *Pinus sylvestris*, gallery forest pollen grains, and local weed pollen dominated.

The first pollen zone was characterized by the prominent ratio of arboreal pollen reflecting gallery forests, which indicates the mixing of material originating from a larger alluvial area. Simultaneously, the ratio of prostrate knotweed (*Polygonum aviculare*) was significant as well, reflecting vigorous trampling, disturbance, and human settlements. The pollen ratio of arboreal species was cyclic in this level of the profile, which was related to the higher discharge and pollen accumulation during floods *(Fig. 33)*. The radiocarbon dates (155–160 cm: 1560±50 years) indicate that this pollen zone corresponds to the sixteenth century and to the turn of the sixteenth and seventeenth centuries.

Barcs, filled-up riverbed by the palisaded fort, pollen zone 2 (148–114 cm)

The second pollen zone could be identified in a fine bedded and organic material-rich marshy oxbow lake layer. Aquatic plants and spores dominated in this level of the profile, especially sedges, parrot's feather, fern *(Filicales)*, water lily *(Nuphar)* and reed. Since these plants occur in a greater volume in eutrophicated boggy lakes and in floating mats, we presume that the oxbow lake gradually eutrophicated and its paludification began after becoming detached from the living river system. As paludification started in the seventeenth century, after the 1610s, the former riverbed could no longer be used for shipping as a result of the fast filling up in the seventeenth century.

This zone saw the appearance of maize (*Zea*) pollen, which is consistent with the evidence from other Hungarian profiles too, according to which maize appeared in the later seventeenth century in the Carpathian Basin. The presence of maize (initially called Turkish wheat) is first documented in the seventeenth-century levels of Romanian, Bulgarian, and Serbian pollen profiles as well, and its increasing and continuous pollen ratio was observed from the eighteenth century onward.

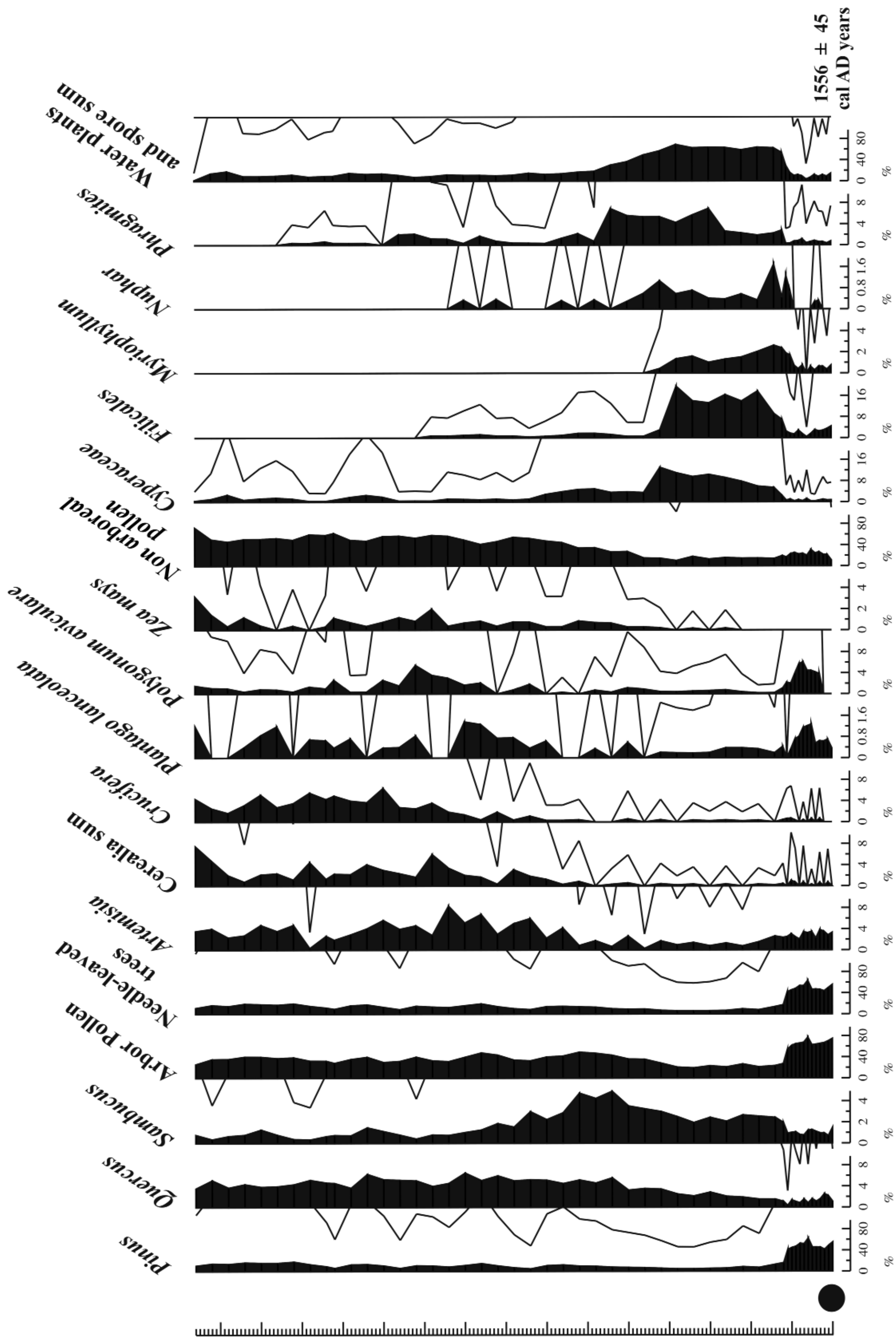

Figure 33. Pollen profile of the undisturbed core sequence in the one-time Drava riverbed by the palisaded fort at Barcs

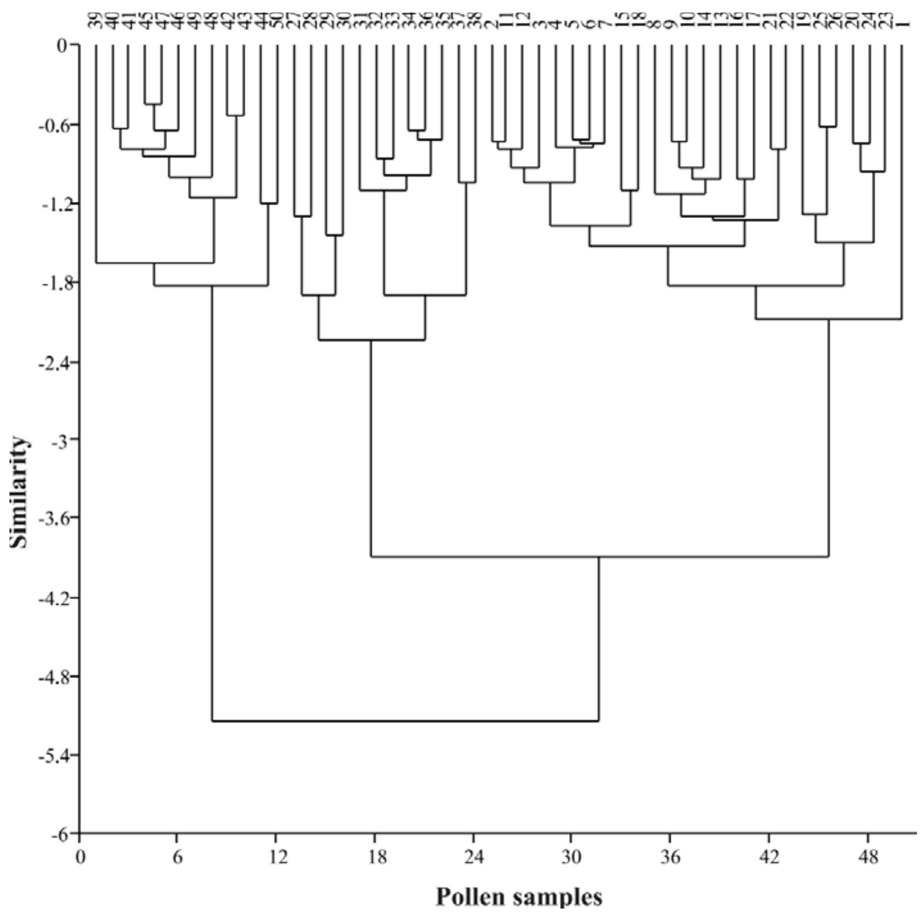

Figure 34. Cluster analysis of pollen assemblages showing vegetation development phases and local pollen zones from the undisturbed core sequence in the one-time Drava riverbed by the palisaded fort at Barcs

Barcs, filled-up riverbed by the palisaded fort, pollen zone 3 (114–82 cm)

The pollen composition of this zone indicated that weed-dominated abandoned areas developed, probably as a result of the abandonment of the settlement (the palisaded fort). The strong rise of alder pollen ratio supports the abandonment of the fort as well. Later, the number of alder pollen decreased, and anthropogenic and trampling-tolerant weeds (plantains, prostrate knotweed) spread. In addition, cereal pollen as well as maize were continuously present. It would appear that although the broader area of the palisaded fort was initially uninhabited, it was later re-populated as shown by the spread of trampling-tolerant weeds and plants indicating arable farming, especially cereal pollen. This pollen zone can probably be correlated with the end of seventeenth century and the eighteenth century.

Barcs, filled-up riverbed by the palisaded fort, pollen zone 4 (82 cm – towards the surface)

In addition to the weed vegetation and cereal pollen originating from the background that reflect a continuous anthropogenic impact, local flowering crop pollen (crucifers, fruit trees such as *Prunus*) that spread to a short distance also appeared. It seems likely that

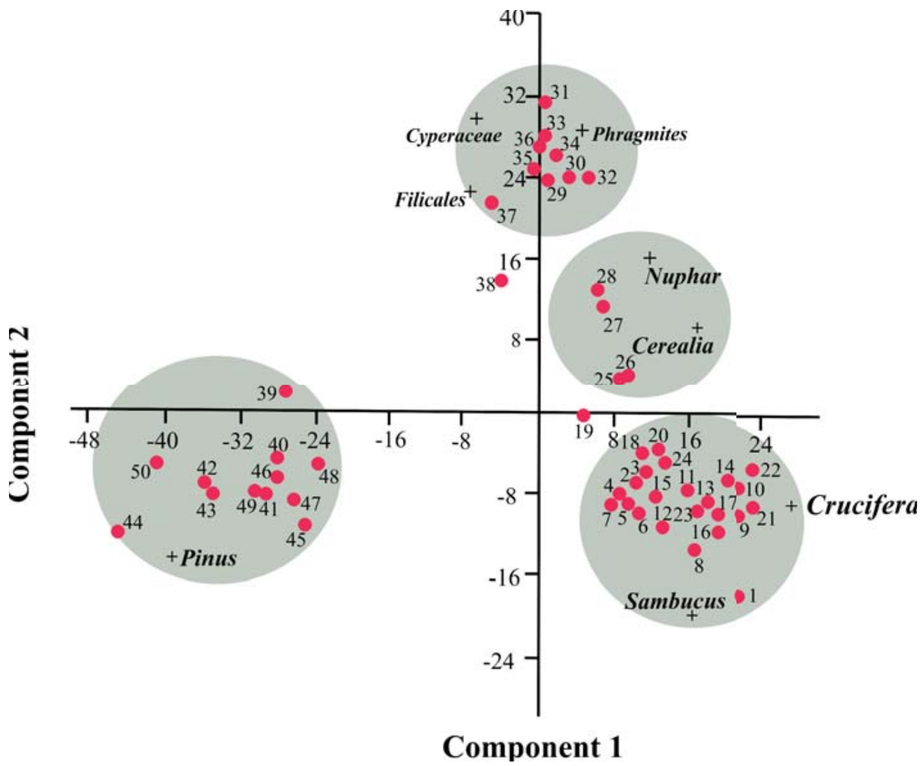

Figure 35. PCA of pollen assemblages showing vegetation development phases and local pollen zones from the undisturbed core sequence in the one-time Drava riverbed by the palisaded fort at Barcs

gardens were created in the vicinity of the sampling location and the filled-up oxbow lake was utilized in horticulture. This pollen zone probably corresponds to the nineteenth and twentieth centuries.

On the basis of our pollen analysis, the riverbed, running directly by the palisade and at the ditch of the palisaded fort in Barcs, functioned as a river channel until the end of the sixteenth century and the beginning of the seventeenth century, roughly until the 1610s as suggested by the radiocarbon dates. Later, a floating mat appeared in the riverbed that became paludified rapidly, which, on the testimony of the maize pollen, can be dated to the later seventeenth century. Simultaneously, the former riverbed (and the palisaded fort) was abandoned and a weed- and shrub-covered area emerged (perhaps at the turn of the seventeenth and eighteenth centuries). The rise in trampling-tolerant weeds and cereal pollen indicates the re-population of the site (eighteenth century) and the increase of human impact in the area of the continuously filled-up riverbed. The pollen horizon of the nineteenth century again reflects a significant change in the area of the sampling location, as a pollen composition typical for horticulture developed. It seems likely that after the river regulations, horticulture expanded to the investigated abandoned riverbed, where it persisted to our days.

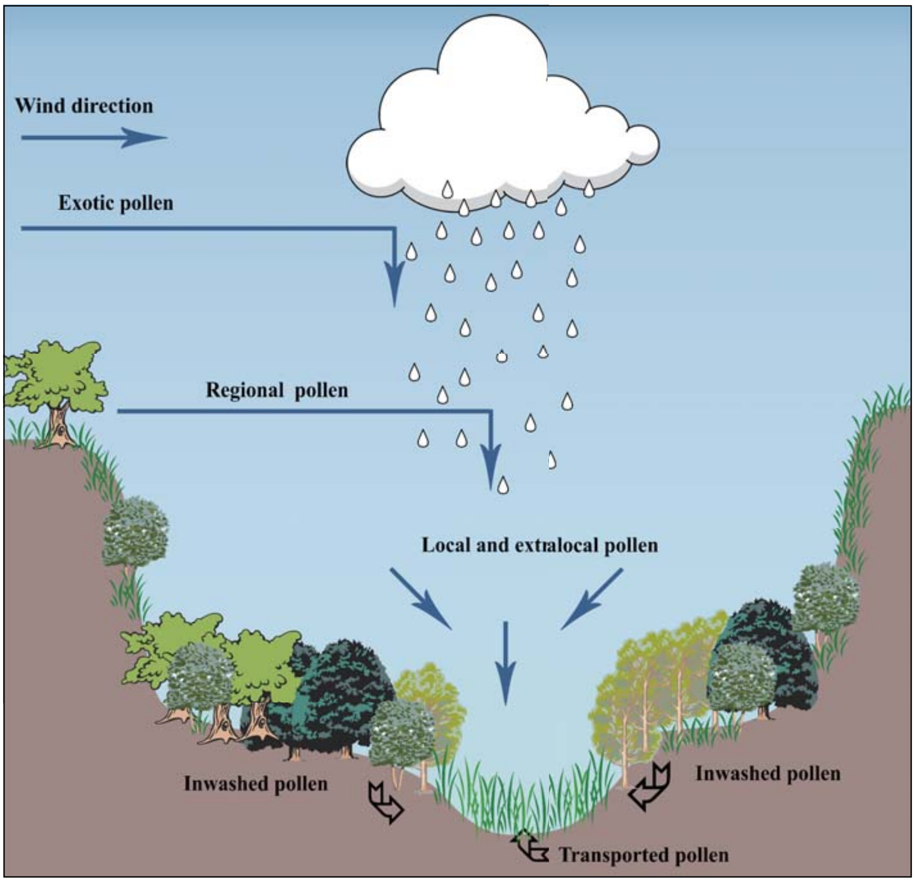

Figure 36. Pollentaphonomic and pollen accumulation process in the alluviums of stream and rivers

Environmental history analysis of the Lankóci-erdő [Lankóci forest], between Berzence, Gyékényes and Csurgó

The study site is a filled-up stream *(Figs 2–3)* in the Lankóci-erdő between the villages of Berzence, Csurgó, and Gyékényes near the Hungarian–Croatian border. The stream, where the coring reached the riverine sandy layers of the bedrock, is located in a neotectonic depression on the fringes of the Drava River alluvium, on a surface separated from the high bluff. The accumulated sediment spans the medieval period; additionally, archaeological surface surveys also found evidence of intensive medieval settlement activity in the broader area of the riverbed. Accordingly, it is one of the region's most promising sites in terms of medieval environmental history research.

The extracted pollen material of the site was abundant and well preserved due to the location and filling-up condition of the stream, and as a result of pollen preservation characteristics. Given the location of the riverbed, we could obtain information not only about the medieval settlement and its economy, but also about medieval forest development and forest management. We did not find traces of human impact, inwash, and convolution in the profile studied macroscopically, and we therefore assumed that natural landscape development would dominate and human impact would be subordinate only.

An examination of the geological map of the Lankóci-erdő and its surroundings revealed that the study area was a small neotectonic depression because the streams of the high bluff run here and a typical geological bay evolved within the high bluff between Porrogszentkirály, Csurgó, and Gyékényes *(Fig. 38)*. In this geological bay, aeolian, terrestrial loess layers covering the surface of the high bluff did not develop; instead, late Pleistocene and Holocene wet surface sediments, alluvial, and fluvial deposits accumulated.

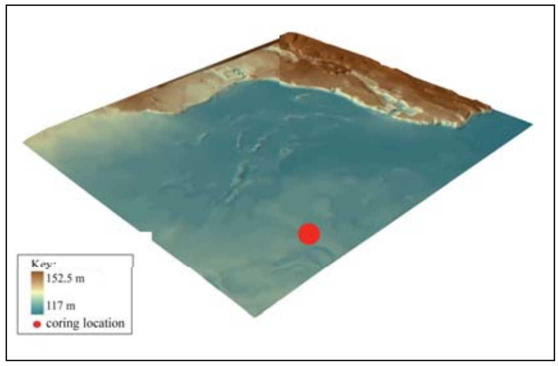

Figure 37. Digital elevation model of the Lankóci-erdő [Lankóci forest] and broader area

The neotectonic depression that is visible on geological maps can be clearly seen on the Google Earth images showing recent vegetation. The floodplain forest that evolved in the depression between Berzence, Gyékényes, and Csurgó conforms to the surface that breaks the edge of the high bluff. It is separated from the high bluff by a significant fall, and from the direction of the Drava alluvium by a mild scarp. The surface separation of the neotectonic depression can best be seen on the outskirts of Csurgó, where a several meters high relief difference can be seen at the edge of the depression.

The extent of the geological depression and the Lankóci-erdő do not exactly overlap since following the river regulations, the water table level decreased, a part of the forest was felled, and the area was drawn into cultivation. Due to its deeper location, this depression channeled the waters flowing from the high bluff towards the Drava depression. Thereby, a stream network evolved flowing downward to the neotectonic depression and midreach streams with typical large curves evolved in the depression *(Fig. 37)*.

We extracted undisturbed cores for environmental history analysis from one of these abandoned, filled-up streams *(Figs 38–39, Table 7)*, and performed pollen and palaeobotanical analyses. Evaluable pollen material did not occur in the dark gray, slightly laminated, silty-sandy layers of the bedrock. Therefore, samples suitable for pollen analysis were taken from the silt and clay-rich sediment from 160 cm towards the surface *(Fig. 40)*.

Since the Holocene chronology of the study site is not known, we submitted samples for radiocarbon dating *(Table 8)*. As a result, we had to reconsider the age of the profile; it seems

Table 7. Lithological description of the core sequence from the filled-up stream in the Lankóci-erdő at Berzence

GPS coordinate	*Depth (cm)*	*Troels-Smith category*	*Lithostratigraphy*
46° 13′ 11.72N 17° 02′ 56.04 E	0–10	Sh2As2	Blackish-brown marshy layer with polyhedric structure.
	10–20	Sh1As3	Dark brown marshy layer with polyhedric structure.
	20–70	As4	Yellowish-brown clayey silt and silty clay with limonite spots and laminas.
	70–80	As4	Greenish-gray clayey silt and silty clay.
	80–150	Sh1As3	Bluish-grey clayey silt and clayey silt with sporadic organic-rich spots and laminas.
	150–160	Ga1Ag3	Dark grayish flaser bedding layer with sporadic sandy lens. Greenish-gray oxbow lake sediment.
	160–200	Ga2Ag2	Dark grayish soft cross-bedded layer with sporadic sandy silt. Stream sediment layer.

Figure 38. The Lankóci-erdő area in Berzence, the streams in the forest, and the coring location in the riverbed on a Google Earth image, March 2006

Figure 39. The Lankóci-erdő area in Berzence, the streams in the forest, and the coring location in the riverbed on a Google Earth image March 2006

likely that the material of the core accumulated from the Migration period to the present, during the past 1600–1700 years. Thus, on the one hand, we could reconstruct the vegetation development of the entire medieval period, and, on the other hand, we could perform a comparative analysis of the eighteenth-century pollen horizon and the vegetation shown on the maps of the First Military Ordnance Survey of Austria-Hungary *(Fig. 41)*.

Evaluable samples for pollen analysis were taken at 4 and 2 cm intervals from the upper 160 cm, a total of 50 samples. The statistical analysis of the pollen composition *(Figs 44–45)* indicated seven local pollen zones characterized by few differences, meaning that seven phases of local vegetation development could be distinguished *(Table 9)*.

Table 8. Radiocarbon (AMS) dates for the core sequence in the Lankóci-erdő at Berzence and their calibration (cal BP and cal AD years) using the IntCal 13 program (after Reimer et al. 2014)

Depth (cm)	*Uncal BP years*	*Cal BP years*	*Cal AD years*	*Code*
69–70	588±27	592±56	1356±56	D-AMS 005121
109–110	983±34	1073±82	872±82	D-AMS 005120
159–160	1606±25	1483±69	466±69	D-AMS 005119

Table 9. Pollen zones and local vegetation changes as reflected by the core sequence from the Lankóci-erdő at Berzence

Depth (cm)	*Age (AD years)*	*Pollen zones and local vegetation changes*
10–0	20th century	Lankóci-erdő pollen zone 7: Forest with weed-rich vegetation. Presence and expansion of *Ambrosia* pollen. The pollen content suggests the presence of a *Carpinus*-dominated gallery forest.
20–10	19th century	Lankóci-erdő pollen zone 6: The strong deforestation process continued with a small settlement activity, together with cultivated fields, pasturelands, and meadows.
40–20	18th century	Lankóci-erdő pollen zone 5: Mass of microcharcoal and burnt charcoal remains suggest that a strong deforestation process started. Arboreal pollen (AP) dominance decreased, weed dominance increased, the forest was disturbed by human impact.
70–40	16th–18th centuries	Lankóci-erdő pollen zone 4: Human impact declined during the Ottoman period. *Sambucus* and AP dominance increased, *Juglans* and weed dominance decreased, marshyland plants covered the oxbow lakeside zone – a depopulation phase.
110–70	medieval period	Lankóci-erdő pollen zone 3: Nut production, forestry, cyclical logging, strong human impact with pasturelands. Cultivated fields with *Avena* around the forested area. Erosion increased around the stream; the sedimentation rate accelerated.
140–110	late Migration period	Lankóci-erdő pollen zone 2: Gallery forest regeneration started; *Quercus, Tilia, Fraxinus,* and *Corylus* pollen dominance increased, weed dominance and human impact decreased.
160–140	early Migration period	Lankóci-erdő pollen zone 1: AP pollen dominance is 80% with a high conifer dominance, suggesting regional pollen effect. *Quercus, Ulmus, Fraxinus, Tilia, Fagus,* and *Carpinus* pollen dominance. Human disturbed forest phase with anthropogenic impact indicator weeds (Chenopodiaceae, *Artemisia,* Centaurea).

Lankóci-erdő pollen zone 1 (160–140 cm, early Migration period)

The ratio of arboreal pollen was over 80% in this level and the number of coniferous pollen was outstandingly high in this horizon. We know that the composition of the pollen rain changed during the Roman Age in the wake of the clearance of large tracts of European deciduous forests to gain agricultural land. Pollen of conifers originating from forests that were less affected by anthropogenic impact dominated. The relative increase of conifer pollen

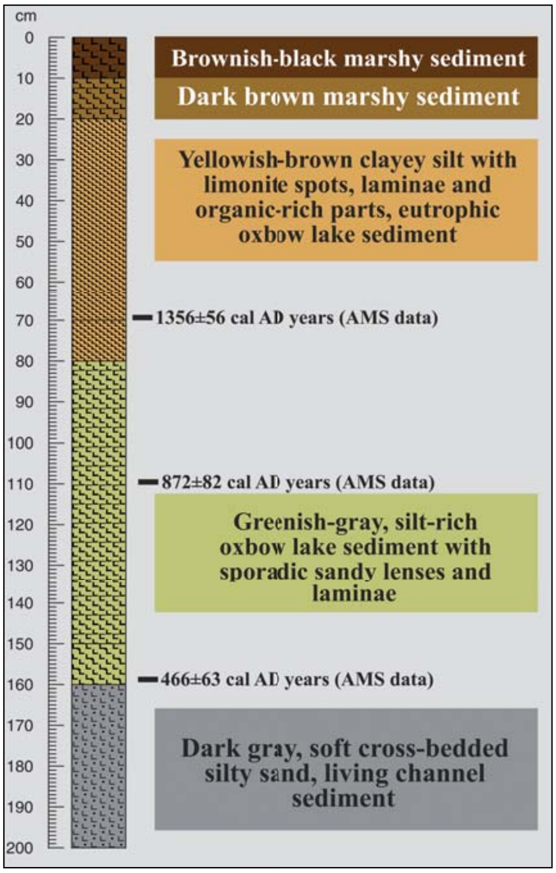

Figure 40. Lithological description of the undisturbed core sequence for pollen and palaeobotanical analysis in the Lankóci-erdő at Berzence

Figure 41. The analyzed stream channel in the Lankóci-erdő at Berzence on the map of the First Military Ordnance Survey of Austria-Hungary from 1782

has been noted everywhere across the European part of the Roman Empire. As a result of arable farming in the deciduous zone, this pollen composition – characterized by the relative increase of conifer pollen – persisted until the seventh century. Besides the regional pollen material, pollen of hardwood gallery forest elements dominated such as oak-elm-ash-lime-beech and hornbeam, which indicates a hardwood gallery forest in the study area during the early Migration period. The high number of weed pollen, goosefoot, centaury, and mugwort implies a disturbed forest ecosystem with grazing fields and hayfields in smaller deforested areas.

Lankóci-erdő pollen zone 2 (140–110 cm, late Migration period)

The pollen ratio of arboreal species was over 80% in this level of the profile as well; however, the number of conifers declined drastically compared to the previous zone. The ratio of elm, oak, lime, ash, and hazelnut increased significantly, while walnut (*Juglans*) disappeared in this zone, reflecting the dominance of local pollen accumulation in the later half of the Migration period. The pollen composition indicates that the degree of human impact strongly

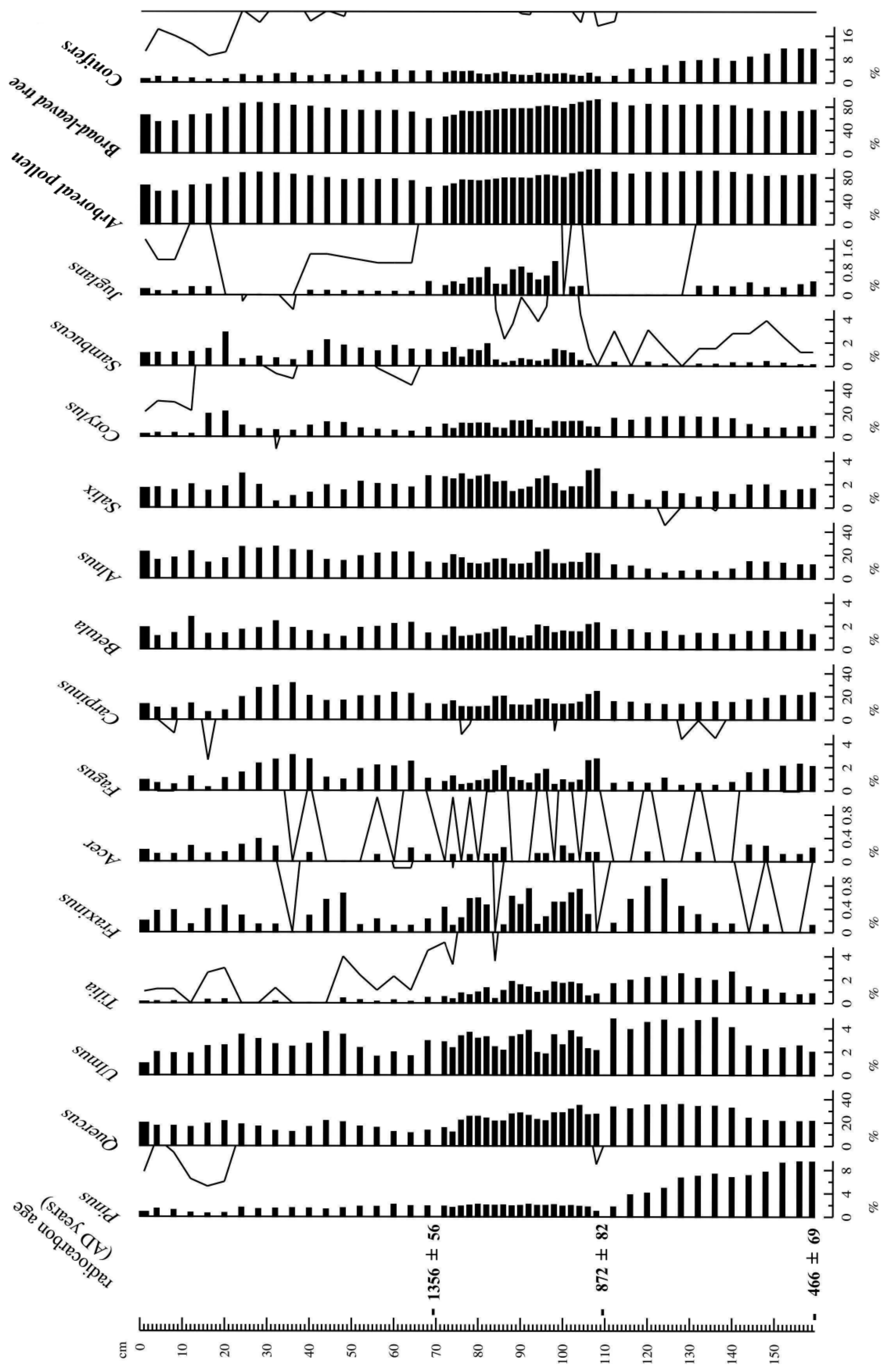

Figure 42. Pollen profile of the undisturbed core sequence in the stream channel in the Lankóci-erdő (arboreal pollen)

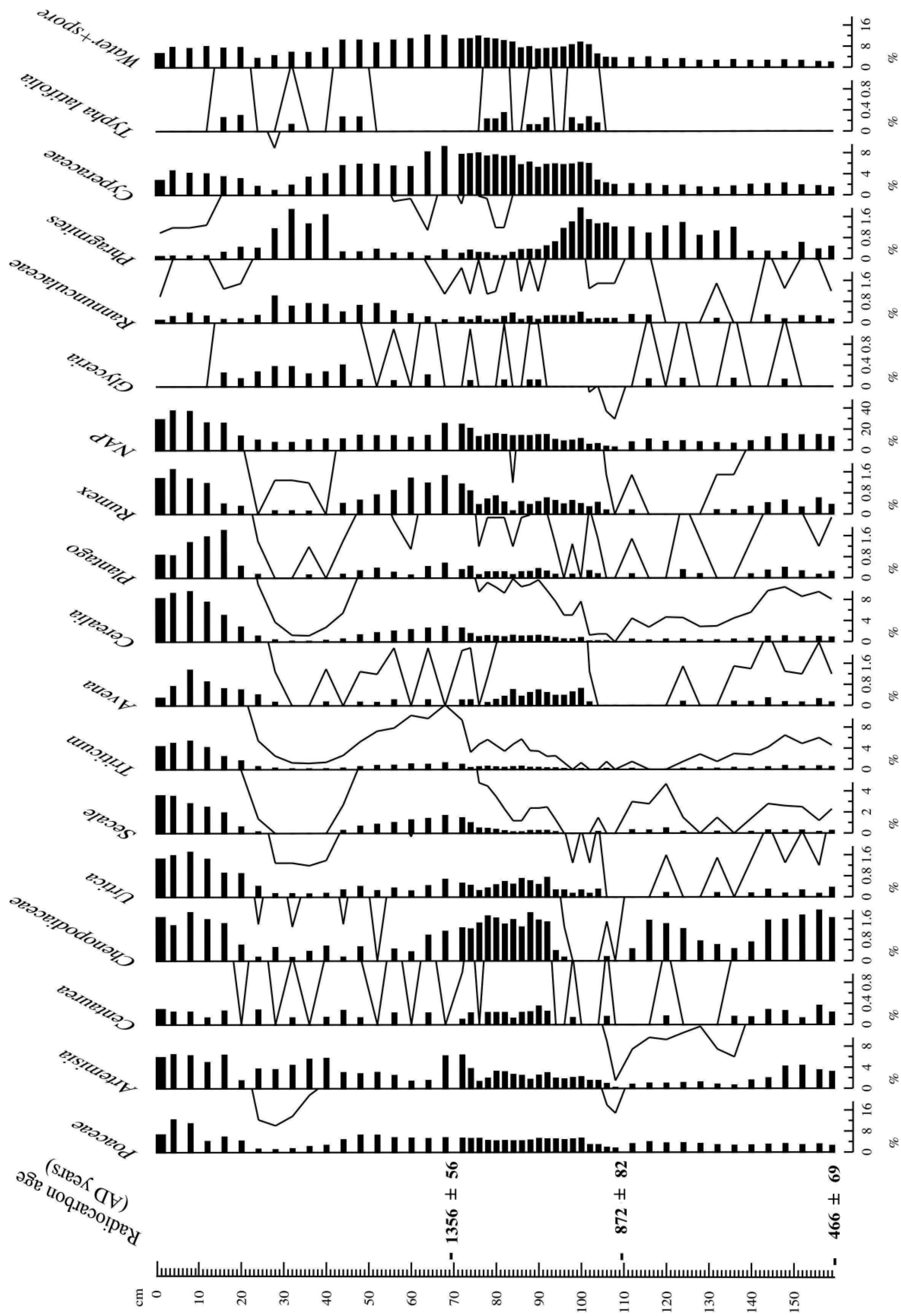

Figure 43. Pollen profile of the undisturbed core sequence in the stream channel in the Lankóci-erdő (non-arboreal pollen)

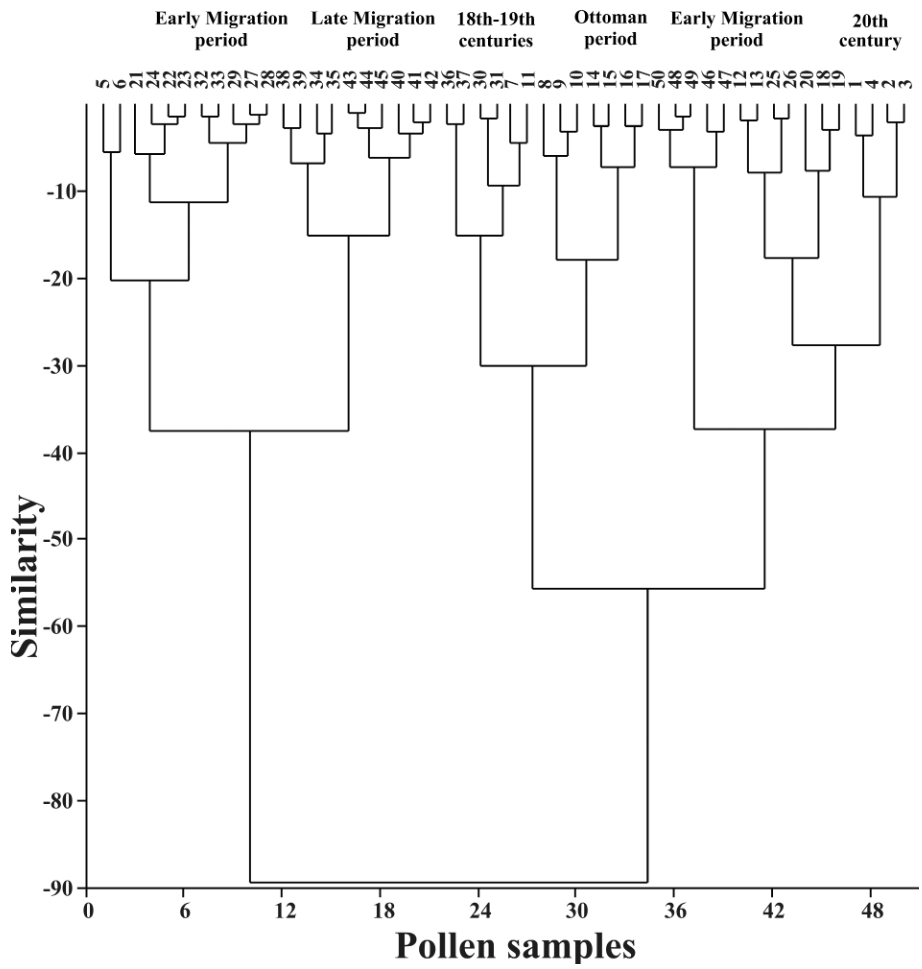

Figure 44. Cluster analysis of pollen assemblages showing vegetation development phases and local pollen zones from the undisturbed core sequence from the stream channel in the Lankóci-erdő

decreased compared to the early Migration period and that forest regeneration started. A hardwood gallery forest dominated in the study area, while the extent of cultivated land and human disturbance decreased as shown by the drop in the number of weed pollen.

Lankóci-erdő pollen zone 3 (110–70 cm, medieval period)

During the medieval period, a stronger human impact can be detected in the profile on the testimony of the pollen samples taken at 2 cm intervals. The pollen ratio of gallery forest species forming the forest canopy decreased cyclically and, simultaneously, the weed vegetation spread. As a result of the cyclical decline of timber production, timber harvesting can be reconstructed on a 100–110-year-long scale *(Figs 42–43).* Walnut pollen appeared again in this zone and their ratio definitely suggests a significant walnut cultivation in this period. It would appear that parallel to the increasing erosion caused by human disturbance, the filling up of the riverbed accelerated. The ratio of bulrush, reed, sedge, and buttercup increased significantly, the riverbed became covered by vegetation and was transformed into a boggy lake.

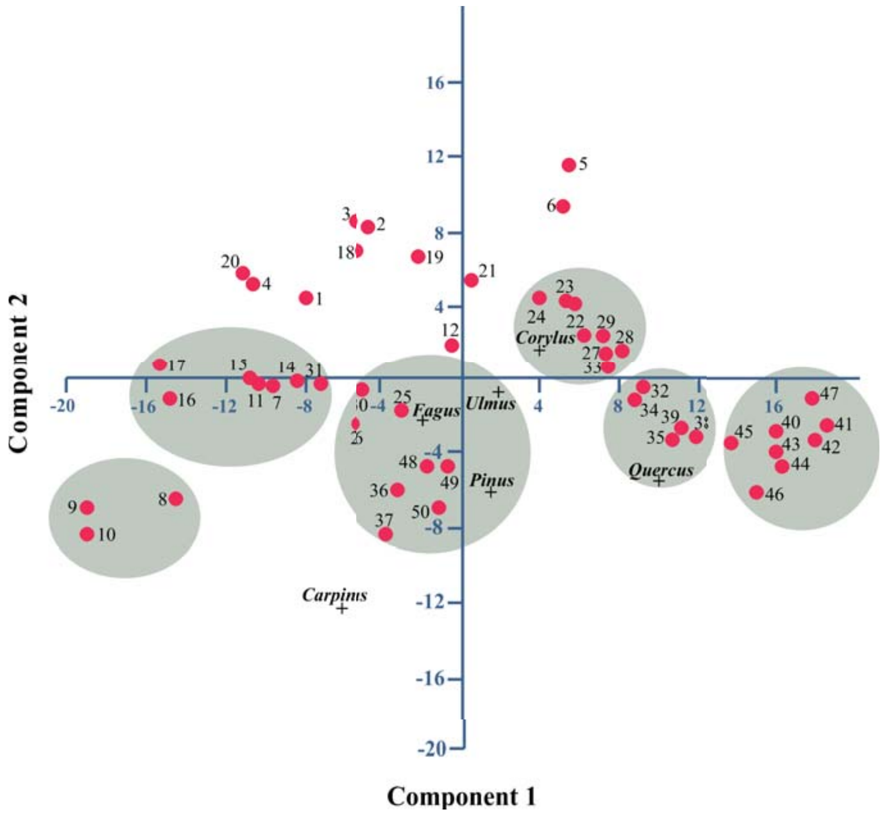

Figure 45. PCA of pollen assemblages showing vegetation development phases and local pollen zones from the undisturbed core sequence from the stream channel in the Lankóci-erdő

Despite the human impact, the arboreal vegetation cover, especially oak, predominated in the study area during the medieval period. The pollen composition indicates that the ratio of oak was between 50 and 60%, hornbeam accounted for 20%, while other species were represented by a ratio of 2–5% per taxon. Based on these data, the medieval Lankóci-erdő was probably a hornbeam-oak forest with elm, alder, and lime, but mixed with birch, willow, and perhaps poplar in the deeper areas and along streams. Other tree species such as ash, maple, and beech played a secondary role and were sporadic in the forest. The significant number of walnut pollen indicates its local origin and cultivation. Trampling-tolerant weeds point to roads and clearings in the forest.

Lankóci-erdő pollen zone 4 (70–40 cm, sixteenth–seventeenth centuries, Ottoman period)

The next pollen horizon developed between 70 and 40 cm, probably in the sixteenth–seventeenth centuries. The extent of the forested area increased and the spread of beech, hornbeam, birch, willow, and alder could be noted. The expansion of alder is particularly remarkable, with its pollen ratio reaching 20%, which reflects the age-old observation that this species expands rapidly in wetland areas where human impact decreases. Simultaneously, the proportion of lime, elm, and oak declined and hornbeam-alder-oak forests were almost completely in balance in the Lankóci-erdő during this period. In addition to the expansion of alder, the strong growth of the shrub level, and the drop in walnut pollen indicate a significant decline of human activity as well as the transformation and closure of the forest.

Simultaneously with the transformation of the forest and the closure of the shrub level, the ratio of weed pollen, especially of trampling-tolerant weeds, decreased significantly, reflecting a major decline in anthropogenic effects. The stream was predominantly covered by aquatic plants; however, the increasing remains of algae indicate a rise in the water level. Consequently, human impact decreased and the area was depopulated, reflected also by the decline in the ratio of cereal and weed pollen indicating anthropogenic effects. The transformation of the forest, the spread of beech, hornbeam, birch, alder, and willow, and the rise in the water level reflect a colder and wetter climate phase in this pollen horizon during the Ottoman period.

Lankóci-erdő pollen zone 5 (40–20 cm, eighteenth century)

Traces of considerable deforestation indicated by ash (microcharcoal) and burnt and charred wood remains could be noted in this level of the profile. Although the arboreal pollen ratio declined, it still predominated, but the proportion of hornbeam and beech decreased markedly. On the basis of the pollen composition, the closed forest made up 70–80% of the forested area with a dominance of oak. The forest was strongly disturbed, trampling-tolerant weeds expanded, indicating the re-population of the study area, where significant anthropogenic activity began. The reconstruction of the vegetation, based on the pollen composition, is consistent with the map of the First Military Ordnance Survey of Austria-Hungary *(Fig. 41)*, according to which the forest opened up and grazing fields and meadows were created in the area in the later eighteenth century. The sedimentation rate calculated from the radiocarbon data (20 cm: 1795–1805 AD) enabled the separation of the eighteenth and nineteenth centuries.

Lankóci-erdő pollen zone 6 (20–10 cm, nineteenth century)

Beech, maple, birch, and lime disappeared almost completely, while oak and hornbeam became dominant; however, the extent of tree- and shrub-covered areas decreased considerably, reflecting intensive deforestation during this century. The ratio of weeds, especially of trampling-tolerant weeds (plantains), increased and weed-dominated areas evolved. The increase of cereal pollen indicates intensive arable farming in the broader area of the forest. Farming activity connected to the settlements extended to the forest as well, where forest hayfields, meadows and grazing fields were created. Extensive cultivated lands, pasture lands, and meadows lay in the vicinity of the forest, encroaching on it in some places.

Lankóci-erdő pollen zone 7 (10 cm to the surface, twentieth century)

In contrast to our general practice, we also analyzed and evaluated the profile section near the modern surface in order to compare the pollen composition with current forestry maps and wood composition data. The appearance of *Ambrosia* pollen clearly indicates that this level of the profile developed in the twentieth century. The pollen composition reflects the dominance of hornbeam-oak forests, mixed alder-oak forests, and local alder-willow marsh forests during the last century. One interesting feature is that there were probably elm-ash-oak residual forests and that this forest association presumably included wild pear (*Malus sylvestris*), which was detected in this level.

The extensive weed vegetation indicates that the forest was strongly disturbed and managed in the twentieth century. It is likely that the forest communities that could be reconstructed from the pollen composition developed according to the hydroseries in the twentieth century.

Our conclusions drawn from the pollen analysis and the vegetation survey conducted along a transect in the Lankóci-erdő are wholly supported by recent botanical analyses.

In addition to the recent botanical data, we tried to collect recent climate data on the study area. Unfortunately, the weather station in the study site has only been active since 1999, and therefore we used the region's nearest public data set to prepare its Walter-Lieth diagram *(Fig. 46).*

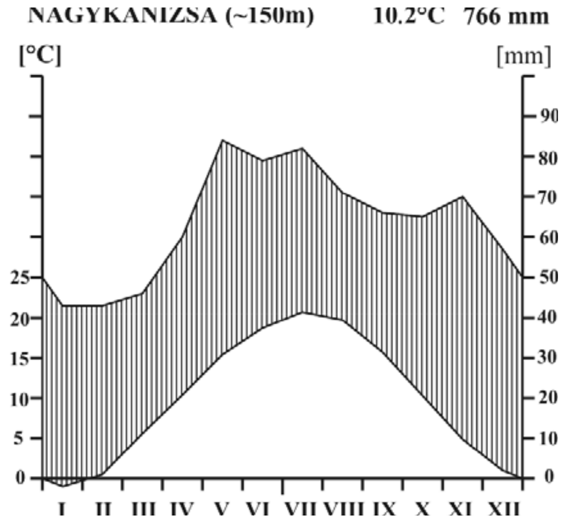

Figure 46. Walter-Lieth diagram of southern Transdanubia (Nagykanizsa) characterized by balanced, high precipitation, Atlantic and sub-Mediterranean climate effects

SUMMARY AND COMPARATIVE ANALYSIS

Since studies on the medieval environmental history of southern Transdanubia are in their infancy, the regional correlation of our findings is not an easy task. We used the Baláta-tó [Lake Baláta] reference profile of vegetation development in southern Transdanubia during the past 3000 years for the regional interpretation of our data *(Fig. 47).*

It is clear from the profile from Decs-Ete that the direct vicinity of the sampling location was under anthropogenic impact and was cultivated land from the Roman Age to the Ottoman period *(Fig. 47).* Human impact (deforestation, grazing, and the creation of meadows, hayfields, and ploughfields) was so extensive that we cannot speak of an even semi-natural landscape development in the area of the sampling location.

The pollen profiles unambiguously demonstrate that without human impact, 80–90% of the study area would have been covered by forest vegetation. There were minimal differences in the ratio and nature of cultivated land between the Migration period and the Early Modern Age. Nevertheless, the stabilization of weed pollen and cultivated crops is so significant – approximately from the eleventh–twelfth centuries – that a continuously occupied settlement with an outer zone characterized by cultivated fields, gardens, meadows, and pastures can be reconstructed.

From the Ottoman period, this environment changed into an abandoned, wild environment, where softwood gallery forest elements and non-trampling-tolerant weeds colonized the area relatively quickly. In addition, oak and elm trees appeared in the vicinity of the abandoned settlement.

A temporary landscape regeneration occurred after the collapse of the medieval agro-ecosystem, which was interrupted again in the eighteenth century, when a cultivated landscape characterized by increasing human impact emerged in the study area *(Fig. 47).*

The analysis of the riverbed at the palisaded fort in Barcs enabled a description of the successive stages and nature of how the riverbed had filled up. The riverbed by the palisaded fort had functioned as an active channel until the end of the sixteenth century or the

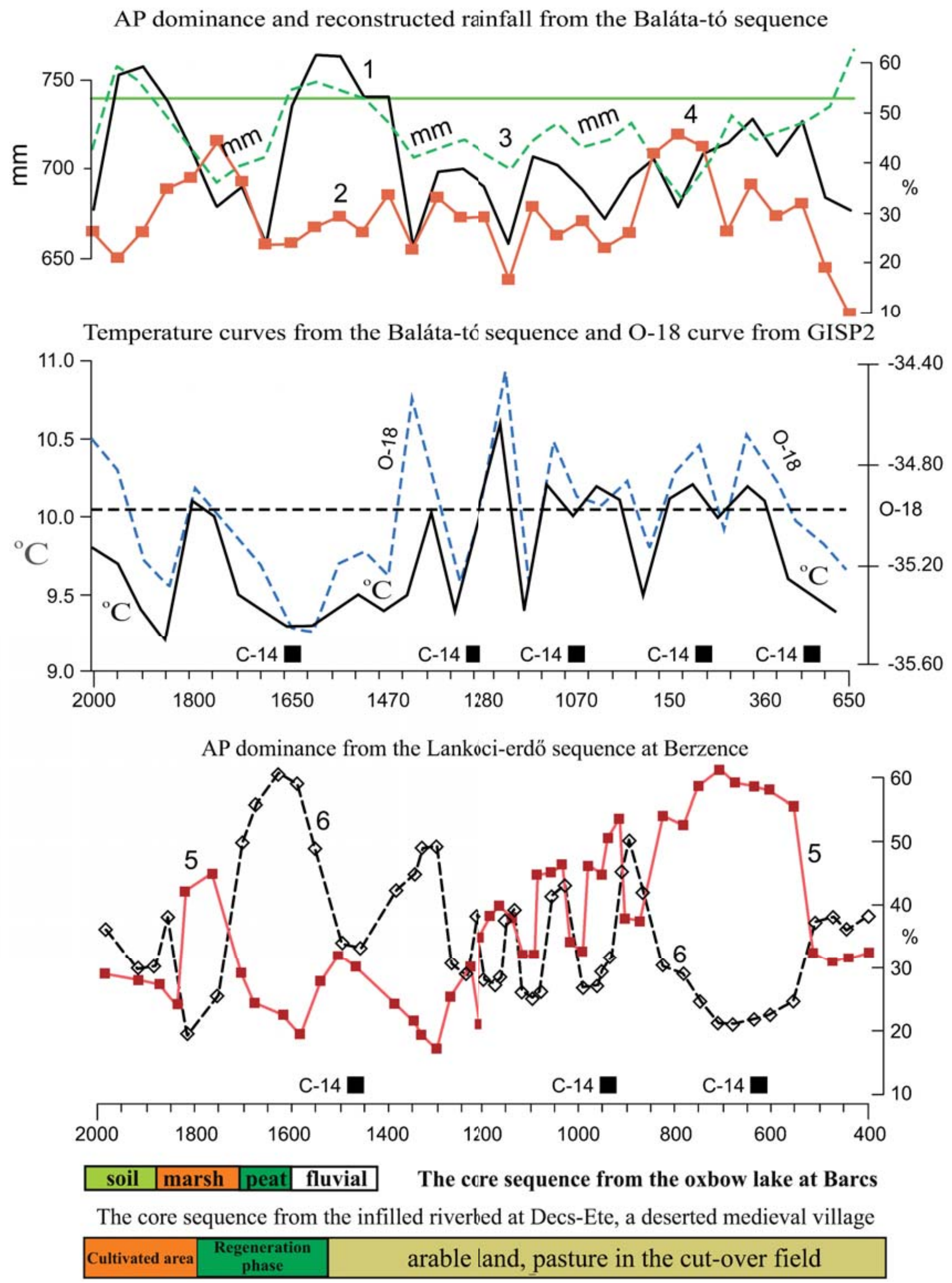

Figure 47. Comparative analysis of the *locus typicus* profiles of the cores from Baláta-tó and from the study areas in the Drava and Danube alluvia in terms of climate change during the last 3000 years.
1: *Betula*, *Alnus*, *Fagus*, *Carpinus* pollen dominance curve, 2: *Quercus*, *Ulmus*, *Tilia*, *Fraxinus* pollen dominance curve, 3: pollen-based reconstructed precipitation, 4: mean temperature of the last 3000 years in the study area, 5: *Betula*, *Alnus*, *Fagus*, *Carpinus* pollen dominance curve, 6: *Quercus*, *Ulmus*, *Tilia*, *Fraxinus* pollen dominance curve

beginning of the seventeenth century at the latest, after which it paludified fairly rapidly and became an oxbow lake in the later seventeenth century *(Fig. 47)*. Due to continuous filling up and vegetation cover, the marshy lake became paludified in the eighteenth century. In the nineteenth century, as a result of drainage and groundwater regulations, soil formation began. A hydromorph soil has formed during the past 150–200 years over the filled-up and dried-out oxbow lake, simultaneously accompanied by land cultivation.

Neither the profile at Barcs, nor the one at Decs-Ete could be used for correlating changes over a larger area because both profiles reflected local environmental changes and significant human impact.

In contrast, the analysis of the pollen material from the profile of Lankóci-erdő at Berzence yielded data that indicated trends for a larger area *(Fig. 47)*. Although the two profiles could not be correlated to an annual scale owing to the different temporal resolution of the pollen samples, a look at the findings on a decades-long scale provided a suitable comparative basis.

The following conclusions could be drawn from the comparative analysis of the Baláta-tó environmental history data and the oxygen isotope curves of the Greenland ice sheet used for global climate change reconstruction, taking into account the Hungarian pollen proxy data based on pollen-climate transfers.[16]

(1) The Baláta-tó and Berzence cores both indicated a relatively colder climate phase that was 0.5°C colder than the mean temperature of the past 3000 years at the beginning of the Migration period, approximately in the fifth–sixth centuries. The regional precipitation conformed to the average of the past 3000 years, or was slightly below the average by some 5–10 mm *(Fig. 47)*. Considering the recent climate data of the region *(Fig. 46)*, the continentality of the climate probably increased, while the temperature of the winter months probably decreased.

(2) A relatively milder climate phase, some 0.1–0.2°C warmer than the mean temperature of the past 3000 years could be detected in the cores from Baláta-tó and Berzence between the sixth and the tenth–eleventh centuries. The regional precipitation of this phase was 10–50 mm less than the average of the past 3000 years *(Fig. 47)*. Considering the recent climate data *(Fig. 46)* of the site, the sub-Mediterranean and continental climate effect probably increased, as reflected in the temperature increase of the summer months.

(3) A relatively colder climate phase, 0.2–0.3°C colder than the mean temperature of the last 3000 years could be detected in the Baláta-tó and Berzence cores in the eleventh century *(Fig. 47)*.

(4) A short, but definitely dry climate phase was detected in the thirteenth century, when a climate phase with 60–80 mm less precipitation than the average of the past 3000 years could be noted in the Baláta-tó and Berzence cores, and a relatively milder climate could be reconstructed. Considering the recent climate data of the site *(Fig. 46)*, sub-Mediterranean and continental climate effects probably increased, reflecting by the temperature rise of summer months and the decrease of precipitation of the growing period. Highly similar climatic effects have been noted during dry years in southern Transdanubian areas in the twentieth century.

(5) Subsequently, a double cold peak developed in the study area at the end of the fifteenth century and the beginning of the sixteenth century; while the second one evolved in the seventeenth century. There was a 1°C decrease in the mean annual temperature *(Fig. 47)*. The combination of continental and Atlantic climate effects grew. As a result of the continental effect during winter and the Atlantic effect during the summer months, a colder and wetter climate phase developed. These cold peaks obviously influenced the forest composition.

16 Sümegi et al. 2009a.

(6) A short and mild climate phase was detected in the Baláta and Berzence cores in the eighteenth century that was a few tenths of a degree milder than the average.

(7) In addition to the climate changes, very strong human impacts could be identified. This was particularly noticeable in the forested areas of Berzence where cyclical (4+1 distinctive cycles) and significant forest clearance activities can be reconstructed from the drastic drop in arboreal pollen in 100–110-year-long cyclical periods before the Ottoman period (tenth, eleventh, twelfth, thirteenth, and fifteenth centuries). Since the length of these cycles corresponds to the maturing period of trees in Hungary, it seems likely that these were conscious forestry interventions, indicating that forest management practices other than coppicing also existed during the medieval period. Nevertheless, some of these interventions served not only timber production, but also reflect changes in cultivation practices (meadow, pasture and arable lands).

Our findings prove that archaeologically and historically relevant data regarding forestry and arable farming in the medieval and the Ottoman periods can be obtained from the geoarchaeological and palaeoecological analysis of sedimentary basins, even in the lack of written sources. Our studies and innovative approach represent the first steps in this region, and it is our hope that this work will be continued and that our reconstructions will be supplemented and refined by additional investigations of sedimentary basins, broadening our knowledge of the environment of the medieval and Ottoman periods.

(8) The pollen studies in southern Transdanubia were not conducted in isolation. Since the creation and activity of the Palaeoecological Research Group in Debrecen in 1986 (by founding members Pál Sümegi, Tünde Törőcsik, Mihály Braun, and Albert Tóth, and by their students Edina Zita Rudner, Enikő Magyari, Gusztáv Jakab, and Péter Sólymos), cores from over a hundred sedimentary basins were processed as part of the palynological research by Tünde Törőcsik, Katherine Jane Willis, and Keith David Bennett[17] during the past thirty years. Following the break-up of the Palaeoecological Research Group in Debrecen in 1999, we continued our research in a complex laboratory in Szeged, where an Environmental History and Geoarchaeological Research Group was established as a collaborative venture between the Archaeological Institute of the Hungarian Academy of Sciences (currently the Institute of Archaeology, Research Centre for the Humanities, Hungarian Academy of Sciences) and the Department of Geology and Palaeontology of the University of Szeged.[18] As a result of the work of the two research groups and of students, a total of 102 undisturbed cores have been processed using the same pollen analytical methods for the medieval and Ottoman period in the Carpathian Basin in 45 National Scientific Students' Associations Conference research papers, 117 BSc and MSc diploma works, and 18 PhD theses, alongside the archaeobotanical work of Elvira Bodor and Zsófia Medzihradszky.[19] These are supplemented by the ongoing investigations on profiles and by independent work performed with the same methods *(Fig. 48)* carried out by different researchers, including our students. Consequently, 131 pollen profiles are available for the medieval period in the Carpathian Basin, that have been analyzed using the same method, whose geochronological age has been determined by radiocarbon dating *(Fig. 48)*.[20]

17 Braun et al. 1991; 1992; 1993; Willis et al. 1995; 1997; 1998; 2000; Sümegi 1990; 1995; 1996; 1998; Sümegi – Vissi 1991; Sümegi et al. 1994.

18 Pál Sümegi, Katalin Náfrádi, Gergő Persaits, Dávid Misi, Rita Judit Töviskes, Tünde Törőcsik, Gábor Bácsmegi, Ádám Bede, Dávid Gergely Páll, and Renáta Sándor.

19 Sümegi et al. 2015a; 2015b.

20 The environmental history research conducted in the Pilis Mountains (Hungary) and in Transylvania (Romania) was funded by a grant from the Hungarian Scientific Research Fund (OTKA Grant K 112318).

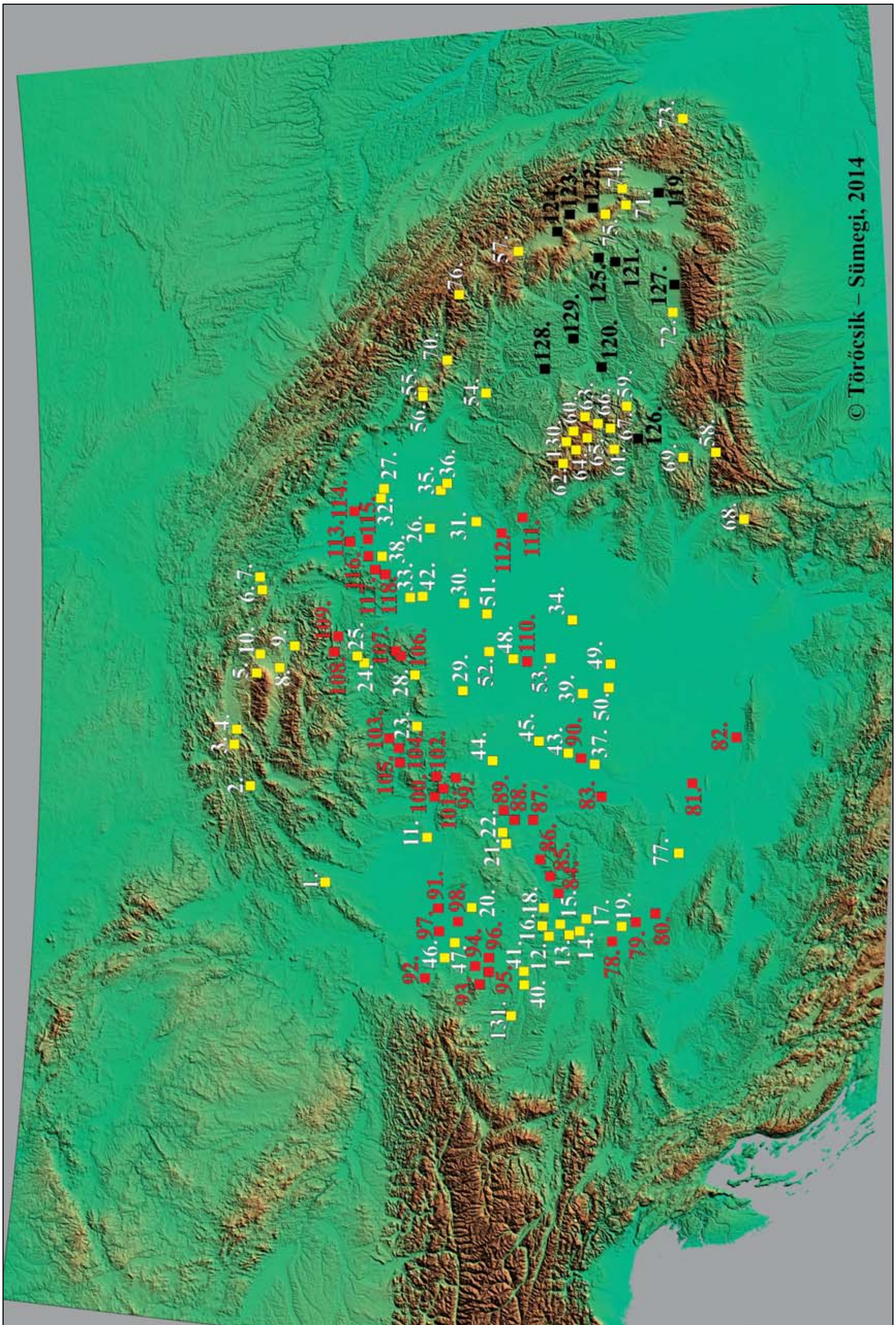
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Figure 48. Medieval Pollen Database of the Carpathian Basin
red: Sampling locations of the Palaeoecological Research Group of Debrecen and the Environmental History and Geoarchaeological Research Group of Szeged, blue: Sampling locations of Enikő Magyari, Gusztáv Jakab, and Mihály Braun, black: sampling locations in Transylvanian sedimentary basins, yellow: sampling locations of earlier palaeoecological research groups.

Sampling locations: 1 = Tlstá hora, Biele Karpaty, Slovakia, 2 = Kubríková, Západné Beskydy, Slovakia, 3 = Dolina Zlatného potoka, Podbeskydská brázda, Slovakia, 4 = Oravská kotlina, Bobrov (Bobró), Slovakia, 5 = Busov, Regetovka (Regettő), Slovakia, 6 = Ondavská vrchovina, Kružlová (Ruzsoly), Slovakia, 7 = Popradská kotlina, Hozelec (Őszelec), Slovakia, 8 = Volovské vrchy, Šafárka, Slovakia, 9 = Sivárňa Spišká Magura, Slovakia, 10 = Popradcké pleso, Štrebké pleso, Slovakia, 11 = Parížske marsh, Nová Vieska (Kisújfalu), Slovakia, 12 = Kis-Balaton, Alsópáhok, Hungary, 13 = Kis-Balaton, Zalavár 1, Hungary, 14 = Kis-Balaton, Zalavár 2, Hungary, 15 = Kis-Balaton, Fenékpuszta, Hungary, 16 = Kis-Balaton, Keszthely-Úsztatómajor, Hungary, 17 = Kis-Balaton, Fönyed, Hungary, 18 = Balaton, Balatonederics, Hungary, 19 = Baláta-tó, Kaszó, Hungary, 20 = Szélmező, Mezőlak, Hungary, 21 = Sárrét, Nádasdladány, Hungary, 22 = Sárrét, Sárkeszi, Hungary, 23 = Nádas-tó, Nagybárkány, Hungary, 24 = Kis-Mohos, Kelemér, Hungary, 25 = Nagy-Mohos, Kelemér, Hungary, 26 = Nagy-Mohos, Kállósemjén, Hungary, 27 = Nyíres, Csaroda, Hungary, 28 = Nyírjes, Sirok, Hungary, 29 = Meggyes-erdő, Jászberény, Hungary, 30 = Halasfenék, Zám, Hungary, 31 = Töviskes paleochannel, Pocsaj, Hungary, 32 = Báb-tó, Csaroda, Hungary, 33 = Sarlóhát paleochannel, Tiszagyulaháza, Hungary, 34 = Fehér-tó, Kardoskút, Hungary, 35 = protected marsh, Bátorliget, Hungary, 36 = marshside profile, Bátorliget, Hungary, 37 = Vörös-mocsár I. core profile, Császártöltés, Hungary, 38 = Tisza paleochannel, Tiszacsermely, Hungary, 39 = protected freshwater carbonate profile, Csólyospálos, Hungary, 40 = peat-bog, Szőce, Hungary, 41 = peat-bog, Farkasfa, Hungary, 42 = Tisza paleochannel, Polgár, Hungary, 43 = Őrjeg, Kecel, Hungary, 44 = Selyemrét, Ócsa, Hungary, 45 = Kolon-tó, Izsák, Hungary, 46 = Fertő tó, Hidegség, Hungary, 47 = peat-mine, Osli, Hungary, 48 = Rokkantföldek, Rákóczifalva, Hungary, 49 = Pana, Maroslele, Hungary, 50 = Maty-ér, Szeged, Hungary, 51 = Kunkápolnás, Nagyiván, Hungary, 52 = Tisza paleochannel, Tiszapüspöki, Hungary, 53 = Tisza paleochannel, Tiszaalpár, Hungary, 54 = Turbuţa, Transylvanian Basin, Romania, 55 = Preluca Ţiganului, Gutâi Mts, Romania, 56 = Steregoiu, Gutâi Mts, Romania, 57 = Iezerul Căliman, Căliman Mts, Romania, 58 = Tăul dintre brazi, Retezat Mts, Romania, 59 = Ic Ponor, Apuseni Mts, Romania, 60 = Padiş Ponor I, Apuseni Mts, Romania, 61 = Padiş Plateau, Apuseni Mts, Romania, 62 = Bergerie, Apuseni Mts, Romania, 63 = Căpăţâna, Apuseni Mts, Romania, 64 = Molhaşul Mare, Apuseni Mts, Romania, 65 = Călineasa, Apuseni Mts, Romania, 66 = Pietrele Onachii, Apuseni Mts, Romania, 67 = Tăul Zănogutii, Retezat Mts, Romania, 68 = Semenic, Banat Mts, Romania, 69 = Peşteana, Poiana Ruscă Mts, Romania, 70 = Văratec, Lăpuş Mts, Romania, 71 = St Anna, Ciomatu Mare Mts, Romania, 72 = Avrig-1, Făgăraş basin, Romania, 73 = Bisoca, Carpaţii de Curbură Mts, Romania, 74 = Mohos, Ciomatu Mare Mts, Romania, 75 = Luci (Lucs), peat-bog, Hargita Mts, Romania, 76 = Poiana Ştiol 3, Rodnei Mts, Romania, 77 = Drava paleochannel, Drávaszabolcs, Hungary, 78 = Lankóci-erdő, Berzence, Hungary, 79 = Drava paleochannel, Barcs, Hungary, 80 = Drava paleohannel, Drávatamási, Hungary, 81 = Danube paleochannel, Veresmart (Zmajevac), Croatia, 82 = Danube paleochannel, Atyavár (Sarengrad), Croatia, 83 = Batta channel (Ete), Decs, Hungary, 84 = Balaton, Balatonkeresztúr, Hungary, 85 = Balaton, Balatonboglár, Hungary, 86 = Balaton, Zamárdi, Hungary, 87 = Sárvíz, Soponya, Hungary, 88 = Sárrét, Sárszentmihály, Hungary, 89 = Nádas-tó, Gárdony, Hungary, 90 = Kaszálók, Hajós, Hungary, 91= Barbacsi-tó, Barbacs, Hungary, 92 = Malom-tó, Sopron, Hungary, 93 = Égeres, Velem, Hungary, 94 = Borzó-patak, Zanat, Hungary, 95 = Surány-patak, Nemesbőd, Hungary, 96 = Hosszú-völgy, Vát, Hungary, 97 = Tóköz, Lébény, Hungary, 98 = Lórét, Csorna, Hungary, 99 = peat-bog, Csikóvár, Hungary, 100 = Búbánatvölgy, Esztergom, Hungary, 101 = Apátkúti-völgy, Pilisszentlászló, Hungary, 102 = Szentléleki-völgy, Pilisszentlélek, Hungary, 103 = Ménes-völgy I, Karancsság, Hungary, 104 = Ménes-völgy II, Karancsság, Hungary, 105 = Nagy-tó, Ipolyszög, Hungary, 106 = Petény cave, Peskő, Hungary, 107 = Rejtek-zsomboly, Répáshuta, Hungary, 108 = Aggteleki-tó, Aggtelek, Hungary, 109 = Vörös-tó, Aggtelek, Hungary, 110 = Ecseg-tó, Ecsegfalva, Hungary, 111 = Daru-láp, Kókad, Hungary, 112 = Baia 1 Mai (Püspökfürdő), Haiu, Romania, 113 = Bodrog valley, Kráľovský Chlmec (Királyhelmec), Slovakia, 114 = Szirnye swamp, Haty (Gát), Ukraina, 115 = paleochannel, Karcsa, Hungary, 116 = paleochannel, Karos, Hungary, 117 = paleochannel, Viss, Hungary, 118 = paleochannel, Zalkod, Hungary, 119 = Nyír, Reci (Réty), Romania, 120 = Tăul fără fund, Băgău (Magyarbagó), Romania, 121 = Kerek tó ('round lake'), Sânpaul (Homoródszentpál), Romania, 122 = Mlaştina Csemő, Vrabia (Csíkverebes), Romania, 123 = Mănăstirea franciscanilor, Şumuleu Ciuc (Csíksomlyó), Romania, 124 = peat-bog, Voşlăbeni-Senetea (Vasláb-Szenéte), Romania, 125 = Lacul Racului (Rák tava), Porumbenii Mari (Nagygalambfalva), Romania, 126 = Turbăria Calul de Piatră, Bistra (Bisztra), Romania, 127 = Mlaca Tătarilor peat bog, Arpaşu de Sus (Felsőárpás), Romania, 128 = Mureş paleochannel, Sâncraiu de Mureş (Marosszentkirály-Náznánfalva), Romania, 129 = Sic (Szék-Nádas-tó), reeds, Romania, 130 = Padiş Ponor II, Apuseni Mts, Romania, 131 = Rohr – Heugraben, Austria

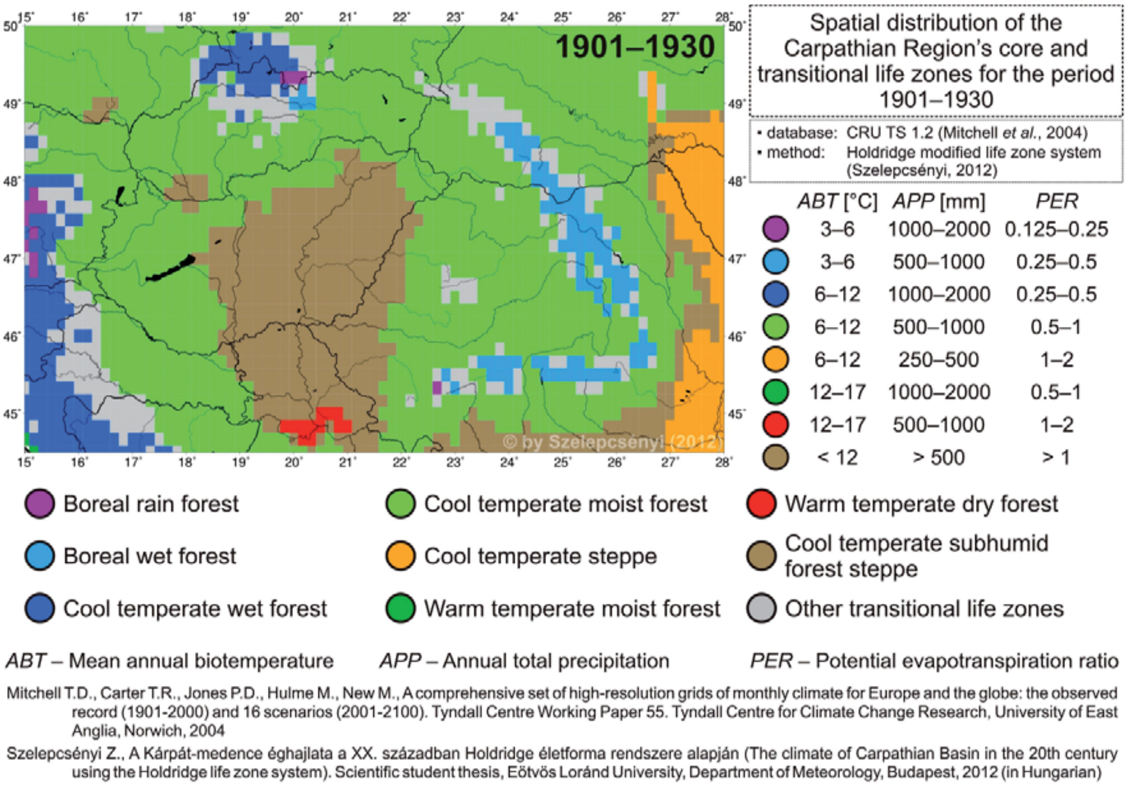

Figure 49. Spatial distribution of life zones for the period between 1901 and 1930

Although this appears to be an impressive number, it is far from optimal, as the Carpathian Basin covers over 300,000 km^2 and the available pollen profiles are not evenly distributed over this territory *(Fig. 48)*, which is characterized by the meeting and partial overlap of four climate zones *(Fig. 49)*.[21] As a result, different ecoregions[22] with diverse environmental and climatic conditions evolved in the Carpathian Basin. These ecoregions basically determined subsistence and food production *(Fig. 49)* of the communities settling here in the Neolithic,[23] the Copper Age,[24] and the Bronze Age,[25] as well as of other historical populations.[26]

Our investigations have also demonstrated that diverse environmental conditions characterized different regions and ecoregions of the Carpathian Basin during the medieval period,[27] and that the populations settling in diverse regions cultivated different plants and had diverse crop rotation systems.[28]

One of these ecoregions evolved in the southern part of Transdanubia.[29] The ecoregions in the Carpathian Basin influenced not only the type of crops grown, the crop composition, and crop yields, but they also offered attractive conditions for the settlement of populations with different social organizations and diverse farming systems, and thus promoted

21 Réthly 1933; Réthly – Aujeszky 1948; Bacsó 1959; Borhidi 1961; 1981; Sümegi 1995; 1996; 2007; Sümegi – Bodor 2000; Sümegi et al. 2012a; 2012b; Szelepcsényi et al. 2009; 2014.
22 Sümegi et al. 2015a; 2015b.
23 Sümegi 2003; 2003a; Sümegi et al. 1998; 2003.
24 Sümegi et al. 2002; 2003.
25 Sümegi – Bodor 2000; 2005.
26 Sümegi 1998; 2000; Sümegi et al. 2009a; 2009b.
27 Sümegi et al. 2015a.
28 Sümegi 2000.
29 Sümegi 1995; 1996; 2007; Sümegi et al. 1998; 2002; 2003.

interaction between different communities.[30] In other words, environmental diversity and the development of ecoregions in the Carpathian Basin has provided and still provides opportunities to communities with different economic and cultural backgrounds to settle, co-reside, and survive.[31]

In our view, one of the perhaps most important directions of future work is the identification and separation of different ecoregions through comparative analyses, of which the determination of the role of southern Transdanubia in the economic system of the medieval Hungarian Kingdom represents an important aspect. Another is the study of the impact of the Ottoman population on the emergence of new traditions in crop cultivation that differed from previous practices and the examination of the influence of the Early Modern Age on the economy and, in particular, on arable farming in the Carpathian Basin. In this respect, the appearance and spread of maize are particularly important issues because our comparative agrohistorical analyses indicate that this plant species played a prominent role in the transformation of the traditional meadow-pasture land-forest and floodplain economies as well as of the arable farming practices in the Carpathian Basin.

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REFERENCES

Bacsó 1959 — Bacsó, N.: *Magyarország éghajlata* [Climate of Hungary]. Budapest: Akadémiai Kiadó, 1959.

Bennett 1992 — Bennett, K. D.: 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 (992) 11–12.

Berglund – Ralska-Jasiewiczowa 1986 — Berglund, B. E. – Ralska-Jasiewiczowa, M.: Pollen analysis and pollen diagrams. In: *Handbook of Holocene Palaeoecology and Palaeohydrology.* Ed.: Berglund, B. E. Chichester – Toronto: J. Wiley & Sons Ltd., 1986, 455–484.

Beug 2004 — Beug, H. J.: *Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Gebiete.* München: Pfeil Verlag, 2004.

Birks – Birks 1980 — Birks, H. J. B. – Birks, H. H.: *Quaternary Palaeoecology.* London: Edward Arnold Press, 1980.

Borhidi 1961 — Borhidi, A.: Klimadiagramme und Klimazonale Karte Ungarns. *Annales Universitatis Scientiarium Budapestiensis de Lorando Eötvös Nominatae, Sectio Biologica* 4 (1961) 21–50.

30 Sümegi 2000; 2011.
31 Sümegi 2000; 2011.

Borhidi 1981	Borhidi, A.: Magyarország éghajlatának néhány vonása [Some characteristics of the climate in Hungary]. In: *Növényföldrajz, társulástan és ökológia*. Eds.: Hortobágyi, T. – Simon, T. Budapest: Tankönyvkiadó, 1981.
Braun et al. 1991	Braun, M. – Mészáros, I. – Sümegi, P. – Szűcs, L. – Lakatos, Gy.: Distribution of lead in a peat-bog of NE-Hungary. In: *Proceedings of the "International symposium on Ecological Approaches of Environmental Chemicals" April 15–17, 1991, Debrecen/Hungary*. GSF Berichte (1991), 15–21.
Braun et al. 1992	Braun, M. – Lakatos, Gy. – Mészáros, I. – Sümegi, P. – Szűcs, L. – Szöőr, Gy.: A kállósemjéni Nagy-Mohos láp fejlődéstörténete üledékföldtani, geokémiai, malakológiai és pollenanalitikai vizsgálatok alapján [Development of the Nagy-Mohos fen at Kállósemjén on the basis of sedimentological, geochemical, malacological and pollen analyses]. In: *Fáciesanalitikai, paleobiogeokémiai és paleoökológiai kutatások*. Ed.: Szöőr, Gy. Debrecen: MTA Debreceni Akadémiai Bizottság, Debrecen, 1992, 205–246.
Braun et al. 1993	Braun, M. – Sümegi, P. – Szűcs, L. – Szöőr, Gy.: A kálló-semjéni Nagy-Mohos láp fejlődéstörténete (Lápképződés emberi hatásra és az ősláp hipotézis) [Development of the Nagy-Mohos fen at Kállósemjén]. *Jósa András Múzeum Évkönyve* 33–35 (1993) 335–366.
Clark 1982	Clark, R. L.: Point count estimation of charcoal in pollen preparations and thin sections in sediments. *Pollen et Spores* 24 (1982) 523–535.
Engström – Wright 1984	Engström, D. R. – Wright, H. E.: Chemical stratigraphy of lake sediments as a record of environmental change. In: *Lake Sediments and Environmental History*. Eds.: Haworth, E. Y. – Lund, J. W. G. Minneapolis: University of Minnesota Press, 1984, 11–69.
Jakab – Sümegi 2004	Jakab, G. – Sümegi, P.: A lágyszárú növények tőzegben található maradványainak határozója mikroszkópikus bélyegek alapján [Key and description for the identification of fossil plant remains in peat]. *Kitaibelia* 9 (2004) 93–129.
Jakab et al. 2004	Jakab, G. – Sümegi, P. – Magyari, E.: New Quantative Method for the Palaeobotanical Description of Late Quaternary Organic Sediments (Mire-Development Pathway and Palaeoclimatic Records from Southern Hungary). *Acta Geologica Hungarica* 47 (2004) 373–409.
Jankó et al. 2005	Jankó, A. – Oross, A. – Timár, G.: *A második katonai felmérés – A Magyar Királyság és a Temesi Bánság nagyfelbontású színes térképei* [The Second Military Ordnance Survey – High-resolution colored maps of the Kingdom of Hungary and Temes]. DVD-ROM. Budapest: Arcanum, 2005.
Mackereth 1966	Mackereth, F. J. H.: Some chemical observation on post-glacial lake sediments. *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 250 (1966) 165–213.

Marsigli 1726 — Marsigli, L. F.: *Danubius Pannonico – Myscius, Observationibus geographicis, astronomicis, hydrographicis, historicis, physicis perlustratus*. Hague 1726.

Moore et al. 1991 — Moore, P. D. – Webb, J. A. – Collinson, M. E.: *Pollen Analysis*. Oxford: Blackwell Scientific Publications, 1991.

Reille 1992 — Reille, M.: *Pollen et Spores d'Europe et d'Afrique du Nord*. Marseille: Laboratoire de Botanique Historique et Palynologie, 1992.

Reimer et al. 2013 — Reimer, P. J. – Bard, E. – Bayliss, A. – Beck, J. W. – Blackwell, P. G. – Bronk Ramsey, C. – Buck, C. E. – Cheng, H. – Edwards, R. L. – Friedrich, M. – Grootes, P. M. – Guilderson, T. P. – Haflidason, H. – Hajdas, I. – Hatté, C. – Heaton, T. J. – Hogg, A. G. – Hughen, K. A. – Kaiser, K. F. – Kromer, B. – Manning, S. W. – Niu, M. – Reimer, R. W. – Richards, D. A. – Scott, E. M. – Southon, J. R. – Turney, C. S. M. – van der Plicht, J.: IntCal13 and MARINE13 radiocarbon age calibration curves 0–50,000 years cal BP. *Radiocarbon* 55 (2013) 1869–1887.

Réthly 1933 — Réthly, A.: Kísérlet Magyarország klímatérképének szerkesztésére a Köppen-féle klímabeosztás értelmében [An attempt to create a climatic map of Hungary based on Köppen's climatic classification]. *Időjárás* 37 (1933) 105–115.

Réthly – Aujeszky 1948 — Réthly, A. – Aujeszky, L.: *Agrometeorológia* [Agrometeorology]. Budapest: Quick Kiadó, 1948.

Síkhegyi 2008 — Síkhegyi, F.: A *Somogyi- és Zalai-dombság neotektonikája – morfostrukturális vizsgálatok* [Neotectonics of Somogy and Zala Hills – morphostructural analyses]. PhD Thesis, University of West Hungary, Sopron 2008.

Stockmarr 1971 — Stockmarr, J.: Tablets with Spores Used in Absolute Pollen Analysis. *Pollen et Spores* 13 (1971) 615–621.

Sümeghy 1953 — Sümeghy, J.: Medencéink pliocén és pleisztocén rétegtani kérdései [Pliocene and Pleistocene stratigraphy in Hungarian basins]. *Földtani Intézet Évi Jelentése 1951-ről*, 1953, 83–107.

Sümegi 1990 — Sümegi, P.: Első adatok a nyírségi lápok pleisztocén végi kialakulásáról [First data for the Late Pleistocene development of marshes in the Nyírség region, Hungary]. *Calandrella* 4 (1990) 13–15.

Sümegi 1995 — Sümegi, P.: Az utolsó 30.000 év változásainak rekonstrukciója őslénytani adatok alapján a Kárpát-medence centrális részén [Reconstruction of the last 30,000 years on the basis of paleontological data in the central part of the Carpathian Basin]. In: *Berényi Dénes professzor születésének 95. évfordulója tiszteletére rendezett tudományos emlékülés előadásai.* Debrecen: KLTE Meteorológiai Tanszék – Magyar Meteorológiai Társaság Debreceni Csoportja – MTA Debreceni Területi Bizottsága, Meteorológiai Munkabizottság, 1995, 244–258.

Sümegi 1996 — Sümegi, P.: A bátorligeti láp fejlődéstörténete [The development of the Bátorliget fen]. *Calandrella* 10 (1996) 151–160.

Sümegi 1998 — Sümegi, P.: Az utolsó 15000 év környezeti változásai és hatásuk az emberi kultúrákra Magyarországon [Environmental changes and their effects on human cultures in Hungary during the last 15,000 years]. In: *A régésztechnikusok kézikönyve* I. Panniculus Ser. B. No. 3. Ed.: Ilon, G. Szombathely: Savaria Múzeum, 1998, 367–397.

Sümegi 2000 — Sümegi, P.: A középkori Kárpát-medence éghajlati és környezeti viszonyai [Climate and environment of the Carpathian Basin during the medieval period]. In: *A középkori magyar agrárium*. Eds.: Bende, L. – Lőrinczy, G. Ópusztaszer: Ópusztaszeri Nemzeti Történeti Emlékpark Közhasznú Társaság, [Szeged]: Csongrád Megyei Múzeumok Igazgatósága, 2000, 9–25.

Sümegi 2003 — Sümegi, P.: *Régészeti geológia és történeti ökológia alapjai* [Basis of geoarcheology and environmental ecology]. Szeged: JATEPress, 2003.

Sümegi 2003a — Sümegi, P.: Early Neolithic man and riparian environment in the Carpathian Basin. In: *Morgenrot der Kulturen*. Frühe Etappen der Menschheitsgeschichte in Mittel- und Südosteuropa. Festschrift für Nándor Kalicz zum 75. Geburtstag. Eds.: Jerem, E. – Raczky, P. Budapest: Archäologische Institut der Eötvös Loránd Universität – Archaeoligua, 2003, 53–60.

Sümegi 2004 — Sümegi, P.: The results of palaeoenvironmental reconstruction and comparative geoarcheological analysis for the examined area. In: *The geohistory of Bátorliget Marshland.* Example for the Reconstruction of Late Quaternary Environmental Changes and Past Human Impact from the Northeastern Part of the Carpathian Basin. Eds.: Sümegi, P. – Gulyás, S. Budapest: Archaeolingua, 2004, 301–348.

Sümegi 2007 — Sümegi, P.: *Magyarország negyedidőszak végi környezettörténete* [Late Quaternary ennvironmental history of Hungary]. DSc Dissertation, Hungarian Academy of Sciences. Budapest – Szeged 2007.

Sümegi 2011 — Sümegi, P.: A link between regions – The role of the Danube in the life of European communities. In: *Ten Thousand Years along the Middle Danube. Life and Early Communities from Prehistory to History*. Eds.: Kovács, Gy. – Kulcsár, G. Varia Archaeologica Hungarica 26. Budapest: Archaeological Institute of HAS, 2011, 9–44.

Sümegi – Bodor 2000 — Sümegi, P. – Bodor, E.: Sedimentological, pollen and geoarcheological analysis of core sequence at Tököl. In: *SAX: Százhalombatta Archaeological Expedition. Annual Report 1 – Field season 1998.* Eds.: Poroszlai, I. – Vicze, M. Százhalombatta: Matrica Museum, 2000, 83–96.

Sümegi – Bodor 2005	Sümegi, P. – Bodor, E.: 2005. Geoarcheological and archaeobotanical investigations in the valley of the Benta (Békás) creek. In: *SAX: Százhalombatta Archaeological Expedition. Report 2 – Field season 2000–2003.* Eds.: Poroszlai, I. – Vicze, M. Százhalombatta: Matrica Museum, 209–236.
Sümegi – Vissi 1991	Sümegi, P. – Vissi, E.: A pocsaji láp kialakulása és fejlődéstörténete [The development of the Pocsaj fen]. *Calandrella* 5 (1991) 15–27.
Sümegi et al. 1994	Sümegi, P. – Braun, M. – Hertelendi, E. – Patakné Félegyházi, E. – Vissi, E. – Szabó, E. – Tóth, A. – Szöőr, G.: A pocsaji láp kialakulása és fejlődéstörténete I. [Palaeoecological studies on the Pocsaj fen I]. In: *I. Kelet-magyarországi vad és halgazdálkodási természetvédelmi konferencia kiadványa*. Debrecen: Agrártudományi Egyetem, 1994, 359–362.
Sümegi et al. 1998	Sümegi, P. – Hertelendi, E. – Magyari, E. – Molnár, M.: Evolution of the environment in the Carpathian Basin during the last 30 000 BP years and its effects on the ancient habits of the different cultures. In: *Archeometrical Research in Hungary*. Eds.: Költő, L. – Bartosiewicz, L. Budapest: Hungarian National Museum – Directorate of Somogy Museums, 1998. II. 183–197.
Sümegi et al. 2002	Sümegi, P. – Krolopp, E. – Rudner, E.: Negyedidőszak végi őskörnyezeti változások térben és időben a Kárpát-medencében [Late Quaternary environmental changes in the Carpathian Basin in space and time]. *Földtani Közlöny* 132 (2002) 5–22.
Sümegi et al. 2003	Sümegi, P. – Kertész, R. – Rudner, Z. E.: Palaeoenvironmental History of Hungary. In: *Hungarian Archaeology at the Turn of the Millennium.* Ed.: Visy, Zs. Budapest: Ministry of National Cultural Heritage – Teleki László Foundation, 2003, 51–56.
Sümegi et al. 2009a	Sümegi, P. – Jakab, G. – Majkut, P. – Törőcsik, T. – Zatykó, Cs.: Middle Age palaeoecological and palaeoclimatological reconstruction in the Carpathian Basin. *Időjárás* 113 (2009) 265–298.
Sümegi et al. 2009b	Sümegi, P. – Törőcsik, T. – Jakab, G. – Gulyás, S. – Pomázi, P. – Majkut, P. – Páll, G. D. – Persaits, G. – Bodor, E.: The environmental history of Fenékpuszta with a special attention to the climate and precipitation of the last 2000 years. *Journal of Environmental Geography* 2 (2009) 5–14.
Sümegi et al. 2012a	Sümegi, P. – Persaits, G. – Gulyás, S.: 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 Palaeobotanical and Mollusk Remains. In: *Ecotones Between Forest and Grassland*. Ed.: Myster, R. W. New York: Springer Press, 2012, 17–57.

Sümegi et al. 2012b — Sümegi, P. – Gulyás, S. – Persaits, G. – Szelepcsényi, Z.: Az erdőssztyepp hosszú távú fejlődése az Alföldön palaeoökológiai adatok alapján [Environmental change in the forest steppe habitat of the Great Hungarian Plain based on paleoecological data]. In: *Sokarcú klímaváltozás*. Eds.: Rakonczai, Z. – Ladányi, Zs. – Pál-Molnár, E. Szeged: GeoLitera, 2012, 7–24.

Sümegi et al. 2015a — Sümegi, P. – Bede, Á. – Szilágyi, G.: Régészeti geológiai, geoarcheológiai és környezettörténeti elemzések régészeti lelőhelyeken – a földtudományok és a régészet kapcsolata [Analyses of archeological geology, geoarcheology and environmental history on archeological sites. Contact between earth sciences and archeology]. *Archeometriai Műhely* 12 (2015) 135–150.

Sümegi et al. 2015b — Sümegi, P. – Náfrádi, K. – Törőcsik, T. – Jakab, G.: A komplex archeobotanikai nemzetközi és magyarországi kutatástörténete [History of complex archaeobotany in Hungary and worldwide]. In: *Komplex archeobotanika*. Eds.: Törőcsik, T. – Náfrádi, K. – Sümegi, P. Szeged: GeoLitera, 2015, 61–95.

Szelepcsényi et al. 2009 — Szelepcsényi, Z. – Breuer, H. – Ács, F. – Kozma, I.: Biofizikai klímaklasszifikációk (1. rész: a módszerek bemutatása) [Biophysical climatic classifications – part 1: methods]. *Légkör* 54 (2009) 21–26.

Szelepcsényi et al. 2014 — Szelepcsényi, Z. – Breuer, H. – Sümegi, P.: The climate of Carpathian Region in the 20th century based on the original and modified Holdridge life zone system. *Central European Journal of Geosciences* 6 (2014) 293–307.

Timár et al. 2008a — Timár, G. – Molnár, G. – Székely, B. – Plihál, K.: Lázár térképe és a ptolemaioszi vetület [The map of Lazarus (1528) and the Ptolemian projection]. *Geodézia és Kartográfia* 60 (2008) 20–26.

Timár et al. 2008b — Timár, G. – Molnár, G. – Székely, B. – Biszak, S. – Jankó, A.: *Magyarország topográfiai térképe a második világháború időszakából* [Topographic maps of Hungary from World War 2]. DVD-ROM. Budapest: Arcanum, 2008.

Timár et al. 2011 — Timár, G. – Biszak, S. – Székely, B. – Molnár, G.: Digitized Maps of the Habsburg Military Surveys: Overview of the Project of ARCANUM Ltd. (Hungary). In: *Preservation in digital cartography. Lecture Notes in Geoinformation and Cartography*. Ed.: Jobst, M. Berlin – Heidelberg: Springer, 2011, 273–283.

Willis et al. 1995 — Willis, K. J. – Sümegi, P. – Braun, M. – Tóth A.: The Late Quaternary environmental history of Bátorliget, N.E. Hungary. *Palaeogeography, Palaeoclimatology, Palaeoecology* 118 (1995) 25–47.

Willis et al. 1997 — Willis, K. J. – Braun, M. – Sümegi, P. – Tóth A.: Does soil change cause vegetation change or vice-versa? A temporal perspective from Hungary. *Ecology* 78 (1997) 740–750.

Willis et al. 1998 — Willis, K. J. – Sümegi, P. – Braun, M. – Bennett, K. D. – Tóth, A.: Prehistoric land degradation in Hungary: who, how and why? *Antiquity* 72 (1998) 101–113.

Willis et al. 2000 — Willis, K. J. – Rudner, E. – Sümegi, P.: The full-glacial forests of central and southeastern Europe: Evidence from Hungarian palaeoecological records. *Quaternary Research* 53 (2000) 203–213.

GEOMORPHOLOGICAL RESEARCH IN AND AROUND BERZENCE, ON THE BORDER OF THE DRAVA VALLEY AND INNER SOMOGY MICROREGION, HUNGARY

István Viczián

INTRODUCTION

The geographical features of the environment may determine the everyday life of its inhabitants in many ways at any given time, yet the landscape also bears imprints of society's impact on the environment. An interdisciplinary approach, collaboration between the social and natural sciences, is therefore especially important in research of human-environmental interactions. Geomorphological research can be of aid not only in the pre-fieldwork planning of archaeological research and fieldwork, but also in the interpretation of its findings, the reconstruction of environmental conditions in various time periods, and the way those geographical features were used. At the same time, the results of archaeological and historical explorations can also be of great assistance to geomorphological research, providing useful data for environmental conditions and changes.

Within the framework of a research project undertaken at the Institute of Archaeology of the Research Centre for the Humanities of the Hungarian Academy of Sciences between 2008 and 2013,[1] Csilla Zatykó carried out historical and archaeological explorations in and around Berzence in Somogy County, with the aim of reconstructing the features of medieval land use, settlement structures, and farming. The research was based on the findings of several disciplines, including exceptionally detailed descriptions of the area from two fourteenth-century deeds distributing estates, data recorded in the course of archaeological field surveys, and the analysis of geoarchaeological samples as well as the results of the geomorphological survey presented in this study.

The study of human-environmental interaction conducted in the Hungarian-Croatian border zone focused on three Hungarian settlements of Somogy County: Berzence, Somogyudvarhely, Gyékényes, and two villages in Croatia: Gola and Ždala *(Fig. 1)*.

A decisive part of the study area is located on the alluvial plain of the Drava River and its tributaries where arable lands dominate the landscape at present, although historical sources and archaeological data describe lakes, a mill, fishing places, and extensive marshes in the same area.[2]

The primary aim of this geomorphological study is to identify the medieval environmental (geological, geomorphological, hydrographical, hydrological) conditions under which the region's inhabitants lived and to complement historical and archaeological research with an understanding of geomorphological processes and human impacts on the environment. Historical sources and maps were also consulted to reconstruct the human-environment relationship.

1 "Studies on Settlement Archaeology and Environmental History in Southern Transdanubia, 1300–1700" (Hungarian Scientific Research Fund [OTKA] Grant K 72231).

2 Zatykó 2010; Viczián – Zatykó 2011.

Figure 1. Location of the study area. 1: Drava plain, 2: territories rising above the Drava plain with steep slopes, 3. Hungarian-Croatian border, 4: study area

GEOGRAPHICAL AND GEOMORPHOLOGICAL CONDITIONS

The study area is divided into two microregions with different characteristics. The major part belongs to the microregion of the Central Drava Valley, while the eastern–northeastern part to the Inner Somogy microregion. The border of the two microregions is clearly demarcated by a steep bluff, which is 8–10 meters high between Gyékényes and Berzence, and averages a height of 30 meters between Berzence and Somogyudvarhely *(Figs 2–3)*.

The Holocene evolution of the alluvial fan of the Drava River and its tributaries basically determines the geomorphological features of the area *(Fig. 4)*. Landforms of the abandoned meanders of the Drava River are still well recognizable at the foot of the bluff. The Zsdála Stream that forms the border between Hungary and Croatia also flows in a partly filled up palaeochannel of the Drava River, 2–5 kilometers south of the bluff. The current channel of the Drava River lies 8–10 kilometers from the bluff.

The repetitive avulsions, the riverbed migration to the south are mainly related to the differential tectonic movements in the Drava Valley.[3] The Drava *Graben* [ditch] is divided into several sub-basins *(Fig. 5)*. The line of the bluff also follows the margin of a basin. The river valley narrows at the Zákány block, then widens to the north into the study area, which tectonically corresponds to the Gyékényes-Gola sub-basin and then turns to the south approaching the bluff at Bélavár.

Apart from the tectonic movements, climate changes have also had a significant impact on the river channel migration and the evolution of the floodplain. Climatic factors affect river discharge, incision, and aggradations processes. The subsidence of the sub-basins and the river incision lead to the lowering of the local base level of the river, consequently the low-

[3] Lovász 1964; 1972; Bognár et al. 2009.

Figure 2. The bluff at Somogyudvarhely
(photograph by István Viczián, 2010)

Figure 3. The bluff at Berzence
(photograph by Zsuzsa Miklós, 2012)

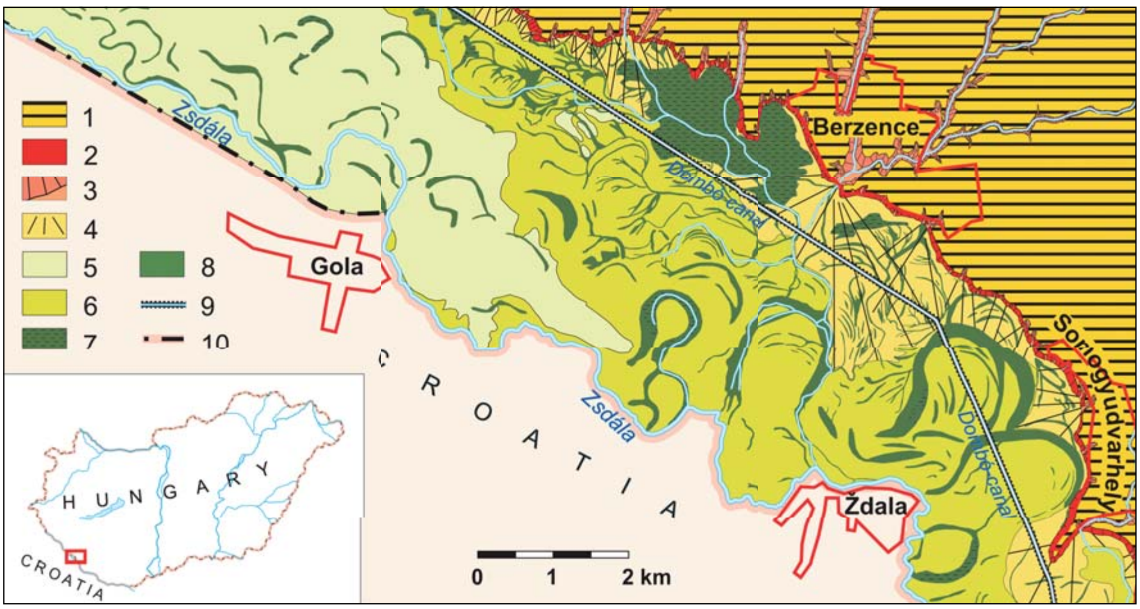


Figure 4. Geomorphological map of the study area
1: alluvial plain with wind-blown sand forms, 2: escarpments, 3: stream valleys and gullies, 4: alluvial fans, 5: higher alluvial plain, 6: lower alluvial plain, 7: wetlands and marshy areas, 8: low-lying paleochannels and channels of the perennial and ephemeral streams, 9: Dombó-csatorna, 10: Hungarian-Croatian border

lying surfaces became the sites of active floodplain development. With the lowering of the base level, the former fluvial floodplains remained on a higher elevation, and from then on, they were rarely or no longer affected by the river. However, relict landforms (river channels, oxbow lakes, backswamps) remained defining elements of the environment for long and acted as reservoirs for lakes, swamps, and marshes, until they gradually became filled up.

Three tectonically and geomorphologically successive stages can be distinguished in the evolution of the Drava River's alluvial plain in the Gyékényes-Gola sub-basin, depending on how, when, to what degree, and in what range the river dominated its surroundings or lost direct contact with it.[4] In the earliest period, at the end of the Pleistocene and the beginning of the Holocene, the Drava River flowed significantly farther north, approximately in the strip bordered by the Zsdála Stream and the bluff.

4 Bognár et al. 2009.

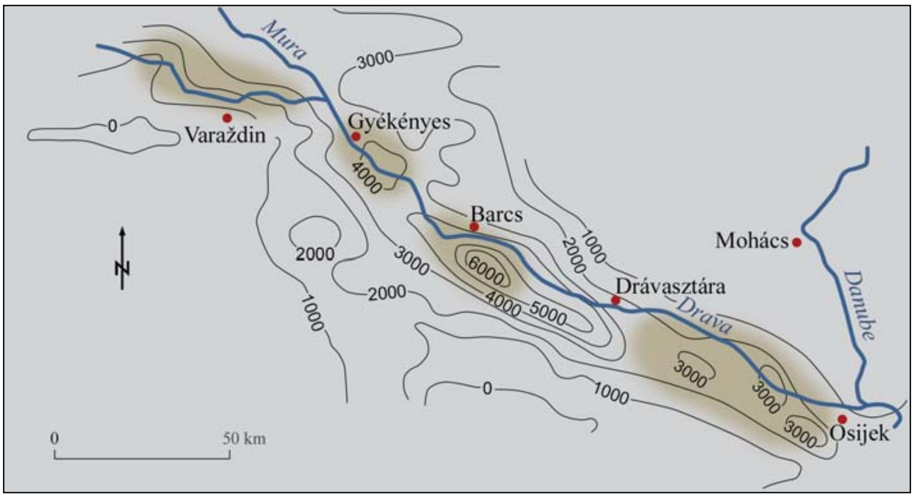


Figure 5. Depth of the pre-Neogene basement in the Drava Valley (after Bognár et al. 2009)

The bluff also marks the tectonic demarcation between the uplifting Inner Somogy microregion and the subsiding Drava Valley. The river's lateral erosion has played a fundamental role in shaping the steep wall. The sandy sediments making up the bluff deposited by the meandering Drava River were partly reworked by the wind.[5] In the second phase, in the Early Holocene, the subsidence of the Drava basin and the uplift of the Zala Hills became more intensive. The Drava River built an alluvial fan and shaped its floodplains. This phase determined the most current geological and geomorphological conditions in the Central Drava Valley; the remains of the riverbed are still in evidence *(Fig. 6)*. In the third phase, during the second half of the Holocene, the channel of the Drava River migrated further to the south and the river gradually occupied its present location.[6]

After this brief introduction of the phases, let us consider the geomorphological and environmental conditions of the study area from north to south. Since the archaeological explorations covered the area of the Drava Valley for the greater part, less attention is accorded to the areas within the Inner Somogy microregion. Its landforms are not shown in detail on the geomorphological map either. Drillings on the margin of the Inner Somogy microregion near the bluff typically yield fluvial sand with silt, sand, and gravel horizons deposited by the Drava River. The area elevated in the Würm and its surface was no longer shaped by the fluvial processes of the Drava River, but rather by wind and stream erosion.[7] The wavy plane of this area is covered by wind-blown sand and different sand forms. The southern part of the Inner Somogy microregion is dissected by gullies and stream valleys.

The bluff forms the border between the two microregions; its formation can be dated to the end of the Pleistocene and the early Holocene.[8] The curves of the former riverbed of the Drava River are clearly recognizable on the geomorphological map *(Fig. 4)* as it flowed by the foot of the bluff, washing it away by lateral erosion. Even the line of the bluff's escarpment follows the former meandering line of the river.

Flat alluvial fans are being deposited by the streams (e.g. the Tekeres-berek, Lipék, and Vadaskerti-árok at Berzence) arriving from the Inner Somogy microregion and entering the

5 Marosi 1970.
6 Bognár et al. 2009.
7 Lovász 1964.
8 Bognár et al. 2009.

Drava Valley at the foot of the bluff. Their sediments are filling up the remains of the Early Holocene bed of the Drava River. In some places, marshy areas or fragments of former Drava channels are located between the fans. The waters of the marshes and swamps found in a 1 to 2 km strip along the bluff are replenished not only by the streams, but also by the groundwater and branching watercourses flowing through the alluvial fans and occasionally appearing at the foot of the bluff as springs. The valleys cutting across the bluff provide a suitable passage from the settlements lining the edge of the bluff to the lower-lying areas of the Drava Valley. The surfaces of the major alluvial fans that are higher than their surroundings still mark the possible routes leading across the wetlands, even farther away from the bluff.

Figure 6. The Zsdála Stream bed (on the left) and a former meander surrounded by forest (in the background) (photograph by István Viczián, 2010)

The geomorphological and sedimentary features of the Central Drava Valley microregion were basically affected by the fluvial evolution of the Drava River and the subsidence of the sub-basin in the early Holocene. Its geomorphology is characterized by the channel migration of the Drava River and the twisting beds of its tributary streams and the rich variety of landforms in its floodplains. The streams entering the floodplain of the Central Drava Valley split into several channels and flow towards the lower-lying areas along the lines of the former meanders of the Drava River, creating swampy and marshy areas in some places. The gravel and sandy gravel mined in these areas were deposited by the Drava River. The composition of the surface layers depends on the various fluvial processes and floodplain landforms.

The alluvial plain of the Drava River can be divided into two geomorphological units according to the average altitude of their surfaces: the lower-lying alluvial plain and the alluvial plain extending on a higher level *(Fig. 4)*.

The lower alluvial plain lies at 114 to 119 m above sea level. The area of the plain is defined by the remnants of the Early Holocene abandoned channels of the Drava River, as well as by the slightly protruding point bars and the series of low-lying scroll bars between them. The northern part of the area lying below the bluff is covered by the sandy deposits of the streams of the Inner Somogy microregion. The surface of the interconnected alluvial fans is dissected by perennial, ephemeral, and abandoned channels of the streams and forms a gentle slope towards the lower-lying alluvial plains located to the south and southeast.

A number of abandoned meanders of the Drava River are well recognizable on the lower-lying alluvial plain, especially in the regions of the Zsdála Stream and the settlements of Berzence and Somogyudvarhely. The former meanders collected the waters of the region and led them first into the Zsdála Stream and then into the Drava River. The channels of the streams entering the Drava Valley followed the course of these riverbeds until the Dombó-csatorna was built. The remnants of former river channels are quite filled up at present. Wetland still can be found only in their lower-lying areas. The groundwater flows easily in the near-surface gravel deposits of the area. The groundwater level is highly dependent on the water regime of the Drava River. Its general level has decreased notably over the last centuries, which resulted in a significant shrinkage of the periodic and permanent ponds formed in the meanders, as well as in the areas covered by the swamps and marshes. The mechanization of agriculture has also contributed considerably to the vanishing of abandoned meanders. The few-meter-deep shallow depressions of former meanders disappeared, especially in areas that have been deforested and drawn into cultivation. Prior to the completion of the water regulation works, the lower-lying alluvial plain was covered by patches of swamp and marshland, wide areas were recurrently affected by inland water, with the appearance of the landscape dominated primarily by extended floodplain forests.

Traces of the former meanders of the river can also be found on the alluvial plain extending on a higher level, although in much fewer numbers and even more filled up. The Zsdála Stream also crosses it, its channel following a former Early Holocene Drava bed or its branches. Former abandoned beds of the Zsdála Stream can be noted running parallel to the current stream. The average altitude of the higher-lying alluvial plain is 119–122 meters a.s.l., barely rising above the lower-lying alluvial plain by a few meters, although the role of the Drava River in shaping the surface became subordinate at an earlier stage in this area than in the lower-lying parts. Currently, apart from the effects of fluvial and aeolian processes and mass movements, the main factors in surface development were primarily anthropogenic impacts, especially the consequences of arable farming. The former meanders were gradually filled up, with their wet, swampy remains restricted to a few areas.

The separation of the surface of the higher alluvial fan from the lower-lying areas must have already occurred in the Early Holocene. As a consequence of the rising of the Zala Hills, the streams heading for the Drava River from the north deposited a significant amount of alluvial sediments. Northwest of the study area, but nevertheless affecting it, an alluvial fan was formed by two torrential streams in the area of Zákány, pushing the riverbed of the Drava River south, and blocking it by partly filling up the former meanders.[9] The higher-lying alluvial plain became a high floodplain terrace. The development of the higher ground surface cannot be explained only by the alluvial fan formation. Multi-phase differential tectonic movements characterize certain parts of the recent Gyékényes-Gola basin. Based on the geomorphological position and the level of sediments filling up former riverbeds as observed in the area of the Drava Valley, it can be presumed that the subsidence of the area surrounded by Berzence, Gola, and Somogyudvarhely was stronger than in the areas lying to its northwest and west. These former subsided areas were part of the Drava River's sphere of influence for longer; its fluvial landforms retained their shape to a greater extent than the meander remains of the higher-lying alluvial plain and its oxbow lakes, which are in a later phase of being filled up. The incision of the watercourse collecting the streams from the Inner Somogy microregion (currently the Dombó-csatorna) kept abreast of the subsidence, leaving its mark on them as it undercut the bluff, and deepened the valley at the foot of the alluvial fan of the streams, while consequently filling out and reshaping the former meanders of the Drava River. The tangled network of streams, marshy, and swampy areas diversified the landscape. Next to the Dombó-csatorna, 1.5–3 km west-southwest of Berzence, a series of flat ridges (called *göröndi* in Hungarian) are found, behind which watery groves lay in the past.

GEOMORPHOLOGICAL AND HYDROLOGICAL CHANGES IN THE REGION

Despite the seeming uniformity of the Drava Valley plains, it is a mosaic of areas with different characteristics. Their traits are geomorphologically defined by the remains of the palaeochannels of the Drava River filled partially or completely with sedimentary deposits,

9 Lovász 1964.

stream channels, and other floodplain landforms. Such environmental diversity is highly significant for human settlement and land use.

The territorial extent of individual environment types, the character of the region was continuously transforming to a significant degree – within certain limits – even during the study period. The floodplains' environment is a fragile system whose environs can easily be changed drastically even through small effects, both natural (climate change, tectonic movements, hydrological changes, etc.) and human (digging of dikes, draining or raising of water levels in ponds or marshes, channeling of rivers, agricultural activity, hydro-power plants, etc.). It is the presence of water that principally determines the environmental traits that greatly determine possible human strategies: either adapting to them, exploiting the advantages they offer, or adapting them appropriately to a given purpose. The rise of the rivers' water level or of the groundwater level can cause significant environmental changes, as the existence of marshes and ponds, the change of groundwater levels, the gathering of inland water, the magnitude and frequency of floods as well as the persistence of inundation depends on it. In the alluvial plains of the Drava Valley, a difference of even a few meters in the height of landforms can determine whether a given area forms a pond, a marsh, a place susceptible to inland waters, or a safe terrain suitable for settlement and construction.

The area no longer belongs to the immediate sphere of influence of the Drava River, as it flows at a distance of quite a few kilometers and its floods do not impact the area directly. Even so, it still has a significant effect on its hydro-geographical conditions, and the level of groundwater in an indirect way. However, the environmental role of the Drava River was greater in the historical period discussed here. Not only natural processes, but also human intervention to reshape the region is responsible to a large extent for the diminution of its role.

The geomorphological examination of the Drava Valley and a schematic understanding of the successive phase in its surface development based on it indicate that the gradual southward movement of the riverbed, a decrease in the direct impact of the river in shaping the land surface, and the filling up and increasing dryness of the region were the general tendency during the Holocene. Nevertheless, the trajectory of this process may have been altered significantly due to the climate, or even reversed in wetter climatic periods. The hydrological regime and the state of the environment could change substantially, depending on the given climatic conditions. When investigating the environmental history of the region, the way in which the climate changed over the last thousand years has to be taken into account. Hubert Lamb[10] was the first to present evidence that pointed to a notably warm climate in many parts of the world that lasted a few centuries round 1000–1200 AD, and was followed by a decline of temperature levels between 1500 and 1700, the coldest phase since the last Ice Age. There is now growing evidence in the international literature for the existence of the Medieval Warm Period and the Little Ice Age, and, in particular, there is increasing evidence for the medieval climatic variability in Hungary.[11]

Archaeological sites from the eleventh–fourteenth centuries found on small, low-elevation Danube islands (Felső-sziget at Neszmély, Helemba-sziget at Esztergom, and Óbudai-sziget at Budapest) reflect a stable, warmer climate with low water levels and rare flood events.[12]

During the Little Ice Age (fourteenth to nineteenth centuries), mountain glaciers expanded in the Alps.[13] Extreme cold winters and cool and wet summers occurred, frequent

10 Lamb 1965.
11 Vadas 2010; Kiss – Laszlovszky 2013.
12 Viczián 2014.
13 Holzhauser et al. 2005; Schimmelpfennig et al. 2014.

floods, famines, epidemics, and wars raged throughout Europe.[14] A complex analysis of lake and peat-bog sediments in Hungary shows that in the late fourteenth century, apart from one short warmer period, a sustained period of cooling set in and lasted up to the later nineteenth century, when the temperature started to rise steeply.[15] In the German section of the Danube, maxima of flood frequency occurred in 1500, 1650, and 1750, respectively.[16] Archaeological and sedimentary investigations pointed to a general rise in Danube water levels, frequent flood occurrences, and a significant increase in groundwater levels along the river during the fourteenth–sixteenth centuries, with a peak in the later sixteenth century.[17]

On the basis of historical sources, geographical and archaeological observations, and maps decipting the Berzence region[18] a wetter, swampy, pond-filled environment can be assumed here in the medieval and modern periods. This can be explained in part by the fact that the former meanders were not as filled up as they are now, and that the wetter conditions were also due to the more humid climate period and a more moderate evaporation because of the colder climate. Most importantly, however, it was due to the fact that the impact of the water management and river regulation works carried out during the nineteenth–twentieth centuries had not yet been in effect.

Several Árpádian Age sites on the lower alluvial plain yielded finds related to iron smelting activity, such as slag, iron blooms, and tuyère fragments.[19] The formation of bog iron is typical in reductive environments, in areas with a high groundwater level, swampy and marshy lands, just like this area used to be during most of the Holocene.

It can be assumed that the warmer, dryer, more balanced climate of the Medieval Warm Period resulted in a decrease of groundwater levels and thus the former meanders were also less waterlogged than in the ensuing colder, more humid periods. Descriptions from the ensuing centuries speak of more extensive swamps and ponds. A 1377 deed distributing an estate in the Drava Valley, south of Berzence, mentions at least twenty ponds and places for fishing in addition to plots of land and meadows. The deed names the ponds and places for fishing as fishing ponds (*piscina* in Latin), but the frequent use of the expressions *strug* and *geregye* can be related to slow-flowing, shallow waterways used for weir fishing.[20]

Centuries later, we again find evidence for wet, floodplain environments. In his account of the siege of Berzence in 1664, the Turkish traveler Evliya Çelebi[21] describes the marshes along the line of the modern Dombó-csatorna and the destruction of the castle. He reports that marshes extend for two hours' travel far on the southeastern and western side of the castle.

A more detailed understanding of the changing state of earlier existing swamps and ponds, and of the natural and human influences behind them remain the subject of further research. Their location, however, can be determined with the aid of geomorphology. Where could these ponds and fishing places mentioned in the deeds have been located? The damming of streams that cut into the land surface of the Inner Somogy microregion would have enabled the creation of ponds. Such ponds still exist in the area of Berzence and to its north, using the water of Tekeres-berki-patak, and also to the southeast of Csurgó.

Within the Drava Valley, the former meanders might have served as fishing ponds or places suitable for weir fishing. Among them, those that are deeper and have more significant surface and subsurface water sources, and were filled up more, are most likely to have been ponds.

14 Behringer 2010.
15 Sümegi et al. 2009.
16 Böhm – Wetzel 2006.
17 Kiss – Laszlovszky 2013; Mészáros – Serlegi 2011.
18 Viczián – Zatykó 2011.
19 Zatykó 2013.
20 Zatykó 2010; Zatykó 2013.
21 Evlia Cselebi 1985.

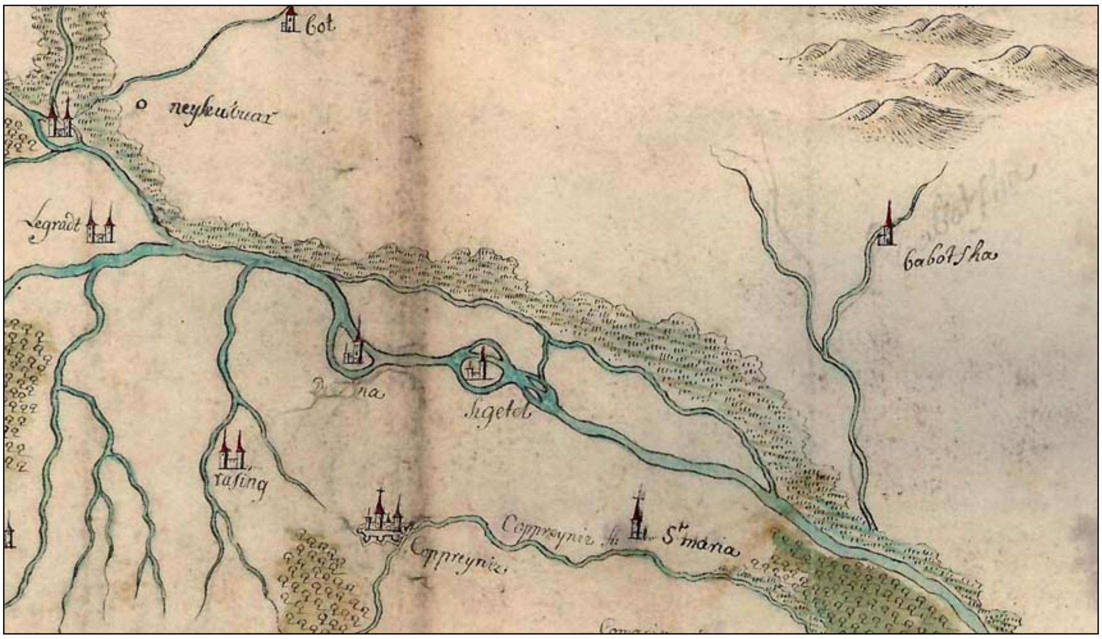
These attributes are especially true of the meanders between the settlements of Gola, Berzence, and Zsdála *(Fig. 2)*: particularly in the double meander stretching a little to the west and the meander more to the east, which drained the waters of the streams. A copious stream probably ran through the latter prior to the construction of the Dombó-csatorna, collecting the waters coming from the north and draining them into the Zsdála Stream. When the groundwater level had averaged higher than at present, the voluminous stream gathering the nearby waters supplied the area of the meander not yet silted up with ample water. The location of the meander allows for placing a dam on the stream to back its waters up.

Figure 7. Detail of a map from 1850 showing the Zsdála Stream as a branch of the Drava River, National Széchényi Library (OSZK TK 1851)

The other place worthy of consideration as suitable for fishing would be the double meander lying 500 meters west of the previous one. Currently, a gravel pit operates in the area of the former meanders. No watercourse from a distant source can be found among the ones supplying the network of meanders. However, under conditions when the groundwater level was higher, or there were sources of groundwater, or confined aquifers on the surface of the margin of higher-lying alluvial fan, or in the meanders, and under certain other circumstances, the Zsdála Stream could have supplied enough water to ensure a constant water coverage in two permanent ponds here. Further water supply is possible through the damming of the nearby Zsdála Stream (e.g. around the site once called the Postamalom [Post office-mill]). The more southern meander is shown as a pond on a map from 1851 in the Map Collection of the National Széchényi Library (OSZK TK 1851) *(Fig. 7)*, called N(agy) Gerend (today: Kis- és Nagy-Gerendai-dűlő). It is still an alder marsh at present.

Regarding the medieval hydrography of the study area, it is an important issue whether the Zsdála Stream functioned as a side-channel of the Drava River in the period, and to what extent the floods of the Drava River affected the region. A number of maps in the National Széchényi Library depict the Zsdála Stream as a by-channel of the Drava River – among them a map from 1685 (OSZK TK 2149), and one from around 1790 (OSZK TK 358) *(Fig. 8. 1–2)* – with the area surrounded by the river and the stream shown as Répás-sziget on many of the maps. János Hunfalvy[22] describes the Drava River as follows: "it often splits into a series of branches and encloses smaller or larger islands. […] One of the largest of its islands is Répás-sziget at Berzence, southeast of Légrád, located in Novo Selo." On the map of the First Military Ordnance Survey of the area in 1784, the Zsdála Stream is depicted merely as a stream whose source is somewhere in the hills by Zákány, and many other maps of the eighteenth–nineteenth centuries depict it in similar fashion. It should be noted, though, that the Zsdála Stream flows in an Early Holocene Drava meander or side-channel, and was probably related to the river even in the second half of the Holocene. By now, its bed has filled up dramatically in the west, and barely a kilometer separates it from the river near Gyékényes. Numerous detailed maps show the Zsdála *Graben* draining into the Drava River

22 Hunfalvy 1865.



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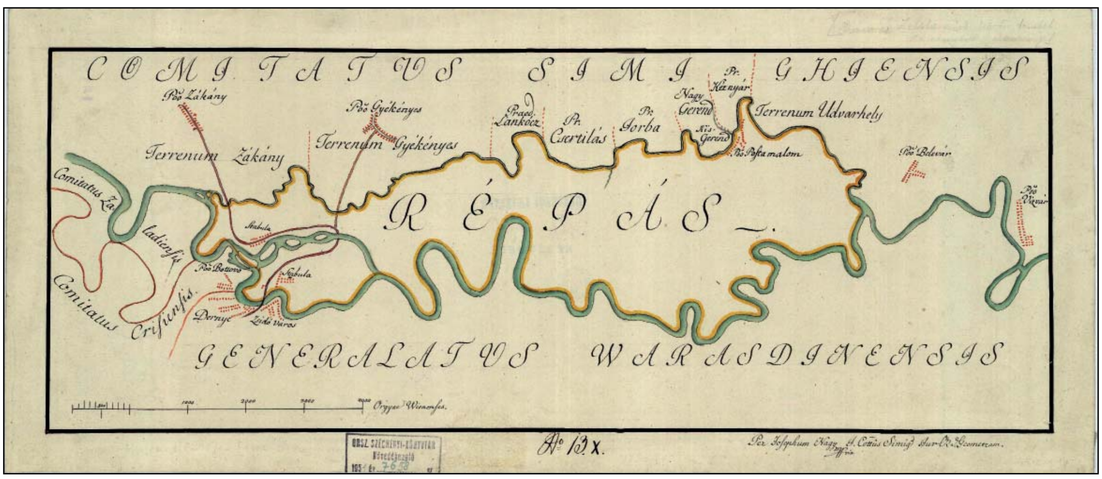

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Figure 8. The Zsdála Stream as a branch of the Drava River on maps from the Map Collection of the National Széchényi Library. 1: 1685 (OSZK TK 2149), 2: around 1790 (OSZK TK 359)

to the south of Zákány.[23] As shown on the map from 1786, it is an *"Einflus der Sdalla Grabens* (Einfluss des Sdalla Grabens [the inflow of the Zsdála Graben])", with a little arrow denoting that the waters flowed towards the Drava River *(Fig. 9)*. It is likely on the above grounds that water reaching the former, by now gradually filled bed of the Drava River drained into the river partly south of Zákány, and in part through the current bed of the Zsdála Stream, it flowed east and then drained into the Drava River at Bélavár.

At times of the exceptionally heavy, devastating peakfloods of the Drava River, the waters must have found their way into the old riverbeds, and a lesser part of the flood would have even been drained by the Zsdála Stream. Whether there was a more significant link between the two watercourses in the medieval period, and when the branch of the Drava

23 Hungarian National Archives, MOL S 12 Div 13 No. 70:7 and 70:8 of 1786; MOL S 12 Div 13 No. 237:1 and 237:2 of 1793; MOL S 12 Div 18 No. 72:2 and 73:2 of 1802; and MOL S 12 Div 12 No. 24 of 1822.

River that gave its bed to the Zsdála Stream became detached yet remains to be clarified. What must be borne is mind is that at times of the Drava River floods, the Zsdála Stream might have taken much of the backwater from the river, making the area wetter and keeping it waterlogged for a longer period.

In the course of our geomorphological fieldwork, the canal character of the Zsdála bed, as we traversed its course, was quite striking. The water travels a rather lengthy distance in an artificially constructed canal, with its deepened bed playing a role in draining the surrounding marshland. Yet, on the basis of the maps drawn in recent centuries, it can be safely asserted that its location and length have not changed significantly.

Figure 9. Map from 1786 showing the connection of the Zsdála Stream and the Drava River at Zákány: "*Einflus* (Einfluss) *der Sdalla Grabens*" – the inflow of the Zsdála Graben (MOL S 12 Div 13 No. 70:7)

As far as various aspects of the medieval geography of these lands are concerned, the settlements – both the abandoned and the still inhabited ones – also offer information, with their locations marking the perimeters of former lakes, swamps, streams, and the lands suitable for building houses on. Considering the current conditions, it may be observed that the settlements are at present typically found on the edge of the bluff and on the higher alluvial fan. There are no settlements of importance in the lower areas of the lower-lying alluvial fan, broken up by meanders. On the border of the two disparate microregions, the settlements built on the bluff are generally situated by valleys cut by streams, which offer not only use of the water, but further advantages too. The valleys provide useful means of accessing the areas in the Drava Valley, while the alluvial fans of the streams make for a

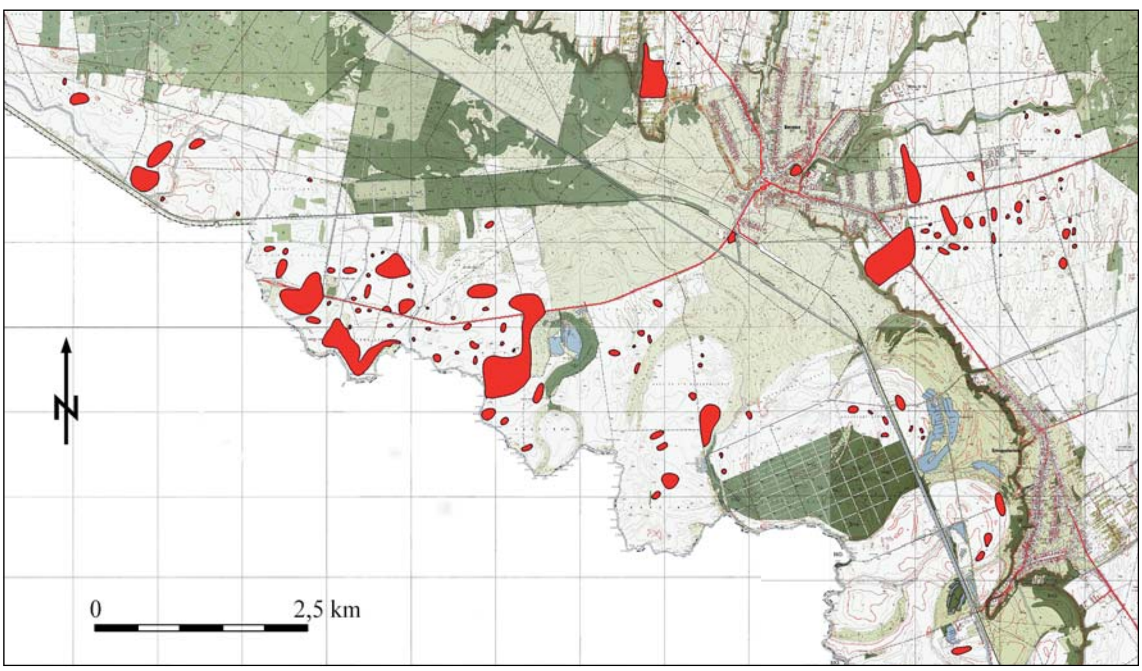

Figure 10. Archaeological sites with finds from the medieval period in the study area (after Zatykó 2013)

higher surface than their surroundings, safe from inland waters, and therefore appropriate for transport.

Based on the results of the archaeological field survey, the area in the vicinity of Berzence was densely populated during the medieval period *(Fig. 10)*. Comparing the northern (Inner Somogy microregion) and southern (Drava Valley) medieval sites shown on the archaeological site map of the area, it is strikingly apparent that while there are numerous small sites yielding a few finds between the four larger, village-like settlements of the Drava Valley, criss-crossed by former meanders and oxbow lakes, there are larger areas devoid of sites between the abandoned villages of the northern, hilly area above the bluff. It is characteristic of the location of the small sites found between the larger settlements in the southern area that they show a more even distribution in the western part of the floodplain that lies somewhat higher (at 118–120 meters). In contrast, they are strung out along the former meanders and oxbow lakes in the eastern part of the plain, which lies lower (at 115–117 meters), and they were thus more exposed to water.[24]

ANTHROPOGENIC FACTORS IN LAND FORMATION DURING THE NINETEENTH–TWENTIETH CENTURIES

As a result of human activities in reshaping the environment, the environmental conditions of the area have changed a great deal since the medieval period. The relationship between the river and the study area has been transformed significantly by the artificial meander cutoffs, the construction of hydro-power dams, and flood-protection installations affecting certain sections of the river. The hydrographical conditions and environmental traits of the Drava Valley have also changed substantially through various types of water management, the construction of canals, arable farming, and the mining of gravel.

The water system and hydrological conditions of the area were transformed by the construction of the Dombó-csatorna. A significant number of the former marshes were drained when the canal was built, leaving only a few spots of marshes and swamps. The First Military Ordnance Survey map of 1784 does not show the canal and does not even indicate arable land in the Drava Valley. With the exception of Udvarhelypuszta, only forests, fields, groves, and marshy, swampy patches are shown. On the map of the Second Military Ordnance Survey of 1859 and on a map prepared in 1868 in the Széchényi Library (OSZK TK 1975), entitled *Berzence mezőváros határának tagosítási térképe* [Cadastral map of the land of the market-town of Berzence] *(Fig. 11)*, the canal is already shown, and the changes in the use of the land are also apparent. In the area of the Drava Valley, an increasing number of arable fields, forests, and cleared forests drawn into agricultural use, typically divided into small plots of land. The meadows and pastures were mostly restricted to the areas close to the bluff and near the Dombó-csatorna. The canal and the drainage works were realized in accordance with the period's social and economic expectations: the areas that had formerly had a permanently high water level could now be drawn into agricultural use. New arable lands had been obtained, while the development also served to make safer the rail line between Barcs and Murakeresztúr, which had been inaugurated in 1868. The construction of the canal can be dated to the very beginning of the nineteenth century,[25] leading to a drop in the average level of groundwater and a significant shrinkage of the inland water areas, the groves along the foot of the bluff, as well as the area covered by the ponds and marshes occupying the Early Holocene meanders of the Drava River.

24 Viczián – Zatykó 2011; Zatykó 2013.
25 Szállási 1936.

Figure 11. Cadastral map of the market-town of Berzence from 1868 (OSZK TK 1975)

The system of waterways was significantly altered by the construction of the Dombó-csatorna. Earlier, the streams arriving from the north had covered a greater area, and found different ways to the Zsdála Stream. The extensive network of former riverbeds joined to the south of Berzence and then drained into the Zsdála Stream through the former Drava meander between Berzence and Zsdála/Ždala settlements. The area called *Postamalom* on the map of the Second Military Ordnance Survey and on a number of other maps can be found near the mouth. The name suggests that a stream of suitable strength to turn a mill had once flown here. The Dombó-csatorna runs roughly parallel to the line of the bluff, the canal and the system of drainage dikes linked to it collected the flowing water from the area and led it into the Drava River south of Somogyudvarhely, at Bélavár. Through its construction and the diversion of the water, the current of the streams has diminished, the amount of water accumulated in the Drava meander at *Postamalom* has dropped extraordinarily, and the environmental conditions of the area have been altered substantially. In addition, the area covered by ponds and marshes has shrunk and their silting up has accelerated. Similarly, the smaller streambeds in the area have become drier.

In addition to the construction of the Dombó-csatorna, canalizing and water drainage works took place in the study area west of Berzence as well as south of Csurgó, in the swampy, marshy areas at the foot of the bluff, following the course of the stream valley. The canalization and water management works of recent centuries have resulted in the drying out of the area and the disappearance of the earlier ponds, swamps, and watercourses.

The hydrological and environmental conditions of the area were also fundamentally influenced by the engineering works on the Drava River. In consequence of the canalization and water management works of the past centuries, the area dried out and former watercourses disappeared. Between 1805 and 1848, the most intense period of river management, 62 river meander cutoffs were made within 75 km along the section between the mouth of Mura River to the Drava River and the mouth of Drava River to the Danube River, and the river was shortened to 60% of its previous length. Smaller meander cutoffs were performed later on, including meanders immediately affecting the studied river section: one at Botovo in 1981, and another at Bélavár in 1980.[26] The meander cutoffs reduced the length of the channel, which triggered a shorter duration of flood propagation, thus the inundation of the floodplains also lasts for a shorter period of time. The shortening of the periods of high waters, the reduction of the flood-affected area results in a substantial decrease in infiltration on the floodplains. The wet habitats of the floodplains, the areas previously inundated either permanently or periodically no longer receive the same amount of water during floods as earlier.

One of the most important consequences of the meander cutoffs is that the shorter river channel has greatly enhanced the force of the water. Depending on the section of the Drava River, this may have caused incisions of several meters in some cases. With the incised riverbed, the level of the groundwater has also dropped – not only in the areas immediately next to its banks, but also in more remote areas of the Drava Valley. According to the gauge at Botovo, the average water level of the Drava River has dropped by nearly two meters in the monitored period between 1876 and 1998. This effect can also be observed in the April average levels of the groundwater in Répás-erdő, a southern immediate neighbor across the border of the study area. In 1900, the inland water inundated 40% of the area of Répás-erdő. Since 1990, the water level has never reached the ground level.[27] It is clear that the study area has undergone a similar process both in terms of tendency and the level of impact, and this has led to a shrinkage of the ponds, swamps, inland waters, and the area of the land inundated by floods.

A series of hydro-electric power plants built on the Drava River has also had a significant impact on the floodplains and their wider environment. Large amounts of water are kept behind the dams, bringing about a decrease in the level of high waters and shortening the period of floods.

Another cause for the shrinkage of the areas inundated by floods is the construction of flood control dikes. A total of 123.4 km of dikes were built on the left bank of the Drava River, 136 km on the right bank, and 86.5 km along the tributaries.[28] Dikes are found in the vicinity of the study area between Botovo and Répás/Repaš on both banks of the river.

In sum, we may say that the anthropogenic effects are reinforcing each other in their impact on the dynamics of the river, along with the water management works on the Drava River. These have led to a marked drop in average groundwater levels, considerably curbing the development and impact of floods. Technological interventions are contributing significantly to the natural processes that affect the drying and filling up of the area.

CONCLUSION

Geomorphological observations indicate the channel's migration to the south and a significant incision of the Drava's riverbed, and confirm that the processes of floodplain development shifted to increasingly lower levels. However, abandoned meanders and other landforms continued to have a great importance for the environment. Two main geomorphological levels, a higher and a lower alluvial fan can be distinguished south of the bluff according

26 Sečen et al. 2003.
27 Sečen et al. 2003.
28 Sečen et al. 2003.

to the condition of their landforms and to the progress of sedimentation. The determining factors in surface formation are tectonic movements and changes in climatic or fluvial conditions, as well as human impacts.

Geomorphological conditions and surface and underground waters play a decisive role in terms of human settlement. Environmental changes have a marked impact on the possible modes of land use due to the sensitivity of the floodplain areas. Natural processes also led to the drying out and filling up of the area, but human impact on the environment (canalization, water management, flood protection, meander cutoffs, construction of hydro-electric dams, etc.) have considerably accelerated these processes.

The various water management works, both on the Drava River and on the tributaries of the Zsdála Stream, have resulted in a significant drop of several meters in the groundwater level and caused the shrinkage or disappearance of the swampy, marshy areas and ponds. The areas that previously had a high groundwater level or were periodically inundated became drier. Due to human intervention, the environment underwent significant changes over the last few centuries. It is clear from the above why historical sources and maps paint a picture of the area as one that used to have a more intense hydrological network, higher groundwater levels, more exposure to the influence of the Drava River, and was richer in swamps, ponds, islands, and active riverbeds than at present.

REFERENCES

Behringer 2010	Behringer, W.: *A Cultural History of Climate*. Cambridge: Polity Press, 2010.
Bognár et al. 2009	Bognár, A. – Lovász, Gy. – Nagyváradi, L.: A Dráva-völgy bilaterális geomorfológiai kutatásának legújabb eredményei [Bilateral geomorphological research of the Drava Valley. Contemporary results]. In: Szabó-Kovács, B. – Tóth, J. – Wilhelm, Z.: *Környezetünk természeti-társadalmi dimenziói.* Pécs: IDResearch Kft. – Publikon Kiadó, 2009, 29–38.
Böhm – Wetzel 2006	Böhm, O. – Wetzel, K.-F.: Flood history of the Danube tributaries Lech and Isar in the Alpine foreland of Germany. *Hydrological Sciences Journal* 51 (2006) 784–798.
Evlia Cselebi 1985	*Evlia Cselebi török világutazó magyarországi utazásai 1660–1664* [The journey of Evliya Çelebi, the Turkish traveler, through Hungary 1660–1664]. Budapest: Gondolat, 1985. Berzence vára [The castle of Berzence], 555.
Holzhauser et al. 2005	Holzhauser, H. – Magny, M. J. – Zumbühl, H. J.: Glacier and lake-level variations in west-central Europe over the last 3500 years. *The Holocene* 15:6 (2005) 789–801.
Hunfalvy 1865	Hunfalvy, J.: *A magyar birodalom természeti viszonyainak leírása* [Description of the natural conditions of the Hungarian Empire]. Pest, Emich Gusztáv, Hungarian Academy of Sciences, 1865.

Kiss – Laszlovszky 2013	Kiss, A. – Laszlovszky, J.: 14th–16th-century Danube Floods and Long-Term Water-Level Changes in Archaeological and Sedimentary Evidence in the Western and Central Carpathian Basin: an Overview with Documentary Comparison. *Journal of Environmental Geography* 6 (2013) 1–11.
Lamb 1965	Lamb, H. H.: The early medieval warm epoch and its sequel. *Palaeogeography, Palaeoclimatology, Palaeoecology* 1 (1965) 13–37.
Lovász 1964	Lovász, Gy.: *Geomorfológiai tanulmányok a Dráva-völgyben* [Geomorphological studies in the Drava Valley]. MTA DTI Értekezések, 1963. Budapest: Akadémiai Kiadó, 1964.
Lovász 1972	Lovász, Gy.: *A Dráva–Mura vízrendszer vízjárási és lefolyási viszonyai* [Surface run-off of the Drava–Mura drainage system]. Budapest: Akadémiai Kiadó, 1972.
Marosi 1970	Marosi, S.: *Belső-Somogy kialakulása és felszínalaktana* [Development and geomorphology of the Inner Somogy region]. Földrajzi Tanulmányok 11. Budapest: Akadémiai Kiadó, 1970 [1969].
Mészáros – Serlegi 2011	Mészáros, O. – Serlegi, G.: Környezeti változások hatása a középkori településviszonyokra a Dunántúlon [The impact of environmental changes on conditions in Transdanubian medieval settlements]. *Archaeologiai Értesítő* 136 (2011) 215–235.
Sečen et al. 2003	Sečen, V. – Miöetić, S. – Jurić, V. – Bojčetić, Č. – Heček, N. – Ekinović, S.: *Novo Virje Hydroelectric Power Plant Multipurpose System Environmental Impact Study, Transboundary Environmental Impact Assessment, Espoo Convention*. Supplementary Material 3. Zagreb: Elektroprojekt Consulting Engineers, 2003.
Sümegi et al. 2009	Sümegi, P. – Jakab, G. – Majkut, P. – Töröcsik, T. – Zatykó, Cs.: Middle Age paleoecological and paleoclimatological reconstruction in the Carpathian Basin. *Időjárás* 113 (2009) 265–298.
Szállási 1936	Szállási, S.: *Berzence nagyközség szociográfiája* [The sociography of the Commune of Berzence]. Doctoral Dissertation, 1936. Manuscript, Budapest: Néprajzi Múzeum Ethnológiai Adattár, No. 4523.
Schimmelpfennig et al. 2014	Schimmelpfennig, I. – Schaefer, J. M. – Akçar, N. – Koffman, T. – Ivy-Ochs, S. – Schwartz, R. – Finkel, R. C. – Zimmerman, S. – Schlüchter, C.: A chronology of Holocene and Little Ice Age glacier culminations of the Steingletscher, Central Alps, Switzerland, based on high sensitivity beryllium-10 moraine dating. *Earth and Planetary Science Letters* 393 (2014) 220–230.
Vadas 2010	Vadas, A.: *Weather Anomalies and Climatic Change in Late Medieval Hungary: Weather events in the 1310s in the Hungarian Kingdom*. Saarbrücken: VDM Verlag, 2010.

Viczián 2014	Viczián, I.: Archaeological sites on large river's islands as records of Holocene climate and fluvial changes. A geomorphological case study in the Danube river section between Komárom and Paks, Hungary. *Analele Universitatii Ştefan cel Mare din Suceava Seria Geografie* 24 (Spec. issue) (2014) 176–180.
Viczián – Zatykó 2011	Viczián, I. – Zatykó, Cs.: Geomorphology and Environmental History in the Drava Valley, near Berzence. *Hungarian Geographical Bulletin* 60:4 (2011) 357–377.
Zatykó 2010	Zatykó, Cs.: Természeti táj – emberformálta táj: a középkori környezet rekonstrukciójának lehetőségei (Natural landscape – man-made landscape: Possibilities for reconstructing the medieval environment). In: *Középkori és újkori régészetünk legújabb eredményei / Archaeology of the Middle Ages and the Early Modern Period in Hungary* I–II. Eds: Benkő, E. – Kovács, Gy. Budapest: MTA Régészeti Intézete, 2010, 839–852.
Zatykó 2013	Zatykó, Cs.: Settlement pattern, landscape use in medieval Berzence (Hungary) / Obrasci naselja, Korištenje krajolika u srednjovjekovnom Berzencu (Mađarska). *Podravski Zbornik* 39 (2013) 164–172.

ABBREVIATIONS

MOL	Magyar Országos Levéltár (Hungarian National Archives)
OSZK	Országos Széchényi Könyvtár (National Széchényi Library)

Analysis of Archaeological Artifacts

PETROGRAPHIC ANALYSIS OF CERAMICS FROM THE OTTOMAN-TURKISH FORT AT BARCS (HUNGARY) AND THE NEIGHBORING SETTLEMENTS

Attila Kreiter and Péter Pánczél

INTRODUCTION

The 150-year-long Ottoman-Turkish occupation had considerable cultural effects on those parts of Hungary that were controlled by the Ottomans. This effect is clearly visible in contemporary material culture and in the Hungarian language. The analysis of ceramics from the Ottoman-Turkish fort of Barcs provides a good opportunity to examine the nature and extent of Turkish impact on the organization of ceramic production and to analyze how homogeneous or varied ceramic production was. During the analysis, we analyzed the raw materials and tempering of ceramics. We also assessed whether the raw materials of ceramics from different periods are similar and whether there were changes in ceramic technologies through time.

The fort of Barcs was built in 1567 by the Drava River. When it was completed, the Drava flotilla, stationed at Eszék (today Osijek, Croatia) was transferred to Barcs. The fort was burned down during the Fifteen Years' War in 1595, but it remained in ruins and unoccupied only for a short period. It was completely destroyed in 1664, during the winter campaign of Miklós Zrínyi, when the Turks abandoned and burned it down. According to Turkish military pay lists, the garrison of the castle was manned by about two hundred soldiers. The majority of the soldiers came from the Balkans; they were *azab*s and *martaloc*s serving in the flotilla or along the river as foot soldiers.[1] After Kanizsa was captured by the Ottomans in 1600, Barcs became part of the Kanizsa Eyalet.

By now, the fort has completely perished. Its location was identified by Márton Rózsás in the 1970s. Sounding excavations were carried out in the area of the former fort between 1989 and 1994, followed by a smaller excavation in 2002 and a larger rescue excavation in 2003.[2] Approximately 32,000 pieces of ceramics came to light in 2003, almost half of them from stove tiles.

Large groups of kitchen and table wares – considering the requirements and use – linked to the Turkish garrison are comprised of hand-formed baking covers, Balkanic-type vessels made on a slow wheel (mainly pots), glazed Turkish table wares (pedestalled bowls and jars), and jars fired in a reducing atmosphere. The production of these ceramics within the fort could not be proven, as no signs of ceramic production were identified during the excavation. Therefore, they were probably brought to the fort as part of supplies, or were made specifically for Turkish soldiers and traded to the fort. A smaller part of the assemblage belongs to vessels that could not be associated with the above vessel types, and to fine decorated wares that came from the inner parts of the Ottoman Empire or Western Europe as trade items, gifts, or perhaps personal items (porcelain, faience, decorated glazed vessels).

As part of the research project supported by the Hungarian Scientific Research Fund (OTKA Grant K 72231), 55 ceramics were analyzed petrographically in thin sections. Forty

1 Hegyi 2007.
2 Kovács – Rózsás 1996; 2010.

Thin section no.	*ID number on the samples*	*Inventory number*	*Sample code*	*Period (century)*	*Fabric group*
1	25	–	25	16	1
2	104+491	–	104+491	16–17	2
3	108+10	–	108+10	17	4
4	146K	BR.2011.F60.493.	146K	16	6
5	152k	–	152K	16	7
6	112	–	234	16	8
7	244	–	244	16	9
8	382	BR.2011.F55.241.	382	17	6
9	482.3	–	389+483	17	4
10	391	–	391	17	Sample for comparison
11	490	–	490	16	4
12	639	BR.2011.20.520.	639	16–17	6
13	640	–	640	17	11
14	645	BR.2011.16.395.	645	16.	6
15	F60.006	BR.2011.F60.6.	284+196	16	4
16	Br 2011.F60.8	BR.2011.F60.8.	202	16	4
17	Br 2011.F60.015	BR.2011.F60.15.	80	16	4
18	F60.036	BR.2011.F60.36.	196	16	1
19	F60.59	BR.2011.F60.59.	74	16	7
20	F60.97	BR.2011.F60.97.	81	16	12
21	F60.103	BR.2011.F60.101.	85	16	10
22	BR.2011.F65.116	BR.2011.F60.116.	411	16	13
23	F60.163	BR.2011.F60.163.	74	16	6
24	Br 2011.F60.192	BR.2011.F60.192.	202	16	6
25	F60.230	BR.2011.F60.230.	146	16	15
26	F60.294	BR.2011.F60.294.	142	16	6
27	F60.316	BR.2011.F60.316.	244	16	3
28	Br 2011.F60.325	BR.2011.F60.325.	244	16	14
29	F60.335	BR.2011.F60.335.	114	16	16
30	F60.433	BR.2011.F60.433.	123	17	4
31	F65.103	BR.2011.F65.103.	131	16	6

Thin section no.	*ID number on the samples*	*Inventory number*	*Sample code*	*Period (century)*	*Fabric group*
32	F65.111	BR.2011.F65.112.	411	16	5
33	Br 2011.37.44	BR.2011.37.44.	358	16	6
34	Br 2011.40.76	BR.2011.40.76.	161	16	7
35	Br 2011.40.77	BR.2011.40.77.	97	16	7
36	Br 2011.40.92	BR.2011.40.92.	161+489	16	1
37	Br 2011.52.152	BR.2011.52.152.	519	16	4
38	Br 2011.52.156	BR.2011.52.156.	515	16	9
39	Br 2011.52.161	BR.2011.52.161.	519	16	6
40	147	391	?		Sample for comparison
41	graphitic pot	Drávaszentes-Kenderföld		15– 16	Sample for comparison
42	D-K 1	Drávaszentes-Kenderföld	1	14–15	Sample for comparison
43	S-Gy 1	Somogytarnóca-Györgyös	1	14–15	Sample for comparison
44	S-Gy 2	Somogytarnóca-Györgyös	2	14–15	Sample for comparison
45	S-Gy 3	Somogytarnóca-Györgyös	3	14–15	Sample for comparison
46	S-Gy 4	Somogytarnóca-Györgyös	4	15–16	Sample for comparison
47	S-Gy 5	Somogytarnóca-Györgyös	5	15–16	Sample for comparison
48	S-Gy 6	Somogytarnóca-Györgyös	6	15–16	Sample for comparison
49	B-Sz 1	Barcs-Szili-tanya	1	15	Sample for comparison
50	B-Sz 2	Barcs-Szili-tanya	2	14–15	Sample for comparison
51	B-Sz 3	Barcs-Szili-tanya	3	14–15	Sample for comparison
52	B-Sz 4	Barcs-Szili-tanya	4	15	Sample for comparison
53	B-Sz 99.7.5	Barcs-Szelistye	1999.07.05	14–15	Sample for comparison
54	B-Sz 99.7.6	Barcs-Szelistye	1999.07.06	15	Sample for comparison

Figure 1. Overview of the analyzed samples

samples were analyzed from the fort of Barcs, which were compared with ceramics from the neighboring, perished late medieval villages: two samples from Drávaszentes-Kenderföld, six from Somogytarnóca-Györgyös, four from Barcs-Szili-tanya, and three from Barcs-Szelistye *(Fig. 1)*.

During the petrographic analysis the inclusion density, size categories, inclusion sorting, and roundness of the components were determined based on the guidelines of the Prehistoric

Ceramics Research Group.[3] Inclusion density: rare (< 3%), sparse (3–9%), moderate (10–19%), common (20–29%), very common (30–39%), abundant (> 40%). Size classification: very fine (< 0.1 mm), fine (0.1–0.25 mm), medium (0.25–1 mm), coarse (1–3 mm), very coarse (> 3 mm). Inclusion sorting: poorly sorted, moderately sorted, well sorted, and very well sorted. Inclusion roundness: angular, slightly angular, slightly rounded, rounded, and well rounded.

PETROGRAPHIC DESCRIPTION OF CERAMICS FROM THE FORT AND THE DISTRIBUTION OF SAMPLES AMONG VESSEL TYPES

The composition of the analyzed samples shows extensive variability. Sixteen fabric groups could be identified according to their composition, but variability also exists within the fabric groups as well. In the following section, the main characteristics of fabrics, which could be distinguished during petrographic analysis, are described.

Fabric 1 (Figs 2–4)

Three samples belong to this fabric group (pot with incised wavy lines, made on a slow wheel, sixteenth century: 1; rim of a pot with incised wavy lines, made on a slow wheel, sixteenth century: 18; shoulder of a pot, made on a fast wheel, its interior is glazed, sixteenth century: 36). The characteristic of this group is that the amount of inclusions is common (20–29%),

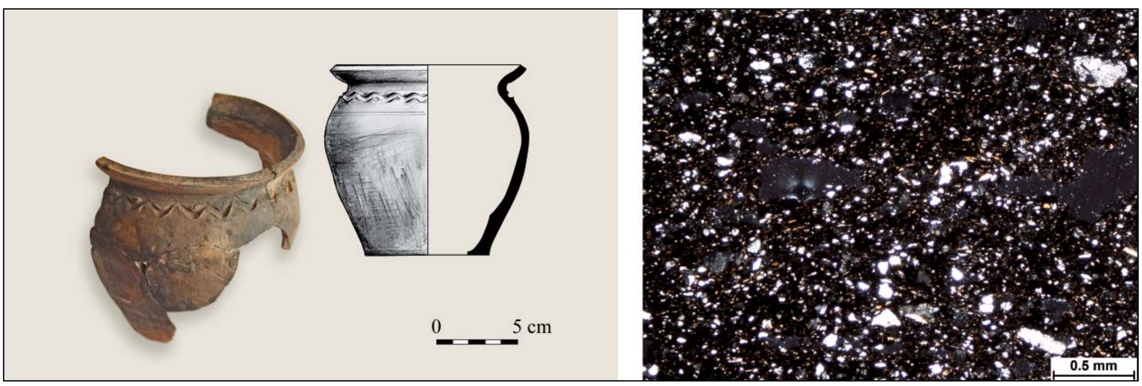

Figure 2. Characteristic appearance of Fabric 1 (Sample 1, Barcs, 40x, +N)

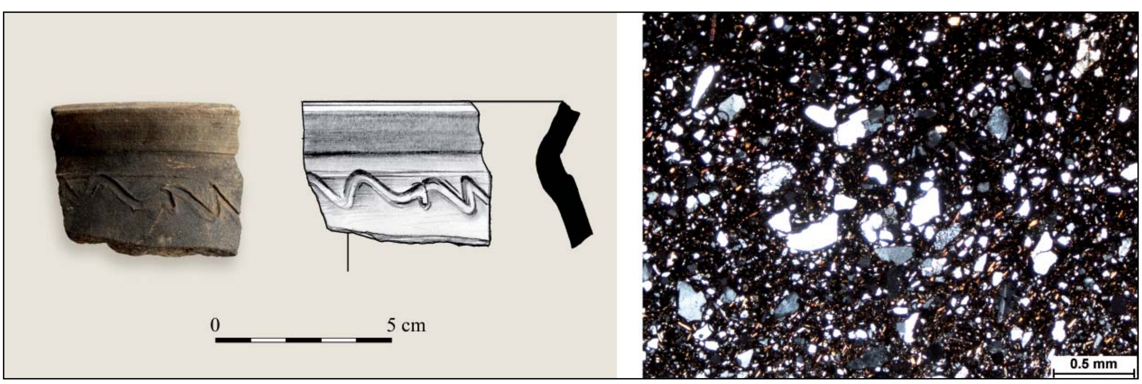

Figure 3. Characteristic appearance of Fabric 1 (Sample 18, Barcs, 40x, +N)

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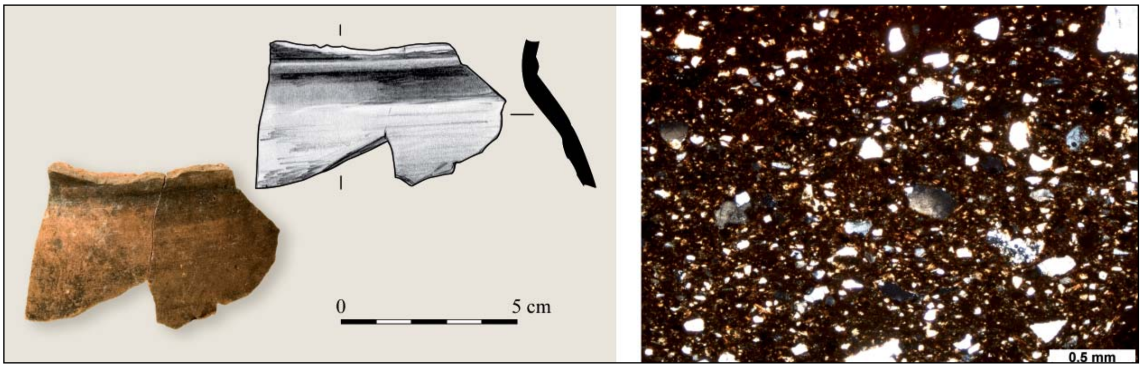


Figure 4. Characteristic appearance of Fabric 1 (Sample 36, Barcs, 40x, +N)

the dominant size of the inclusions is very fine (< 0.1 mm), although sparse amounts of fine grains can also be observed (0.1–0.25 mm).

The fabric of the samples is dense, although pores can be observed. The shape of pores is irregular, elongated, and rounded, their size varies between 0.02–2 mm. The fabric of the samples is hiatal (0.02–0.1 mm and 0.25–0.4 mm). The inclusions are well sorted. The majority of inclusions are monocrystalline quartz grains with straight extinction, the grains are subangular or subrounded. Rare amounts of orthoclase and plagioclase feldspar also appear. Amphibole and tourmaline also appear as accessory minerals. The basic raw materials of these three samples seem very similar, although the raw material of Sample 1 was tempered with sparse amounts of sand, while Sample 18 was tempered with moderate amounts of sand. The amount of tempering in Sample 36 is somewhat between the two other samples.

Fabric 2 (Fig. 5)

One sample belongs to this fabric group (pot with double incised wavy lines, made on a slow wheel, sixteenth–seventeenth century: 2). The characteristic of this group is that the raw material shows increased amounts of muscovite mica (as opposed to other fabric groups) and the fabric shows serial grain size distribution. The amount of inclusions is common (20–29%), the dominant grain size is very fine (< 0.1 mm), although sparse amounts of fine grains also appear (0.1–0.25 mm).

The fabric of the ceramic is dense, although pores can be observed. The shape of the pores is irregular, elongated, and rounded, their size varies between 0.02 and 1.5 mm. The fabric shows a serial grain size distribution (0.02–0.1 mm), the inclusions also show orientation.

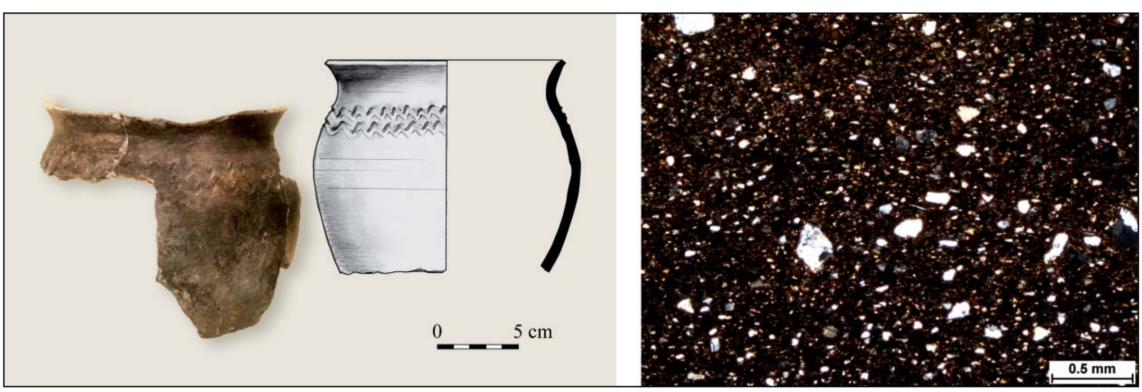


Figure 5. Characteristic appearance of Fabric 2 (Sample 2, Barcs, 40x, +N)

The inclusions are well sorted. The majority of inclusions are monocrystalline quartz grains with straight extinction, the grains are subangular or subrounded. Orthoclase feldspar also appears, as do rare amounts of plagioclase feldspar. Amphibole, tourmaline, and chloritized biotite also appear. No observable tempering could be identified in the ceramic of this fabric group. Probably a naturally very fine grained, mica rich raw material was used for the production of this vessel. In this respect, the raw material of this fabric is characteristically different from that of Fabric 1.

Fabric 3 (Fig. 6)

One ceramic belongs to this fabric group (shoulder of a jar decorated with a stripe with fine incisions on it, fired under reducing conditions, sixteenth century: 27). The characteristic of this fabric group is that similarly to Fabric 2, increased amounts of muscovite mica appear in the fabric, but the grain size distribution of Fabric 3 is hiatal.

The amount of inclusions is also common (20–29%), the dominant grain size falls in the very fine category (< 0.1 mm), although sparse amounts of fine grains can also be observed (0.2–0.25 mm).

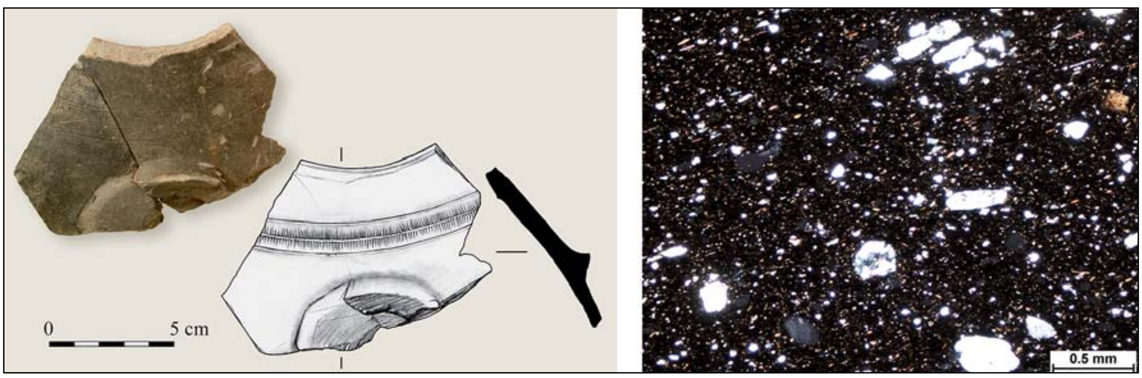


Figure 6. Characteristic appearance of Fabric 3 (Sample 27, Barcs, 40x, +N)

The fabric of the ceramic is dense, although pores appear. The shape of the pores is irregular, elongated, or rounded, their size varies between 0.02 and 1.5 mm. The size distribution of the inclusions is hiatal (0.02–0.1 mm and 0.2–0.3 mm), which can be attributed to sparse amounts of sand tempering. The inclusions are well sorted. The majority of inclusions are monocrystalline quartz grains with straight extinction, the grains are subangular or subrounded. Orthoclase feldspar also appears, as do rare amounts of plagioclase feldspar. Accessory minerals of amphibole, tourmaline, and chloritized biotite also appear.

Fabric 4 (Figs 7–14)

Eight samples belong to this fabric group (shoulder of a larger vessel decorated with wavy lines, seventeenth century: 3; pot with incised wavy line, made on a slow wheel, seventeenth century: 9; pot decorated with a wavy line, made on a slow wheel, sixteenth century: 11; pot rim decorated with rouletting and wavy lines, made on a slow wheel, sixteenth century: 15, 16, 17; pot rim decorated with multiple incised lines, made on a slow wheel, seventeenth century: 30; body fragment of a pot, small ribs on its exterior, made on a fast wheel, sixteenth century:

37). The samples could be divided into two subgroups according to their compositions. Fabric 4a (Samples 3, 9, 11, 16, 17, 30, 37) is characterized by tempering that contains increased amounts of metamorphic inclusions. Fabric 4b (Sample 15) is characterized by tempering that contains mainly granitic inclusions. The amount of inclusions varies between moderate and common (10–29%), the dominant size of inclusions is very fine (< 0.1 mm), although different amounts (sparse – moderate) of medium to coarse inclusions can also be observed (0.25–3 mm).

The fabrics of the ceramics are dense, although pores can be observed. The shape of the pores is irregular, elongated, or rounded, their size varies between 0.02 and 2 mm. The fabrics of the samples are hiatal (0.05–0.1 mm and 0.5–2 mm). The inclusions are poorly or moderately sorted.

The majority of inclusions in Fabric 4a are monocrystalline quartz grains with straight extinction, the grains are subrounded or subangular. Metamorphic grains composed of the intergrowth of polycrystalline quartz and muscovite mica are also characteristic. Orthoclase feldspar and plagioclase feldspar appear in rare amounts. Accessory minerals such as tourmaline and andalusite are also present.

In the case of Fabric 4b, mainly quartz, orthoclase feldspar and plagioclase feldspar can be observed. Muscovite mica, biotite, and amphibole also appear together with quartz and orthoclase feldspar as granitoid fragments.

According to the roundedness of the inclusions of the main fabric group (Fabric 4), the inclusions of the raw material came from sand and small pebbles rather than as a result of the purposeful smashing of rocks. Even though the sandy/small pebble tempering of the samples shows different origin (Fabric 4a metamorphic and Fabric 4b granitic), the basic raw materials of these subgroups show similarities in many respects. Therefore, they are grouped into one main fabric group (Fabric 4).

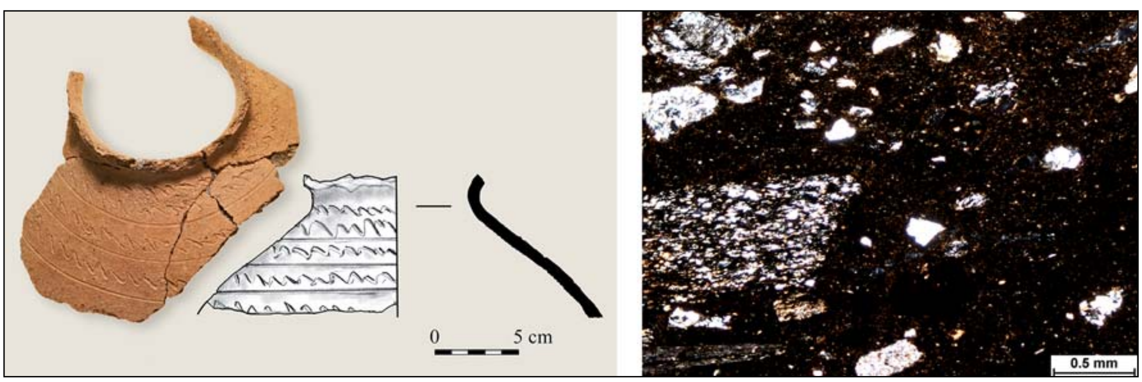


Figure 7. Characteristic appearance of Fabric 4a (Sample 3, Barcs, 40x, +N)

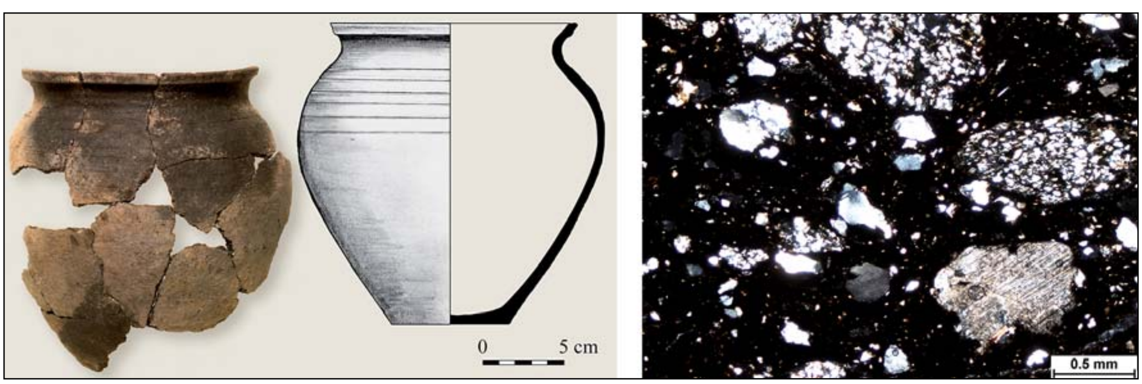


Figure 8. Characteristic appearance of Fabric 4a (Sample 9, Barcs, 40x, +N)

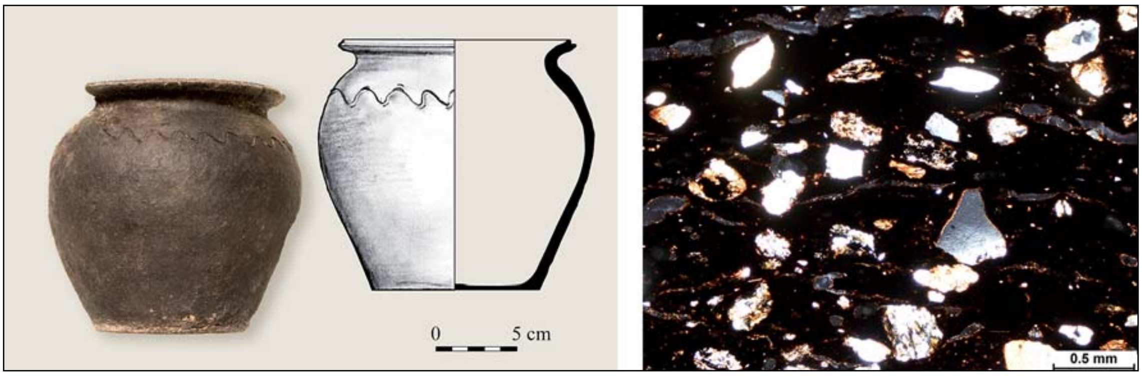


Figure 9. Characteristic appearance of Fabric 4a (Sample 11, Barcs, 40x, +N)

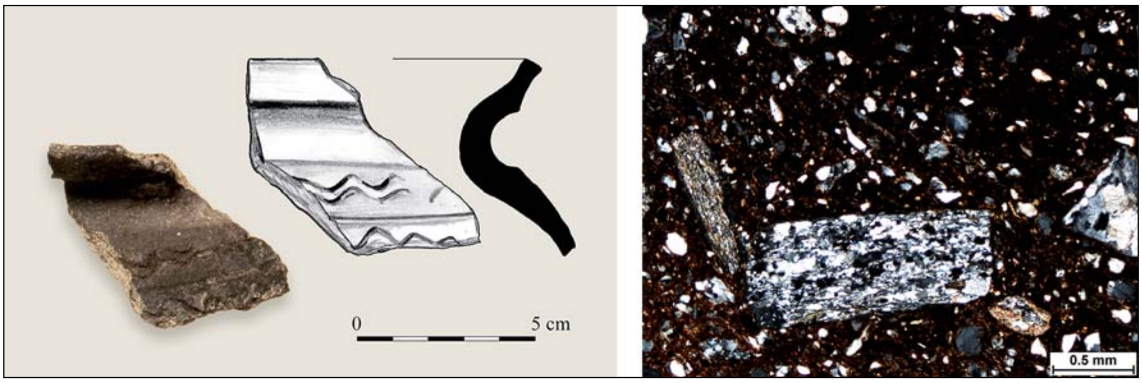


Figure 10. Characteristic appearance of Fabric 4a (Sample 16, Barcs, 40x, +N)

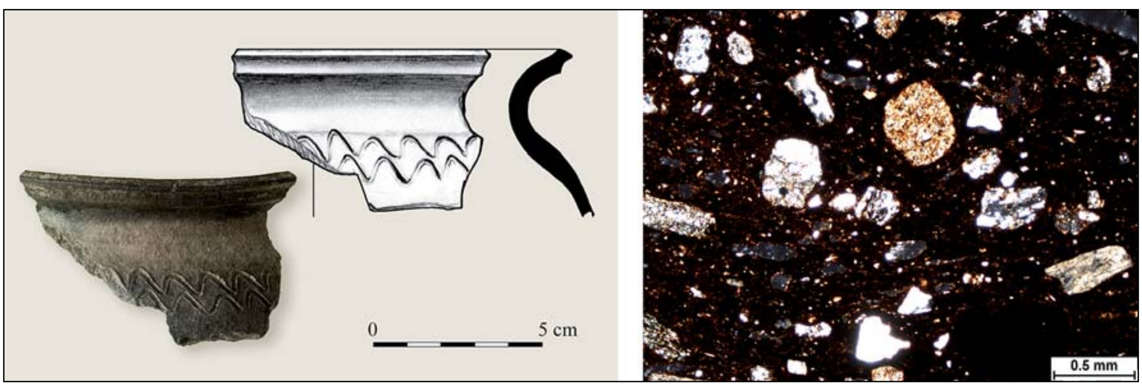


Figure 11. Characteristic appearance of Fabric 4a (Sample 17, Barcs, 40x, +N)

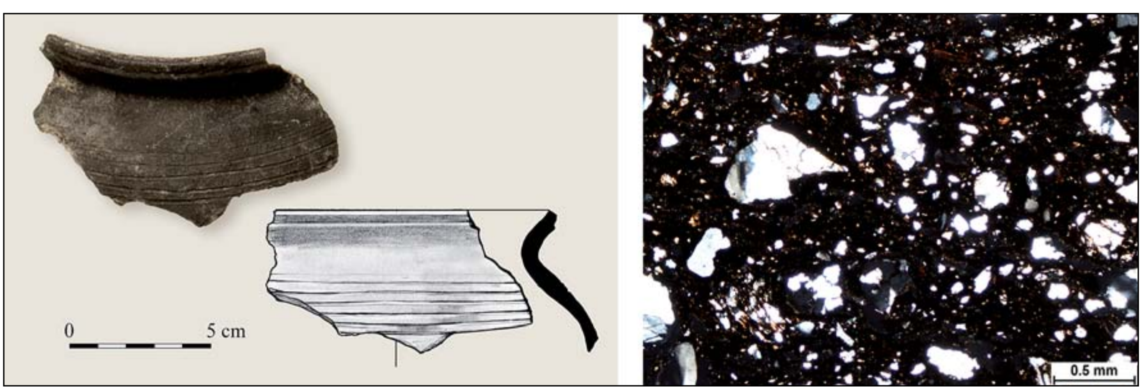


Figure 12. Characteristic appearance of Fabric 4a (Sample 30, Barcs, 40x, +N)

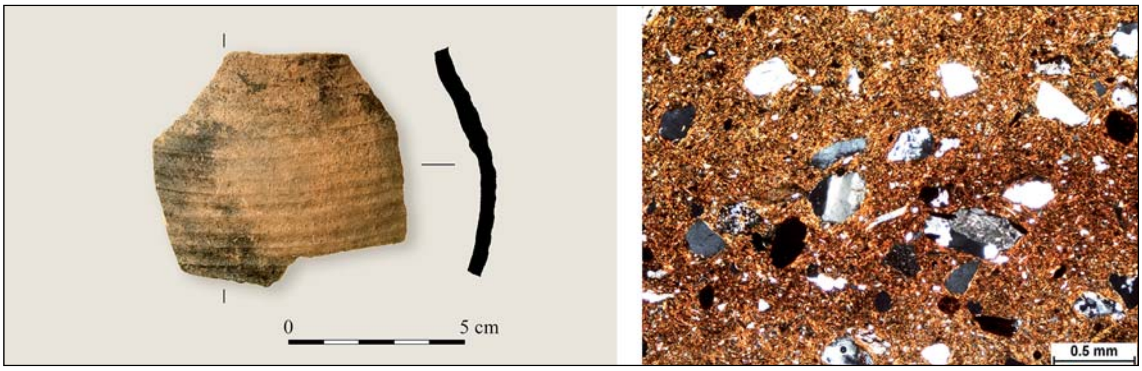


Figure 13. Characteristic appearance of Fabric 4a (Sample 37, Barcs, 40x, +N)

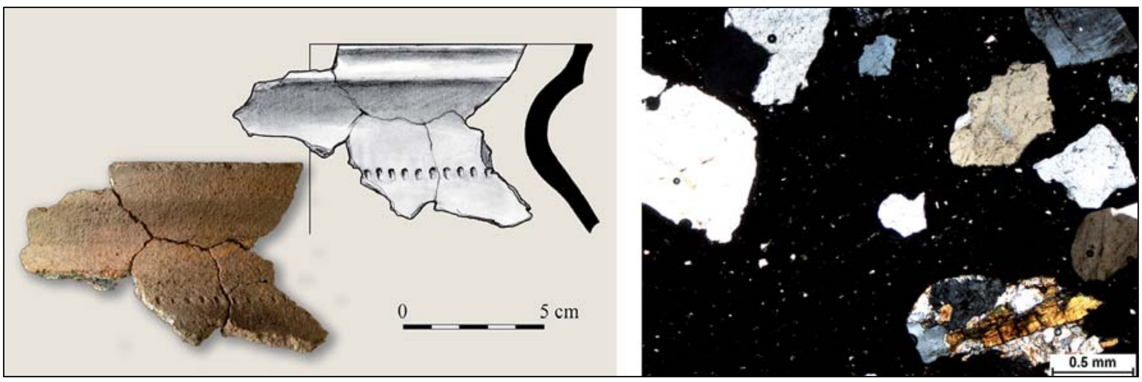


Figure 14. Characteristic appearance of Fabric 4b (Sample 15, Barcs, 40x, +N)

Fabric 5 (Fig. 15)

One ceramic belongs to this fabric (body fragment of a so-called "Bosnian" jar, richly decorated, made on a slow wheel, sixteenth century: 32). This vessel was tempered with sand, although its sand tempering is different from the previously discussed ones in terms of the amount of inclusions. The amount of inclusions is moderate (10–19%), the dominant inclusion size falls in the very fine category (< 0.1 mm), although medium to coarse grains can also be observed (0.25–3 mm).

The fabric of the ceramic is dense, although pores are present. Their shape is irregular, elongated, or rounded, their size varies between 0.02 and 2 mm. The fabric shows hiatal grain size distribution (0.05–0.1 mm and 0.5–1.5 mm). The non-plastic inclusions are poorly

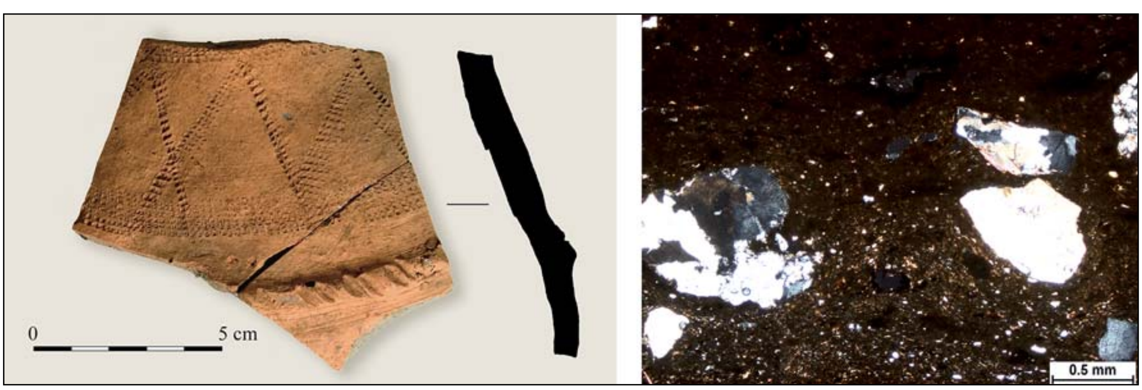


Figure 15. Characteristic appearance of Fabric 5 (Sample 32, Barcs, 40x, +N)

or moderately sorted. The majority of inclusions are monocrystalline quartz grains with straight extinction. The grains are subangular or subrounded. Rare amounts of orthoclase feldspar also appear, as does plagioclase feldspar. Tourmaline and biotite are also present as accessory minerals. Even though the composition of the jar is different from that of the other ceramics, and this is the only vessel in this fabric group, its non-local origin is uncertain. Its fabric shows similarities to that of vessels in Fabric 7, therefore the provenance of the "Bosnian" jar can only be resolved in the future by comparing its fabric to other "Bosnian" jars.

Fabric 6 (Figs 16–35)

Ten samples belong to this fabric (Turkish stove tile, glazed, sixteenth century: 4; Turkish pedestalled bowl, green glazed inside, seventeenth century: 8; rim of a Turkish bowl decorated with sgraffito technique, sixteenth–seventeenth centuries: 12; rim of a vessel with stamped decoration, green glazed, sixteenth century: 14; body fragment of a Turkish bowl decorated with flow glaze, sixteenth century: 23; body fragment of a Turkish green glazed jar with brown stripes, sixteenth century: 24, base of a Turkish pedestalled bowl, green glazed, sixteenth century: 26; fragment of a lid, its interior is decorated with wavy lines, sixteenth century: 31; spout fragment of a Turkish jar, glazed, sixteenth century: 33; shoulder of a jar with red painting, made on a fast wheel, sixteenth century: 39). The majority of vessels in this fabric group belong to the group of glazed Turkish vessels. There is a sixteenth-century green glazed vessel with stamped decoration (Sample 14) among the samples. Even though it seems different in terms of its stylistic and decorative features, its petrographic characteristics are similar to the other vessels in this fabric group. The petrographic similarities of the ceramics in this fabric group may imply that these vessels were made in a similar region, or perhaps they are even products of the same workshop.

The characteristic of this fabric group is that the amount of non-plastic inclusions varies between moderate to common (10–29%), the dominant grain size falls in the very fine category (< 0.1 mm), and fine grains (0.1–0.2 mm) appear only rarely. The fabrics of the vessels are dense, although pores can also be observed. The shape of the pores is irregular, elongated, or rounded, their size is around 0.5 mm. The grain size distribution in the fabrics is serial (0.02–0.1 mm), non-plastic inclusions are very well sorted. The majority of inclusions are monocrystalline quartz grains, although rare amounts of orthoclase feldspar and plagioclase feldspar could also be identified. Tourmaline also appears as an accessory mineral. Four samples (4, 8, 26, 33) also show calcareous concretions. The vessels in this fabric group are most probably untempered; it is assumed that naturally very fine grained raw materials were used for their production.

The petrographic composition of samples in this group is fundamentally similar, although the typological and stylistic features of the samples indicate differences between them. Therefore, minute details in their fabrics were also considered in their classification. As a result, four subgroups could be distinguished.

The majority of vessels belong to Fabric 6a (stove tile: 4; pedestalled bowl: 8, 23, 26; vessel with stamped decoration: 14; lid: 31; spouted jar: 33) *(Figs 26–32)*. The non-plastic inclusions are very fine, their amount is common. The petrographic composition of the samples is very similar; mainly quartz can be identified, although orthoclase feldspar also appears, as does muscovite mica. Only minor differences could be identified in the petrographic composition of samples:

– In Samples 4, 26 and 33 calcareous concretions appear.

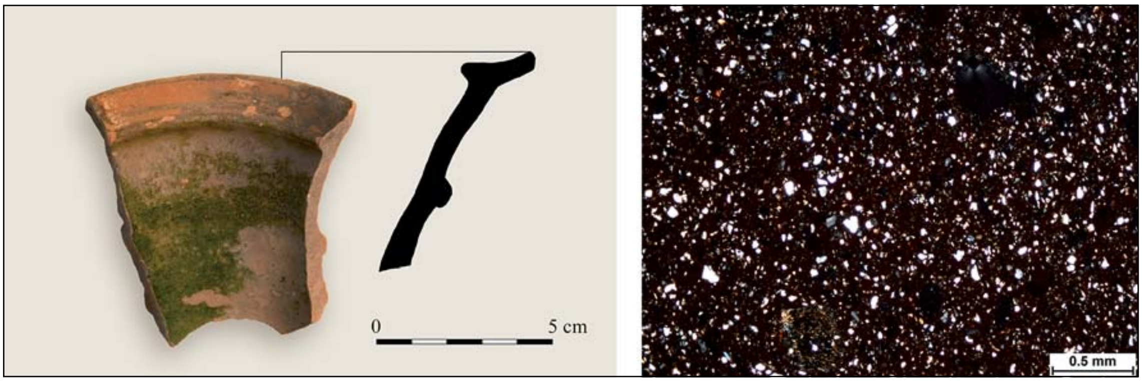


Figure 16. Fabric 6. Sixteenth-century Turkish green glazed stove tile and its characteristic appearance in thin section (Sample 4, Barcs, 40x, +N)

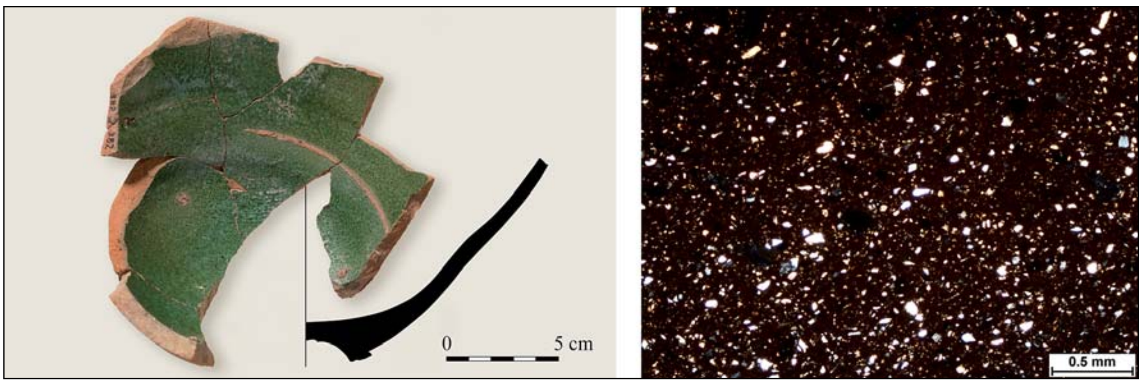


Figure 17. Fabric 6. Seventeenth-century Turkish pedestalled bowl, its interior is green glazed, and its characteristic appearance in thin section (Sample 8, Barcs, 40x, +N)

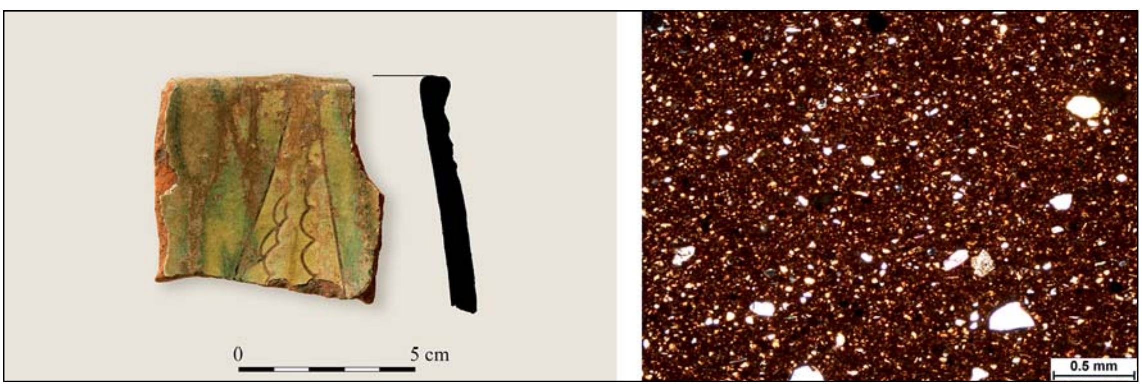


Figure 18. Fabric 6. Sixteenth–seventeenth-century Turkish bowl with sgraffito technique and its characteristic appearance in thin section (Sample 12, Barcs, 40x, +N)

– In Sample 8 isotropic inhomogeneities could be identified in the fabric in which non-plastic inclusions are observed. These inhomogeneities are probably argillaceous fragments, but their composition is slightly different from the incorporating matrix.

– Sample 14 – which according to its typological and stylistic features seems to originate from Germany, Upper Austria, or Styria – has a composition similar to the other vessels in this subgroup and no petrographic features could be identified that would support its different origin. The only visible difference is that Sample 14 shows "patches". Differences in the color of its raw material may indicate that the raw material preparation/homogenization

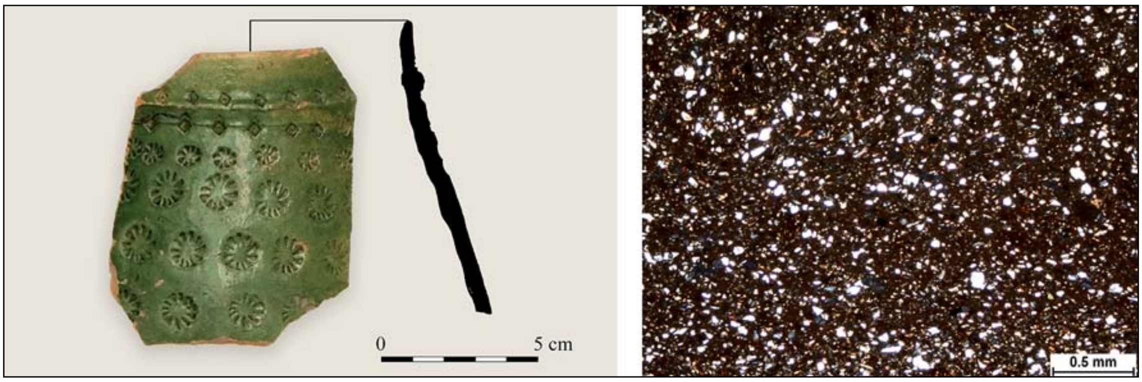


Figure 19. Fabric 6. Sixteenth-century green glazed vessel with stamped decoration and its characteristic appearance in thin section (Sample 14, Barcs, 40x, +N)

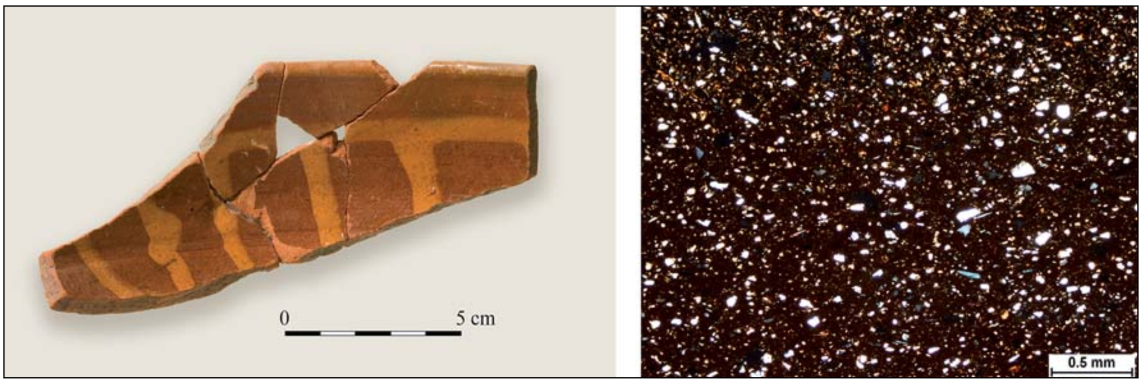


Figure 20. Fabric 6. Sixteenth-century Turkish flow glazed pedestalled bowl and its characteristic appearance in thin section (Sample 23, Barcs, 40x, +N)

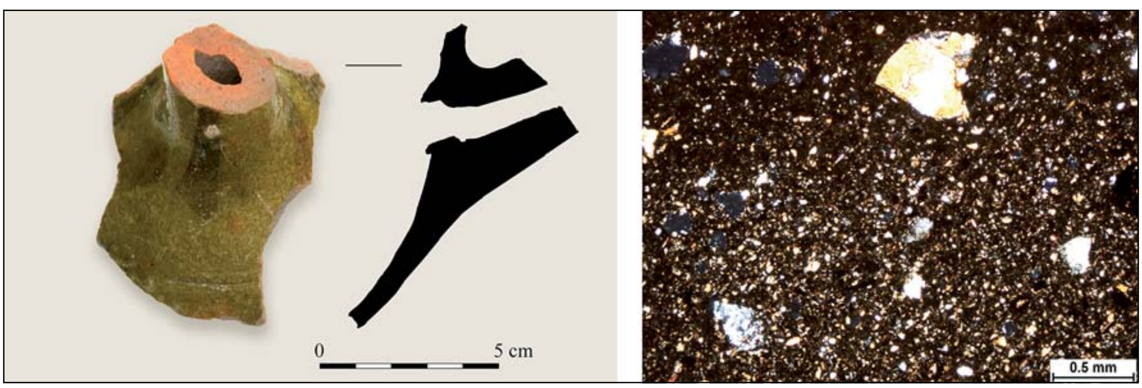


Figure 21. Fabric 6. Sixteenth-century Turkish green glazed spouted jar and its characteristic appearance in thin section (Sample 24, Barcs, 40x, +N)

was not perfect for this vessel, or perhaps different raw materials were mixed together, but were not homogenised appropriately.

Fabric 6b is represented by Sample 12 (bowl) *(Fig. 33)*. The raw material of this vessel is very similar to the previous ones, the only clear distinguishing feature is that rare amounts of fine to medium grains also appear in this sample and muscovite mica also shows two interference colors.

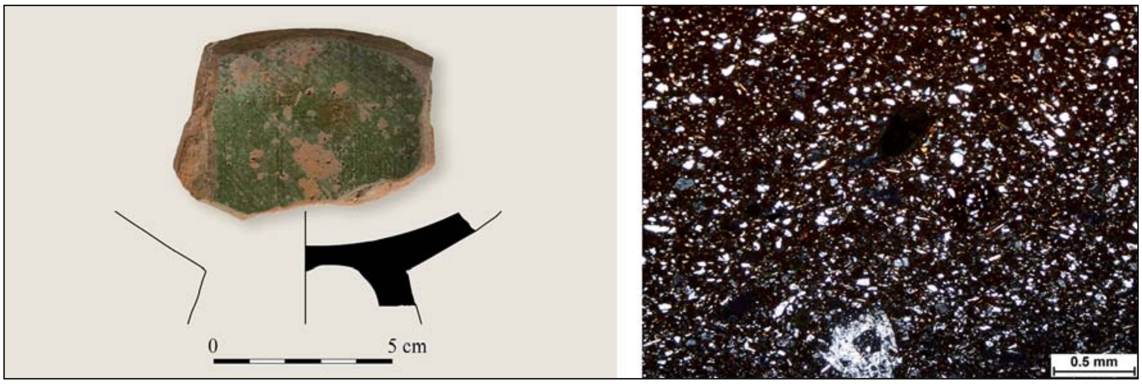


Figure 22. Fabric 6. Sixteenth-century Turkish green glazed pedestalled bowl and its characteristic appearance in thin section (Sample 26, Barcs, 40x, +N)

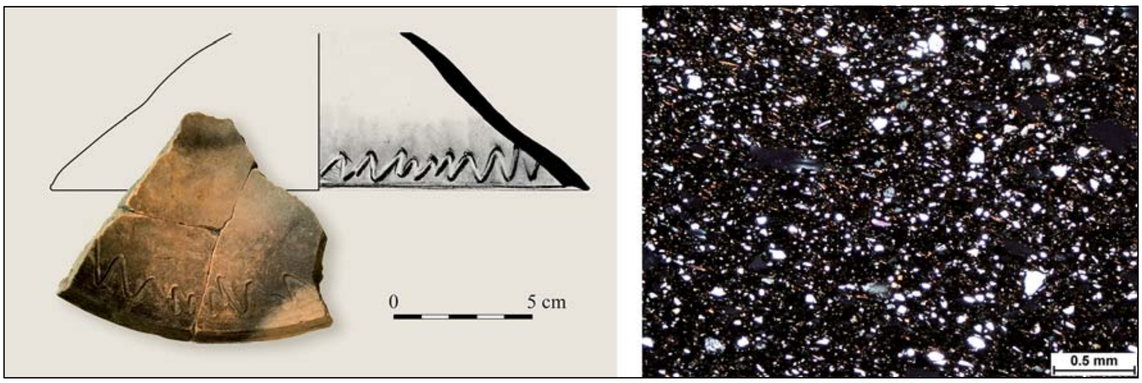


Figure 23. Fabric 6. Sixteenth-century lid, its interior is decorated with an incised wavy line, and its characteristic appearance in thin section (Sample 31, Barcs, 40x, +N)

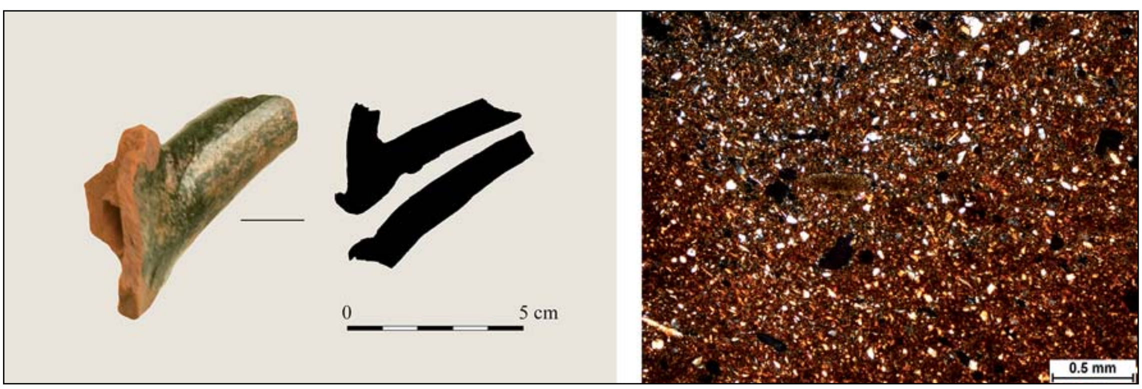


Figure 24. Fabric 6. Sixteenth-century Turkish green glazed spouted jar and its characteristic appearance in thin section (Sample 33, Barcs, 40x, +N)

Fabric 6c is represented by Sample 24 (jar) *(Fig. 34).* The raw material of this vessel is also very similar to the above samples. However, apart from fine to medium non-plastic inclusions, medium to coarse quartz grains also appear, as do pebbles with orthoclase feldspar and quartz.

Fabric 6d is represented by Sample 39 (jar) *(Fig. 35).* The composition of this subgroup is similar to Fabric 6b (quartz, orthoclase feldspar, and larger muscovite mica). However, the amount of non-plastic inclusions and their roundedness are different.

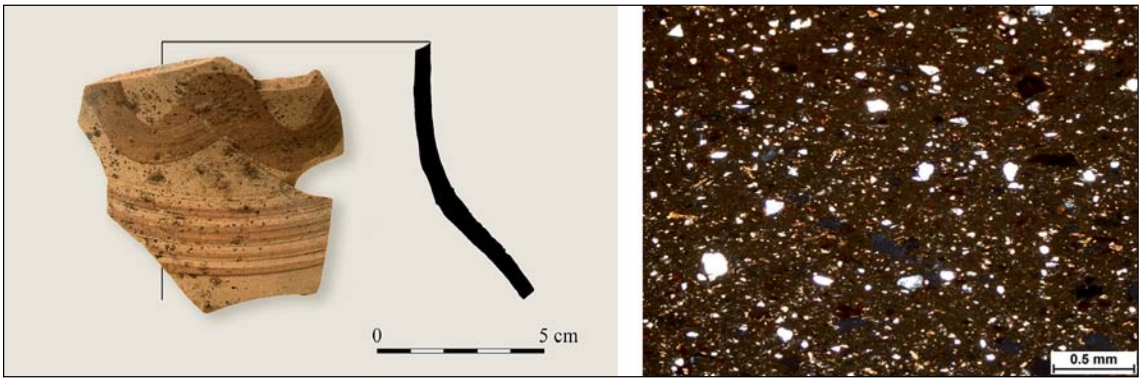


Figure 25. Fabric 6. Sixteenth-century jar with red painting and its characteristic appearance in thin section (Sample 39, Barcs, 40x, +N)

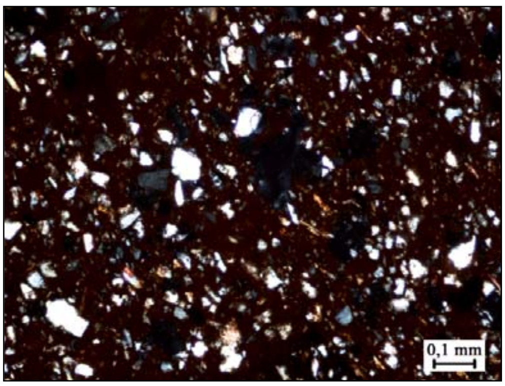


Figure 26. Fabric 6a. High magnification macrograph of a sixteenth-century Turkish green glazed stove tile (Sample 4, Barcs, 100x, +N)

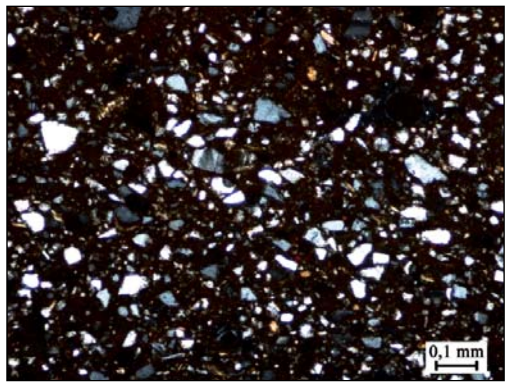


Figure 27. Fabric 6a. High magnification macrograph of a seventeenth-century Turkish pedestalled bowl, its interior is green glazed (Sample 8, Barcs, 100x, +N)

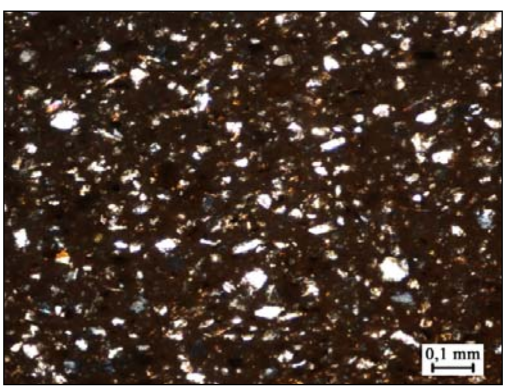


Figure 28. Fabric 6a. High magnification macrograph of a sixteenth-century Turkish green glazed vessel with stamped decoration (Sample 14, Barcs, 100x, +N)

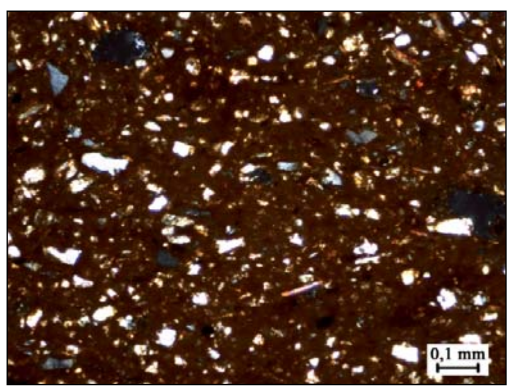


Figure 29. Fabric 6a. High magnification macrograph of a sixteenth-century Turkish flow glazed pedestalled bowl (Sample 23, Barcs, 100x, +N)

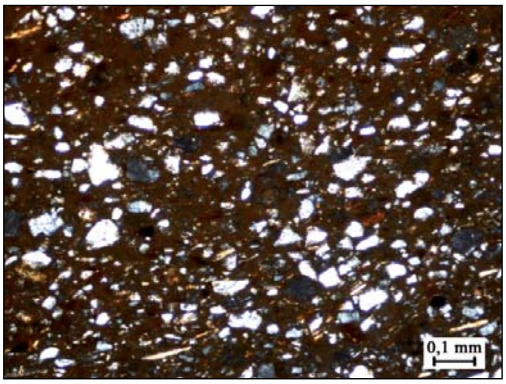


Figure 30. Fabric 6a. High magnification macrograph of a sixteenth-century Turkish green glazed pedestalled bowl (Sample 26, Barcs, 100x, +N)

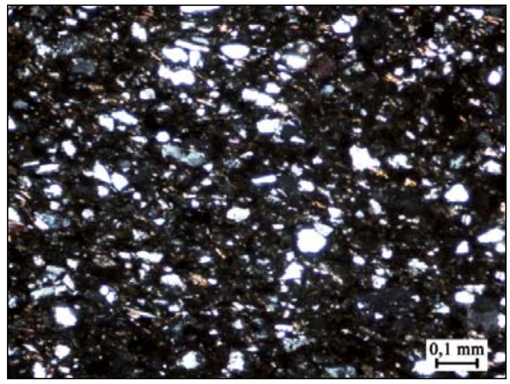


Figure 31. Fabric 6a. High magnification macrograph of a sixteenth-century lid, its interior is decorated with an incised wavy line (Sample 31, Barcs, 100x, +N)

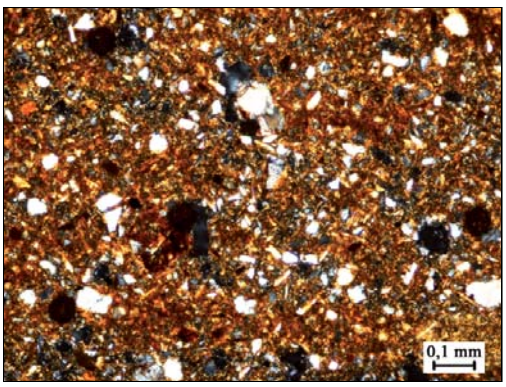


Figure 32. Fabric 6a. High magnification macrograph of a sixteenth-century Turkish green glazed spouted jar (Sample 33, Barcs, 100x, +N)

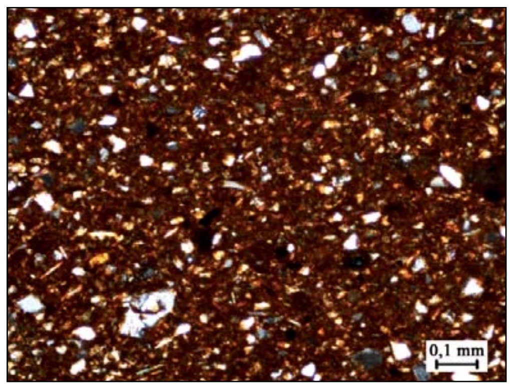


Figure 33. Fabric 6b. High magnification macrograph of a sixteenth–seventeenth-century Turkish bowl with sgraffito technique (Sample 12, Barcs, 100x, +N)

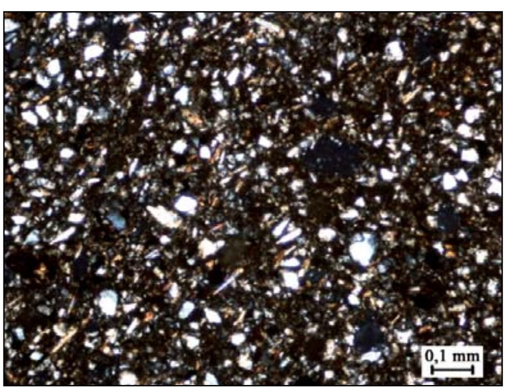


Figure 34. Fabric 6c. High magnification macrograph of a sixteenth-century Turkish green glazed jar (Sample 24, Barcs, 100x, +N)

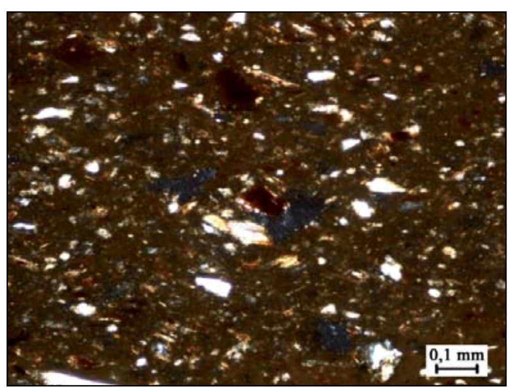


Figure 35. Fabric 6d. High magnification macrograph of a sixteenth-century jar with red painting (Sample 39, Barcs, 100x, +N)

Fabric 7 (Figs 36–39)

Four samples belong to this fabric (cup-shaped stove tile, made on a slow wheel, sixteenth century: 5; shoulder of a pot with stabbed decoration, made on a slow wheel, sixteenth century: 19; shoulder of a red jar with incised wavy lines, sixteenth century: 34; body fragment of a red jar, sixteenth century: 35). This fabric group is different from the rest since sparse amounts of sand tempering could be identified in its very fine to fine grained micaceous raw material (mainly muscovite mica falls in the fine category), it is mainly composed of quartz, orthoclase feldspar, and muscovite mica. The amount of inclusions is common (20–29%), the dominant size range of inclusions is fine (< 0.1–0.25 mm), although moderate amounts of medium grains can also be observed (0.25–1 mm).

The fabrics of the vessels are dense. The shape of the pores is elongated and rounded, their size varies between 0.02 and 2 mm. The fabric of the samples shows hiatal grain size distribution (0.02–0.1 mm and 0.25–1 mm). The non-plastic inclusions are moderately sorted. The majority of inclusions are monocrystalline quartz grains with straight extinction, the grains are subangular or subrounded. This fabric also shows more muscovite mica than the other fabrics. Rare amounts of orthoclase feldspar and plagioclase feldspar also appear, as do accessory minerals of biotite and tourmaline.

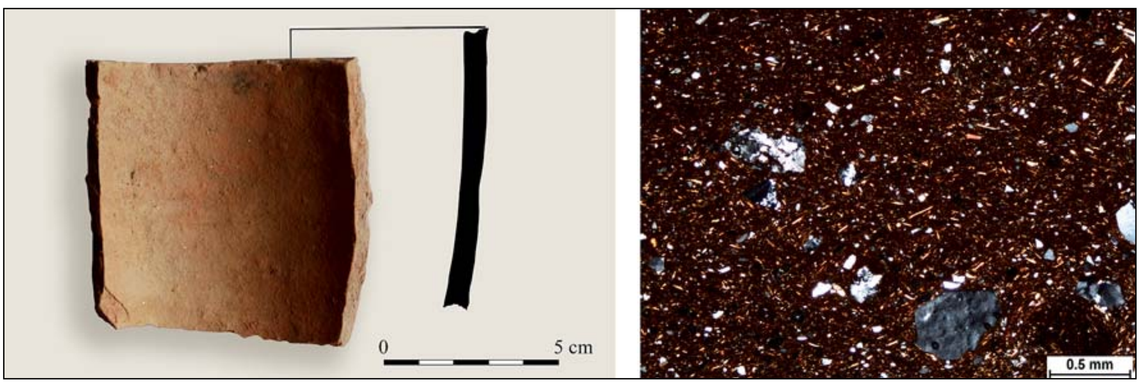


Figure 36. Characteristic appearance of Fabric 7 (Sample 5, Barcs, 40x, +N)

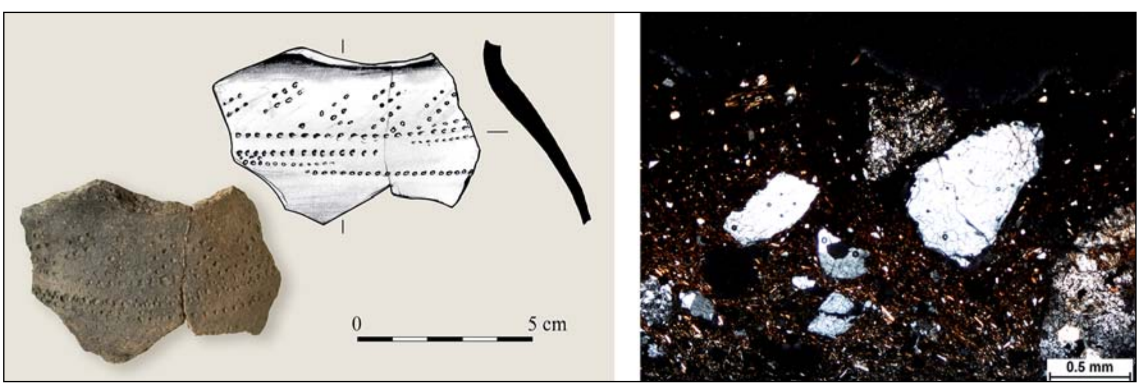


Figure 37. Characteristic appearance of Fabric 7 (Sample 19, Barcs, 40x, +N)

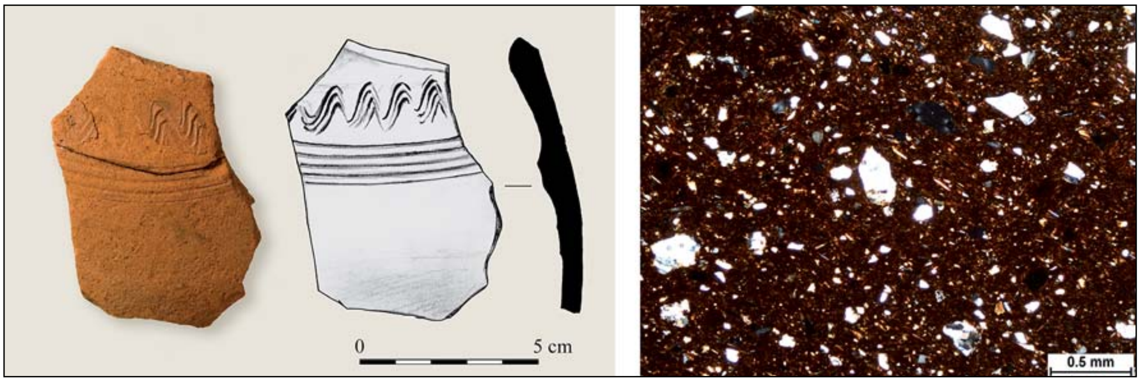


Figure 38. Characteristic appearance of Fabric 7 (Sample 34, Barcs, 40x, +N)

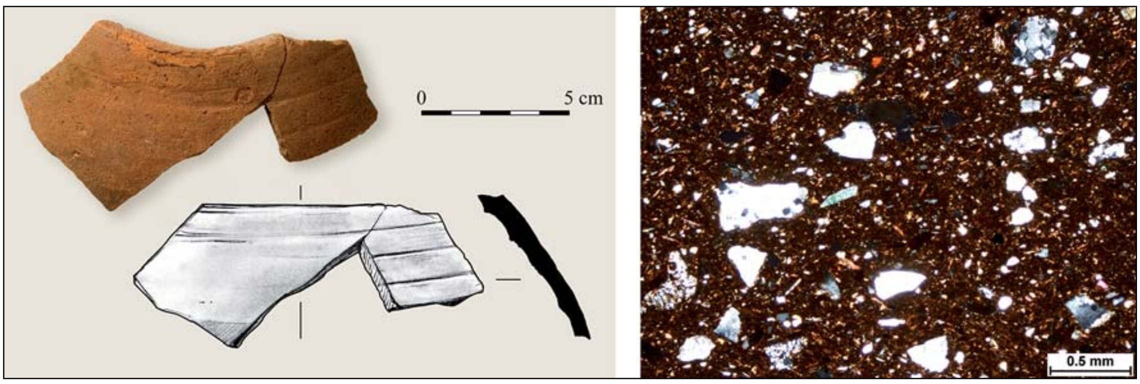


Figure 39. Characteristic appearance of Fabric 7 (Sample 35, Barcs, 40x, +N)

Fabric 8 (Figs 40–41)

One sample belongs to this fabric (handle of a baking cover, hand-formed, sixteenth century: 6). The characteristic of this fabric is that it shows moderate amounts (10–15%) of siliceous sponges in its basic raw material (Fig. 41), which are not present in other samples at all. That is, the raw material of the baking cover is characteristically distinct from the other ceramics. Siliceous sponges are elongated and rounded in cross section. The amount of non-plastic inclusions in this sample is common (20–29%), the dominant grain size falls in the fine category (0.1–0.25 mm), although sparse amounts (3–9%) of medium to coarse grains

Figure 40. Characteristic appearance of Fabric 8 (Sample 6, Barcs, 40x, +N)

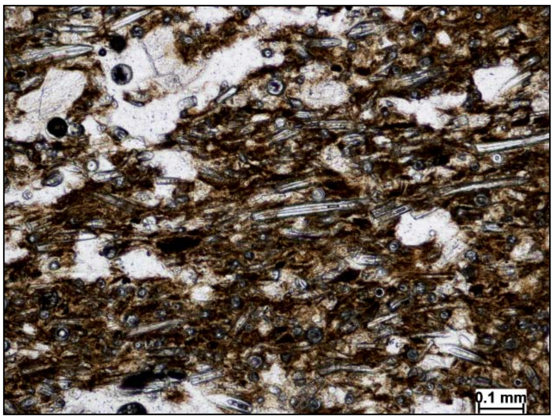


Figure 41. Siliceous sponge remains in Sample 6 (Barcs, 100x, 1N)

(0.25–3 mm) can also be observed. There is a plastered layer on the sample, whose raw material seems to be similar to the raw material of the baking cover, although coarse pebble tempering (2–7 mm) could be observed in the plastering layer.

The shape of the pores in the sample is elongated or rounded, their size varies between 0.02 and 2 mm. The grain size distribution in the sample is hiatal (0.02–0.1 mm and 0.5–3 mm). The non-plastic inclusions are poorly sorted. The majority of inclusions are monocrystalline quartz grains with straight extinction and orthoclase feldspar, although among the coarser grains, apart from monocrystalline quartz, polycrystalline quartz and orthoclase feldspar, plagioclase feldspar also appears.

Fabric 9 (Figs 42–43)

Two samples belong to this group (rim of a bowl with marbled glaze, sixteenth century**:** 7; base of a small bowl, its interior is glazed, painted, sixteenth century: 38). It must be noted that Sample 16 seems to be an import according to its typological and stylistic features; however,

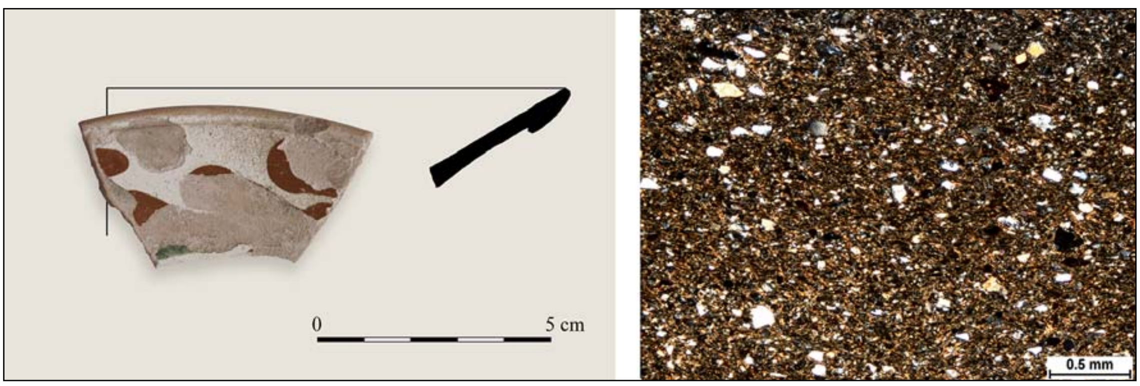


Figure 42. Characteristic appearance of Fabric 9 (Sample 7, Barcs, 40x, +N)

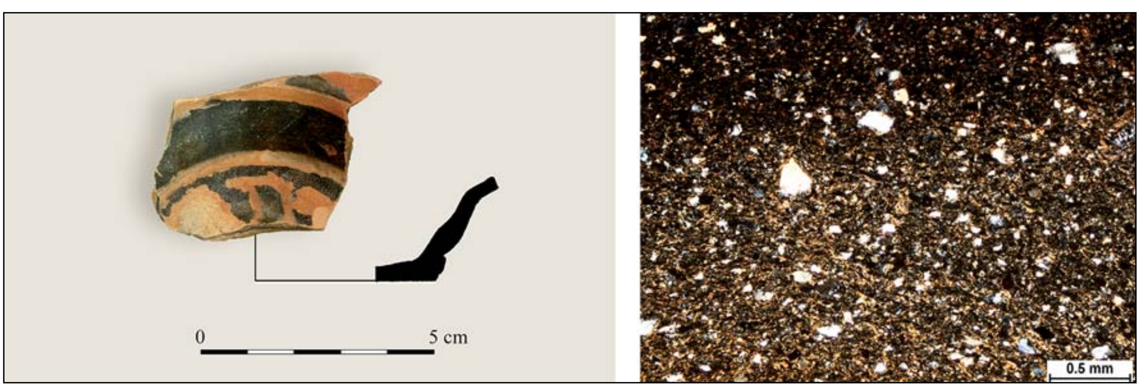


Figure 43. Characteristic appearance of Fabric 9 (Sample 38, Barcs, 40x, +N)

it is similar petrographically to the assumedly locally made vessels of this fabric group. These samples are characterized by fine inclusions. The amount of non-plastic inclusions is common (20–29%), the dominant grain size falls in the very fine category (< 0.1 mm), although sparse amounts of fine grains also appear (~0.1 mm), which are slightly smaller than what we could observe in Fabric 1. Therefore, the raw material of the ceramics in Fabric 9 is different from that of the other fabric groups.

The fabrics of the vessels are dense. The shape of the pores is irregular, elongated, or rounded, their size varies between 0.02 and 2 mm. The fabrics show serial grain size distribution (0.02–0.1 mm). Non-plastic inclusions are well or very well sorted. The majority of inclusions are monocrystalline quartz grains with straight extinction, the shape of the grains is subangular or subrounded. Rare amounts of orthoclase and plagioclase feldspar also appear and tourmaline could also be identified.

Fabric 10 (Fig. 44)

One sample belongs to this fabric (shoulder of a jar with short incised lines, fired under reducing conditions, sixteenth century: 21). Regarding the characteristic of this group, the amount of non-plastic inclusions is sparse (3–9%), the dominant grain size falls in the very fine category (< 0.1 mm), although rare amounts of fine grains also appear. The shape of the pores is irregular, elongated, or rounded, their size varies between 0.02 and 0.5 mm. The fabric of the sample shows serial grain size distribution (0.05–0.1 mm), the inclusions are very well sorted. The majority of inclusions are monocrystalline quartz grains with straight extinction, the quartz grains are rounded. Rare amounts of orthoclase and plagioclase feldspar, and muscovite mica also appear. This fabric is distinguished from the other untempered fabrics in that the amount of inclusions is sparse.

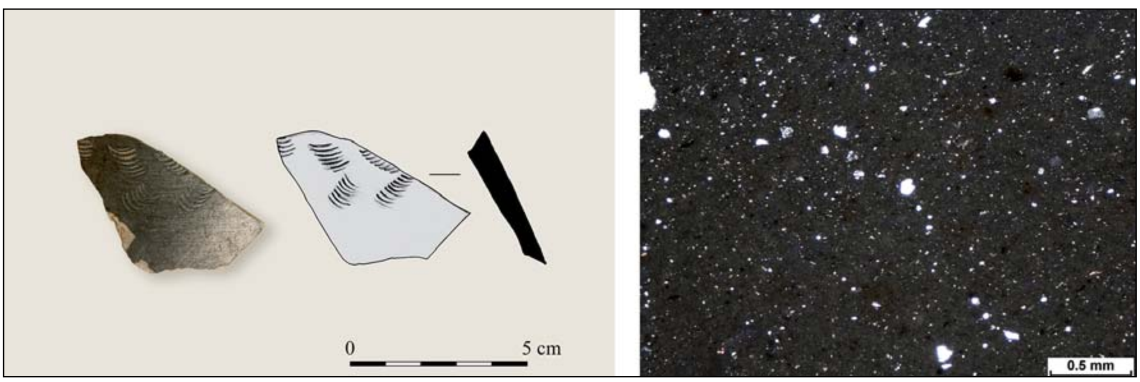


Figure 44. Characteristic appearance of Fabric 10 (Sample 21, Barcs, 40x, +N)

Fabric 11 (Fig. 45)

One sample belongs to this fabric (faience, decorated with blue painting on a white base, seventeenth century: 13). The characteristic of this group is that the amount of non-plastic inclusions is rare-sparse (2–5%), the dominant size of the inclusions is very fine (< 0.1 mm). The majority of inclusions are so small that they can hardly be observed by a polarizing microscope. The fabric of the sample is serial (0.02–0.05 mm), and the inclusions are very well sorted. The majority of inclusions are rounded monocrystalline quartz grains with straight

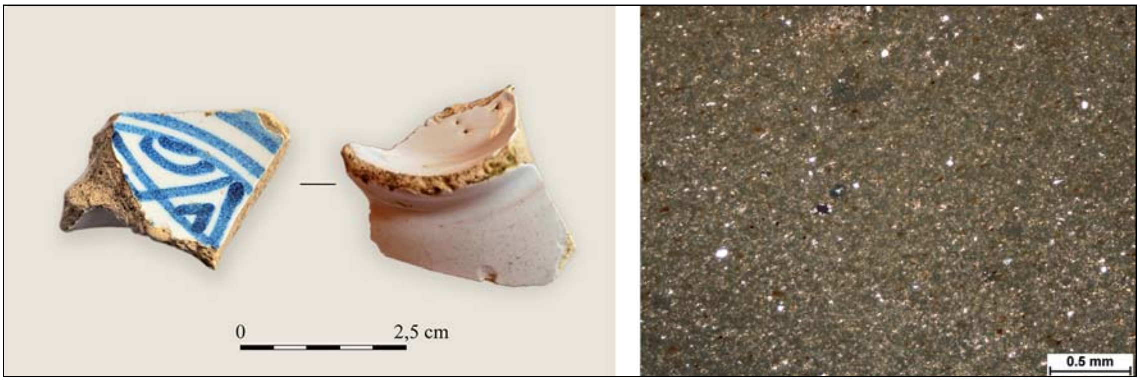


Figure 45. Characteristic appearance of Fabric 11 (Sample 13, Barcs, 40x, +N)

extinction. Rare amounts of orthoclase feldspar and muscovite mica also appear. The raw material of the sample is calcareous.

The sample is covered with a white lead glaze and has blue painted motifs. The glaze shows rare amounts of quartz grains in thin section, and air bubbles can also be identified. This fabric is distinguished from the other untempered fabric groups in that the raw material of this faience is so fine that the inclusions can hardly be observed by a polarizing microscope. The unique raw material of this sample suggests that it is of non-local origin.

Fabric 12 (Fig. 46)

One sample belongs to this fabric group (neck of a jar, fired in a reducing atmosphere, sixteenth century: 20). The characteristic of this fabric group is that the amount of non-plastic inclusions is medium-common (10–29%), the dominant size of the inclusions is very fine (< 0.1 mm), although rare amounts of fine and medium grains (0.1–1 mm) also appear.

The shape of the pores is irregular, elongated, or rounded, their size varies between 0.02 and 1 mm. The grain size distribution of the sample is hiatal (0.05–0.1 mm and 0.2–0.5 mm), the inclusions are moderately sorted. The majority of inclusions are rounded monocrystalline quartz grains with straight extinction. Among the larger grains of polycrystalline quartz, orthoclase feldspar and some larger (0.7 mm) muscovite mica specs can be observed. This ceramic was tempered with sand. It is different from the other sand tempered vessels in that the larger grains are strongly altered polycrystalline quartz with cracks.

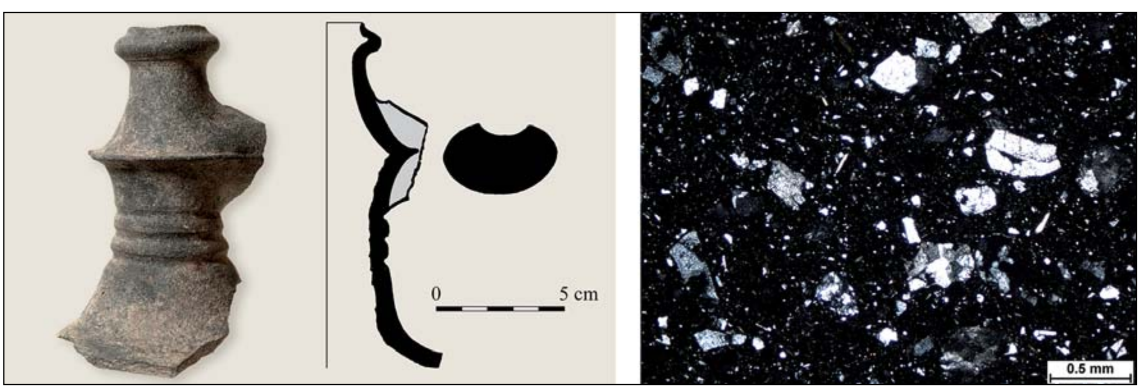


Figure 46. Characteristic appearance of Fabric 12 (Sample 20, Barcs, 40x, +N)

Fabric 13 (Fig. 47)

One sample belongs to this fabric (shoulder of a jar, decorated, fired in reducing atmosphere, sixteenth century: 22). This fabric is characterized by fine inclusions. The amount of non-plastic inclusions is common (20–29%), the dominant grain size falls in the fine category (0.1–0.25 mm), although sparse amounts of medium grains (0.25–0.7 mm) can also be observed, which are well rounded; these are mainly quartz grains.

The fabric of the ceramic is dense. The shape of pores is irregular, elongated, or rounded, their size varies between 0.1 and 2 mm. The fabric of the sample shows hiatal grain size distribution (~0.1 mm and ~0.5 mm), the raw material was tempered with sand. The inclusions are moderately sorted. The dominant non-plastic inclusions are subangular or subrounded monocrystalline quartz grains, although rare amounts of orthoclase feldspar, plagioclase feldspar, and larger polycrystalline- and monocrystalline quartz grains with undulose extinction can also be observed. Accessory minerals of tourmaline and biotite are also present.

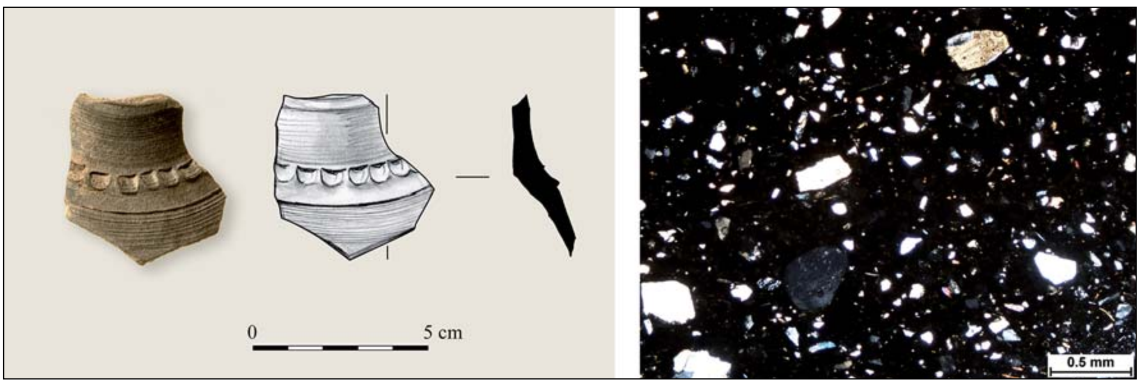


Figure 47. Characteristic appearance of Fabric 13 (Sample 22, Barcs, 40x, +N)

Fabric 14 (Fig. 48)

One sample belongs to this fabric (rim of a jar, green glazed, sixteenth century: 28). Similarly to Fabric 13, this fabric is also characterized by fine inclusions, although the appearance of grains is different. In Sample 28 the quartz grains are more elongated, showing a "splintered" appearance. The amount of non-plastic inclusions is common (20–29%), the dominant grains

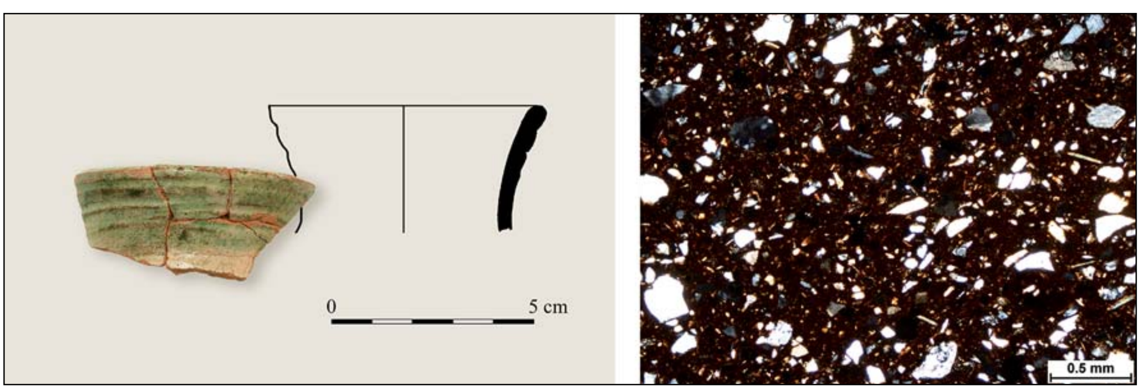


Figure 48. Characteristic appearance of Fabric 14 (Sample 28, Barcs, 40x, +N)

are fine (0.1–0.25 mm). Apart from the "splintered" quartz, the grains are well rounded, these are also mainly quartz grains. Sparse amounts of medium grains also appear. These are unevenly distributed in the fabric – they even appear in groups, suggesting that this raw material was tempered with sand. Nevertheless, it differs from the other sand tempered samples in that the appearance of the grains is different.

The fabric of the sample is dense. The shape of the pores is irregular, elongated, or rounded, their size varies between 0.1 and 2 mm. The grain size distribution in this fabric is hiatal (0.1–0.15 mm and 0.3–0.5 mm), the inclusions are moderately sorted. The dominant inclusions are subangular or subrounded monocrystalline quartz grains. Rare amounts of orthoclase and plagioclase feldspar also appear. Tourmaline is present as accessory.

Fabric 15 (Fig. 49)

One sample belongs to this fabric (rim and shoulder of a pot, decorated with incised lines on the shoulder, sharply defined rim, made on a slow wheel, sixteenth century: 25). The characteristic of this fabric is that the amount of non-plastic inclusions is common (20–29%), the dominant size of the grains falls in the fine and medium categories (~0.25–0.35 mm).

The shape of the pores is irregular, elongated, or rounded, their size is around ~1 mm. The fabric of the sample shows serial grain size distribution (0.2–0.5 mm), the inclusions are well sorted. The dominant inclusions are rounded monocrystalline quartz grains with straight extinction and orthoclase feldspar, although plagioclase feldspar, muscovite, and biotite mica are also observed. This fabric is distinguished from the other fabrics in that the dominant inclusion size is larger than in the other samples, the inclusions are well sorted and very similar in size. It could not be decided equivocally whether the potter used a raw material that was naturally medium grained or used a "clean" raw material (hardly containing non-plastic inclusions) that was tempered with sieved sand. The latter is more likely since grain size distribution within the fabric is "suspiciously" even.

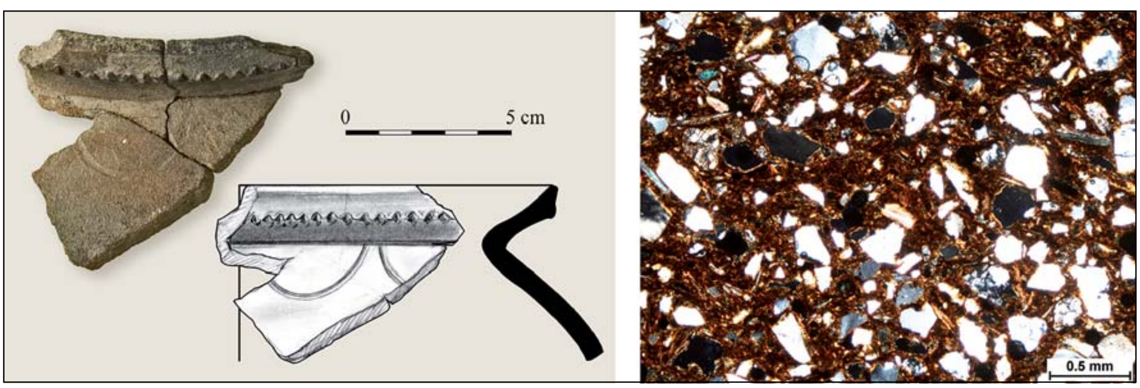


Figure 49. Characteristic appearance of Fabric 15 (Sample 25, Barcs, 40x, +N)

Fabric 16 (Fig. 50)

One sample belongs to this fabric (rim of a pot decorated with rouletting, made on a slow wheel, sixteenth century: 29). Regarding the characteristic of this group, a very fine to fine grained raw material was tempered with limestone. The amount of inclusions is common

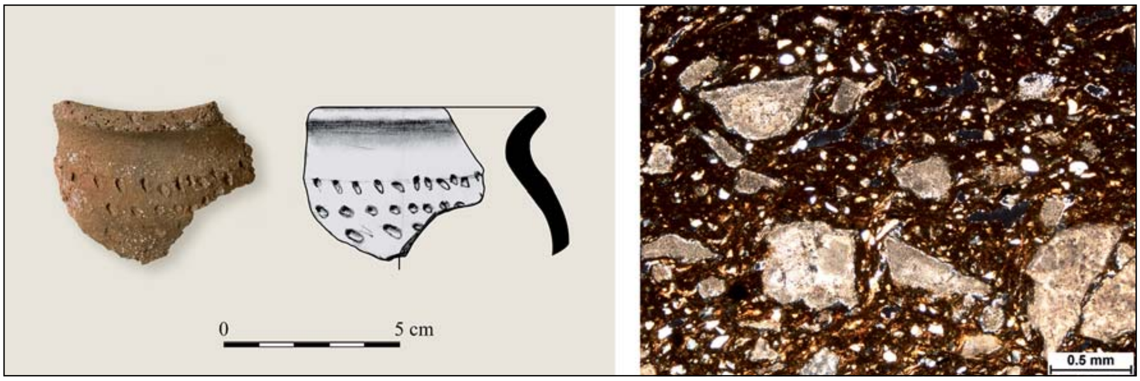


Figure 50. Characteristic appearance of Fabric 16 (Sample 29, Barcs, 40x, +N)

(20–29%), the dominant grain size in the basic raw material is very fine to fine (< 0.1–0.25 mm), while the limestone grains used for tempering are coarse or very coarse (1–5 mm).

The shape of the pores is irregular or elongated, their size varies between 0.5 and 4 mm. The grain size distribution in the fabric is hiatal (0.1–0.2 mm and 2–5 mm), the inclusions are poorly sorted.

The majority of inclusions are rounded monocrystalline quartz grains with straight extinction and orthoclase feldspar, although plagioclase feldspar and muscovite mica can also be observed. The coarse and very coarse grains are rounded or subrounded micritic limestone fragments.

Petrographic analysis of plastering (Fig. 51)

One plaster fragment (seventeenth century: 10) was chosen for petrographic analysis. Since plastering was most likely made from locally available raw materials, its petrographic comparison with ceramics could help us in identifying ceramics that had possibly been locally made. The amount of non-plastic inclusions in the sample is common (20–29%), the dominant grain size falls in the very fine category (< 0.1 mm). Sparse amounts of medium (~0.25 mm), well rounded quartz grains can also be observed.

The shape of the pores is irregular, elongated, or rounded, and their size varies between 0.02 and 1 mm. The grain size distribution in the fabric is hiatal (0.05–0.1 mm and 0.25 mm), and the raw material of the plaster was tempered with sand. The inclusions are moderately

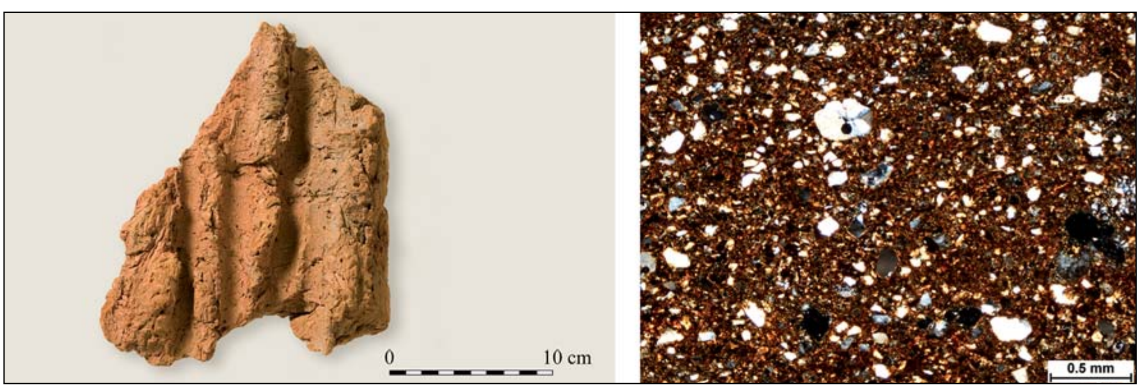


Figure 51. Plaster and its thin section (Sample 10, Barcs, 40x, +N)

sorted. The dominant inclusions are subrounded monocrystalline quartz grains with straight extinction. Rare amounts of orthoclase and plagioclase feldspar also appear. Sparse amounts of about 0.25 mm, rounded monocrystalline quartz with undulose extinction can also be observed. These quartz grains were probably part of the sand tempering. This fabric is distinguished from other sand tempered fabrics in that the inclusions are well rounded, such grains and in such amount only appear in this sample. Therefore, a different raw material was used for making plaster than for the ceramics.

Petrographic analysis of daub (Fig. 52)

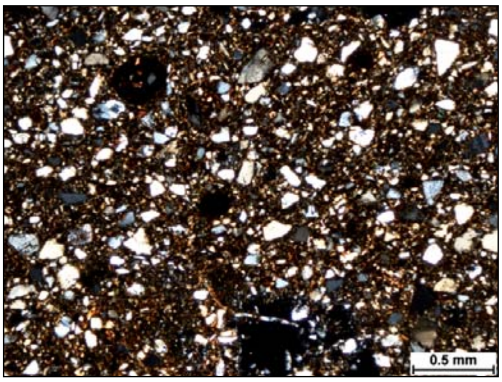


Figure 52. Thin section of a plaster (Sample 40, Barcs, 40x, +N)

One daub fragment (sample 40) was chosen for petrographic analysis in order to compare its composition to the ceramics. Since daub, similarly to plaster, was most probably made from a local raw material, comparing it to ceramics could also help in narrowing down locally made vessels.

The amount of non-plastic inclusions in the daub is common (20–29%), the dominant grain size is very fine (0.1–0.25 mm), and the maximum size of grains does not exceed 0.5 mm. The shape of the pores is irregular or elongated, and their size varies between 0.5 and 6 mm. The grain size distribution in the fabric is serial (0.1–0.25 mm), the inclusions are well sorted. The majority of inclusions are rounded monocrystalline quartz grains with straight extinction and orthoclase feldspar, although rare amounts of plagioclase feldspar and muscovite mica can also be observed. According to the petrographic characteristics of this sample, it is very similar to Fabric 15, and it also shows resemblance to Fabric 13 and to the plaster as well.

Distribution of fabric groups according to vessel types

Pots

There were thirteen pots in the analyzed assemblage, which were made from four distinct raw materials. Apart from different types of sand tempering (Fabric 1: 1, 18, 36; Fabric 4: 9, 15, 16, 17, 19, 30, 37; Fabric 7: 19; Fabric 15: 25), pots also appear to be made from very fine to fine raw materials without tempering (Fabric 2: 2) and with limestone tempering (Fabric 16: 29).

Jars

The nine analyzed jars belong to seven fabric groups. Of these, three are characterized by very fine to fine raw materials (Fabric 6: 33, 39; Fabric 10: 21; Fabric 14: 28), which were not tempered. A further four groups are characterized by different types of sand tempering (Fabric 3: 27; Fabric 5: 32; Fabric 7: 34, 35; Fabric 13: 22). Sample 32 from Fabric 5 is the body fragment of a "Bosnian" jar, while Sample 33 from Fabric 6 is the body fragment of a Turkish jar.

Large vessel (storage?)

One sample represents this vessel type. It was tempered with sand (Fabric 4: 3).

Stove tiles
Two samples belong to stove tiles. One of them is very fine grained without observable tempering (Fabric 6: 4), the other is sand tempered (Fabric 7: 5).

Baking cover
Only one baking cover was analyzed. It was made from a raw material that naturally contained siliceous sponges, and it was tempered with sand and small pebbles (Fabric 8: 6).

Bowls
Six bowls were analyzed, of which four are Turkish types (8, 12, 23, 26). All bowls were made from very fine to fine grained raw materials (Fabric 6: 8, 12, 23, 26; Fabric 9: 7, 38).

Vessel
One unidentifiable vessel type (perhaps a bowl) was analyzed. Judging from its decoration, it is an imported vessel (Fabric 6: 14).

Faience
One sample was analyzed from this vessel type; it was made from a very fine grained raw material. Its raw material can characteristically be distinguished from the raw materials of the other vessels (Fabric 11: 13).

Lid
One sample belongs to this group. It was made from a very fine to fine grained raw material (Fabric 6: 31).

PETROGRAPHIC ANALYSIS OF CERAMICS FROM NEIGHBORING SITES

In the following, ceramic raw materials from settlements (perished late medieval settlements) in the neighboring areas of the fort[4] are compared with the composition of ceramics from the fort.

Drávaszentes-Kenderföld

Sample 41 (rim of a Viennese graphite tempered pot, fifteenth–sixteenth centuries): the amount of graphite is common (20–29%). This sample is completely different from the other samples; it has no relationship with the other fabric groups *(Fig. 53)*. In the case of graphite tempered vessels, the provenance of graphite can be assessed by the rocks and minerals associated with graphite in the analyzed thin section.[5] In this case, however, the graphite could have been thoroughly cleaned, and the rock which incorporated the graphite thoroughly removed, because graphite appears without its incorporating rock in the analyzed thin section. Therefore, the provenance of the graphite could not be assessed.

Sample 42 (rim of a pot, made on a slow wheel, fourteenth–fifteenth centuries): according to the grain size and the characteristics of non-plastic inclusions, this pot has a similar fabric to Fabric 4a of Barcs. The only difference is that in Sample 42 no inclusions showing intergrowth of polycrystalline quartz and muscovite mica could be observed *(Fig. 54)*. This

4 Stray finds collected by Márton Rózsás.
5 Kreiter et al. 2009.

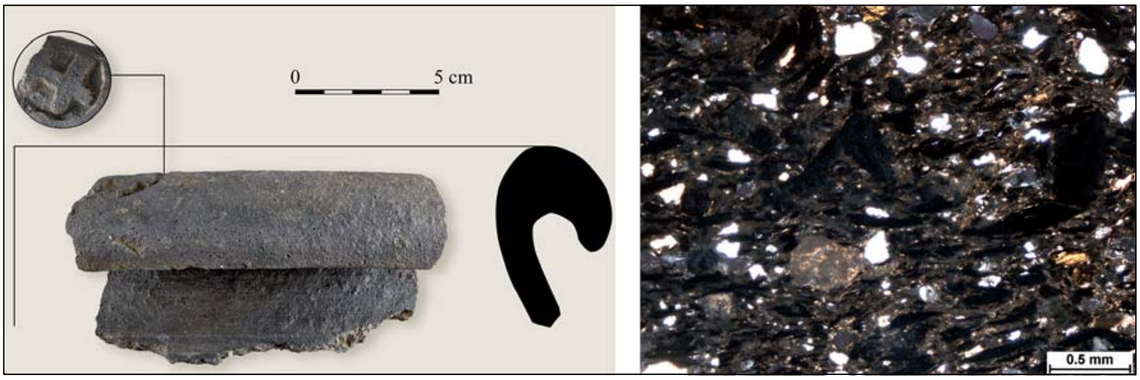


Figure 53. Viennese graphite tempered pot and its thin section (Sample 41, Drávaszentes-Kenderföld, 40x, +N)

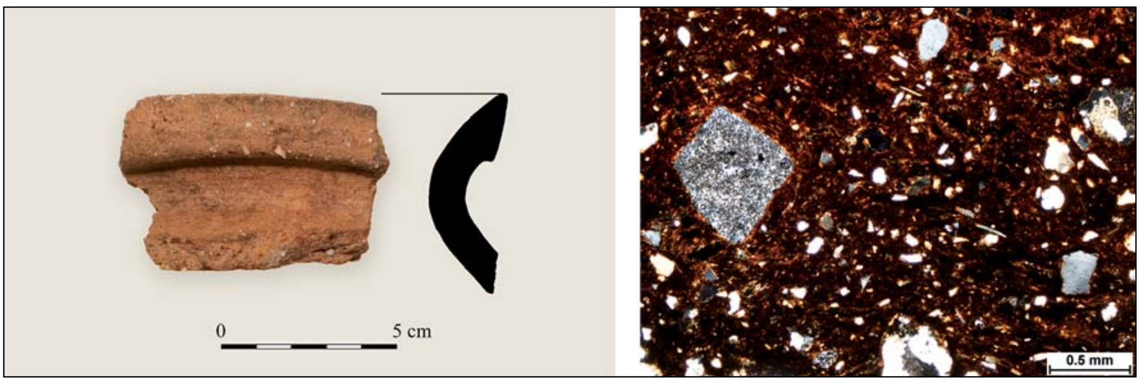


Figure 54. Sample 42 and its thin section (Drávaszentes-Kenderföld, 40x, +N)

phenomenon may imply that the raw material of this sample is different from those of Barcs, although these differences may also be the result of variability in local raw materials. Of course, there is also a possibility that some of the ceramics at Barcs were made from such locally available raw materials, which were available in a larger area, even in Drávaszentes-Kenderföld.

Somogytarnóca-Györgyös

Sample 43 (rim of a pot, made on a slow wheel, fourteenth–fifteenth centuries): according to its non-plastic inclusions, it is similar to Fabric 4b of Barcs, although Sample 43 also shows coarser non-plastic inclusions *(Fig. 55)*.

Sample 44 (rim of a pot, made on a slow wheel, fourteenth–fifteenth centuries): according to its non-plastic inclusions, it is, similarly to Sample 42, also analogous to Fabric 4a of Barcs, although Sample 44 also shows coarser non-plastic inclusions *(Fig. 56)*.

Sample 45 (rim of a pot, made on a slow wheel, fourteenth–fifteenth centuries): it shows similarities to Fabric 4a of Barcs *(Fig. 57)*.

Sample 46 (rim of a pot, fifteenth–sixteenth centuries): its composition shows a strong resemblance to that of the pot of Fabric 15 of Barcs. In Sample 46 the non-plastic inclusions are also well sorted, fine to medium grained, and the types of inclusions are also similar to those of Fabric 15 *(Fig. 58)*.

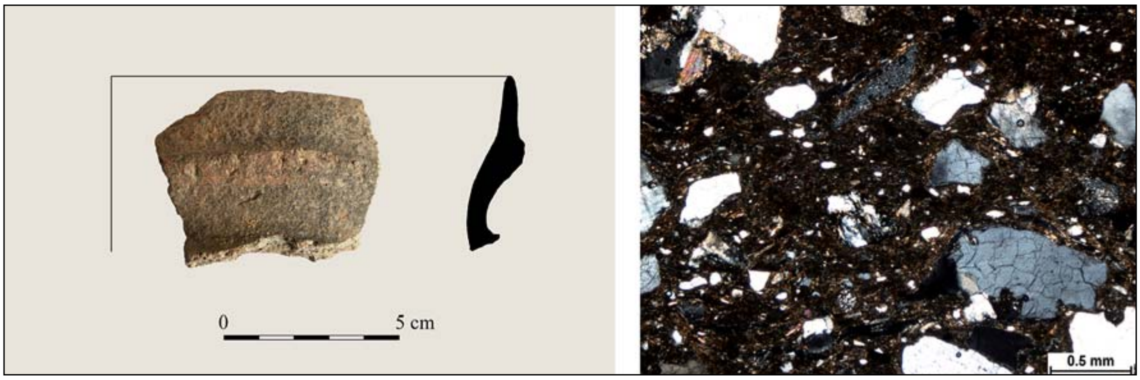


Figure 55. Sample 43 and its thin section (Somogytarnóca-Györgyös, 40x, +N)

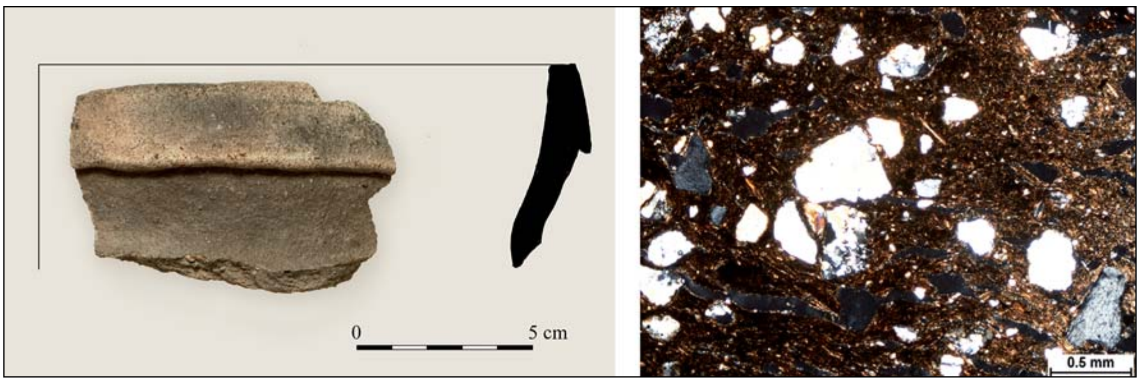


Figure 56. Sample 44 and its thin section (Somogytarnóca-Györgyös, 40x, +N)

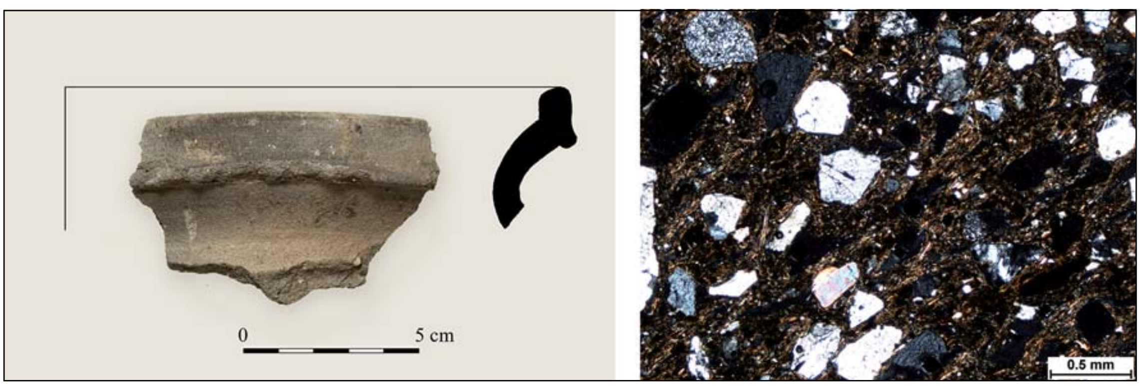


Figure 57. Sample 45 and its thin section (Somogytarnóca-Györgyös, 40x, +N)

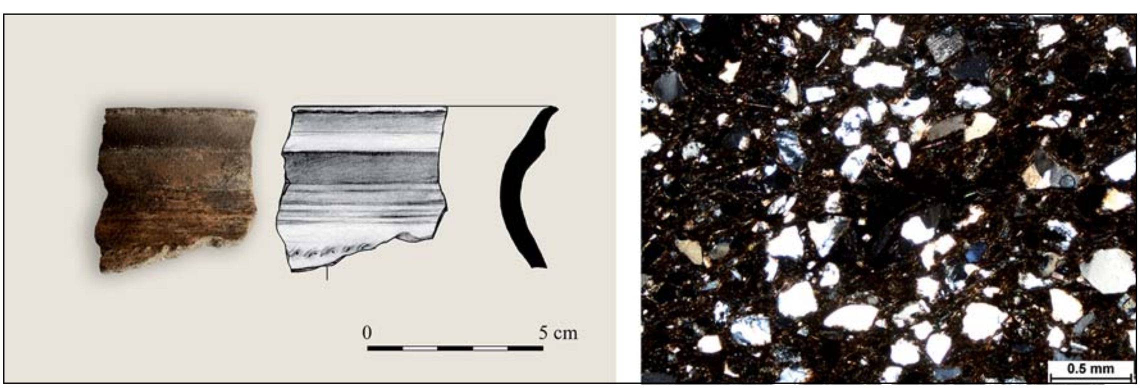


Figure 58. Sample 46 and its thin section (Somogytarnóca-Györgyös, 40x, +N)

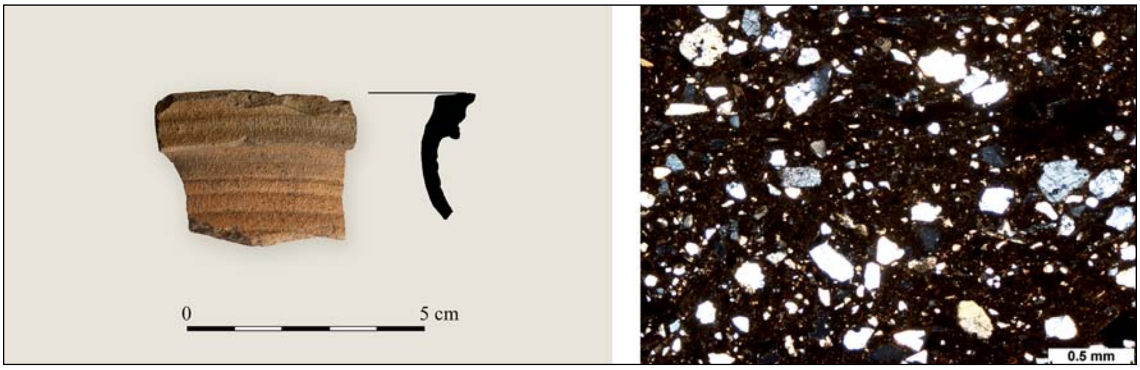


Figure 59. Sample 47 and its thin section (Somogytarnóca-Györgyös, 40x, +N)

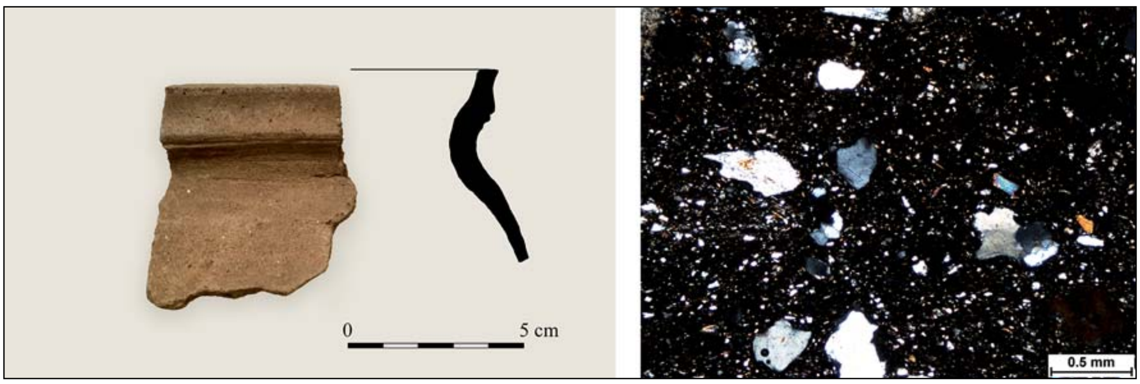


Figure 60. Sample 48 and its thin section (Somogytarnóca-Györgyös, 40x, +N)

Sample 47 (rim of a pot, fifteenth–sixteenth centuries): according to its non-plastic inclusions, it is similar to Fabric 15 of Barcs, although, compared to Sample 46, the inclusions are smaller and less well sorted in Sample 47 *(Fig. 59)*.

Sample 48 (rim of a pot, made on a slow wheel, fifteenth–sixteenth centuries): in the fabric of this pot granitic fragments that were observed in Fabric 4b of Barcs could be identified. Petrographically, this sample is very similar to that from Barcs in that intergrowth of amphibole, orthoclase feldspar, and quartz also appear *(Fig. 60)*.

Barcs-Szili-tanya

Sample 49 (rim of a pot, made on a slow wheel, fifteenth century): according to its non-plastic inclusions, it shows the closest resemblance to Fabric 4 of Barcs *(Fig. 61)*.

Sample 50 (rim of a pot, made on a slow wheel, fourteenth–fifteenth centuries): according to its non-plastic inclusions, it has the closest similarity to Fabric 4a of Barcs *(Fig. 62)*.

Sample 51 (rim of a pot, made on a slow wheel, fourteenth–fifteenth centuries): its fabric shows the closest resemblance to that of the pot of Fabric 15 of Barcs, although a few larger grains also appear in Sample 51, therefore the grain size distribution in the fabrics is slightly different *(Fig. 63)*.

Sample 52 (rim of a cup coated with engobe, fifteenth century): its fabric does not show any resemblance to any other fabrics. Its raw material is very well sorted, the majority of inclusions are fine (0.2–0.25 mm); finer or coarser inclusions than that are not present in the fabric, therefore this sample is unique among the examined ceramics *(Fig. 64)*.

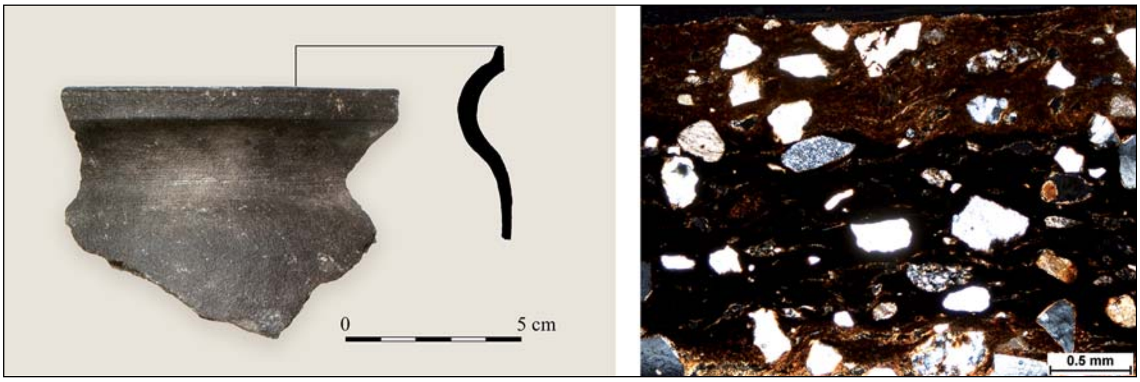


Figure 61. Sample 49 and its thin section (Barcs-Szili-tanya, 40x, +N)

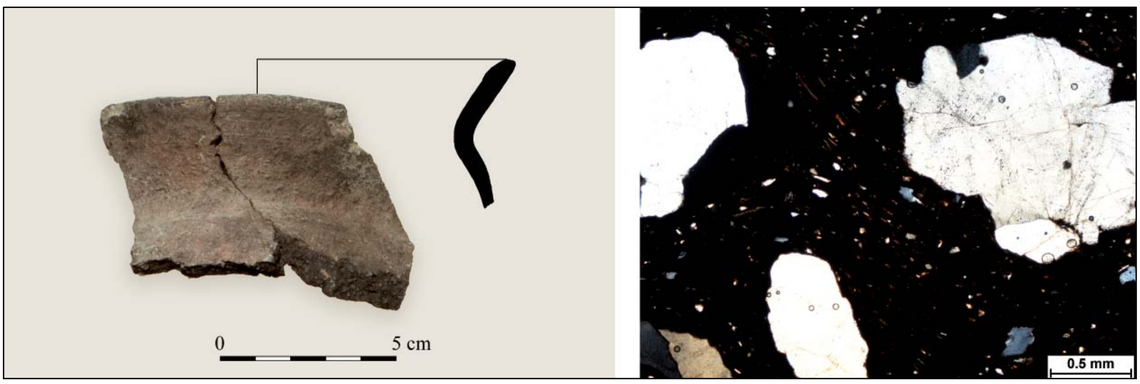


Figure 62. Sample 50 and its thin section (Barcs-Szili-tanya, 40x, +N)

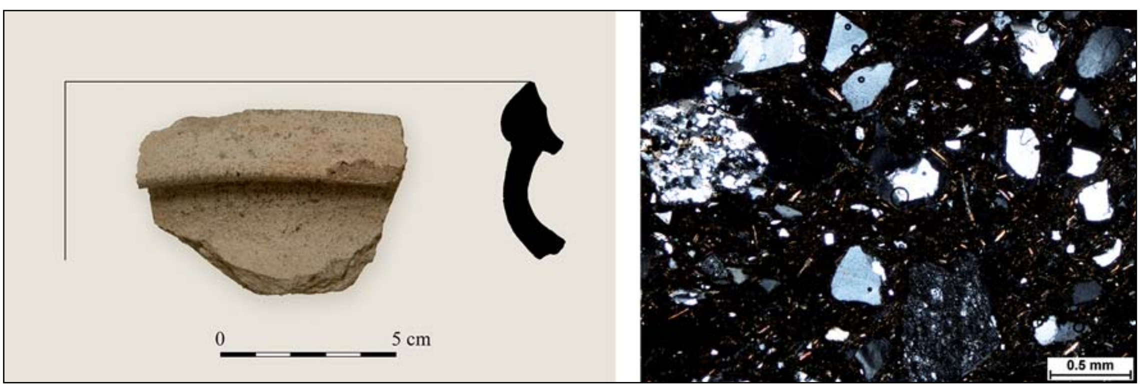


Figure 63. Sample 51 and its thin section (Barcs-Szili-tanya, 40x, +N)

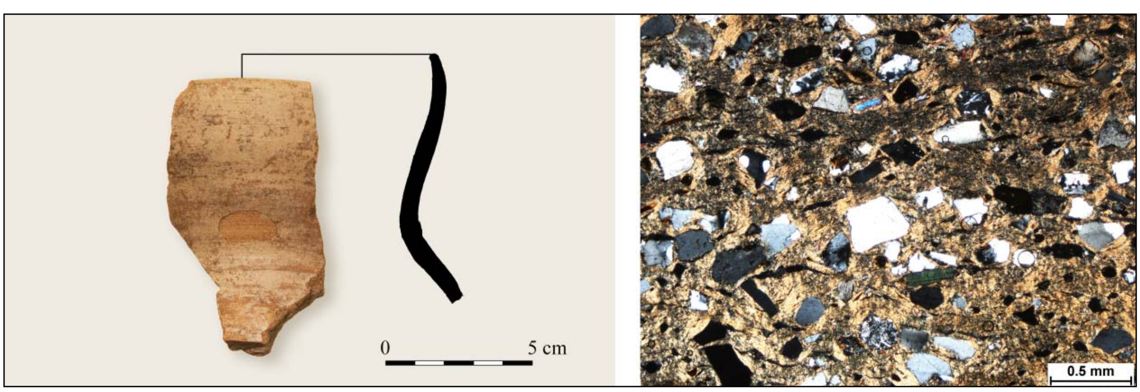


Figure 64. Sample 52 and its thin section (Barcs-Szili-tanya, 40x, +N)

Barcs-Szelistye

Sample 53 (rim of a pot, made on a slow wheel, fourteenth–fifteenth centuries): according to its non-plastic inclusions, it shows the closest similarity to Fabric 4b of Barcs *(Fig. 65)*.

Sample 54 (rim of a pot, made on a slow wheel, fourteenth–fifteenth centuries): although its fabric is finer than Fabric 4, it has the closest similarity to that among the fabrics. Alternatively, Sample 54 may represent a distinct fabric (together with Sample 55) *(Fig. 66)*.

Sample 55 (rim of a pot, fifteenth century): its fabric is finer than Fabric 4, but it shows the closest resemblance to that among the fabrics. Alternatively, Sample 54 may represent a distinct fabric (together with Sample 54) *(Fig. 67)*.

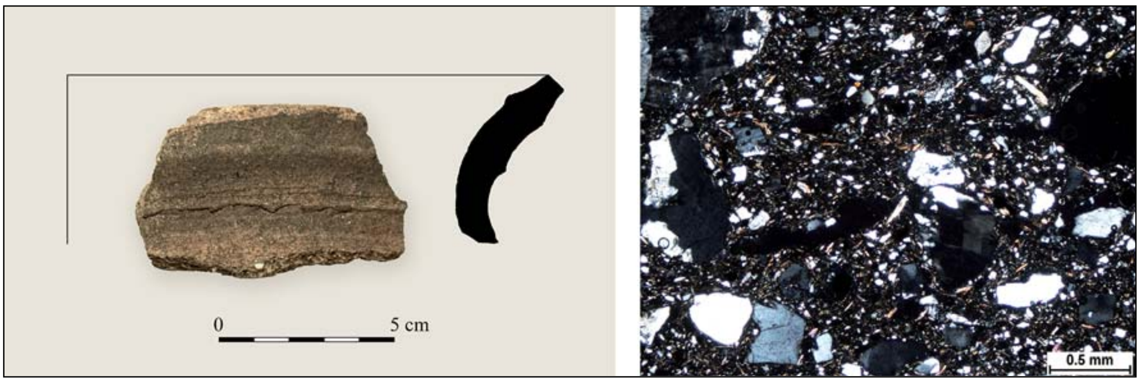


Figure 65. Sample 53 and its thin section (Barcs-Szelistye, 40x, +N)

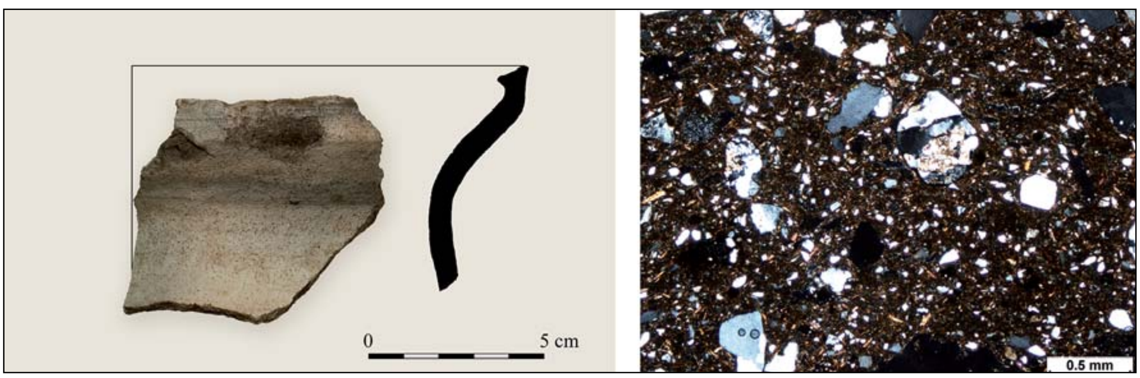


Figure 66. Sample 54 and its thin section (Barcs-Szelistye, 40x, +N)

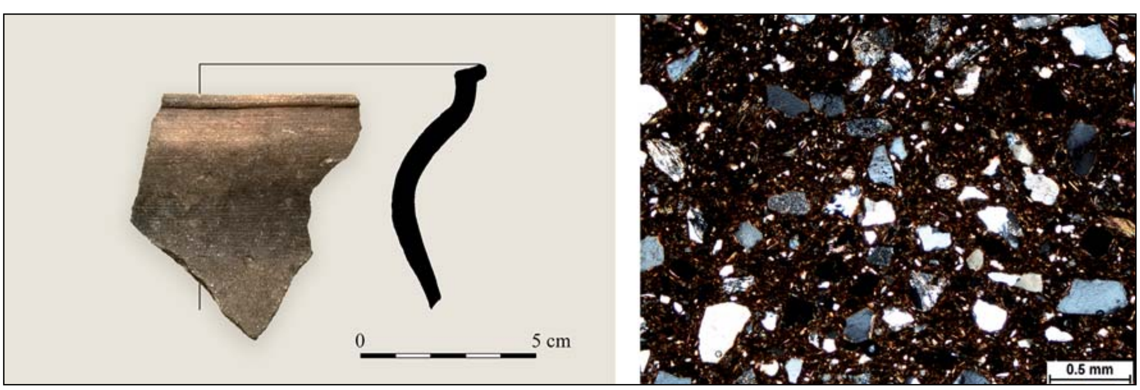


Figure 67. Sample 55 and its thin section (Barcs-Szelistye, 40x, +N)

EVALUATION OF RESULTS – SUMMARY

The fabrics of the analyzed ceramics from Barcs show a high variability that we did not observe previously at other medieval sites. Variability in technological practices is indicative of the organization of ceramic production.[6] Regarding a given vessel type, a potter does not change raw materials or tempering, and it also appears that a potter/workshop used one recipe for all vessel types they produced.[7] According to the petrographic results, the analyzed vessels were most probably made by several potters or workshops. This conclusion can be reinforced by the utilization of different building techniques (slow and fast wheel) as well. Our assumption is also supported by the fact that there are considerable differences between the raw materials of the examined ceramics. These differences require different knowledge and experience from potters since these raw materials behave very differently during drying and firing.[8] Since compositional differences in the fabrics resulted in qualitative differences between the ceramics,[9] these may also support the notion that the products of several potters/workshops were present at Barcs.

In the case of Barcs, however, no local ceramic production (within the fort) can be assumed, but rather, an extensive trade relationship is suggested. As a result, the inhabitants of the fort acquired their ceramic vessels from several places. In order to define the scale of pottery production within the fort, we would need to know details of ceramic production (workshop, kiln, wasters). However, no signs of pottery production were found during the excavation. Nevertheless, ceramic production can be assumed in neighboring larger settlements like Szigetvár or Babócsa. The high variability in raw materials within the smaller, examined region can also be explained by variability in local geology. As it will be shown later, river deposits may show extensive variability in their compositions.

In order to compare the ceramic technological variability found at Barcs, the ceramics of earlier examined sites are also considered: Dunaszentgyörgy-Alsó-Csámpa TO 23[10] from the Árpádian Age and Vác-Piac utca[11] from the thirteenth–seventeenth centuries. By comparison, thirteenth–fourteenth-century ceramics from Vác were essentially made from four different raw materials, but the amount of tempering and the size of tempering agents show high variability. That is, ceramics belonging to the same period were also made from several raw materials and were tempered differently at Vác. Therefore, no period-specific raw material use could be identified. Ceramics from the fifteenth–sixteenth centuries at Vác have similar raw materials as the ones from the thirteenth–fourteenth centuries. Thus, ceramics were made by very similar tempering, and ceramics belong to similar fabric groups from the thirteenth to the sixteenth centuries.

By comparing fifteenth–sixteenth- and sixteenth–seventeenth-century ceramics, however, characteristic differences could be identified in raw material use, since sixteenth–seventeenth-century ceramics were made from different raw materials compared to the earlier ones. Thus, change can be assessed in ceramic raw materials at Vác. This change at Vác can be associated with the Ottoman-Turkish rule that resulted in that sixteenth–seventeenth-century ceramics show a much more homogenized raw material use than earlier ceramics. Therefore, it can be assumed that sixteenth–seventeenth-century ceramic production or ceramic trade

6 Kreiter 2010.

7 DeBoer – Lathrap 1979, 116–117; Plog 1980, 86–87; Tobert 1984, 226–227; Chávez 1992, 85; Sillar 1997, 8; Frank 1998, 83.

8 Rice 1987, 104; Kilikoglou et al. 1995; 1998; Kilikoglou – Vekinis 2002.

9 Budden 2008.

10 Kreiter 2009.

11 Kreiter – Viktorik in press.

at Vác was concentrated in "fewer hands". Thus, fewer workshops produced ceramics, or ceramics arrived to Vác from fewer places, trade became more restricted. At Barcs, however, a completely opposite tendency can be observed; extensive ceramic technological variability can be identified during the Ottoman-Turkish rule.

Árpádian Age ceramic production also shows less variability at Dunaszentgyörgy than in Barcs. Considering the results from Dunaszentgyörgy, ceramics were made from "clean" raw materials containing less non-plastic inclusions and they were tempered with sand and small pebbles. This technological practice is only characteristic of Fabric 4 of Barcs. As opposed to this, Barcs shows a considerable higher ceramic technological variability than the ceramics at Dunaszentgyörgy and Vác.

Similarly to the ceramics of Vác, where characteristically sand and small pebble tempering were identified, sand and small pebble tempering dominate at Barcs and the neighboring sites too. Apart from these, further tempering practices could be observed. It must be noted that raw material preparations cannot be clearly assessed even within the most characteristic fabric groups, since in the case of sand and pebble tempered Fabric 4, two subgroups could be distinguished according to the composition of tempering materials. One of the subgroups contained metamorphic inclusions, while granitic fragments could be identified in the other. There was no overlap between the two: either the first or the second tempering practice was used by the potters to make the vessels. In several cases, well prepared raw materials could be identified without tempering. In these cases, the fabric groups were distinguished by the size of non-plastic inclusions or other differences between the inclusions. In considering the above, there can be several reasons for the observed variability in raw materials at Barcs:

(1) Geology: The most fundamental explanation of ceramic raw material variability is that Barcs is situated on a flat plateau filled up by the deposits of the Drava River, where mainly young sediments can be found. River sediments can show high variability in terms of inclusion types since the composition of sediments greatly depends on the rocks of the ablation area (in this case, metamorphic, granitic, and limestone) and on the physical condition of the sedimentation process (in the case of slower drift, mica specs can be settled, creating a mica rich deposit layer).

(2) Trade: According to petrographic and typological/stylistic research, the fort of Barcs was a "collecting place" of ceramics arriving from different directions. Ceramics may have arrived to Barcs not only from the surrounding areas, but, since Barcs was also a port, through river trade – even from a long distance (e.g. faience). Table wares (jars and bowls) seem to have been more often acquired by trade. It is probably not an accident that the raw materials of jars show the greatest variability. Thus, jars may have arrived to Barcs from several places, they could have been made in several workshops, and some of the table wares were even made from special raw materials (e.g. faience, Fabric 11, Sample 13).

(3) History and geographical position: The fort of Barcs is situated close to the east-west trade route of the Drava River. The fort was in the hands of the Turks all along. It was burned down in 1595 and it remained in ruins until it was rebuilt – it had no "Hungarian owner". After 1600, the border of the Ottoman-Turkish occupied area was extended towards the west; therefore, Barcs became a hinterland fort from a fringe fort. These changes in the life of the fort may have also resulted in extensive variability in raw material use for potting, extensive supply, and trade.

In the analyzed assemblage there are several ceramics which, according to their typological and/or stylistic features, seem to be imported, or at least different from local wares – so-called Turkish type vessels. One of the assumed imported vessels is a white faience with blue painting (Fabric 11, Sample 13). The raw material of this vessel is very fine, calcareous, and it hardly contains observable non-plastic inclusions (with polarizing microscope). This raw material is unique, this vessel is most probably an import, but since there are no comparative samples to this fabric, its provenance cannot be assessed petrographically. According to its typological features, a Turkish (Anatolian) or Italian provenance can be assumed.

Another assumedly imported vessel (more precisely, not locally made) is a "Bosnian" jar (Sample 32), which belongs to Fabric 5. Its raw material shows some similarities to the pot decorated with rouletting (Sample 19) of Fabric 7, but their similarity is not conclusive. Since no clear similarities could be identified between the "Bosnian" vessel and other examined ceramics, the non-local origin of the former can be assumed, but cannot be stated with reassuring certainty since its uniqueness may be the result of sample selection. The latter is a likely scenario because the composition of ceramics from Barcs shows high variability and there are several fabrics with only one sample. It is also important to note that the ceramics of the examined period are understudied in Hungary. In order to draw comprehensive conclusions, systematic ceramic analysis is required, whereby the raw material of the jar could be compared to similar jars from other sites.

Despite the increased variability of the entire assemblage, the raw materials of ceramics of Fabric 6 can clearly be distinguished from the other ceramics. Within Fabric 6 some minor differences are present in the composition of the ceramics, but this does not necessarily mean that different raw materials were used for their production. Small variabilities can be accounted for within the raw material.

The assumedly not locally made green glazed stamped vessel (Sample 14) turned out to be very similar petrographically to the samples in Fabric 6, to subgroup 6a within that. Therefore, it was most probably made from the same raw material from which the other vessels in Fabric 6a were made. However, the other ceramics in Fabric 6a cannot be considered to be German, Upper Austrian, or Styrian imports. Therefore, the German, Upper Austrian, or Styrian provenance of Sample 14 is uncertain. According to the petrographic analysis, this vessel belongs to the same group as glazed Turkish vessels. As a result, there is a possibility that this vessel was made in Ottoman territory. An important momentum regarding the provenance of this vessel was brought to our attention from Eszék/Osijek in 2015. This vessel is a green glazed Turkish-type lid with similar stamped decoration as the one on Sample 14 from Barcs.[12] This analogy may imply that the vessels from Barcs (Fabric 6) were made in Slavonia, in a Turkish influenced area, together with Turkish vessels. Croatian ceramic materials from the sixteenth–seventeenth centuries are generally not fully assessed, therefore the provenance of the lid from Eszék/Osijek – similarly to the finds from Barcs – is still unknown. Nevertheless, the finds indicate their possible relationships; but to prove this, further research is required. The solution to the question of provenance can be brought forward by analyzing Styrian vessels (e.g. from Bajcsa), but it would be important to compare them with glazed Turkish vessels from different parts of Hungary because their raw materials seem very homogeneous macroscopically, but their provenance is assumedly different.

Sample 29 also has to be mentioned (Fabric 16), because it is the only sample among the examined ones that contains limestone tempering. It is well known that limestone causes lime spalling: even at a relatively low firing temperature limestone grains blow out from the vessel wall. The use of calcareous raw materials requires more experience since during firing the loss of water (dehydration) produces carbon dioxide and lime (CaO). High temperature destabilizes the calcareous material, and the created gas in a clay matrix can lead to lime spalling.[13] By creating pores in the ceramic matrix, lime spalling weakens the physical

12 Mladen 2015, Fig. 91.
13 Rye 1981, 114; Rice 1987, 98; Hoard et al. 1995, 824–825; Feathers 2006, 92.

properties of the end products and increases permeability.[14] Several attempts were made to assess the temperature range when this process starts, but different measurements resulted in different temperature ranges. It is clear, however, that this process appears between the temperature ranges of about 600 and 900°C,[15] and apart from the firing temperature and firing circumstances, it also depends on the amount of calcareous inclusions, the length of firing, and the composition of clay.[16]

Lime spalling is well known to potters, and they pay great attention to avoid this problem even today.[17] The use of calcareous raw materials may increase the heat resistance of vessels (if they survive firing), which is useful for vessels which are often exposed to heat (e.g. cooking pots).[18] Therefore, the use of calcareous raw materials may have been functional. However, Ann J. Woods[19] highlighted that in England, from the Neolithic to the Middle Ages, there is no clear relationship between cooking vessels and certain raw materials, including calcareous raw materials, and several tempering practices were known.

Limestone appears close to Barcs on the surface close to Siklós and on the western side of the Mecsek Mountains. Therefore, the limestone tempered vessel at Barcs may have come from a farther place or, alternatively, the deposits of the Drava River contained limestone (limestone coming from the feet of the Alps). The latter version is less likely since, if this was the case, more vessels with limestone tempering should be present at Barcs. It must be noted that Sample 29 is the fragment of a pot, which is a general type among the vessels.

Another unique sample that needs to be mentioned is Sample 6 (baking cover), whose fabric shows an increased amount of siliceous sponges. Siliceous sponges do not appear in any other ceramics, not even in traces. Nevertheless, in the coring samples around the fort of Barcs there is a sediment that contains siliceous sponges. [20] As a result, the baking cover is considered to be locally made.

Even though the neighboring sites perished in the first half of the sixteenth century, their ceramics show similarities to Fabrics 4 and 15 of Barcs. Fabric 4 is characterized by sand and small pebble tempering; however, in the samples of the fort, the size of the grains are somewhat finer. Considering their petrographic composition, both metamorphic and granitic grains appear among the coarser inclusions.

The samples from the neighboring sites, which have similar compositions as Fabric 15 of Barcs, show a relationship to ceramics from the fort in terms of grain size and inclusion type. However, the composition of the samples is so fine that their common provenance could not be assessed with reassuring certainty. Nevertheless, it can be assumed that the ceramics of Fabrics 4 and 15 from Barcs were made from raw materials whose composition is similar to the ceramics from the neighboring sites.

In summary, we can say that there is extensive variability among the raw materials of the ceramics at Barcs, and no unified or homogeneous raw material preference or raw material preparation could be identified. It can, however, be assessed that sand and small pebble tempering (Fabric 4), and a fabric without tempering and moderate to common amounts of inclusions (Fabric 6) are distinct from the other fabrics since they account for almost one-half of the samples.

14 Shepard 1965, 30; Rice 1987, 98; Csupor – Csuporné Angyal 1998, 19; Kreiter 2007, 110, Fig. 61.
15 Rye 1976, 120, 600°C; Stimmell et al. 1982, 219, 600°C; Rice 1987, 98, 870°C.
16 Hoard et al. 1995, 824.
17 Woods 1986, 168–169; Csupor – Csuporné Angyal 1998.
18 Hoard et al. 1995.
19 Woods 1986, 163–165.
20 Pál Sümegi, personal communication.

There are different explanations for the variability in raw materials and tempers, but the most likely scenario is that the geographical position of the fort increased the amount of ceramics arriving by trade and supply. That is, local ceramic production within the fort may not necessarily have existed. More comparative ceramic technological analysis is needed to understand the possible reasons behind the abovementioned variability in ceramic raw materials. At present, no such comparative ceramic thin sections are available in appropriate number. No clear distinction could be recognized between the ceramic raw materials of the different periods, since ceramics can belong to the same fabric even if they represent different periods (see *Fig. 1*). Therefore, the Ottoman-Turkish control over the fort did not bring a decrease in the variability of ceramic raw materials, but rather the flourishing of ceramic trade/supply can be assumed.

The results indicate well that ceramic petrography is an essential tool in archaeological interpretation, and it provides additional information on the raw materials of ceramics and on possible technological relationships between the ceramics. As a result, in this research project we received a more fine grained understanding on the relationship between ceramics and provenance. Such a relationship was also discovered between seemingly distinct ceramic stylistic groups, which could not be assessed by traditional typological/stylistic analysis (e.g. the raw materials of vessels in Fabric 6). This research also demonstrates that petrography is indispensable in the typological/stylistic assessment of ceramics and, as a result, petrographic analysis has become more important in Hungarian and international ceramic research in recent years. At the same time, it must be noted that ceramic analysis carried out in this research project is considered to be a basic research in Hungary, since such systematic analysis on such a high number of ceramics from the Ottoman period has not been previously performed in Hungary. The ceramics analyzed in this project provide a very good springboard for further research and ceramic technological comparison.[21]

REFERENCES

Budden 2008 — Budden, S. A.: Skill amongst the sherds: understanding the role of skill in the Early to Late Middle Bronze Age in Hungary. In: *Breaking the mould: challenging the past through pottery.* Ed.: Berg, I. Prehistoric Ceramic Research Group Occasional Paper 6. BAR IS 1861. Oxford: Archaeopress, 2008.

Chávez 1992 — Chávez, M. K. L.: The organization of production and distribution of traditional pottery in south Highland Peru. In: *Ceramic production and distribution: an integrated approach.* Eds.: Bey III, G. J. – Pool, C. A. Oxford: Westview Press, 1992, 49–92.

Csupor – Csuporné Angyal 1998 — Csupor, I. – Csuporné Angyal, Z.: *Fazekaskönyv* [Book of pottery]. Jelenlévő múlt sorozat. Budapest: Planétás Kiadó, 1998.

DeBoer – Lathrap 1979 — DeBoer, W. – Lathrap, D.: The making and breaking of Shipibo-Conibo ceramics. In: *Ethnoarchaeology: implications of ethnography for archaeology.* Ed.: Kramer, C. New York: Academic Press, 1979, 102–138.

21 The illustrations were prepared by Zsolt Réti on the basis of drawings by Katalin Nagy, photographs of ceramics by Károly Kozma and Gyöngyi Kovács, thin section micrographs made by Péter Pánczél.

Feathers 2006 — Feathers, J.: Explaining shell-tempered pottery in prehistoric Eastern North America. *Journal of Archaeological Method Theory* 13:2 (2006) 89–133.

Frank 1998 — Frank, B. E.: *Mande potters and leather workers. Art and heritage in West Africa.* Washington DC: Smithsonian Institution Press, 1998.

Hegyi 2007 — Hegyi, K.: *A török hódoltság várai és várkatonasága* [The Castles and Garrisons of Ottoman Hungary] I–III. Budapest: História – MTA Történettudományi Intézete, 2007.

Hoard et al. 1995 — Hoard, R. J. – O'Brien, M. J. – Khorasgany, M. G. – Gopalaratnam, V. S.: A material-science approach to understanding limestone-tempered pottery from the Midwestern United States. *Journal of Archaeological Science* 22:6 (1995) 823–832.

Kilikoglou – Vekinis 2002 — Kilikoglou, V. – Vekinis, G.: Failure prediction and function determination of archaeological pottery by finite element analysis. *Journal of Archaeological Science* 29:11 (2002) 1317–1325.

Kilikoglou et al. 1995 — Kilikoglou, V. – Vekinis, G. – Maniatis, Y.: Toughening of Ceramic Earthenwares by Quartz Inclusions: An Ancient Art Revisited. *Acta Metallurgica et Materialia* 43 (1995) 2959–2965.

Kilikoglou et al. 1998 — Kilikoglou, V. – Vekinis, G. – Maniatis, Y. – Day, P. M.: Mechanical performance of quartz-tempered ceramics. Part I: strength and toughness. *Archaeometry* 40:2 (1998) 261–279.

Kovács – Rózsás 1996 — Kovács, Gy. – Rózsás, M.: A barcsi török palánkvár (The Turkish Hoarding [palisaded] Castle of Barcs). *Somogyi Múzeumok Közleményei* 12 (1996) 163–182.

Kovács – Rózsás 2010 — Kovács, Gy. – Rózsás, M.: A barcsi török vár és környéke. Újabb kutatások (1999–2009) (The Ottoman-Turkish Castle at Barcs and its surroundings. New Research, 1999–2009). In: *A középkor és a kora újkor régészete Magyarországon / Archaeology of the Middle Ages and the Early Modern Period in Hungary* I–II. Eds.: Benkő, E. – Kovács, Gy. Budapest: MTA Régészeti Intézete, 2010, II: 621–642.

Kreiter 2007 — Kreiter, A.: *Technological choices and material meanings in Early and Middle Bronze Age Hungary: understanding the active role of material culture through ceramic analysis*. BAR International Series 1604. Oxford: Archaeopress, 2007.

Kreiter 2009 — Kreiter, A.: *Árpád-kori kerámiák petrográfiai vizsgálata Dunaszentgyörgy TO 23 lelőhelyről* [Petrographic analysis of Árpádian Age ceramics from Dunaszentgyörgy TO 23]. Manuscript, 2009. Magyar Nemzeti Múzeum Régészeti Adatbázis, http://archeodatabase.hnm.hu/hu/node/1629 (last accessed June 15, 2016).

Kreiter 2010 — Kreiter, A.: Crafting difference: Early Neolithic (Körös culture) ceramic traditions in north-east Hungary. In: *Neolithization of the Carpathian Basin: northernmost distribution of the Starčevo/Körös culture.* Eds.: Kozłowski, J. K. – Raczky, P. Kraków: Polish Academy of Arts and Sciences – Budapest: Institute of Archaeological Sciences of the Eötvös Loránd University, 2010, 177–193.

Kreiter et al. 2009 — Kreiter, A. – Bajnóczi, B. – Havancsák, I. – Szakmány, Gy. – Tóth, M.: Kelta kerámiák makroszkópos és petrográfiai vizsgálata – Macroscopic and petrographic analysis of Celtic ceramics. In: *Település- és temetőfeltárás Dunaszentgyörgy határában. A 6 sz. főút 121+650–124+800 km szakasza között, a rehabilitációs munkálatokat megelőző régészeti feltárások (2007) eredményei.* Ed.: Kvassay, J. VIA. Kulturális Örökségvédelmi Kismonográfiák 1. Monographia Minor in Cultural Heritage performed 1. Budapest: Kulturális Örökségvédelmi Szakszolgálat, 2009, 157–199.

Kreiter – Viktorik in press — Kreiter, A. – Viktorik, O.: Kerámiák petrográfiai vizsgálata [Petrographic analysis of ceramics]. In: *Régészeti kutatás a középkori Vác német városrészben. A Piac utcai mélygarázs területének megelőző feltárása.* Ed.: Mészáros, O. Budapest: Martin Opitz, in press.

Mladen 2015 — Mladen, R.: *Osijek i sira okolica u osmanskom periodu – Osijek and surrounding area in the Ottoman Period.* Exhibition catalog. Osijek: Muzej Slavonije Osijek, 2015.

PCRG 2010 — *The Study of Later Prehistoric Pottery: General Policies and Guidelines for Analysis and Publication.* Prehistoric Ceramic Research Group: Occasional Papers Nos 1 and 2. 3rd edition revised, 2010.

Plog 1980 — Plog, S.: *Stylistic variation in prehistoric ceramics.* Cambridge: Cambridge University Press, 1980.

Rice 1987 — Rice, P. M. 1987. *Pottery analysis: a sourcebook.* Chicago: University of Chicago Press, 1987.

Rye 1976 — Rye, O. S.: Keeping your temper under control: materials and the manufacture of Papuan pottery. *Archaeology and Physical Anthropology in Oceania* 11 (1976) 106–137.

Rye 1981 — Rye, O. S.: *Pottery technology: principles and reconstruction.* Manuals on Archaeology 4. Washington: Taraxacum, 1981.

Shepard 1965 — Shepard, A. O.: *Ceramics for the archaeologist.* Washington: Carnegie Institution of Washington, 1965.

Sillar 1997 — Sillar, B.: Reputable pots and disreputable potters: individual and community choices in present-day pottery productions and exchanges in the Andes. In: *Not so much a pot, more a way of life.* Eds.: Cumberpatch, C. G. – Blinkhorn, P. W. Oxford: Oxbow, 1997, 1–20.

Stimmell et al. 1982 — Stimmell, C. – Heimann, R. B. – Hancock, R. G. V.: Indian pottery from the Mississippi valley: coping with bad raw materials. In: *Archaeological ceramics.* Eds.: Olin, J. S. – Franklin, A. D. Washington: Smithsonian Institution Press, 1982, 219–228.

Tobert 1984 — Tobert, N.: Potters of El-Fasher: one technique practiced by two ethnic groups. In: *Earthenware in Asia and Africa.* Ed.: Picton, J. London: Percival David Foundation, 1984, 219–237.

Woods 1986 — Woods, A. J.: Form, fabric and function: some observations on the cooking pot in antiquity. In: *Technology and style.* Ed.: Kingery, W. D. Ceramics and civilization. Volume 2. Columbus: The American Ceramic Society Inc., 1986, 157–172.

OBJECTS MADE FROM TUSK, BONE, AND ANTLER FROM THE OTTOMAN-TURKISH FORT AT BARCS, HUNGARY

Erika Gál

The Ottoman-Turkish palisaded fort at Barcs was one of the new strongholds in the network of border fortresses in the northern zone of the Ottoman Empire that occupied much of Hungary. Built on the left bank of the Drava River in 1567 and destroyed in 1664, its fate was bound up with that of the Szigetvár and Babócsa forts. No traces of this stronghold have been preserved on the modern surface. Between 1989 and 1994, a series of trial trenches were opened in the area. Salvage excavations were conducted over an extensive surface in 2003.[1]

Relatively few worked animal remains were brought to light during the archaeological excavations. The thirteen tools and ornamental objects analyzed in this study represent only a selection of the worked objects, and a small fraction (*ca.* 0.15%) of the entire assemblage of non-worked animal bone finds.[2] However, it must be noted that this small set of finds shows a great variety both in terms of origins and function, contributing even some masterpieces to the inventory of small finds recovered from the area of the Barcs fort.

ARTIFACT MADE FROM TUSK

The most interesting piece of worked animal hard tissue was recovered near the 60/25 coordinate in the 2003 grid system from a fill dated to the last third/end of the sixteenth century *(Table 1)*. It was a decorative plate, carved from a slice of walrus (*Odobenus rosmarus* L. 1758) tusk cut from the basal part of the tooth in a transversal direction *(Figs 1–2)*.[3] The length of this object is 52.3 mm, its width measures 39.1 mm. Its thickness ranges between 6.5 and 7.0 mm. The thick proximal section of the tusk was identified on the basis of the large size and shape of the piece, ground into a symmetric ornamental object. The internal dentine structure of walrus tusk is reminiscent of marble, surrounded by a cracked layer of enamel. The edge of this object is decorated by carved ridges, while the visible external surface was ornamented with two pairs of tendril-like motifs. The tusk plaque was fastened to something at three points of an equilateral triangle, using three pairs of iron rivets, resulting in six holes and remains of iron in the object. During the course of perforating and/or fastening this plate, the brittle raw material cracked at several points.[4]

Judging from comparable elephant ivory artifacts of similar sizes and shapes from mid-sixteenth-century Istanbul, this object was identified as a belt-plaque.[5] Walrus is a large-

1 For the fort's history and its archaeological investigation, see Kovács – Rózsás 1996; 2010. For a description of the project, including the preliminary assessment of Barcs, see Kovács et al. 2014. The research project was funded by the Hungarian Scientific Research Fund (OTKA Grant K 72231).

2 The finds have been curated in the Drava Museum, Barcs.

3 Gál – Kovács 2011.

4 Grateful thanks are due to Zsuzsanna Tóth who took microphotographs of the object as part of project no. TÁMOP-4.2.1/B-09/1/KMR-2010-0003 of the Institute of Archaeological Sciences at the Eötvös Loránd University in Budapest.

5 Çagman 1983, 164–165.

Figure 1. Walrus-tusk belt plaque (left: front side, right: reverse side)
(photograph by Erika Gál)

bodied marine mammal of circumpolar distribution, meaning that the raw material of this object could not have originated in Hungary. The pair of upper canine teeth in both sexes develops into long tusks. In males, these grow larger and may be as long as 50 cm with a basal circumference as large as 20 cm. The same circumference of the tusk is smaller in females, approximately 13 cm.[6]

Despite being extremely special, the Barcs walrus find is not unique in Hungary. During the excavations at the Holy Virgin Mary Monastery near Veszprém in 2001, the fragment of a Tau-shaped crosier was recovered. The raw material of this sacral object, dated to the thirteenth–fourteenth centuries, was also identified as walrus ivory.[7] Hilts of several eighteenth-century Balkanic yatagans housed in the Museum of Military History in Budapest, whose provenance is not known, were also carved from walrus tusk.[8]

There is evidence for walrus hunting from the ninth–tenth centuries, while the manufacturing of tusks has been attested since the tenth–eleventh centuries, predominantly in the northern areas of Europe. Data from eleventh–twelfth-century Cologne indicate that by that time, the working of this rare and valuable raw material was not limited to Scandinavia and that walrus tusks were also worked in more centrally located regions of Europe.[9] Unsurprisingly, trading in the thus produced decorative objects also began at this time, as is shown by over three hundred utilitarian and ornamental walrus tusk artifacts brought to light in the city of Novgorod in Russia. The majority of these objects became the property of affluent Russian boyars during the eleventh–twelfth centuries.[10]

In addition to precious furs, walrus ivory was one of the most important trade items in sixteenth–seventeenth-century Russia. It was also used for paying taxes to the Mongol Tartars who inhabited the Crimea. From the earlier seventeenth century onwards, there are detailed tax records concerning payments by Russia. Walrus ivory is sometimes mentioned among the contributed exotic items. This raw material was then turned into magnificent knife handles and dagger hilts in the Crimea.[11] Crimean Tartars then passed on such valuable products as presents.

Walrus ivory was held in high esteem in the Sublime Porte of Istanbul. Documentary sources reveal that during the reign of Süleyman the Magnificent (1520–1566), master

6 Petzsch 1966, 305.
7 Fülöp – Koppány 2004.
8 Sudár – Szőllősy 2014, 248.
9 O'Meadhra 2001.
10 Smirnova 2001.
11 Ivanics 1994, 33–34.

Figure 2. Microscopic images of the walrus-tusk belt plaque (a-b: details of the front side, c-d: details of the reverse side) (microphotographs by Zsuzsanna Tóth)

craftsmen used both elephant ivory (*fildişi*) and walrus tusk (*balık dişi*) to produce numerous types of belt buckles and belt plaques as well as hilts for daggers and yatagans. These were then presented to the sultan on the occasion of festivities.[12] According to a list of donations dated to the time of Süleyman the Magnificent,[13] most walrus tusks were worked into belt mounts, combs, dagger hilts, back-scratchers, and inkwells. Sometimes, however, head-dresses and spoons were also made from this precious material.

The belt plaque carved from walrus ivory may seem a surprising find from a small Ottoman-Turkish fort along the Drava River. However, several hypotheses can be proposed to explain its import to this distant location. It may have belonged to a soldier who served in the Eszék (Osijek, Croatia) Ottoman flotilla, which was stationed at Barcs from 1567 onwards. Alternatively, it may have been owned by a Mongol Tartar chieftain who had fought in the region during military operations. It is also possible, however, that the belt plaque was circulated through the well-documented intensive exchange and/or trade north of the Drava River.

12 Atil 1987, 120.

13 Topkapu Sarayı, D. 9602, no date available, probably from the first half of Kanuni Sultan Süleyman's reign. Meric 1963, 766–770. I am grateful to Ibolya Gerelyes (Hungarian National Museum, Budapest) for this information.

Table 1. Bone, tusk and antler objects from Barcs

Figures	*Object*	*Raw material*	*Inv. no. (1989–1994)*	*Ref. no. and 2003 field coordinates*	*Feature*	*Date*
1–2	Belt plaque	Walrus tusk		60/25	Brown layer, 0–30 cm	Late 16th–end of the 16th c.
3a-b	Fragment of a gun-powder flask	Large ungulate (cattle?)		683/2003 50/25	From burnt debris, –40 cm	17th c.
4	Double-edged comb	Large ungulate (cattle?)		672/2003	Pit 18	Late 16th c.
5	Fragment of a sled runner	Horse	BR.95.7.1	109/1991	Layer, –25–45 cm	17th c.
6	Sled-runner-like object	Cattle		55/15–60/10	Layer	Probably 17th c.
7a-b	Knife handles	Large ungulate (cattle?)	BR.92.1.48	1989		16th–17th c.
			BR.95.4.22	128/1991	Pit 2, –125–150 cm	Late 16th c.
8	Bone ring	Catfish	BR.95.7.2	121/1991	Pit 1	17th c.
9	Bone button		BR.95.7.5	45/1990	Pit 4, under 17th-c. destruction layer –80–100 cm	Late 16th or early 17th c.
10	Knife (?) handle fragment	Red deer antler		676/2003	Feature 37 (house)	Late 16th c.
11	Mount for a rifle butt	Red deer antler	BR.92.1.25	1989	From burnt debris, –45 cm	Probably 17th c.
12	Ring	Roe deer antler	BR.95.7.3	235/1994	Gray sandy layer, –70–85 cm	Late 16th c.

ARTIFACTS MADE OF BONE

The most beautiful object carved from bone is a gun-powder flask made from the femur diaphysis of a large ungulate, probably cattle *(Fig. 3a-b)*. It was decorated with floral motifs of tulips and another, petalled flower. The greatest length of this object is 178.3 mm, its greatest width measures 48.9 mm. The greatest thickness of the compact bone wall is 4.2 mm. Several typological parallels to this object, made from red deer antler, are known from sixteenth–seventeenth-century contexts. These include the powder flasks from Ugod,[14] Hollókő and Ozora,[15] and a fragment recovered from a late Ottoman-period pit at the medieval church in Vál (the site of a former palisaded Turkish stronghold).[16]

A fragment of another attractive utilitarian object was brought to light: a double-sided comb with more broadly spaced teeth on one side and more densely on the other *(Fig. 4)*. It was made from the diaphysis of a long bone from a large ungulate, probably cattle. The greatest length of this fragment is 59.8 mm, while its greatest width measures 32.4 mm. The greatest width of the bone cortex is 3.4 mm.

14 Vörös 1988.
15 Borsos 1982.
16 Hatházi – Kovács 1997, 220 and Fig. 16.5.

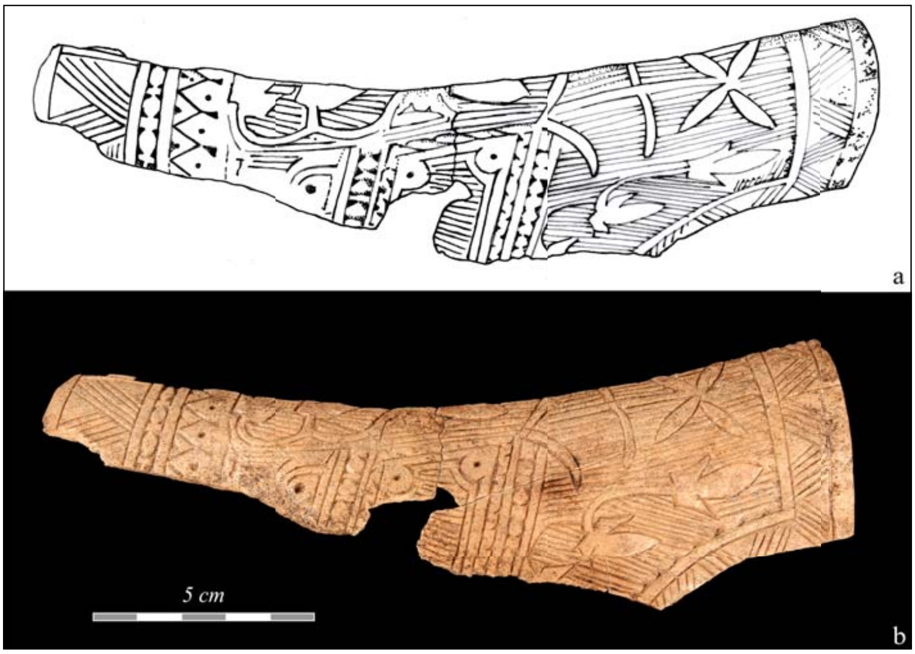


Figure 3. Fragment of a bone powder flask with decorative carving
(a: drawing by Magda Éber, b: photograph by Erika Gál)

A bone comb of similar form, dated to the last third of the sixteenth century, is known from the Christian fort of Bajcsa, located some 100 km north of Barcs.[17] The raw material of this specimen has not been analyzed yet. Not only bone, but wood and elephant ivory were also used as raw materials for producing combs during the fifteenth–sixteenth centuries, as evidenced by a number of finds from the Buda Castle as well as the Upper and Lower Castle of Visegrád. Since ivory raw material was not found at either of these sites, these combs must have been imported or brought by individuals as personal belongings,[18] similarly as in the case of the walrus tusk plaque found at Barcs.

A fragment of a sled runner was recovered during the 1991 excavation season *(Fig. 5)*. It was made from a horse radius. The proximal part of the bone was recently broken. An irregular hole of 12 mm was drilled through the bone at the meeting point of the diaphysis and distal epiphysis in a dorso-palmar direction. Ethnographic analogies suggest that the legs of a small stool may have been inserted here into

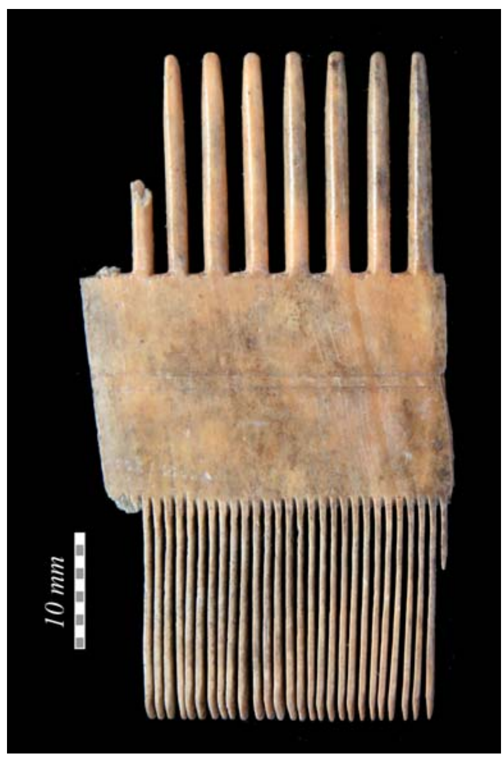


Figure 4. Double-sided bone comb
(photograph by Erika Gál)

17 *Bajcsavár* 2002, Kat. 81. No closer raw material identification is available.
18 Choyke – Kováts 2010.

the pair of bone runners. The distal epiphysis was carved into a point, and slight use-wear is visible on the dorsal surface of the bone. The greatest length of this object is 267.8 mm, its greatest medio-lateral width is 70.5 mm. The greatest thickness of the runner is 36.6 mm.

During the late Middle Ages, home-made sled runners and skates carved from bone using simple tools became common in the Carpathian Basin.[19] One of them has been described from the fifteenth–sixteenth-century rural site of Szentkirály on the Great Hungarian Plain.[20] Summaries of ethnographic parallels were published by Ottó Herman.[21] One recent find was recovered from House 2 at the fifteenth–sixteenth/seventeenth-century rural site of Csekefalva/Lok in Transylvania (western Romania). This sled runner was carved from the radius of a not fully grown cattle.[22]

In contrast to skates that run on the ice only, sledges can be also used on snow. Moreover, ethnographic data offer evidence that the so-called "foot slides" were used on mud, grass, or stubble for transporting hay or other summer products.[23] Carving skates and sledges from horse radii dates back to the Bronze Age in the Carpathian Basin. Since then, these objects have been produced in most of subsequent periods too, later also from cattle radii, although there seems to have been a turning point regarding their form and use between the Middle and Late Bronze Age. Interestingly, bone skates and slides appeared in the Carpathian Basin with the spread of domestic horse. Although cattle were available already by the Neolithic, the skeletal parts of this species were seldom used even in later periods.[24]

A similar-looking object made from another cattle radius may have been intended for a different function *(Fig. 6)*. It has a regular-shaped hole drilled through the proximal

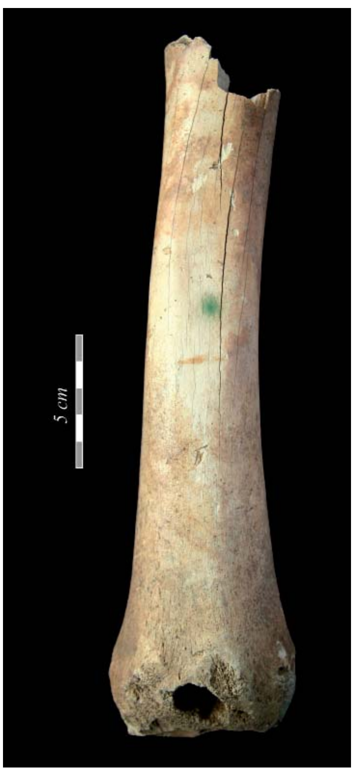


Figure 5. Fragment of a sled runner made from a horse radius (photograph by Erika Gál)

Figure 6. Perforated cattle radius of unknown function (photograph by Erika Gál)

19 Kováts 2008, 114.
20 Pálóczi Horváth 1989, 114, Fig. 69c.
21 Herman 1902; 1980, 41–54.
22 Gál 2012, 683, Fig. 18.
23 Ortutay 1981, 550–551.
24 Choyke – Bartosiewicz 2005.

Figure 7. Knife handle fragments (a: decorated; b: plain) (photograph by Erika Gál)

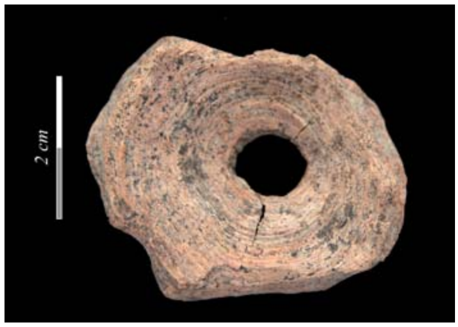


Figure 8. Bone ring made from a catfish vertebra (photograph by Erika Gál)

Figure 9. Small bone button (photograph by Erika Gál)

epiphysis in a dorso-palmar direction that may have served for suspension. No other evidence of manufacturing or use-wear could be identified on this bone or on the edge of the hole.

Many knives encountered in the Barcs find material had bone handles. The specimens under study were recovered during the course of the trial excavations. Knife handles were covered using long bone diaphysis sheets from large ungulates (most probably cattle). One handle (inv. no. BR.92.1.48) is decorated with a dot pattern *(Fig. 7a)*, another specimen (inv. no. BR.95.4.22) is plain *(Fig. 7b)*. The third knife handle fragment (inv. no. BR.92.1.33) probably also originated from the diaphysis of a cattle long bone. It was turned on a lathe. Subsequently, this knife handle was exposed to extensive heat and thus became calcined. The dimensions of the knife handles are as follows:

Inventory no.	*Greatest length, mm*	*Greatest width, mm*	*Greatest thickness, mm*
BR.92.1.48	46.5	19.5	8.1
BR.95.4.22	54.5	17.3	6.6
BR.92.1.33	32.0	16.0	6.8

In fifteenth-century Steyr (Upper Austria), cutlers employed craftsmen (*Schroter*) who carved bone and wooden handles. The cutler only fitted the handle to the knife, then polished it, and sold the finished product. According to a decree from 1470, the handle of knives had to be prepared from cattle bone, horn, boxwood, or yew tree. Only second-class knives could have handles made from cheaper wood. A list of knife samples from the end of the sixteenth century reveals that various forms were produced for farther-lying market districts. In addition to the *Basler*, *Grazern* and *Ungarische* types, the designation *Türkische* indicates that a particular form was manufactured for regions under the rule of the Ottoman Empire.[25]

Two pieces of worked bone also came to light from the trial trenches. One was a bone ring *(Fig. 8)* made from a large catfish (also called wels or sheatfish) vertebra whose diameters measured 44.1 mm and 35.0 mm, respectively. The thickness of this ring was 12.1 mm, while the small natural opening in the middle of the vertebra was enlarged into a hole measuring 9.7 and 8.5 mm, respectively. The other specimen, a small, round bone button *(Fig. 9)* was made from a sawn-off bone plate. Its diameters measured 21.5 and 20.6 mm, respectively, while its thickness was 5.7 mm.

25 Holl 1994–1995; Kováts 2008, 114.

ARTIFACTS MADE OF ANTLER

Relatively fewer objects were made from antler than from skeletal bone; only four antler artifacts were examined. Two antler artifacts were decorated with ornamental carving. The first of these came to light from Feature 37 during the 2003 excavation. It is a knife (?) handle fragment *(Fig. 10)* whose greatest length is 55.7 mm, while its greatest width measures 22.7 mm. The greatest thickness of this object is 11.0 mm.

Another thin plaque carved from red deer antler was used as a decorative mount on a rifle butt *(Fig. 11)*. It is ornamented with a spiral scroll-like design. The greatest length of this object is 51.4 mm. Its greatest width measures 18.8 mm, while its greatest thickness is a mere 3.0 mm. Similar rifle butt decorations were also brought to light during the aforementioned excavations at Bajcsa.[26]

Figure 10. Decorated handle made from red deer antler (photograph by Erika Gál)

Figure 11. Antler sheet used as a mount for a rifle butt (photograph by Erika Gál)

Figure 12. Roe deer antler ring (photograph by Erika Gál)

A ring *(Fig. 12)*, similar to the bone ring shown in *Figure 8*, was carved from the base of a roe deer antler, with a regular hole in the middle measuring 17.7 and 19.2 mm, respectively. The remains of the antler burr are still visible at the edge of this object. This pattern may have been retained as a decorative element, but it also increased the ring's thickness, i.e. strength. The diameters of this ring measure 70.6 and 69.1 mm, respectively, its greatest thickness is 20.8 mm.

In addition to these finished artifacts, some pieces of bone and antler debitage were also found at the site. They include sawn-off epiphyseal ends of long bones, pieces of antler as well as a red deer skull fragment.

Although the worked osseous objects from the Barcs fort presented here are small in number, they include some rare and spectacular artifacts. Their raw materials are diverse. In addition to rare walrus tusk, bones of cattle and horse were also worked. The worked catfish vertebra further broadens the zoological spectrum of resources. Finally, red deer and roe deer antler also served as raw materials for artifacts.

[26] *Bajcsavár* 2002, cat. nos 236–239. No closer raw material identification is available.

Aside from the belt plaque carved from walrus tusk, typological parallels to these osseous objects are also known from contemporaneous forts and settlements, although the publications often lack the precise zoological identification of raw materials. A number of individual objects most likely served as personal costume accessories (e.g. the walrus tusk belt plaque, the powder flask, and the knife). Some of them were made from rare and valuable raw materials and/or required specialized, high-level craftsmanship. These objects were distributed by large-scale trading networks (for example, some knives, although not the ones discussed here, originated from Steyr in Upper Austria). Meanwhile, simple utilitarian objects such as the sled runner, the bone comb, and the antler plaque may have been made on the household level, as suggested by the manufacturing debris also encountered at Barcs.

REFERENCES

Atil 1987 — Atil, E.: *The Age of Sultan Süleyman the Magnificent*. Exhibition Catalogue – National Gallery of Art. Washington – New York: Harry N. Abrams, 1987.

Bajcsavár 2002 — *Weitschawar / Bajcsa-Vár. Egy stájer erődítmény Magyarországon a 16. század második felében* [Weitschawar / Bajcsa-Vár. A Styrian stronghold in Hungary in the second half of the 16th century]. Ed.: Kovács, Gy. Zalaegerszeg: Zala Megyei Múzeumok Igazgatósága, 2002.

Borsos 1982 — Borsos, B.: *Magyar vadász lőportartók* [Hunters' powder flasks from Hungary]. Budapest: Corvina Kiadó, 1982.

Çagman 1983 — Çağman, F.: Ottoman art. In: *The Anatolian Civilisations III. Seljuk/Ottoman*. Exhibition Catalogue – Topkapi Palace Museum. Eds.: Tapan, M. – Çagman, F. Istanbul: Turkish Ministry of Culture and Tourism, 1983, 97–315.

Choyke – Bartosiewicz 2005 — Choyke, A. M. – Bartosiewicz, L.: Skating with Horses: continuity and parallelism in prehistoric Hungary. *Revue de Paléobiologie* 10 (Vol. spéc.) (2005) 317–326.

Choyke – Kováts 2010 — Choyke, A. M. – Kováts, I.: Tracing the personal through generations: Late Medieval and Ottoman combs. In: *Bestial Mirrors: Animals as Material Culture in the Middle Ages* 3. Eds.: Pluskowski, A. – Kunst, G. K. – Kucera, M. – Bietak, M. – Hein, I. ViaVias 3. Wien: Universität Wien, 2010, 115–127.

Fülöp – Koppány 2004 — Fülöp, A. – Koppány, A.: A crosier from the territory of the Veszprémvölgy convent. *Acta Archaeologica Academiae Scientiarum Hungaricae* 55 (2004) 115–135.

Gál 2012 — Gál, E.: Állatcsontleletek a középkori Székelyföldről [Animal bone finds from medieval Sekler Land]. In: Benkő, E.: *A középkori Székelyföld* I–II. Budapest: MTA Bölcsészettudományi Kutatóközpont, Régészeti Intézet 2012, II, 663–750.

Gál – Kovács 2011 — Gál, E. – Kovács, Gy.: A walrus-tusk belt plaque from an Ottoman-Turkish castle at Barcs, Hungary. *Antiquity* 85:329 (2011) Project Gallery. http://antiquity.ac.uk/projgall/gal329/ (last accessed March 24, 2016).

Hatházi – Kovács 1997	Hatházi, G. – Kovács, Gy.: A Post-medieval Assemblage from Vál. *Acta Archaeologica Academiae Scientiarum Hungaricae* 49 (1997) 195–225.
Herman 1902	Herman, O.: Ironga, szánkó, kece [Runner, sled, dragnet]. *Természettudományi Közlöny* 1902, 18–26.
Herman 1980	Herman, O.: *Halászélet, pásztorkodás* [Fishermen's life and pastoralism]. Ed.: Kósa, L. Budapest: Gondolat Kiadó, 1980.
Holl 1994–1995	Holl, I.: A középkori késes mesterség (Messererhandwerk in Mittelalter). *Archaeologiai Értesítő* 121–122 (1994–1995) 159–188.
Ivanics 1994	Ivanics, M.: *A Krími Kánság a tizenöt éves háborúban* [The Crimean Khanate during the Fifteen Years' War]. Körösi Csoma Kiskönyvtár 22. Budapest: Akadémiai Kiadó, 1994, 33–34.
Kovács – Rózsás 1996	Kovács, Gy. – Rózsás, M.: A barcsi török palánkvár (The Turkish Hoarding [palisaded] Castle of Barcs). *Somogyi Múzeumok Közleményei* 12 (1996) 163–182.
Kovács – Rózsás 2010	Kovács, Gy. – Rózsás, M.: A barcsi török vár és környéke. Újabb kutatások (1999–2009) (The Ottoman-Turkish Castle at Barcs and its Surroundings. New Research, 1999–2009). In: *A középkor és a kora újkor régészete Magyarországon / Archaeology of the Middle Ages and the Early Modern Period in Hungary* I–II. Eds.: Benkő, E. – Kovács, Gy. Budapest: MTA Régészeti Intézete, 2010, II: 621–631.
Kovács et al. 2014	Kovács, Gy. – Bartosiewicz, L. – Éder, K. – Gál, E. – Miklós, Zs. – Rózsás, M. – Tóth, J. A. – Zatykó, Cs.: Medieval and Ottoman-period (14th–17th c.) archaeology in the Drava River region, Hungary. Results of an interdisciplinary project. *Acta Archaeologica Academiae Scientiarum Hungaricae* 65 (2014) 155–168.
Kováts 2008	Kováts, I.: A középkori csontmegmunkálás [Medieval bone manufacturing]. In: *Középkori magyar gazdaságtörténet a régészet és az anyagi kultúra tükrében*. Eds.: Kubinyi, A. – Szabó, P. – Laszlovszky, J. Budapest: Martin Opitz Kiadó, 2008, 113–115.
Magyar Néprajzi Lexikon 1981	*Magyar Néprajzi Lexikon*. Negyedik kötet [Hungarian Ethnographic Encyclopedia. Volume 4]. Ed.: Ortutay, Gy. Budapest: Akadémiai Kiadó, 1981.
Meric 1963	Meric, R. M.: Bayramlarda Padişahlara Hediye Edilen San'at Eserleri ve Karşılıkları I. Sûret-i defter oldur ki usta kârlar bayramlık getürdiklerin beyân ider [Artworks Gifted to Sultans at Festivities and Presents Given in Return I. Defter of the festive products of craftsmen]. *Türk San'ati Tarihi. Araştırma ve Incelemeleri* 1 (Istanbul 1963) 766–770.
O'Meadhra 2001	O'Meadhra, U.: Kräklan. Ett unikt och viktigt fynd [The distaff. A unique and important find]. In: *Biskopen i museets trädgård. En arkeologisk gåta*. Eds.: Tesch, S. – Edberg, E. Sigtuna Museers skriftserie 9. Stockholm: Sigtuna Museum, 2001, 67–90.

Pálóczi Horváth 1989 — Pálóczi Horváth, A.: *Pechenegs, Cumans, Iasians: Steppe peoples in medieval Hungary*. Budapest: Corvina, 1989.

Petzsch 1966 — Petzsch, H.: *Urania Tierreich* V. Leipzig: Urania, 1966.

Smirnova 2001 — Smirnova, L.: Utilization of rare bone materials in medieval Novgorod. In: *Crafting Bone: Skeletal Technologies through Time and Space*. Eds.: Choyke, A. M. – Bartosiewicz, L. British Archaeological Reports International Series 937. Oxford: Archaeopress, 2001, 9–17.

Sudár – Szőllősy 2014 — Sudár, B. – Szőllősy, G.: A Hadtörténeti Múzeum Hidegfegyver Gyűjteményében őrzött jatagánok egy sajátos csoportja (A Special Group of Yatagans in the Edged Weapons Collection of the Hungarian Military History Museum). *Acta Musei Militaris in Hungaria* 14 (2014) 219–237.

Vörös 1988 — Vörös, I.: Középkori agancs lőportartók az ugodi várból (Mittelalterliche Pulverfässe aus Geweih gefertigt in der Burg von Ugod). *Acta Musei Papensis* 1 (1988) 131–135.

LITHIC ARTIFACTS FROM THE OTTOMAN-PERIOD SITE AT BARCS CASTLE (SOMOGY COUNTY, HUNGARY)

Katalin T. Biró

Late medieval lithic artifacts are seldom investigated by petroarchaeological methods. The modest Ottoman-period assemblage from Barcs Castle is especially significant in this respect. The lithic artifacts were collected from the excavations conducted by Gyöngyi Kovács and Márton Rózsás in 1989–1994 and 2002–2003.[1] The studied assemblage of twenty-nine pieces came from the salvage excavations conducted in 2003 on an extensive surface *(Figs 1–4)*. In addition, black-and-white photos of some of the artifacts from previous sounding excavations are presented in *Figure 4. a-f.*

Barcs is located some 30 km southwest of Szigetvár, immediately on the Hungarian-Croatian border. The Ottoman-Turkish palisaded fort was constructed on the banks of the Drava River in 1567 and was finally destroyed in 1664, during the winter campaign of Miklós Zrínyi. According to the contemporary military payrolls, the garrison of the fort comprised some two hundred soldiers, most of them from the Balkans.[2]

Most of the artifacts are hone stones and their fragments (sixteen pieces altogether, *Fig. 1. 1–7; Fig. 2. 2–6; Fig. 3. 6–8*). They can be cigar-shaped *(Fig. 1. 3)*, elongated with quadrangular *(Fig. 2. 2, 4)* or oval *(Fig. 2. 5)* cross-section; large, flat, longish pieces *(Fig. 1. 5, 7)* or large, irregular ones. A "finger-cake"-shaped hone stone was also found *(Fig. 1. 4)*. Their raw material is typically very fine-grained sandstone of unidentified origin, possibly from the Papuk Mountains in Croatia. A light greenish metamorphic rock, presumably chlorite schist, was also used as the raw material of the hone stones. Another two fragments (in fact, three, but two could be refitted based on the fresh fracture, *Fig. 1. 1–2*) were made of siliceous schist, and probably came from a larger hone stone. These two latter rock types were probably obtained from the eastern Alps. An almost complete hand-mill (lower disc) was also found on the site, broken into two large and several smaller fragments *(Fig. 4. 1)*, of which only a fragmented sample was investigated. The form is typically late medieval, whose parallels are known from the castles at Szendrő (excavated by Gábor Tomka)[3] and Csókakő (excavated by Gábor Hatházi and Gyöngyi Kovács).[4] The raw material is coarse sandstone with large pebble-sized grains. One possible source of the raw material is the Mecsek Mountains (Jakabhegy red sandstone), but further comparative studies are necessary for an exact identification.

Traces of use-wear are visible on several pieces. The large irregular hone stone bore polished traces of red mineral pigment (perhaps haematite). Haematite was found also in the form of a nugget or pebble. Another rectangular piece, probably also a hone stone, was made of iron-rich sedimentary rock.

1 Kovács – Rózsás 1996; 2010.

2 Hegyi 2007, II: 1327–1329, III: 1590–1594.

3 Made of Domoszló andesite, Péterdi et al. 2016.

4 Unpublished. The piece from Csókakő (Fejér County) was unearthed in the sixteenth-century (probably early Ottoman period) layer, similarly to the quernstone from Barcs.

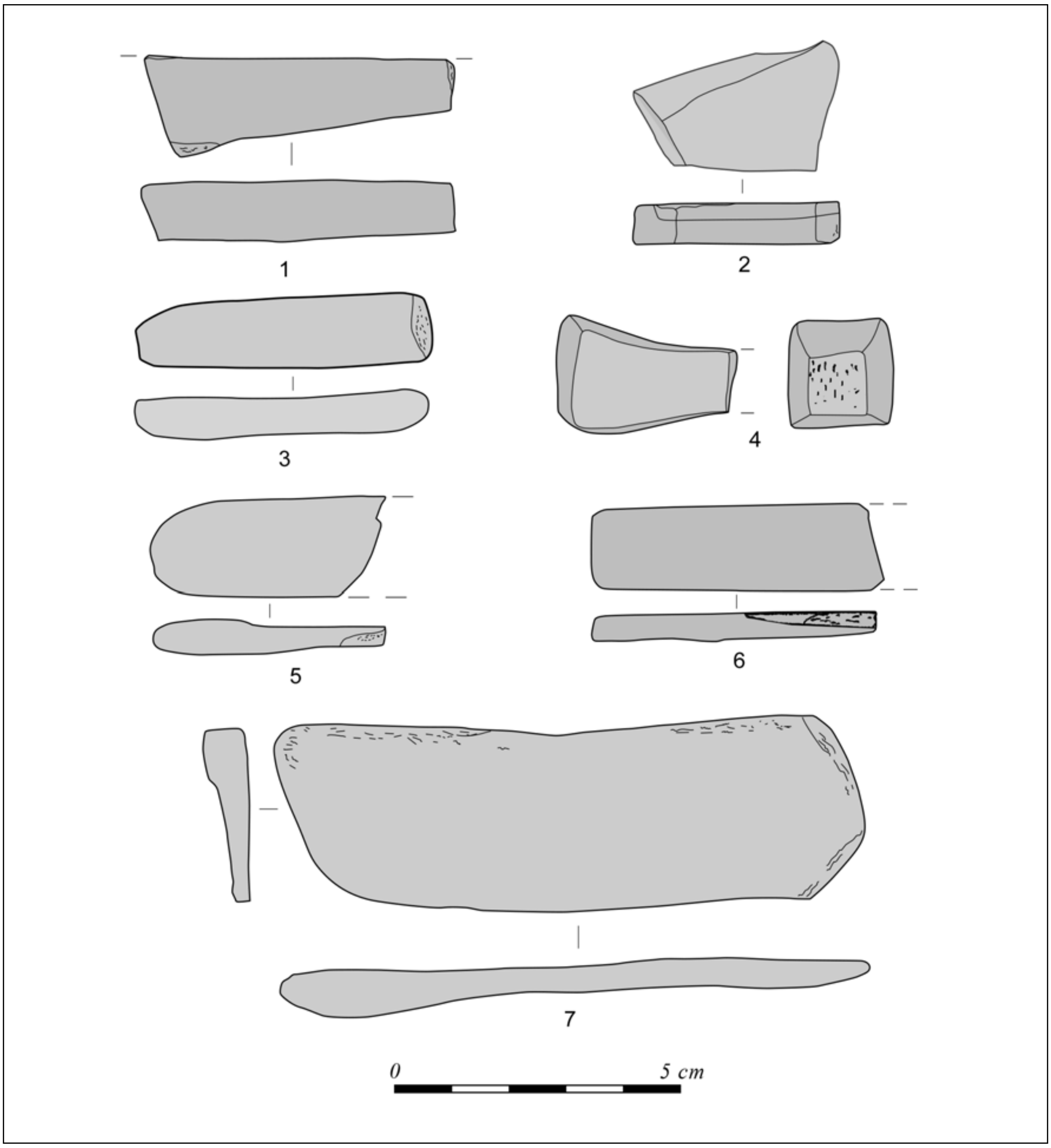


Figure 1. Lithic artifacts from the Ottoman-period site at Barcs Castle
(drawing by Katalin T. Biró)

There are also general stone implements (a grinding stone and polisher) in the assemblage in smaller number. The most interesting one is a flat, rounded, hand-held grinding stone of medium-grained dark grey sandstone *(Fig. 2. 1).* A piece of agate-chalcedony of bluish-white color may have serve as raw material, e.g. for beads, although chalcedony beads are more typical in other contexts such as Roman Age barbarian (Sarmatian) ones. The origin of these bulky homogeneous chalcedony pieces has not been clarified yet.

An interesting aspect of the small lithic assemblage is the presence of chipped stone artifacts *(Fig. 3. 2–5).* On the basis of their form and use-wear traces, they can be considered fire-flints. Éva Garam recently published a detailed description of the flints for striking

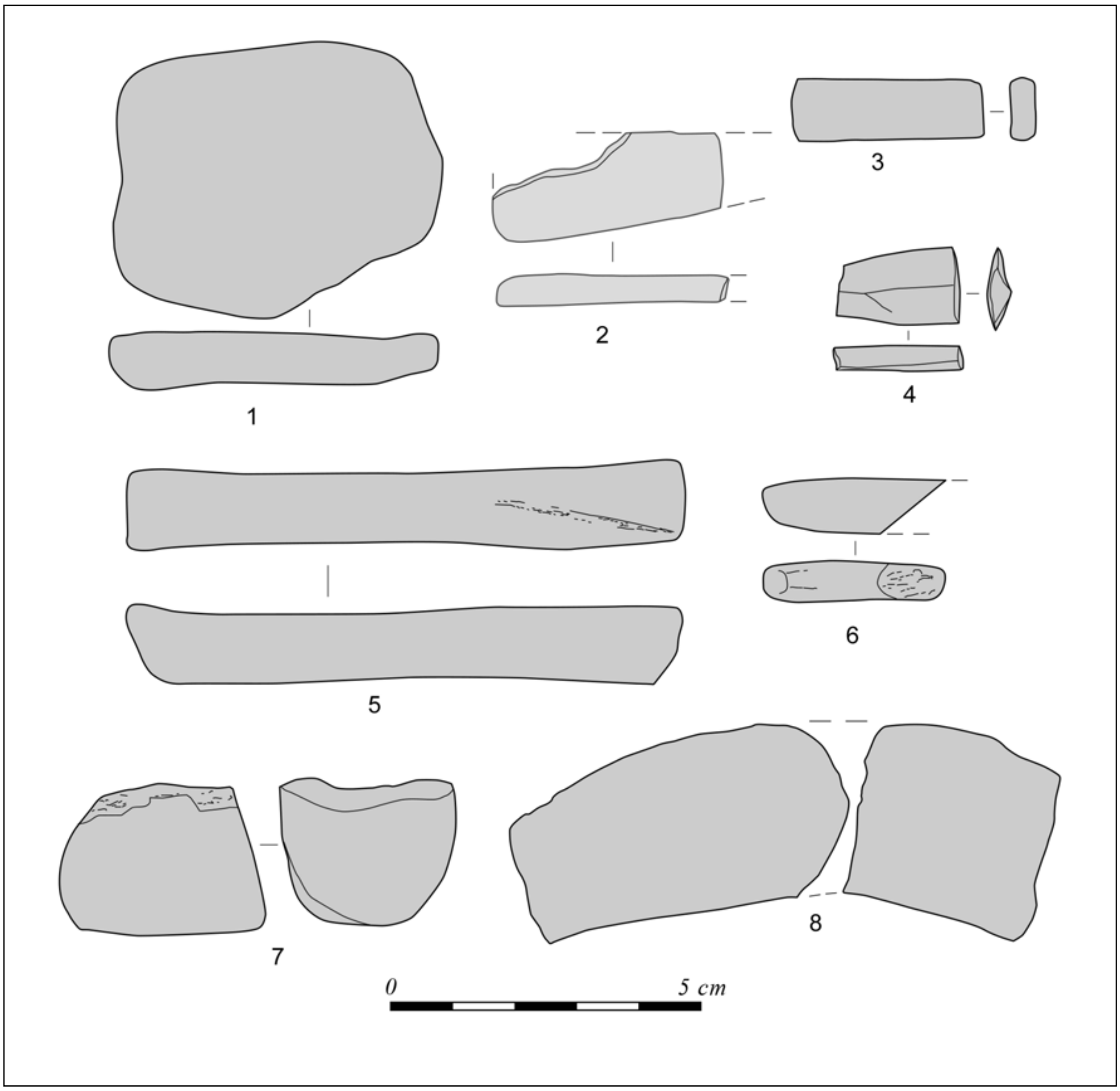


Figure 2. Lithic artifacts from the Ottoman-period site at Barcs Castle
(drawing by Katalin T. Biró)

fire recovered from funerary contexts.[5] There are gaps in our knowledge of fire-flints from settlement contexts because it is difficult to identify them without a very specific personal context (such as a tinder set kept in a pouch hanging on the belt). Most of the fire-flints, even the ones from graves, turned out to be secondarily re-used prehistoric artifacts, sometimes in elaborate form, but more typically unworked flakes. In modern (ethnographic) contexts, gunflint and re-used prehistoric artifacts both occur.[6] In the case of the Barcs assemblage, we have core remnants and a knife-like flake as well as an amorphous fragment, all of them made of radiolarite, probably from the Mecsek Mountains and also from Croatia. They can be used for provenancing with caution only, as it is unclear whether the fire-flint was transported from a more distant archaeological site or from localities closer to Barcs Castle.

The greater part of the small assemblage can be tentatively identified as coming from Croatia. Some pieces can be linked to the Mecsek Mountains, while others possibly originated

5 Garam 2014.
6 Hála 1986.

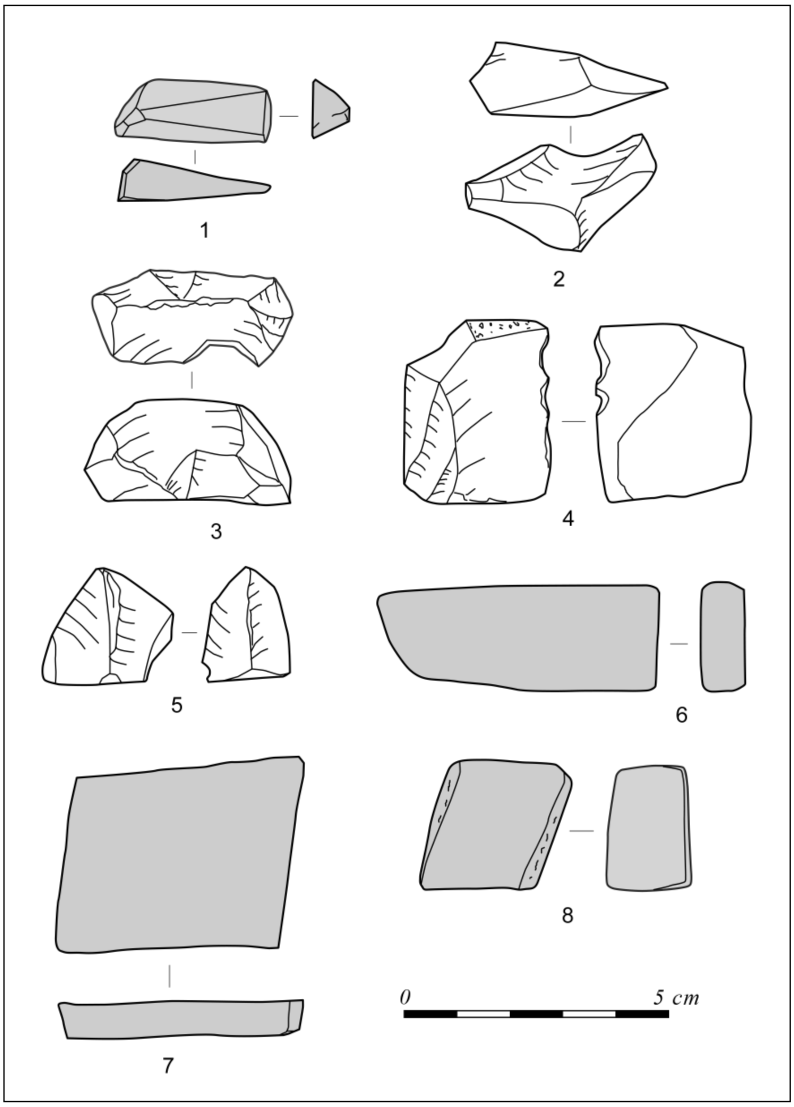


Figure 3. Lithic artifacts from the Ottoman-period site at Barcs Castle (drawing by Katalin T. Biró)

from the eastern Alps. This is consistent with the geographical position of the Ottoman-Turkish stronghold and the known data on the origin of the garrison.[7] Most of the stone artifacts were probably personal implements used by the soldiers, obtained or brought from the surroundings of the fort, but mainly from more southerly regions.

Altogether, the reliable provenancing of the small assemblage needs further work and considerations. [8]

7 In 1568/69, soldiers were transferred to Barcs from the region south of the Drava River, from three Croatian border fortresses in the environs of Verőce (Virovitica, Croatia), namely Brezovica, Moslavina, and Sopje to Szigetvár and Barcs (Hegyi 2006, 97).

8 The study was supported by a grant from the Hungarian Scientific Research Fund (OTKA Grant K 72231).

Figure 4. Lithic artifacts from the Ottoman-period site at Barcs Castle (photograph by Gyöngyi Kovács). a-f: selection of the stone tools from the sounding excavations in 1989–1994 (photograph by Tibor Kádas)

Table 1. Type / raw material matrix of the Barcs assemblage

Type code	*Mecsek radio-larite*	*Bakony (?) radiolarite*	*Croatian (?) radiolarite*	*Fine sand-stone*	*Medium sandstone*	*Coarse sand-stone*	*Chlo-rite schist*	*Siliceous schist*	*Other*	***Total***
B2	1		1							**2**
B2w		1								**1**
B3			1							**1**
csi.				1						**1**
csi9						2				**2**
fen.				2			1		1	**4**
fen9				7			2	2	1	**12**
kav9									1	**1**
őrl.					1	1				**2**
tör.	1								2	**3**
Total	**2**	**1**	**2**	**10**	**1**	**3**	**3**	**2**	**5**	**29**

REFERENCES

Garam 2014 — Garam, É.: "…Der Feuerschläger". In: *Aeolian scripts. New ideas on the lithic world. Studies in honour of Viola T. Dobosi.* Eds.: T. Biró, K. – Markó, A. – P. Bajnok, K. Inventaria Praehistorica Hungariae. Budapest: Magyar Nemzeti Múzeum, 13 (2014) 183–196.

Hála 1986 — Hála, J.: Archaic methods for lighting fire in the Carpathian Basin, with special regard to the use of siliceous materials. In: *International Conference on Flint Mining and Lithic Raw Material Identification in the Carpathian Basin, Sümeg 1986* (1). Ed.: T. Biró, K. Budapest: Központi Múzeumi Igazgatóság, 1986, 323–342.

Hegyi 2006 — Hegyi, K.: A török végvár [The Ottoman border castle]. In: *Szigetvár története*. Eds.: Bősze, S. – Ravazdi, L. – Szita, L. Szigetvár: Szigetvár Város Önkormányzata – Szigetvári Várbaráti Kör, 2006, 93–108.

Hegyi 2007 — Hegyi, K.: *A török hódoltság várai és várkatonasága* [The Castles and Garrisons of Ottoman Hungary] I–II. Budapest: História – MTA Történettudományi Intézete, 2007.

Kovács – Rózsás 1996 — Kovács, Gy. – Rózsás, M.: A barcsi török palánkvár (The Turkish Hoarding [palisaded] Castle of Barcs). *Somogyi Múzeumok Közleményei* 12 (1996) 163–182.

Kovács – Rózsás 2010 — Kovács, Gy. – Rózsás, M.: A barcsi török vár és környéke. Újabb kutatások (1999–2009) (The Ottoman-Turkish Castle at Barcs and its surroundings. New Research, 1999–2009). In: *A középkor és a kora újkor régészete Magyarországon / Archaeology of the Middle Ages and the Early Modern Period in Hungary* I–II. Eds.: Benkő, E. – Kovács, Gy. Budapest: MTA Régészeti Intézete, 2010, II: 621–642.

Péterdi et al. 2016 — Péterdi, B. – T. Biró, K. – Tóth, Z.: Domoszló: Grinding stone and millstone production center in Hungary. Presented on the conference "Raw materials exploitation in Prehistory: Sourcing, processing and distribution". Faro (Portugal), 2016, in prep.

APPENDIX

Fig. 1.1 = Fig. 4.3. **fen9**, hone stone fragment, siliceous schist (?), brick colored, red-grey with mica, 110 × 33 × 20 mm (ref. no. 834)

Fig. 1.2. **fen9**, hone stone fragment, two refittable fragments, probably parts of no. 834, siliceous schist (?), brick colored, red-grey with mica, 65 × 47 × 20 mm (ref. no. 845)

Fig. 1.3 = Fig. 4.8. **fen**. hone stone, cigar-shaped with oval cross-section, complete, fine-grained sandstone, reddish-light grey, 100 × 23 × 14 mm (ref. no. 837)

Fig. 1.4 = Fig. 4.7. **fen9**, hone stone fragment, finger-cake-shaped with angular cross-section, fine-grained sandstone, yellowish-grey, 60 × 40 × 23 mm (ref. no. 836)

Fig. 1.5 = Fig. 4.5. **fen9**, hone stone fragment, long and flat with rounded end, the other side is fragmented, light green foliated metamorphic rock (chlorite schist?), 80 × 34 × 10 mm (ref. no. 838)

Fig. 1.6 = Fig. 4.4. **fen9**, hone stone fragment, long and flat with fragmented end, grey fine-grained sandstone, 98 × 30 × 8 mm (ref. no. 846)

Fig. 1.7 = Fig. 4.9. **fen.**, hone stone, large, long and flat, glued together from several parts, light greenish-grey foliated metamorphic rock (chlorite schist?), 210 × 64 × 16 mm (ref. no. 842)

Fig. 2.1. **őrl.**, hand-held grinding stone, flat and small (mano), glued together from several fragments, dark brownish-grey, porous volcanic rock (andesite?), 102 × 86 × 14 mm (ref. no. 852)

Fig. 2.2. **fen9**, hone stone fragment, with longitudinal split, fine-grained grey sandstone with small mica, 78 × 28 × 9 mm (ref. no. 855)

Fig. 2.3. **fen9**, hone stone fragment with oval section, two ends fragmented, fine-grained sandstone, light grey, slightly calcareous, 59 × 19 × 9 mm (ref. no. 853)

Fig. 2.4. **fen9**, hone stone fragment, blade-like form, medial fragment, fine-grained sandstone, light grey, 40 × 25 × 8 mm (ref. no. 857)

Fig. 2.5 = Fig. 4.2. **fen.**, hone stone, glued together from three fragments, long with rectangular section, with traces of use-wear, fine-grained sandstone, light grey, calcareous, 176 × 26 20 mm (ref. no. 858)

Fig. 2.6. **fen9**, hone stone fragment with rectangular section, fine-grained sandstone, light grey with small brown patches, 52 × 15 × 13 mm (ref. no. 858)

Fig. 2.7. **csi9**, fragment of a polisher or coarse hone stone fragment, with oval/rectangular section, medial fragment, coarse red sandstone with pebble-size grains, 57 × 54 × 57 mm (ref. no. 859)

Fig. 2.8. **csi9**, fragment of a polisher or coarse hone stone, with oval/rectangular section, probably from the same piece as no. 859, but not directly fitting, coarse red sandstone with pebble-size grains, 100 × 50 × 43 mm (ref. no. 859)

Fig. 3.1. **fen.**, hone stone, small, complete, carefully polished, longish, obliquely narrowing, red siliceous haematite, 28 × 9 × 7 mm (ref. no. 839)

Fig. 3.2. **B2**, (recycled prehistoric) core remnant used as fire-flint, Mecsek radiolarite, grayish-pink, 36 × 20 × 15 mm (ref. no. 840)

Fig. 3.3. **B2**, (recycled prehistoric) core remnant used as fire-flint, end-scraper form, dark red/bluish-grey radiolarite with marbly pattern, Croatian (?), 37 × 17 × 20 mm (ref. no. 841)

Fig. 3.4 = Fig. 4.6. **B3**, (recycled prehistoric) flake used as fire-flint or gun-flint, knife-blade made on a pebble, bluish-grey radiolarite with yellowish-brown pebble cortex, 34 × 26 × 13 mm (ref. no. 843)

Fig. 3.5. **B2w**, (recycled prehistoric) micro-core remnant used as fire-flint, slightly burnt, reddish brown-grey Transdanubian radiolarite, 20 × 22 × 17 mm (ref. no. 844)

Fig. 3.6. **fen9**, hone stone fragment with rectangular cross-section, oblique polished end, the other terminal part is broken, fine-grained sandstone, light grey with mica, 54 × 20 × 9 mm (ref. no. 850)

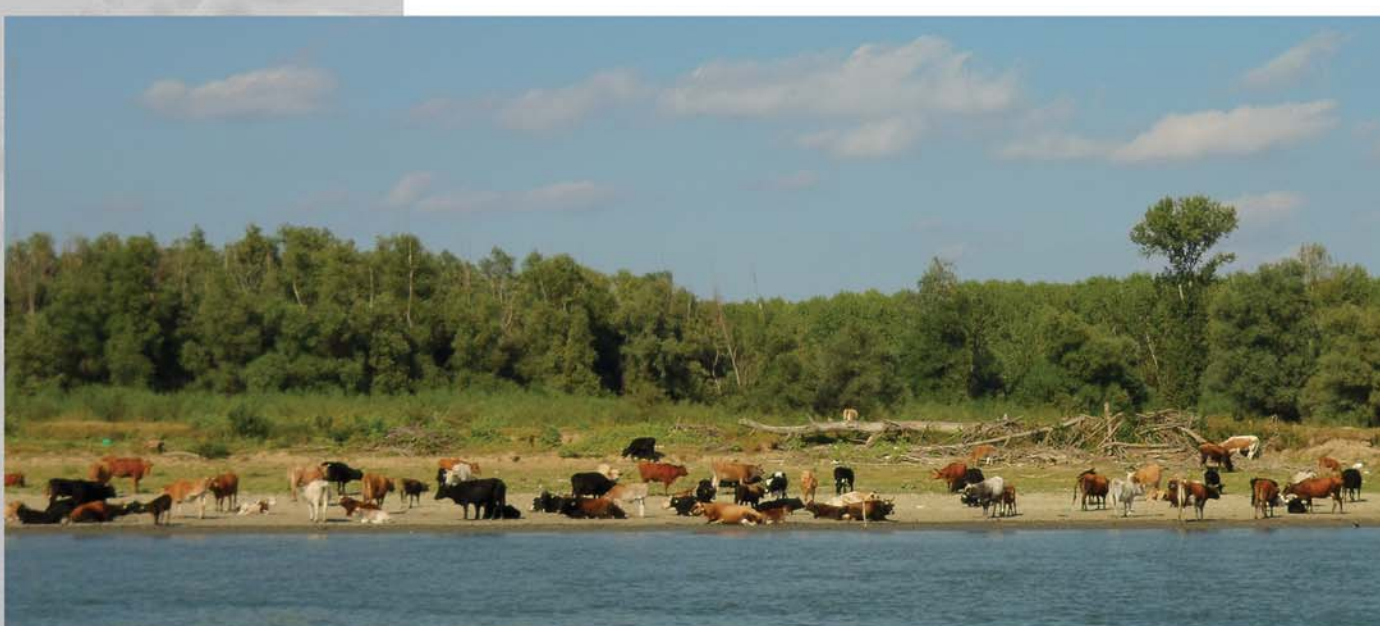
Fig. 3.7. **fen9**, hone stone (?) fragment, flat, quadrangular, dark brown sediment, limonitic rock (bog iron?), 46 × 33 × 10 mm (ref. no. 848)

Fig. 3.8. **fen9**, hone stone medial fragment with rectangular cross-section, light greenish-grey metamorphic rock (chlorite schist?), 25 × 23 × 17 mm (ref. no. 851)

Fig. 4.1. **őrl9**, rimmed quernstone (lower part of a hand-mill), fragments, coarse sandstone, reddish-grey with pebble size grains, 440 × 440 × 100 mm (ref. no. 670)

Figure 4.10. **csi.**, large irregular hone stone or polisher, with traces of red pigment (haematite?), fine-grained sandstone, yellowish-grey, 160 × 80 × 50 mm (ref. no. 835)

Archaeozoology



ANIMAL REMAINS FROM THE LATE MEDIEVAL *CASTELLUM* OF ŐCSÉNY-OLTOVÁNY, SOUTHERN HUNGARY

László Bartosiewicz

INTRODUCTION

Archaeozoology is devoted to the identification, analysis, and interpretation of animal remains from archaeological sites. The reconstruction of everyday life in the medieval period has become unimaginable without considering archaeological phenomena, as emphasis tends to be placed on outstanding events and personalities at the expense of the simple matters of life that characterized daily practices even in well-documented situations. It is especially challenging to investigate whether medieval documentary sources match the evidence of archaeological animal bone assemblages. Moreover, such written sources are frequently missing and the study of artefactual remains is the only way medieval daily life can be understood.

This study is the summary of meat consumption and animal use at the late medieval site known today as Őcsény-Oltovány in Tolna County, Hungary. The only written reference to the castle of Györke that once stood at this location is indirect (*castellanus castelli Gywrke*), originating from a 1446 legal document supporting the typochronological dating of the archaeological finds covering the time interval between the period of the Árpád Dynasty (ending in 1301) and the beginning of the Ottoman-Turkish occupation of Hungary in 1526 that probably also marked the end of the small castle's history.[1]

LANDSCAPE, ENVIRONMENT, AND EXCAVATIONS

The site called Oltovány was discovered some half a kilometer north of the edge of present-day Őcsény, a village in southern Transdanubia, Hungary. In a broad sense, the site is located near the ecotone between the Transdanubian hill region and the floodplain of the Sió River, a major right bank tributary to the Danube. The castle lay in the plain below the 100 m contour line above the Baltic sea level *(Fig. 1)*. The immediate region around Őcsény-Oltovány is called Sárköz, a name which in Hungarian refers to mud, i.e. the marshy nature of the floodplain habitat which developed on the top of tens of meters of windblown loess deposited on the sandy-gravelly substrate of the Palaeo-Danube River during the Pleistocene. Today, this is a monotonous landscape with only traces of oxbows, natural levees, and terraces reminiscent of the surface prior to the 1881–1885 river regulation works along this section of the Danube.

1 This paper is dedicated to the memory of Zsuzsa Miklós (1948–2014), leader of the excavation of the site, who entrusted me with the analysis of this find material. Her monograph on the castles of Tolna County was published only in Hungarian and is quoted extensively in this chapter to offer an archaeological background to my own faunal investigations. *Figures 2, 3, 7,* and *8* were taken from her work (Miklós 2002) with the publisher's kind permission. The final manuscript was prepared within the framework of OTKA Grant No. K 72231 of the Hungarian Scientific Research Fund.

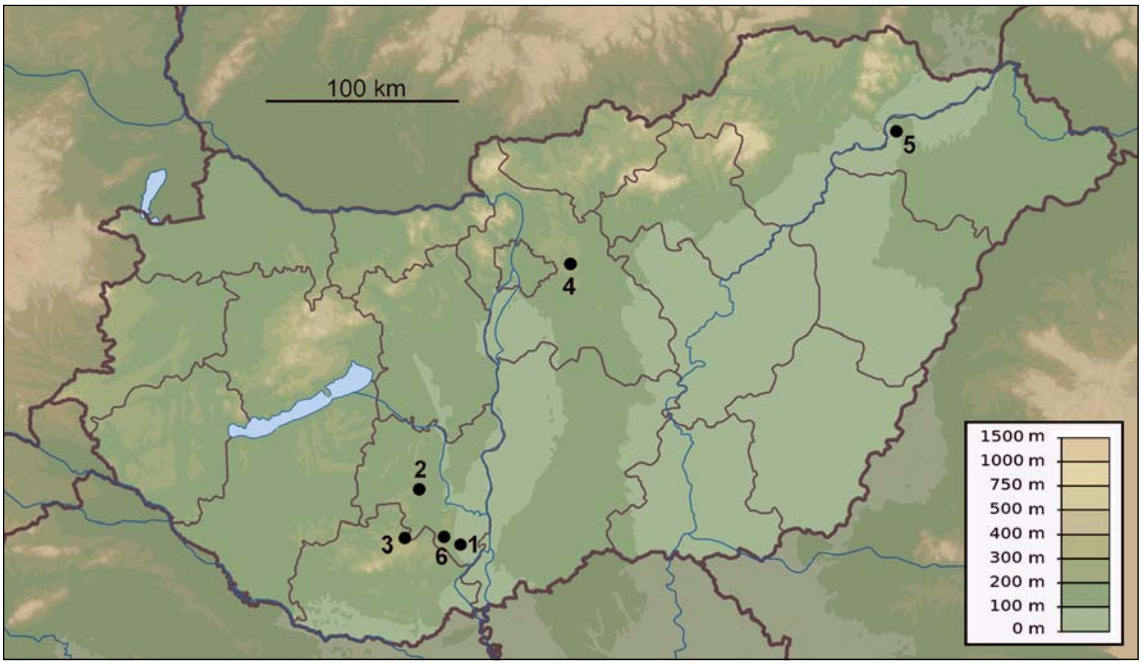


Figure 1. The geographical distribution of sites mentioned in the study
1: Őcsény-Oltovány, 2: Murga-Schanz, 3: Váralja-Várfő, 4: Mende-Lányvár, 5: Szabolcs-Földvár, 6: Szekszárd-Palánk. For details, see *Table 3*

The medieval environment may thus be characterized as a wetland with arable terraces in the floodplain zone.

According to detailed archaeological surveys, within this flat area the site occupies heights between 86–91 m asl, with the actual remains of the castle once built on a *ca.* 3 m high elevation (91 m asl) stretching along the left bank of the Báta Stream *(Fig. 2)*. The castle once faced the northern edge of a peninsular area surrounded by this stream. Today, Báta Stream is part of the Szekszárd-Báta main channel, a strongly eutrophic small river, whose course seems to have changed little, at least during the past three centuries.

According to an 1888 description by Frigyes Pesty, "there is a place demarked by a broad rampart with ruins of a building where, according to folklore, the lady friend of the Szekszárd pasha lived during Ottoman times. … The popular name of the road the pasha had built across the then marshy space is called Devil's stretch even today, perhaps due to the great hardships suffered during its difficult construction."[2] Although the rampart later turned out to have been of Roman origin, Pesty's vivid description of the toponym gives a reliable impression of the landscape before the river regulations.

Having interviewed local dignitaries in Tolna County during 1891 regarding potential archaeological sites, archaeologist Mór Wosinsky visited Oltovány himself.[3] In addition to the features visible today, he had also observed an external moat *(Fig. 3)*, which had largely disappeared by the 1950s.

The site was again identified by Zsuzsa Miklós in 1977. The habitation area of the medieval castle covered some 30 m by 30 m along the stream and was surrounded by a 4 m deep and 10–15 m wide, semi-circular moat at the time. Beyond the moat, the remains of a 15–20 m wide and 100–150 cm high earthwork were recognized. The survey continued in 1985 before the interior of the castle was excavated by a team of the Archaeological Institute

2 Pesty 1888.
3 Wosinsky 1896.

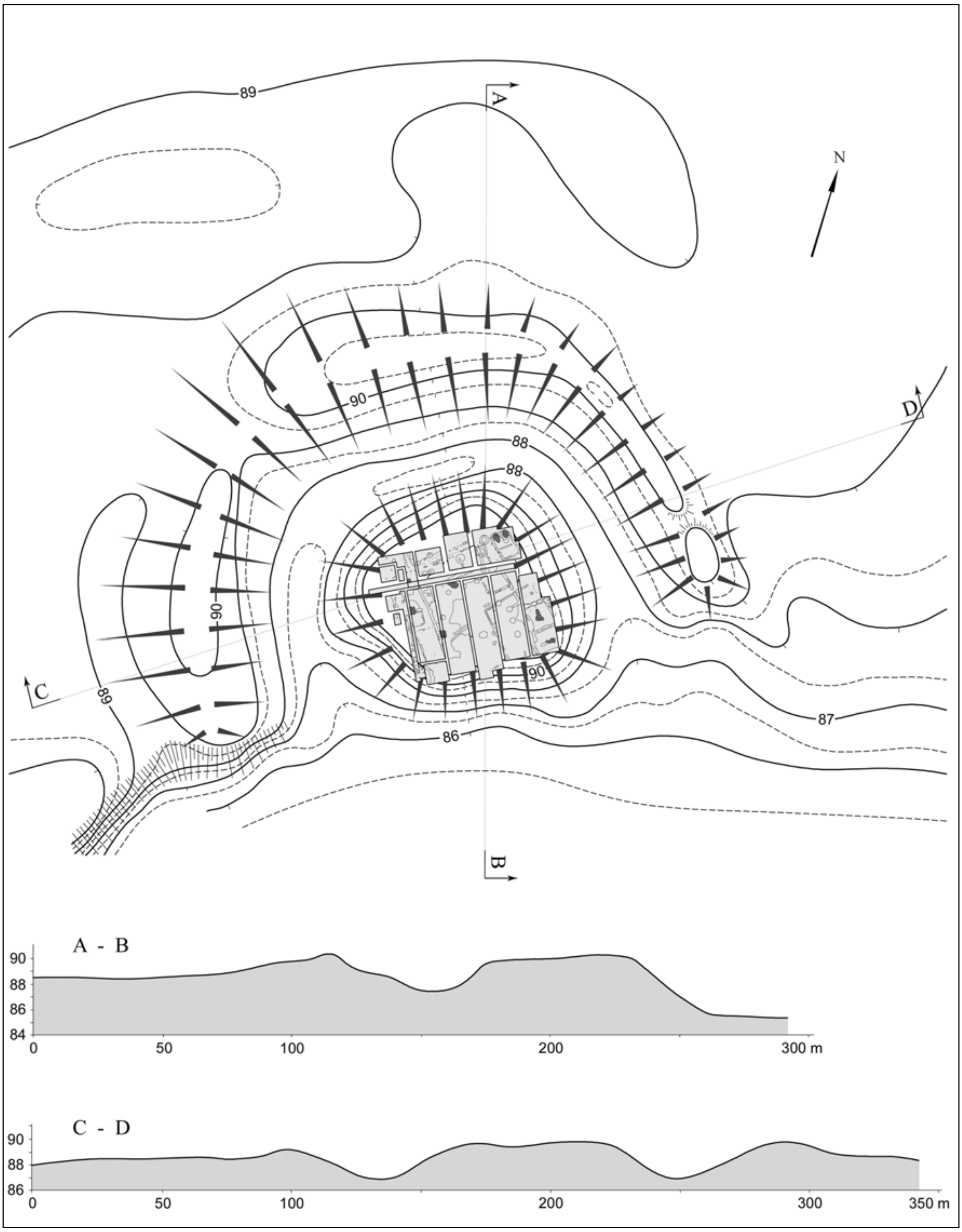


Figure 2. The topographic position of the site based on field surveys by Gyula Nováki and György Sándorfi (1985), and Endre Egyed (1991) (after Miklós 2002)

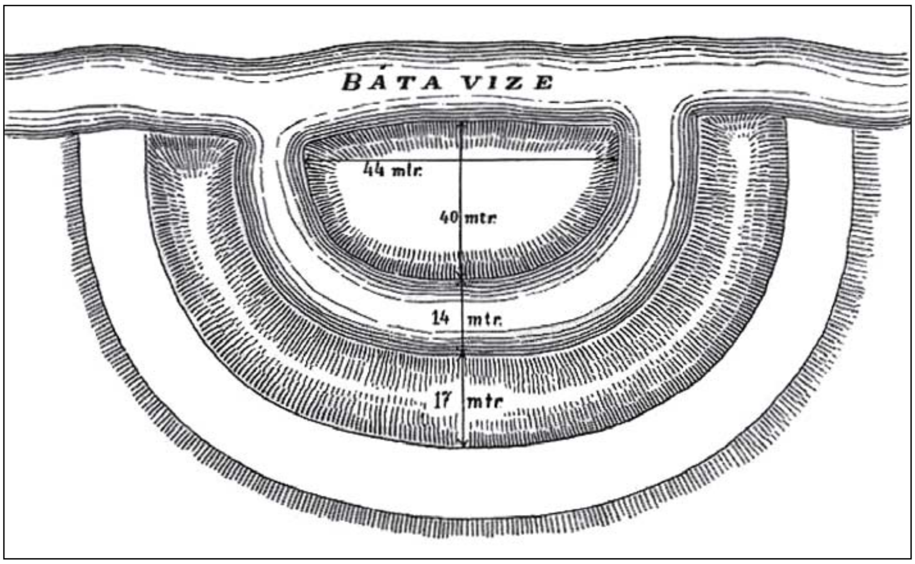


Figure 3. The plan of the site published by Mór Wosinsky in 1896
(after Miklós 2002)

of the Hungarian Academy of Sciences under the direction of Zsuzsa Miklós. Work began by opening test trenches in the centre in 1988. During 1990–1992, almost the entire internal territory was excavated, revealing five houses of various structures, refuse pits, and remains of the inner palisade, all dated to between the fourteenth and sixteenth centuries.[4] According to the 1992 excavation results, the inner moat was 4.6 m deep relative to the level of the inside habitation area. Remains of palisades were also identified along both Báta Stream and the defensive ditches.[5]

THE ANIMAL BONES

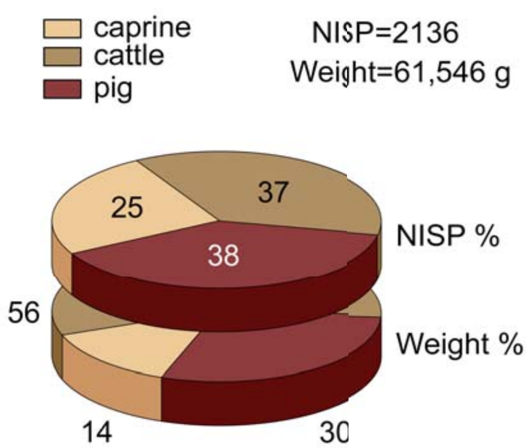


Figure 4. Differences between the proportions of main livestock species (100%) in terms of the numbers of identifiable specimens (NISP) and bone weights

Excavations at the site brought to light 2,662 pieces (70 kg) of remarkably well-preserved animal bones, the overwhelming majority (*ca*. 90%) originating from domestic animals. Due to the relatively small degree of fragmentation, most of the bones were identifiable to species, fewer than 300 fell into the generic "small" or "large ungulate" categories denoting sheep/goat (caprine) or pig, and cattle or horse or red deer, respectively. The share of non-identifiable material was 10% in terms of fragment numbers; however, these unrecognizable bone fragments contributed far less to the material in terms of bone weight due to their small sizes (average weight < 20 g).

4 Miklós 2002.

5 Miklós 2002, 288.

Water-sieving or at least dry screening is a precondition for the statistically representative recovery of bones from smaller vertebrates such as birds or fish. Nevertheless, refined techniques of recovery are almost unknown in medieval archaeology in Hungary. Consequently, it is only the largest fish species such as sturgeons, whose bones can be occasionally studied from medieval sites.[6] Despite the alluvial environment of the fortified castle, no fish bones were found in the Oltovány assemblage and only two wild bird bones (weighing only *ca.* 3.5 g each) could be recovered by hand collection.

It became clear already during the first inspection that the animal remains from the site represented food refuse, many originating from meat-bearing regions of the animal carcasses, damaged by marks of both primary and secondary butchery, usually identifiable as left by high quality metal tools. The taxonomic composition of the material is listed in *Table 1* by the number of identifiable bone specimens (NISP) and bone weights. The percentual contribution of main domesticates (cattle, pig, caprines) by these two parameters are summarized in *Figure 4*. While the number of fragments was evenly distributed between pig and cattle (caprine remains making up only one quarter), bone weights suggest that over half of the meat consumed in the castle must have been beef. This means that while pig remains dominate in the assemblage in terms of absolute fragment numbers, when bone weights are taken into consideration it is evident that approximately twice as much beef was consumed at the site as pork. Meat from caprines was evidently far less significant, as shown by both the relatively small number of identifiable fragments and their small summarized weights. Although sheep and goat are different species, their bones are hardly distinguishable (with the exception of skulls, horn cores, and metapodia). Even though goat is more tenacious and gives a higher amount of milk compared to its body size, sheep bone is usually found more commonly in Hungary. As may be observed at Oltovány Castle as well, there are usually at least 3–4 times more bones from sheep than goat among the precisely identifiable caprine remains, a ratio characteristic of many medieval sites in Hungary.[7]

Horse bones occur scarcely in this assemblage, clearly indicating that this species did not contribute to the meat supply of the castle. At late medieval sites, horse carcasses were processed for manufacturing purposes only: fine cut marks on the bones of the feet often testify to the use of the hide. Horse metapodia were frequently carved due to their strength and straight shape. Bone "skates" or runners occurred commonly until the twentieth century. In the absence of such activities, however, there was no reason to bring body parts of horses into the castle's area.

Dog meat was not consumed either and, therefore, remains of this animal had a smaller chance of ending up in the archaeological material mainly consisting of kitchen refuse. Dog carcasses are thus likely to be discovered intact and in anatomical order. The very few dog bones at the site, however, were disarticulated and probably represent secondary deposition. Medieval attitudes towards dogs were ambiguous: they were symbols of both loyalty and envy. However, by the late medieval period, luxury dogs also became important symbols of social status across Europe,[8] and therefore they must have been present at settlements, especially where hunting was pursued. This hypothesis is strongly supported by the relatively high number of bones in the kitchen refuse gnawed by dogs which must have scavenged on food remains[9] even within the relatively limited area of the castle.

Domestic hen was the main type of fowl kept at almost all medieval settlements. Domestic goose is found only sporadically and, in addition, its bones are usually impossible

6 Bartosiewicz – Bonsall 2008.
7 Bartosiewicz 1999.
8 Bartosiewicz 2011.
9 Daróczi-Szabó 2006.

Table 1. The numbers of identifiable bone specimens (NISP) and bone weights

	NISP	*NISP (%)*	*Weight (g)*	*Weight (%)*	*Mean weight (g)*
Pig (*Sus domesticus* Erxl. 1777)	827	34.9	18,276.7	26.8	22.1
Cattle (*Bos taurus* L. 1758)	785	33.1	34,697.0	50.8	44.2
Sheep or goat (Caprinae)	341	14.4	3,137.2	4.6	9.2
Sheep (*Ovis aries* L. 1758)	146	6.2	4,380.0	6.4	30.0
Goat (*Capra hircus* L. 1758)	37	1.6	1,054.5	1.5	28.5
Horse (*Equus caballus* L. 1758)	3	0.1	333.0	0.5	111.0
Dog (*Canis familiaris* L. 1758)	11	0.5	297.0	0.4	27.0
Hen (*Gallus domesticus* L. 1758)	8	0.3	20.0	0.0	2.5
Goose (*Anser domesticus* L. 1758)	2	0.1	10.8	0.0	5.4
Domestic animals, total	**2,160**	**91.1**	**62,206.2**	**91.1**	
Red deer (*Cervus elaphus* L. 1758)	59	2.5	3,097.5	4.5	52.5
Roe deer (*Capreolus capreolus* L. 1758)	38	1.6	459.8	0.7	12.1
Wild pig (*Sus scrofa* L. 1758)	78	3.3	2,230.8	3.3	28.6
Brown hare (*Lepus europaeus* Pall. 1785)	17	0.7	71.4	0.1	4.2
Beaver (*Castor fiber* L. 1758)	11	0.5	154.0	0.2	14.0
Badger (*Meles meles* L. 1758)	3	0.1	33.0	0.0	11.0
Red fox (*Vulpes vulpes* L. 1758)	4	0.2	50.4	0.1	12.6
Wild mammals, total	**210**	**8.9**	**6,096.9**	**8.9**	
Red deer antler	8	0.3	200.0	0.3	25.0
Identifiable remains, total	**2,370**	**100.0**	**68,302.2**	**100.0**	
Large ungulate bone	179		2,004.8		11.2
Small ungulate bone	111		532.8		4.8
Non-identified bird	2		7.0		3.5
Non-identifiable remains, total	**292**		**2,544.0**		**19.5**

to distinguish from those of the wild ancestor, greylag goose, inhabiting similar marshy habitats. The domestic status of this bird is, therefore, usually assumed on the basis of domestic animals in general dominating in medieval faunal assemblages. Sources describing the selection of geese by color in thirteenth-century Hungary[10] attest to the importance of this species.

Wild pig and red deer are best represented among large game. Animals of this size need a good cover, and therefore they are indicative of forested areas in the relative proximity of the settlement. This is not surprising, as much of the alluvial plain around the site must have been covered by floodplain forests.

The importance of domestic pig and the presence of wild boar in the faunal list of Oltovány Castle raise questions concerning the form of pig keeping. Until recently, pigs have often been herded in woodlands. This practice was aimed at both seasonal feeding on acorn and spontaneously upgrading domestic stock by wild boars. This possibility was studied by looking at the size of the bones from the site. Although no complete long bones

10 Matolcsi 1975, 216.

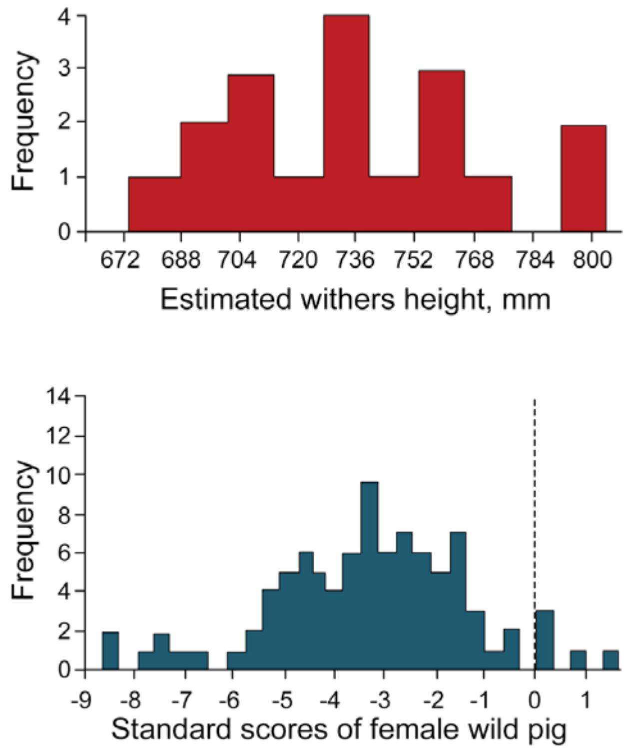


Figure 5. Withers height estimates of pigs from Oltovány Castle (top). Pig bone measurements from Oltovány Castle in relation to the mean value of female wild pig (bottom)

of pig were recovered from Oltovány Castle, withers height estimates could be based on the greatest lengths of astragali and calcanei.[11] In spite of the small number of cases, the results show a near-normal distribution, with only two individuals approaching a stature of 80 cm, possibly boars (*Fig. 5*, top). However, the rest of the individuals were relatively large as well.

Measurable bone fragments (especially the early fusing distal epiphyses of humeri and tibiae) occurred in slightly greater numbers than the bones used in estimating withers heights. They could be visualized against the backdrop of the measurements of ten present-day female wild boars collected near Kızılcahamam in Anatolia, Turkey.[12] It is important to note that the mean values and standard deviations of this reference sample suggest no biological connections between the two sets of bones, but help to appraise variability in the set of medieval pig bones in Hungary.

Pig bone measurements from Oltovány Castle were converted into standard scores using the mean values and standard deviations of the wild boar measurements from Kızılcahamam and plotted in a histogram whose zero value corresponds to the average of modern female wild boar (*Fig. 5*, bottom). The overwhelming majority of measurements taken in the Oltovány material fall left of the average of Anatolian wild sows, showing that most of these animals represented domestic animals. Some small bones in the far left (standard score<-6) may originate from not fully mature individuals whose early fusing epiphyses could not be precisely aged in the absence of the evidently young, unfused half of the same bone. In *Figure 5* (bottom), only five of the largest bones from Oltovány Castle exceed the

11 Teichert 1969.
12 Payne – Bull 1988.

average measurements of modern female wild pig (0 value). The majority cluster between the distances of -1 to -5 standard deviation from this wild female mean. These measurements represent rather large, but probably domestic pigs. The few largest bones (standard scores>0) probably originate from wild boar. The small contribution of the latter form to measurable bones is consistent with the morphological identification by which the proportion of wild boar to domestic pig was 78:827 in the Oltovány assemblage *(Table 1)*, that is only 8.6% of all suid bones could be identified as originating from wild pig. Otherwise, the presence of relatively large (domestic) individuals raises the possibility of mixing with local wild stock. In wetland habitats, rhizomes of reed and aquatic mollusks could be profitably utilized by freely foraging pigs. Due to this widespread practice, medieval pigs in many parts of Central Europe were considered in-between domestic and wild both genetically and conceptually. According to medieval sources in Poland, "swamp hogs" resembled wild boar in flavor, but were considered livestock.[13] Wild boar is followed by *Eynheimisches Schwein* in the cookbook of the Mainz Elector.[14] Therefore, "native pig", distinguished from wild boar and translated as forest hog by János Keszei in the cookbook compiled for Anna Bornemisza,[15] is of special interest. Keeping free-ranging pigs in the forests of Šumadija in Serbia was a historically important phenomenon. [16]

Beaver – an aquatic mammal having scales on its tail – was often considered "fish" and eaten during Lent.[17] Beaver bones were brought to light at this site as well. Their presence is unsurprising from an environmental point of view, given the marshy habitat surrounding the castle of Oltovány. It must be noted, however, that such delicacies eaten at medieval centers usually signify that rather the letter than the spirit of Lent was kept by the *élite* striving for both varied food and self-representation. In Transylvania, beavers were kept in captivity for both their meat and pelts in the sixteenth century.[18]

The bones of hare are interesting from an environmental point of view, as these animals (together with roe deer) prefer drier bushland such as the forest edge and natural vegetation covering levies in the floodplain. Their presence in the diet confirms our hypothesis that the medieval wetland environment was mosaic-like, interspersed with patches of higher, arable elevations.

Modern-day individuals of burrowing carnivores such as fox and badger may have ended up in the archaeological bone assemblage by dying in their burrows. In such cases, the only evidence supporting a medieval dating would be the signs of human alteration such as skinning marks. Such marks, however, could not be identified on the few badger and fox bones recovered at Oltovány.

Meat provisioning at the castle

The animal bones from Oltovány Castle represent a group of assemblages that originate from fortified sites of distinctly non-agrarian character, where possibilities for animal keeping were spatially limited. Meat supply to castle dwellers depended on food production in nearby villages and market towns (such as Decs, lying 4 km south of Oltovány, that coexisted with the castle through most of its medieval history). Remains of a fourteenth–

13 Dembinska 1999, 88.
14 Rumpolt 1581.
15 Lakó (ed.) 1983.
16 Halpern 1999, 83.
17 Bartosiewicz et al. 2010.
18 Bejenaru 2003, 156.

Table 2. The anatomical distribution of identifiable bone weights in the most important meat purpose species

Skeletal element	*Pig*	*Cattle*	*Caprine*	*Horse*	*Red deer*	*Roe deer*	*Wild pig*
Skull	2,956	150	1,331		12	46	95
Mandible	1,699	225	942		272	75	225
Vertebrae	2,651	9,271	1,521		368		171
Ribs	1,691	6,841	607		176		25
Scapula	868	3,662	572		232	95	214
Humerus	1,690	5,241	584		427		372
Radius/Ulna	1,078	1,142	462	212	228	161	311
Metacarpus	439	1,845	214		95	22	31
Pelvis	859	595	241		287	12	68
Femur	1,380	3,326	925		252		276
Tibia/Fibula	1,225	482	662		319		188
Basipodium	822	204	58		128	38	71
Metatarsus	415	741	346		163		111
Phalanges	504	972	107	121	138	11	73
Total weight (g)	**18,277**	**34,697**	**8,572**	**333**	**3,097**	**460**	**2,231**

sixteenth-century rural settlement were also detected opposite the castle on the right bank of the Báta Stream.[19] The meat supply of such settlements was often organized in a way that the animals for slaughter would be driven to the complex on foot before they were killed, and primary butchery into portable carcass parts may have taken place outside habitation areas. The anatomical distribution of bones by weight shown in *Table 2* illustrates this possibility.

Focusing on the most important species of livestock, cattle, pig and caprines, interesting trends of differential selectivity may be observed. When percentages of bone weight are compared to that of a complete skeleton in each species,[20] the relatively high weight proportions of *stylopodium* bones (humerus and femur) and scapula are evident among the pig remains (*Fig. 6*, top). These meat-rich extremity segments of proximal location correspond to valuable cuts commercially termed "shoulder" and "ham". This marked patterning seems to have been indicative of specialized carcass treatment since prehistoric times,[21] including the transport of cured (salted and smoked) pork to the castle. Mandibles also stand out in this comparison. The sizeable masseter muscle, associated tongue, and even the marrow content of the pig mandible represent food value.[22] Cattle remains show a different tendency. Bone weights of high-quality meat-bearing regions of the trunk (vertebrae, scapula, ribs) and humerus are relatively overrepresented in the material (*Fig. 6*, middle). This pattern is indicative of the strong possibility that selected sections of cattle carcasses were taken into the castle during most of its history and less valuable skeletal parts were often left behind at the kill site outside. The pattern obtained for cattle is almost the diametric opposite of skeletal part distributions characteristic of tanneries where the least valuable carcass parts (dry limbs

19 Miklós 2002, 291.
20 Reichstein 1994.
21 Pucher et al. 2013.
22 van Wijngaarden-Bakker 1990, 170.

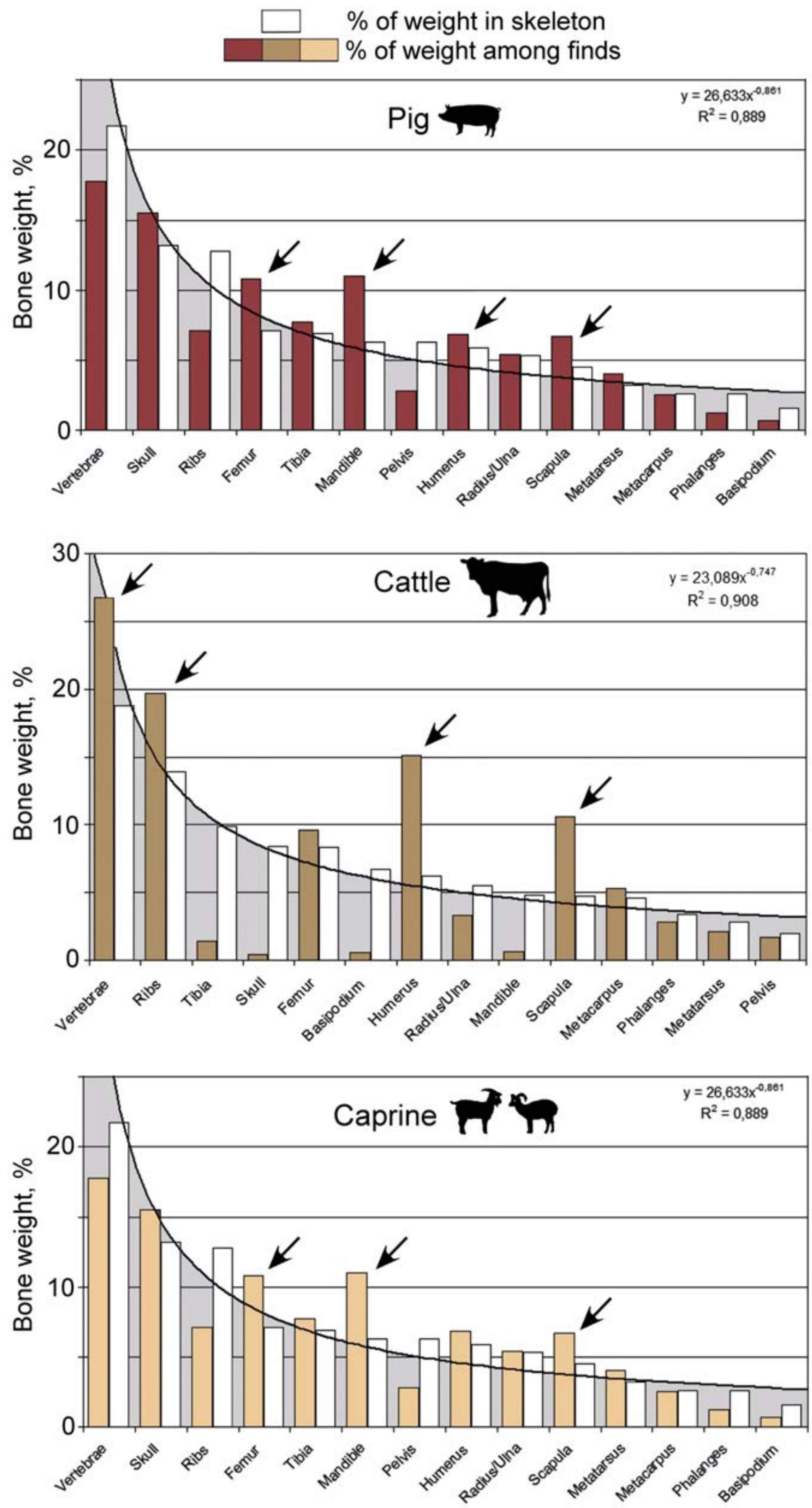


Figure 6. The anatomical distribution of bone weights compared to standard skeletal weights of pig, cattle, and caprines. For raw data, see *Table 2*

and heads) tend to be overrepresented.[23] Bones of the head (both the *calvarium* and mandibles) are practically missing from the Oltovány cattle assemblage. The relatively small weight of caprine bones (representing both sheep and goat without distinction) seems to support the hypothesis that the skeleton of small stock is more evenly represented in the food refuse recovered from within the castle's habitation area (*Fig. 6*, bottom). Although beef played a crucial role in medieval diet in Hungary, inside the earthworks there was simply no room for pasturage. Only animals suitable to be confined to small places (domestic fowl, dogs, and perhaps pigs) could have been kept inside such complexes. Grazing even small bovids within the enclosure would have been out of the question and even pig keeping (a more household-bound form of animal husbandry) would have been similarly impossible on a larger scale. The settlement should be seen as a site of consumption rather than of production.

Undoubtedly, the carcasses of non-meat purpose animals such as horses or dogs were dumped into the moat or disposed of/buried outside the limited inner castle area. As is usual with food refuse, the bones recovered within show signs of heavy butchering, including evidence of hacking that damaged many of the usually measurable bones. Cattle astragali were split lengthwise as seen at other sites;[24] in one case, the *sustentaculum calcanei* was probably also hacked off with the same move. In several cases, the lateral side of the *trochlea humeri* was similarly cut off, precluding bone measurement. Cut marks indicative of defleshing or food preparation were visible on mandibles and ribs. On the other hand, no marks of skinning could be identified, in part due to the relatively small number of autopodium bones in the assemblage. In the absence of completely preserved long bones, the stature of the animals could not be estimated.

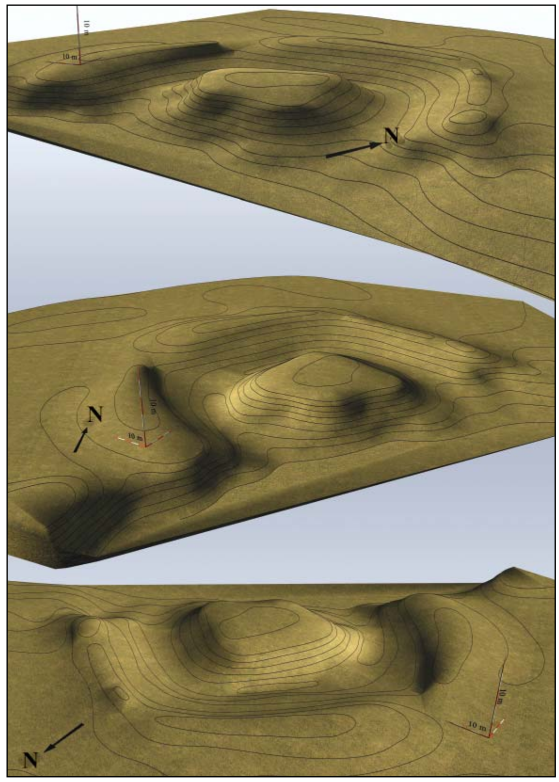


Figure 7. Three-dimensional reconstructions of the site and its moat system seen from the east (top), southwest (middle) and nortwest (bottom) by Zsolt Réti (after Miklós 2002)

Figure 8. Aerial photograph by Zsuzsa Miklós showing traces of intensive habitation within the excavated area (after Miklós 2002)

23 Bartosiewicz 2009.

24 Bartosiewicz 1995.

The approximately 30 m by 30 m habitation area of the castle corresponds to less than 10% of a hectare. Although somewhat larger dimensions are given in Wosinsky's 1896 drawing *(Fig. 3)*, in addition to possible inaccuracies in his method of measurement, the edges of the elevation have indubitably been eroded by over a century of tillage. Even during the settlement's life, however, the internal living space must have been quite limited. The maximum extent of the living space was delineated by the defensive moat. Water must have been diverted from the Báta Stream into the possibly double enclosure system *(Fig. 7)*.[25] These spatial parameters help putting the concentration and qualitative composition of the animal bone assemblage into perspective. The leader of the excavation, Zsuzsa Miklós, a skilled aerial photographer, took advantage of a nearby agricultural airfield and prepared a near-daily documentation of the excavation from the air. Features shown in these pictures offer a glimpse of how crowded the core area of the castle may have been *(Fig. 8)*. Although it is impossible to estimate the potentially oscillating number of inhabitants on the basis of animal remains,[26] the high status of at least some of the quarters is indicated by numerous glass shards, several of them originating from thirteenth–fourteenth-century workshops in Venice, and fragments of elaborate, unglazed openwork stove tiles.[27]

Age distributions and pathological lesions

Ageing the animal remains from Oltovány was carried out by a combination of tooth eruption sequences and epiphyseal fusion data in present-day domesticates derived from reference animals of known ages.[28] However, given the different ossification regimes of epiphyseal plates in various long bones, only the *terminus post quem* absolute ages of animals could be established, a potential source of distortion seldom addressed in the literature. This means that calendar ages at death may look different in the sample depending on the skeletal part available for study. Relative frequencies (NISP per cent) of ageable skeletal elements at medieval Oltovány indicate well-known differences between species rooted in their patterns of exploitation *(Fig. 9)*. Longevity is most characteristic of cattle; even some bones of very old individuals could be identified. Cattle are not slaughtered easily: this is a consequence of their slow reproduction and exploitation for dairy products as well as their potential use in traction. Single meat purpose pigs represent the other extreme: a prolific, multiparous animal whose numerous offspring can be slaughtered for meat even at young ages, but certainly by adulthood, aside from some individuals retained for further breeding. Caprine age profiles (including those of clearly identifiable sheep and goat) fall in-between those of cattle and pig. This may also be related to their secondary exploitation for wool and milk, respectively. These renewable resources can be harvested for several years, before a sheep or goat is killed for meat. Note that the general "caprine" group includes numerous bones from young individuals whose species identification is impossible exactly because of their young ages. This high proportion of young animal bone is an indication of observer bias rather than a sign of special exploitation.

In spite of the rather large size of the assemblage, only two cases of pathological lesions were recorded, both in the case of cattle. This is related to the fact that the remains of mature individuals dominated among cattle bone, as age is a major disposition to a number of

25 Miklós 2002.
26 Miklós 2002, 288, Fig. 275.
27 Guilday 1970.
28 Bartosiewicz et al. 2013, 104, Table 1.

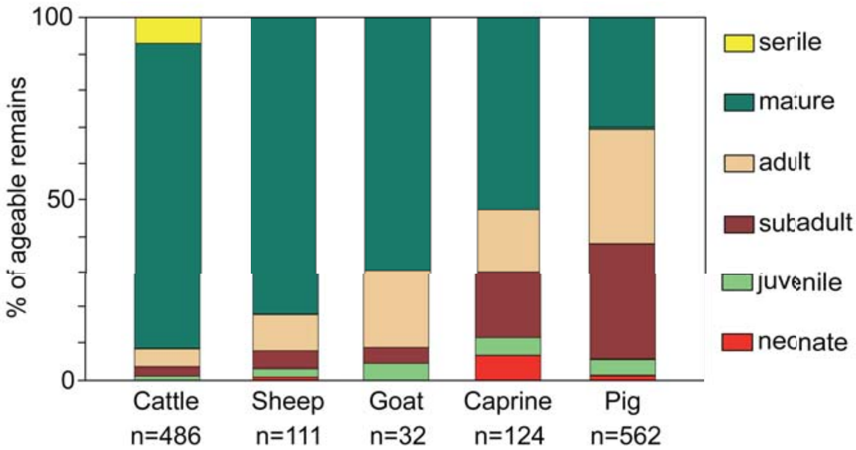


Figure 9. The proportions between ageable remains among meat purpose domestic ungulates

pathological conditions. In addition to natural aging, the probability of cumulative trauma is also greater as time advances.

An *acetabulum* pelvis fragment displayed eburnation on the caudal articular surface *(Fig. 10).* Eburnation is one among the composite of at least three simultaneous symptoms of advanced arthropathy.[29] This ivory-like glossy wear results from the surfaces of the two epiphyses grinding on each other once the protective cartilage cover is gone from the joint surfaces, a symptom especially common in the hip joint of cattle.[30] The innervation of the epiphyseal surface is poor and spectacular polish develops following the most painful, acute phase of inflammatory soft tissue degeneration.

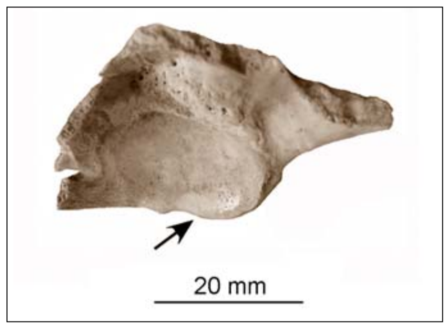


Figure 10. Eburnation on the caudal surface of the acetabulum pelvis in cattle. Medioventral aspect (photograph by Krisztina Pálfay)

Pathological fusion (*ankylosis*) was observed between the centrotarsal bone and the naturally fused 2nd and 3rd tarsal bones in the hock joint of a small cow *(Fig. 11).* A study of 88 cases of cattle spavin from medieval Schleswig-Schild[31] has shown that ankylosis usually begins in-between these two bones of pivotal location before it spreads to the entire tarsal joint. A series of tarsalia showing the advancement of this process in fourteenth–sixteenth-century cattle is known from the Netherlands.[32] Details have further been investigated using magnetic resonance imaging in present-day draught oxen from Romania,[33] demonstrating that degenerated arthrotic bone is first replaced by non-calcareous bone, especially in the centrotarsal region. The sclerosis of this matter is instrumental in the fusion between the affected bones, first in the weight-bearing dorso-medial region of the joint where the ankyloses in both the Oltovány specimen and the modern ox could be observed. Therefore, the Oltovány case may be considered the incipient phase of spavin. Its causal relationship with draught exploitation, however, remains uncertain.

29 Baker – Brothwell 1980, 115.
30 Bartosiewicz 2013, 108.
31 Hüster 1990, 44.
32 Davis 1987, 162, Fig. 7.9.
33 Bartosiewicz et al. 1997.

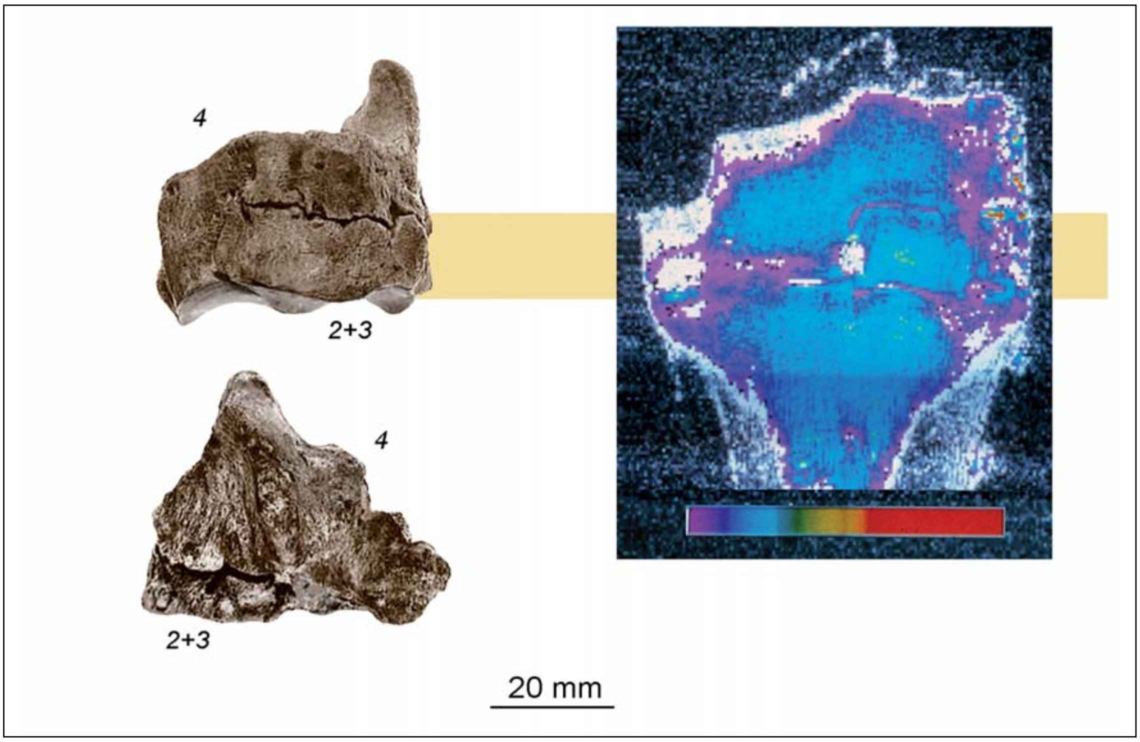


Figure 11. Left: Fusion between the tarsal bones of a small cow. Anterior (top) and posterior aspect (bottom). Numbers indicate the naturally fused 2nd+3rd and normally separate 4th tarsal (centrotarsal) bone (photograph by Krisztina Pálfay). Right: Magnetic Resonance Image of the fully fused tarsal joint of a working ox. The purple outline shows heavy ossification between the 2nd+3rd and 4th tarsal bones within the zone of comparison highlighted by the yellow band (MRI image by Isabelle Mottet)

Bone and antler manufacturing

By the medieval period, mundane bone and antler working was largely overshadowed by easily available iron artifacts. The remaining types of worked bone and antler usually served as parts in composite equipment or as decoration. Two knives found at the site[34] probably had handles made from bone, as is suggested by their shape and good preservation (in contrast to wood), although I had no opportunity to study these objects myself. Two objects made from red deer antler, however, were discovered among the refuse bones available for direct inspection. One of these is a damaged crossbow nut showing signs of heavy use, including a split segment *(Fig. 12)*. It is a stout, cylindrical object with a semilunar incision made to hold the string in a tensed position. This function exerts a major strain on the nut. Due to its special, homogeneous texture (as opposed to skeletal bone of a more lamellar microstructure[35]), the robust base of red deer antler was a preferred raw material for these artifacts. The particularly dense antler of European elk was especially highly valued for this purpose.[36] Crossbow nuts are relatively common finds across Europe,[37] including Hungary. Among others, several sixteenth–seventeenth-century specimens have been reported from

34 Miklós 2002, 289, Figs. 277/2–3.
35 Bartosiewicz 2008a.
36 Lenk 1943, 138, Figs 5–6.
37 MacGregor 1985, 159.

both the Citadel and Lower Castle of Visegrád.[38] The military use of crossbows is indirectly supported by other finds of weaponry at Oltovány: aside from utilitarian metal objects, fragments of armor, a lance head and – most importantly – the tip of a bolt were also recovered in the fort.[39]

The other piece of worked antler is represented by two similar fragments, far more difficult to interpret. These are two, slightly curved, cigarette-size fragments of semi-circular cross-section. One of the fragments has a hole bored into it that retained the small fragment of an antler rivet, once used for fastening. One can only speculate that these pieces formed a rim or edge-cover of some sort. Following soaking in mild acidic liquids, properly softened antler strips can be bent into complex shapes, such as the decorative framing of hem on saddles[40] or high-status upholstery. Due to its rigid, lamellar structure, skeletal bone would be far less fit for this purpose, but antler could be bent into shape after having been soaked even in water.

Figure 12. Damaged crossbow nut made from red deer antler (photograph by Krisztina Pálfay)

INTRA-REGIONAL COMPARISONS

Oltovány Castle forms the easternmost point of a largely equilateral triangle with two other castles with known medieval animal remains. Murga-Schanz (northwest of Őcsény)[41] and Váralja-Várfő (southwest of Őcsény),[42] however, are not only dated to the earlier period of the Árpád Dynasty (the thirteenth century), but they are also located among the rolling hills that form a semicircle around the Sió floodplain. Since the distances between the three castles are only some 35–38 km, these fortified settlements formed a unit of comparable sites, despite the chronological difference. The timber fort of Szekszárd-Palánk, on the other hand (although located only 5 km northwest of Őcsény-Oltovány in a very similar marshland environment), already represents the Ottoman-Turkish occupation during the sixteenth–seventeenth centuries.[43] Animal remains from these sites are summarized in *Table 3*.

There are evident differences between the contributions of major meat species to these assemblages. According to the percentage contribution to the number of identifiable bones *(Fig. 13)*, cattle seems to have been the most important domesticate in terms of fragment numbers at many of the later sites, providing not only beef, but also dairy products and draught power as well as bone and leather used in craft industries. Forms of secondary exploitation and industrial hide processing, however, were unlikely to have taken place at a large scale in the castles themselves. Although no weight data are available from the sites

38 Kováts 2006, 187, 9–10; Kováts 2009, Fig. 8.
39 Miklós 2002, 288, Figs 276/1–2.
40 This possible analogy is supported by a contemporary peasant saddle housed in the ethnographic collection of the Móra Ferenc Museum in Szeged, Hungary.
41 Gál 2004, 245.
42 Bartosiewicz 1998, 157.
43 Bartosiewicz 1995.

Table 3. Animal remains from comparable settlements

Century	*Site*	*cattle*	*sheep*	*goat*	*caprine*	*pig*	*horse*	*camel*	*dog*	*cat*	*poultry*	*game*	*fish*
10–12	Szabolcs-Földvár (611)	243	45			69	32		148		4	70	
13	Váralja-Várfő (1343)	457	29	3	226	463	6		24		87	45	3
13	Murga-Schanz (567)	191	4	1	95	240				2	29	4	1
13	Mende-Lányvár (1255)	398			352	392	12		3		77	21	
13–15	Őcsény-Oltovány (2370)	785	146	37	341	827	3		11		10	210	
17	Szekszárd-Palánk (6102)	1,844	427	153	1,753	452	227	14	117	20	447	191	457

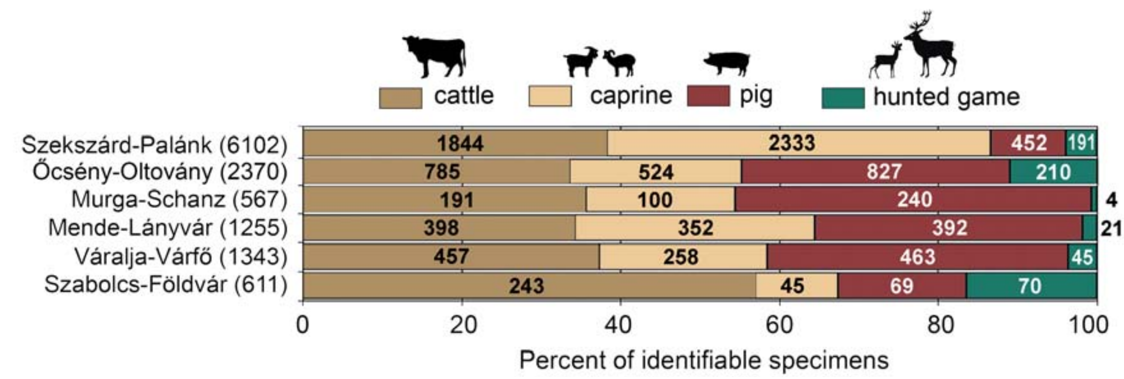


Figure 13. Proportions between the remains of the most important meat producing animals in the assemblages discussed. The diachronic sequence begins at the bottom of the graph

used in this comparison, a strongly selective deposition of bones from meat-bearing parts is a remarkable observation at Oltovány.

Sheep and goats could be exploited for their meat, milk and wool outside the castles, but mutton was consumed in higher proportions only at some Árpád-period and Ottoman-period forts and castles. Pork seems to have dominated in terms of fragment numbers at settlements where less beef was consumed, although the example of Oltovány Castle shows that such numbers could be misleading in the light of bone weights, more closely correlated with the quantities of meat.

The multiparous and omnivorous nature of pigs made them an ideal backyard animal at settlements confined to limited spaces such as the enclosure of Oltovány Castle. Poultry, especially hen keeping, required minimal labor, while it also provided eggs and feathers that could be utilized by the inhabitants of the castle.

The statistically significant differences between assemblages persist even when the remains of cattle, pig and caprines are compared within the "triangle" of the geographically closest medieval sites *(Table 4)*.

The distribution of the three animal groups shown in this table is not homogeneous (Chi^2=12.539, P=0.014, df=4) due to the smaller proportion of caprines and the greater share of pig bones in the relatively small Árpád-period assemblage from Murga-Schanz, originating from the hill region. This may be, however, a random difference related to assemblage size, as no statistically significant difference was found between the proportions of these animals at Őcsény-Oltovány and Váralja-Várfő, in spite of the fact that the latter assemblage also represents the period of the Árpád Dynasty in the hill region. The percentages of bones

Table 4. The contribution of meat-producing livestock to the diet of three medieval sites in Tolna County

Site (NISP)	*cattle*	*caprine*	*pig*	*Total*
Murga-Schanz (567)	36.0	18.8	45.2	100.0
Váralja-Várfő (1343)	38.8	21.9	39.3	100.0
Őcsény-Oltovány (2370)	36.8	24.5	38.7	100.0

originating from beef and pork are similar (*ca*. 38% at both sites), while the contribution of caprine bones is less than a quarter in this sub-set of animal bones. Bone weights *(Fig. 4)* show the unquestionable dominance of beef in the meat diet.

In sharp contrast to widespread *topoi*, the consumption of horse meat is not known to have been explicitly prohibited by the Catholic Church in medieval Hungary. This widely held belief is at least partly rooted in an eighth-century ban by Pope Gregory III,[44] recorded long before Hungarians even settled in the Carpathian Basin. It is, nevertheless, unlikely that the few horse bones excavated at late medieval forts had been deposited as food refuse. Horse flesh consumption in Hungary declined following the mid-thirteenth-century appearance of western settlers after the Mongol invasion. Aside from this historical turning point, horse meat seems to have been more popular in the Great Hungarian Plain,[45] possibly under more direct eastern influence. The forts of Szabolcs-Földvár and Mende-Lányvár,[46] inhabited during the period of the Árpád Dynasty, fall in this category. The custom survived especially in villages of the Great Hungarian Plain (eastern Hungary, e.g. Debrecen-Tócó-part, Tiszalök-Rázom, Kardoskút-Hatablak,[47] Gyál 13,[48] and Hajdúnánás-Fürjhalom[49]). The animal bone assemblage from Oltovány is in sharp contrast with this historically earlier trend.

Although game constituted only a small part of the meat diet at most medieval forts and castles in Hungary, it was included in *Figure 13* instead of horse, as hunting seems to have been practiced by the inhabitants of high-status sites more often than by common people inhabiting the known medieval villages. Bones of wild boar, red deer, roe deer, and hare are usually found at medieval centers. At the Árpád-period bailiff's centre of Szabolcs and the town of Esztergom,[50] remains of European bison were discovered, indicative of probably organized hunting by the aristocracy.

The general characteristics of animal exploitation in castles are clearly recognizable in most of the assemblages; nevertheless, it is hard to reconstruct the precise proportions between the species. Domesticates prevail in all cases, but their ratio varies. Even though there is a general assumption that in the late medieval period the number of sheep and goats gradually decreased as pork became more important in the diet, the trend is not yet strongly pronounced at the two earlier medieval castles forming the aforementioned triangle with Őcsény-Oltovány.

44 Becker 1994, 54.
45 Vörös 2000, 77.
46 Bökönyi 1974.
47 Bartosiewicz 2003.
48 Biller 2007.
49 Gál 2010.
50 Vörös 1989, 1990.

CONCLUSION

The natural environment of any site is of utmost importance. In the landscape surrounding Oltovány Castle, forested, scarcely habited areas were ideal for hunting; dry, hilly terraces were suitable for grazing caprines, while alluvial marshland habitats such as the immediate environment of Oltovány were favorable for pig keeping and grazing cattle.

By the late medieval period, species ratios changed at many sites in Hungary, indicating the increasing importance of pork in the diet, while mutton became less popular, and evidence of horse flesh consumption largely disappeared. This is in part due to typological differences between the settlements known from various medieval periods.[51] Due to the increasing number of urban and high-status settlements, aside from the dominant role played by beef, pork consumption gained more emphasis. This is partly related to the settling of Western, predominantly German-speaking people invited to the territory of the Hungarian Kingdom after the devastating mid-thirteenth-century Mongol invasion. These settlers brought their own food habits that were adopted by the local population, whose meat diet originally included not only more mutton, but also the regular consumption of horses until the thirteenth century. The composition of animal remains from Őcsény-Oltovány is a good example of how these cultural changes became consolidated in the favorable natural environment of the Sió River floodplain prior to the sixteenth-century Ottoman-Turkish occupation, which again caused a decline in pork consumption.

REFERENCES

Baker – Brothwell 1980	Baker, R. J. – Brothwell, D.: *Animal Diseases in Archaeology*. London: Academic Press, 1980.
Bartosiewicz 1995	Bartosiewicz, L.: Camel remains from Hungary. In: *Archaeozoology of the Near East* II. Eds.: Buitenhuis, H. – Uerpmann, H-P. Leiden: Backhuys Publishers, 1995, 119–125.
Bartosiewicz 1998	Bartosiewicz, L.: Medieval animal bones from the castle of Váralja-Várfő (Western Hungary). *A Wosinsky Mór Múzeum Évkönyve* 20 (1998) 157–172.
Bartosiewicz 1999	Bartosiewicz, L.: The role of sheep versus goat in meat consumption at archaeological sites. In: *Transhumant pastoralism in Southern Europe*. Eds.: Bartosiewicz, L. – Greenfield, H. J. Budapest: Archaeolingua Kiadó, 1999, 47–60.
Bartosiewicz 2003	Bartosiewicz, L.: A millennium of migrations: Protohistoric mobile pastoralism in Hungary. *Bulletin of the Florida Museum of Natural History* 44 (2003) 101–130.
Bartosiewicz 2008a	Bartosiewicz, L.: Szarvasagancsok [Antler]. In: *Régészeti nyomozások Magyarországon*. Ed.: Ilon, G. Budapest: Martin Opitz Kiadó, 2008, 31–39.

[51] Bartosiewicz 2008b.

Bartosiewicz 2008b Bartosiewicz, L.: A középkor régészeti állattani kutatása Magyarországon [Medieval archaeozoology in Hungary]. In: *Gazdaság és gazdálkodás a középkori Magyarországon: gazdaságtörténet, anyagi kultúra, régészet*. Eds.: Kubinyi, A. – Laszlovszky, J. – Szabó, P. Budapest: Martin Opitz Kiadó, 2008, 83–90.

Bartosiewicz 2009 Bartosiewicz, L.: Skin and Bones: Taphonomy of a Medieval Tannery in Hungary. *Journal of Taphonomy* 7:2–3 (2009) 95–111.

Bartosiewicz 2011 Bartosiewicz, L.: 17. "Stone Dead": Dogs in a Medieval Sacral Space. In: *The Ritual Killing and Burial of Animals: European Perspectives*. Ed.: Pluskowski, A. Oxford: Oxbow Books, 2011, 220–229.

Bartosiewicz 2013 Bartosiewicz, L.: *Shuffling nags, Lame ducks. The archaeology of animal disease*. Oxford: Oxbow, 2013.

Bartosiewicz et al. 1997 Bartosiewicz, L. – Demeure, R. – Mottet, I. – Van Neer, W – Lentacker, A.: Magnetic resonance imaging in the study of spavin in recent and subfossil cattle. *Anthropozoologica* 25–26 (1997) 57–60.

Bartosiewicz – Bonsall 2008 Bartosiewicz, L. – Bonsall, C. J.: Complementary taphonomies: Medieval sturgeons from Hungary. In: *Archéologie du Poisson. 30 ans d'archéo-ichtyologie au CNRS. Hommage aux travaux de Jean Desse et Nathalie Desse-Berset.* XXVIIIe rencontres internationales d'archéologie et d'histoire d'Antibes. Eds : Béarez, Ph. – Grouard, S. – Clavel, B. Éditions APDCA, 2008, 35–45.

Bartosiewicz et al. 2010 Bartosiewicz, L. – Gyetvai, A. – Küchelmann, H-Ch.: Beast in the feast. In: *Bestial mirrors.* Eds.: Pluskowski, A. – Kunst, G-K. – Kucera, M. – Bietak, M. – Hein, I. Wien: ViaVIAS 03, 2010, 85–99.

Bartosiewicz et al. 2013 Bartosiewicz, L. – Gillis, R. – Flink, L. G. – Evin, A. – Cucchi, T. – Hoelzel, R. – Vidarsdottir, U. – Dobney, K. – Schoop, U-D.: Chalcolithic pig remains from Çamlıbel Tarlası, Central Anatolia. In: *Archaeozoology of the Near East X. Proceedings of the Tenth International Symposium on the Archaeozoology of South-Western Asia and Ajacent Areas*. Eds.: De Cupere, B. – Linseele, V. – Hamilton-Dyer, Sh. Leuven: Peeters Publishers, 2013, 102–120.

Becker 1994 Becker, C.: Pferdfleisch – Notnahrung oder Gaumenfreude? Einblicke in bronzezeitliche Essgewonheiten durch archäozoologische Untersuchungen der Tierreste von Feudvar/Vojvodina. *Das Altertum* 40 (1994) 29–46.

Bejenaru 2003 Bejenaru, L.: *Archaeozoologia spaţiului românesc medieval*. Iaşi: Editura Universităţii „Alexandru Ioan Cuza", 2003.

Biller 2007 Biller, A. Zs.: Vecsés környéki Árpád-kori települések csontanyagának állattani vizsgálata (Archaeological interpretation of the archaeozoological finds of Medieval sites (Árpád-Dynasty period) around Vecsés). *Archeometriai Műhely* 2007:1 (2007) 45–54.

Bökönyi 1974	Bökönyi, S.: *History of Domestic Mammals in Central and Eastern Europe*. Budapest: Akadémiai Kiadó, 1974.
Daróczi-Szabó 2006	Daróczi-Szabó, M.: Variability in medieval dogs from Hungary. In: *Dogs and People in Social, Working, Economic or Symbolic Interaction*. Eds.: Snyder, L. M. – Moore, E. A. Oxford: Oxbow Books, 2006, 85–95.
Davis 1987	Davis, S. J. M.: *The Archaeology of Animals*. London: B. T. Batsford, 1987.
Dembinska 1999	Dembinska, M.: *Food and Drink in Medieval Poland: Rediscovering a Cuisine of the Past*. Philadelphia: University of Pennsylvania Press, 1999.
Gál 2004	Gál, E.: Murga-Schanz 13. századi földvár állatcsontleletei (Animal bone remains from the 13th century Murga-Schanz hillfort). *A Wosinsky Mór Múzeum Évkönyve* 26 (2004) 245–258.
Gál 2010	Gál, E.: Animal remains from the multi-period site of Hajdúnánás-Fürjhalom-dűlő. Part II. Finds from the Árpád Period (10th–13th centuries). *Acta Archaeologica Academiae Scientiarum Hungaricae* 61 (2010) 425–444.
Guilday 1970	Guilday, J.: Animal remains from Archaeological Excavations at Fort Ligonier. In: *Experimental Archaeology.* Eds.: Ingersoll, D. – Yellen, J. E. – MacDonald, W. New York: Columbia University Press, 1970, 121–132.
Halpern 1999	Halpern, J. M.: The ecological transformation of a resettled area, pig herders to settled farmers in Central Serbia (Šumadija, Yugoslavia) during the 19th and 20th centuries. In: *Transhumant pastoralism in Southern Europe*. Eds.: Bartosiewicz, L. – Greenfield, H. J. Budapest: Archaeolingua, 1999, 79–95.
Hüster 1990	Hüster, H.: *Untersuchungen an Skelettresten von Rindern, Schafen, Ziegen und Schweinen ausdem mittelalterlichen Schleswig. Ausgrabung Schild 1971–1975.* Ausgrabungen in Schleswig. Berichte und Studien 8. Neumünster: Karl Wachholtz Verlag, 1990.
Kováts 2006	Kováts, I.: A visegrádi Fellegvár megmunkált csont- és agancsleletei [Worked bone and antler finds from the Visegrád Citadel]. In: *A visegrádi Fellegvár.* Ed.: Buzás, G. Visegrád Régészeti Monográfiái 6. Visegrád: Mátyás Király Múzeum, 2006, 167–191.
Kováts 2009	Kováts, I.: XVI–XVII. századi megmunkált agancsleletek a visegrádi Alsóvárból (Worked antler finds from the 16th–17th century part of the Lower Castle in Visegrád). In: *Csontvázak a szekrényből. Válogatott tanulmányok a Magyar Archaeozoológusok Visegrádi Találkozóinak anyagából 2002–2009.* Eds.: Bartosiewicz, L. – Gál, E. – Kováts, I. Budapest: Martin Opitz Kiadó, 2009, 263–273.
Lakó (ed.) 1983	*Bornemisza Anna szakácskönyve 1680-ból* [The Cookbook of Anna Bornemisza from 1680]. Ed.: Lakó, E. Bukarest: Kriterion, 1983.

Lenk 1943 — Lenk, T.: Medeltidens skjutvapen. In: *Vaaben.* Ed.: Thordeman, B. Stockholm: Albert Bonniers förlag, 1943, 134–150.

MacGregor 1985 — MacGregor, A.: *Bone, antler, ivory & horn. The technology of skeletal materials since the Roman Period.* London – Sydney: Croom Helm, 1985.

Matolcsi 1975 — Matolcsi, J.: *A háziállatok eredete* [The origins of domestic animals]. Budapest: Gondolat, 1982.

Miklós 2002 — Miklós, Zs.: Őcsény-Oltovány. In: Miklós, Zs.: *Tolna megye várai.* Varia Archaeologica Hungarica 22. Budapest: Historiaantik Könyvesház Kiadó, 2002, 281–293.

Payne – Bull 1988 — Payne, S. – Bull, G.: Components of variation in measurements of pig bones and teeth, and the use of measurements to distinguish wild from domestic pig remains. *ArchaeoZoologia* 2 (1988) 27–66.

Pesty 1888 — Pesty, F.: *Magyarország helynevei történeti, földrajzi és nyelvészeti tekintetben* [Toponyms in Hungary in historical, geographical and linguistic perspectives]. Budapest: A Magyar Tudományos Akadémia Történelmi Bizottsága, 1888.

Pucher et al. 2013 — Pucher, E. – Barth, F. E. – Seemann, R. – Brandstätter, F.: *Bronzezeitliche Fleischverarbeitung im Salzbergtal bei Hallstatt*. Mitteilungen der Prähistorischen Kommission Band 80. Wien: Verlag der Österreichischen Akademie der Wissenschaften, 2013.

Reichstein 1994 — Reichstein, H.: *Die Säugetiere und Vögel aus der frühgeschichtlicher Wurt Elisenhof*. Studien zur Küstenarchäologie Schleswig-Holsteins. Serie A, Elisenhof, Band 6. Frankfurt am Main, 1994.

Rumpolt 1581 — Rumpolt, M.: *Ein new Kochbuch*. Franckfort am Mayn: Verlag Sigmund Feyerabendt, 1581.

Teichert 1969 — Teichert, M.: Osteologische Unterschungen zur Berechnung der Widerristhöhe bei vor- und frühgeschichtlichen Schweinen. *Kühn Archiv* 83 (1969) 237–292.

van Wijngaarden-Bakker 1990 — van Wijngaarden-Bakker, L. H. J.: Replication of butchering marks on pig mandibles. In: *Experimentation and reconstruction in environmental archaeology*. Ed.: Robinson, D. E. Oxford: Oxbow Books, 1990, 167–174.

Vörös 1989 — Vörös, I.: Esztergom-Szentgyörgymező Árpád-kori település állatcsont maradványai. Előzetes közlemény [Animal remains from the Árpád-period settlement at Esztergom-Szentgyörgymező]. *Dunai Régészeti Közlemények* 3 (1989) 51–56.

Vörös 1990 — Vörös, I.: Szabolcs ispánsági székhely Árpád-kori állatcsontmaradványai (Árpád Age animal bone finds from the comitat centre Szabolcs). *Jósa András Múzeum Évkönyve* 26–29 (1990) 165–188.

VÖRÖS 2000 — VÖRÖS, I.: Adatok az Árpád-kori állattartás történetéhez [Data to the history of animal husbandry in the Árpád period]. In: *A középkori magyar agrárium. Tudományos ülésszak Ópusztaszeren*. Eds.: Bende, L. – Lőrinczy, G. Ópusztaszer: Ópusztaszeri Nemzeti Történeti Emlékpark Közhasznú Társaság, [Szeged]: Csongrád Megyei Múzeumok Igazgatósága, 2000, 71–119.

WOSINSKY 1896 — Wosinsky, M.: *Tolna vármegye története. Tolna vármegye az őskortól a honfoglalásig* [The history of Tolna County. Tolna County between Prehistory and the Hungarian Conquest] I–II. Budapest: Kiadja a vármegye közönsége, 1896.

ANIMAL REMAINS FROM AN OTTOMAN-PERIOD PIT AT BARCS-PUSZTABARCS, SOUTHWEST HUNGARY

Erika Gál

The archaeological site of Barcs-Pusztabarcs is located northwest of present-day Barcs and preserved features from the Copper Age to the nineteenth century.[1] The site can be identified with the one-time settlement of Barcs inhabited during the medieval and Ottoman period. In the course of a small-scale rescue excavation,[2] an Ottoman-period pit (Pit 3) was uncovered, containing typical Turkish pottery (that was comparable to finds unearthed in the neighboring Ottoman-Turkish fort) and animal bones.[3]

This feature, dated to the sixteenth–seventeenth centuries, yielded a total of 48 animal bones. The majority of finds (19 bones) belonged to swine; the pig bones represented at least two individuals. One of these was a fully grown boar, while the other was a younger individual of approximately 1.5 years. An ulna found in the assemblage exhibited several hacking marks.

The second best represented species was cattle (13 specimens). These remains also originated from at least two adult individuals. A smaller skull fragment with a horn core, round in cross-section, probably belonged to a cow. Marks of hacking are visible on a tibia and two ribs, while round discs of bone – possibly primitive buttons – were cut out of a scapula.

Small domestic ruminants were represented by a single tibia fragment.

The fourth species identified in this assemblage was dog; a skull fragment of this species was deposited in the food refuse.

In addition to domesticates, two species of wild game (red deer and roe deer) and fish were also exploited at the site. Seven finds belonged to red deer; these bones originated from a mature stag and a subadult individual. The antler burr has been preserved on the skull fragment of the stag, although the beam as well as the brow and bey tines were cut off for further manufacturing. The remaining antler burr measured 66.6 mm (largest diameter) and 58.3 mm (smallest diameter), respectively. Transversal cut marks discovered on the metatarsus of the young individual were probably inflicted during skinning.

Roe deer is represented by an almost complete, finely beaded intact antler that originates from and adult bock. It was removed from the skull by hacking. The smallest diameter of the burr was 39.7 mm, while the largest diameter measured 47.3 mm, respectively.

The five fish bones provide evidence for the exploitation of three species: carp, catfish, and pike.[4] These large, commonly occurring fish were most probably caught in the Drava River near the site.

1 The site is completely destroyed by now as a result of the activity of a nearby sand quarry.

2 Rescue excavation conducted by Márton Rózsás. Archives of the Drava Museum in Barcs, 1038–96, 1126–99, 1135–99.

3 The manuscript was prepared within the framework of OTKA Grant No. K 72231 of the Hungarian Scientific Research Fund.

4 The fish bones were identified by László Bartosiewicz.

Table 1. Species distribution
(NISP = the number of identified specimens)

Taxon	*NISP*
Cattle *(Bos taurus)*	13
Caprine (Caprinae)	1
Pig *(Sus domesticus)*	19
Dog *(Canis lupus)*	2
Red deer *(Cervus elaphus)*	7
Roe deer *(Capreolus capreolus)*	1
Carp *(Cyprinus carpio)*	1
Pike *(Esox lucius)*	1
Catfish *(Silurus glans)*	2
Fish (Pisces sp. indet.)	1
Total	**48**

The animal remains recovered at the Barcs-Pusztabarcs site may be considered diverse, especially in the light of the small assemblage size. Due to this fact, the high relative contribution of pigs seems especially important. This is also supported by archaeological data[5] as well as documentary sources[6] on the taxing of pigs, which emphasize the importance of the species among ordinary livestock kept in the region. The fourteenth–seventeenth-century settlement of Pusztabarcs was inhabited by Christians, most of whom were Hungarians. Therefore, the taxonomic composition of bones from this single pit does probably not contradict the general character of the settlement's entire bone refuse material.

Notably, the unusually rich and representative animal bone assemblage of almost ten thousand specimens from the Ottoman-Turkish fort at Barcs hardly contained any pig remains (only 0.55% of NISP).[7] This remarkable underrepresentation of pigs in that large assemblage may be readily explained by the Moslem dietary regulations observed by the soldiers.[8] Although vastly differing sample sizes make a direct comparison between the archaeozoological samples from the Pusztabarcs settlement and the Barcs fort impossible, the differences detected between trends of meat consumption are consistent with the dietary preferences of the two population types expected on religious and even ethnic grounds. Aside from the religious aspect, it may also be presumed that pork played an important role as a local product at this site, while beef may have been more easily controlled and distributed within the framework of large-scale military meat provisioning at the fort.

5 Bartosiewicz 2002; Vörös 2003.
6 Rúzsás 1979, 7–10.
7 See Erika Gál and László Bartosiewicz's study on the animal remains from the Ottoman-Turkish palisaded fort at Barcs in this volume.
8 Kovács et al. 2014.

REFERENCES

Bartosiewicz 2002 — Bartosiewicz, L.: A török kori Bajcsavár állatai. [Animals from the Turkish-period castle of Bajcsa]. In: *Weitschawar – Bajcsa-vár. Egy stájer erődítmény Magyarországon a 16. század második felében.* Ed.: Kovács, Gy. Zalaegerszeg: Zala Megyei Múzeumok Igazgatósága, 2002, 89–100, 242–245.

Kovács et al. 2014 — Kovács, Gy. – Bartosiewicz, L. – Éder, K. – Gál, E. – Miklós, Zs. – Rózsás, M. – Tóth, J. A. – Zatykó, Cs.: Medieval and Ottoman-period (14th–17th c.) archaeology in the Drava River region, Hungary. Results of an interdisciplinary project. *Acta Archaeologica Academiae Scientiarum Hungaricae* 65 (2014) 155–168.

Rúzsás 1979 — Rúzsás, L.: Barcs a feudalizmus korában [Barcs in the feudal era]. In: *Barcs múltja és jelene*. Ed.: Rúzsás, L. Barcs: Barcsi Városi Tanács, 1979, 3–37.

Vörös 2003 — Vörös, I.: Sixteenth- and Seventeenth-century Animal Bone Finds in Hungary. In: *Archaeology of the Ottoman Period in Hungary*. Eds.: Gerelyes, I. – Kovács, Gy. Opuscula Hungarica 3. Budapest: Hungarian National Museum, 2003, 351–364.

ANIMAL REMAINS FROM THE OTTOMAN-TURKISH PALISADED FORT AT BARCS, SOUTHWEST HUNGARY

Erika Gál and László Bartosiewicz

INTRODUCTION

Four small-scale test excavations were carried out in the area of the Ottoman-Turkish palisaded fort at Barcs between 1989 and 1994.[1] An opportunity to excavate a larger surface followed in 2002–2003,[2] resulting in one of the richest Ottoman-period animal bone assemblages in Hungary. The significance of this project is shown by the fact that previously only one single Ottoman-Turkish palisaded fort had been completely excavated at the site of Szekszárd-Újpalánk (*Yeni Palanka*),[3] located over 100 km northeast of Barcs.

Both the construction and destruction dates of the Turkish fort at Barcs are known. Following the 1566 fall of Szigetvár, Iskender Bey, commander of Szigetvár, had a fort built on the left bank of the Drava River at Barcs in 1567. Barcs was thus designated to become a satellite fort to Szigetvár, securing the port on the Drava and controlling traffic across the river. In administrative terms, the Barcs fort belonged to the Szigetvár *sandjak* in the *vilayet* of Buda until 1600, and then it was assigned to the *vilayet* of Kanizsa. A garrison of approximately 200 soldiers oversaw movements in the area, including land and water transport as well as trade. They included a fair number of *azab*s or *martalos*es, lightly armed irregular infantry, in charge of supervising the port that presumably operated in the proximity of the palisade fort. The fort itself was occupied for about a century, during which it was set ablaze by the forces of György Zrínyi in 1595. Although it had been renovated after this incident, it was completely destroyed during the winter campaign conducted by Miklós Zrínyi in 1664.

The location of the fort is clearly marked on a 1799 map.[4] Extensive field walks carried out in the area yielded a rich assemblage of Ottoman-period finds, indicative of the proximity of the Ottoman-Turkish palisaded fort in the area. It became clear already at the beginning of the excavations that the fort had no medieval antecedents: its construction and usage could be unambiguously associated with the Ottoman-Turkish occupation, more exactly, with the Ottoman rule of Hungary.

The remains of this seventeenth-century fort were almost completely eradicated by construction work in the eighteenth and, especially, the nineteenth–twentieth centuries. The find material recovered from the area is dominated by animal bones deposited as food refuse, ceramics, and metal objects. A relatively small assemblage of artifacts made from other raw materials (including bone, stone, glass, etc.) was also found.

By the time soldiers of Miklós Zrínyi arrived here on January 25, 1664, the fort had been evacuated. After they gathered all the usable goods left behind by the Ottoman personnel,

1 Kovács – Rózsás 1996.

2 Kovács – Rózsás 2010. The analysis of the animal remains from both field campaigns was carried out within the framework of OTKA Grant No. K 72231 of the Hungarian Scientific Research Fund.

3 Excavations by Attila Gaál; a summary of the animal remains was published by Bartosiewicz 1995a, 120, Table 1.

4 See in Kovács – Rózsás 1996, Fig. 2b: "Régi Törrök Sántz" [Old Turkish Rampart].

they set the construction on fire the same way as in 1595. The timber palisade as well as the wooden structures of the buildings within must have burnt for days, as shown by melted ceramic shards and deformed metal objects found in the destruction layers of the site.

The composition of the find material offers a good cross-section of the material culture of a satellite fort defending the northern periphery of the Ottoman Empire in Central Europe, guarded by soldiers who worked as peasants and craftsmen in times of peace. Horse gear is represented by *phalerae*, bridles, horseshoes, bells, and harness buckles. The number of imported porcelain and faience fragments was negligible, despite the fact that a larger quantity of such objects may have been expected due to the proximity of the trading route that followed the Drava River. It is rather remarkable that almost nothing in the find assemblage is indicative of the service the military must have performed specifically on the river.

Additional data on the fort are available in the scarce documentary sources: a ground plan appearing in *Mars Hungaricus* by Pál Esterházy (dating from 1664, the time of destruction) and the aforementioned 1799 map of Barcs. The fort occupied a largely square-shaped area on the riverbank. According to Esterházy's pen sketch, three of its corners were defended by bastions of the so-called "Old Italian System", while its southwestern corner was reinforced by a *rondella* of semicircular layout. A smaller bastion of triangular ground plan was built on the south side extending towards the river. Remains of a *castellum* covering an L-shaped area were discovered within the fort, but a mosque marked on the sketch has not been identified in its southwestern corner yet. The gate opened toward the west and was protected by an earthwork of triangular layout. The excavations brought to light the remains of everyday life in a small "Balkan-style village", forced to live within the walls due to the changing fortunes of peace and war. Ottoman-Turkish pay-rolls reveal that most of the soldiers were of Balkanic origin. The material culture of this community is indicative of the origins and modest way of life of the fort's inhabitants.

RESULTS AND DISCUSSION

Almost 10,000 animal bones were collected during all excavation seasons *(Table 1)*. The overwhelming majority (96.36% of all identifiable specimens; NISP) consisted of skeletal remains from domesticates. Among these, the bones of cattle dominated (NISP=7,474), making up 76% of the assemblage. On the basis of sheer numbers, domestic hen followed (NISP=929; 9.45%), although the amount of meat represented by these two species cannot be compared directly. A similar number of bones represent small ruminants (NISP=875, sheep: 344, goat: 78, sheep/goat: 453). On the basis of the bones identifiable to species, the ratio between sheep and goat may have been 4:1. Despite the fact that pig exploitation was of high importance in marshy areas, the contribution of pork to meat supplies was negligible (NISP=55; 0.55%), clearly indicative of the role Moslem religious tradition played in the eating habits of the fort's inhabitants. It is worth mentioning that although pig keeping became increasingly important on the Drava floodplain during the later sixteenth century,[5] this tendency is not mirrored in the fort's find material. Similarly small numbers of bones were recovered from non-meat-purpose domesticates (horse, dog, and cat), and wild animals *(Table 1)*.

5 Rúzsás 1979, 7–10. Among others, this work contains excerpts from the 1579 Turkish *sandjak* tax rolls of Barcs, translated by Előd Vass.

Table 1. Species distribution of the Barcs faunal material
(NISP = number of identifiable specimens)

Taxon	*NISP*	%
Cattle *(Bos taurus)*	7,474	75.98
Sheep *(Ovis aries)*	344	3.49
Goat *(Capra hircus)*	78	0.79
Caprine (Caprinae)	453	4.63
Pig *(Sus domesticus)*	55	0.55
Horse *(Equus caballus)*	36	0.36
Dog *(Canis lupus)*	68	0.70
Domestic cat *(Felis catus)*	28	0.28
Domestic hen *(Gallus domesticus)*	929	9.46
Red deer *(Cervus elaphus)*	39	0.39
Roe deer *(Capreolus capreolus)*	31	0.31
Wild pig *(Sus scrofa)*	8	0.08
Walrus *(Odobenus rosmarus)*	1	0.01
Hare *(Lepus europaeus)*	25	0.25
Great cormorant *(Phalacrocorax carbo)*	2	0.02
Grey heron *(Ardea cinerea)*	1	0.01
Goose *(Anser* sp.*)*	9	0.09
Mallard *(Anas* cf. *platyrhynchos)*	3	0.03
Aves indet.	2	0.02
Tortoise *(Emys* sp. indet.*)*	1	0.01
Carp *(Cyprinus carpio)*	1	0.01
Pike *(Esox lucius)*	3	0.03
Large ungulate	230	2.34
Small ungulate	16	0.16
Total	**9,837**	**100.00**

Cattle

During the Ottoman period in general, cattle was the most frequent and most important domestic species utilized for its meat in villages, towns, and castles alike, as has been shown by a comprehensive study that discusses animal bone assemblages from 38 different sites.[6] As consuming the meat of even a small cow involves a larger group of people (or systematic preservation), beef was a typical form of meat distributed at urban markets or handed out as army provisions. Both the conformations of horn cores and the estimated withers height values suggest a variable cattle population. The three completely preserved horn cores were short and round in cross section. They are indicative of the presence of *brachyceros* type cattle in Barcs. Two of these horn cores, measuring 95.0 and 116.5 mm, respectively, could be attributed to cows, while a 137.5 mm long horn core probably originated from a bull *(Appendix 2)*.

6 Vörös 2003.

Several complete long bones recovered from the site made the estimations of sex[7] and withers height[8] possible. The withers heights of cows ranged between 102.9 and 116.7 cm *(Table 2)*. The mean withers height calculated for 13 cows was 110.9 cm (standard deviation=4.7 cm). The estimated stature of four bulls varied between 105.4–119.0 cm, averaging 113.8 cm (standard deviation=5.9 cm). The single metapodium identified as originating from an ox yielded a withers height estimate of 112.5 cm. Among these values, only the withers height of cows is close to the Ottoman-period average, the single ox and the four bulls identified are 10–20 cm below the expected stature.[9] Therefore, using a Student's t-test, no statistically significant difference was found between the withers heights of cows and bulls from Barcs (P=0.346).

The distribution of ages at death for cattle is indicative of secondary exploitation (milk, draught, manure), as it is dominated by the remains of mature individuals (61.3% of ageable bones), while only a tenth of the bones represented younger age groups *(Table 3)*. Meanwhile, the strategic position of Barcs both in political and economic terms means that this high frequency of bones originating from mature animals may be related to the fort being located along the main cattle driving route crossing southwest Hungary towards Austria and northern Italy.[10]

The even distribution of cattle bones representing various body regions as well as the presence of skull elements and virtually meatless "dry limb" bones is indicative of the possibility that the animals were slaughtered on location *(Table 4)*. The overrepresentation of trunk bones may be attributed to the high number of rib fragments, although the number of vertebrae and meaty limb bone fragments all show that the inhabitants of the palisade fort relied heavily on beef in their meat diet. According to the three-tier categories of meat quality developed by Hans-Peter Uerpmann,[11] bones representing body regions of medium dietary value (category B, head and extremities) occurred in greatest numbers. High quality meat (category A, back musculature and proximal limb segments) were represented by bones in the next largest group *(Table 5)*.

Cut marks inflicted using metal blades could be identified on 12.8% of the finds. A great variety of skeletal parts (vertebrae, bones in the shoulder, hip, elbow, and hock joints) were damaged by intensive hacking. In mature cattle, these articulations are not easily dismembered, and carcass partitioning evidently took a lot of force. Finer cut marks inside the vertebral canal and on the skull are indicative of eating the brain and spine. Transversal hack marks on long bone diaphyses must have been caused during the extraction of marrow. Cut marks also commonly occur on vertebrae and ribs, the latter being indicative of removing the animal's sides. Many of the 1,720 rib fragments (totaling 23% of cattle NISP) originate from strips cut out from the animal's rib cage.

There were no signs of the horns having been cut off or of fine skinning marks despite the large number of cattle bones (these damages would be normally associated with the on-site processing of hides). A perforated long bone was found between field coordinates 55/15–60/10: it was a right cattle radius whose proximal end was drilled through. The resulting hole was of 6 mm diameter and may have served for suspending the bone *(Fig. 1)*. In the absence of additional marks of either manufacturing or use, the exact function of this worked specimen remains unidentified.

7 Nobis 1954.
8 Matolcsi 1970.
9 Vörös 2003, 356.
10 Bartosiewicz 1999a; on trade routes, see also Pálffy 2009, 384.
11 Uerpmann 1973.

Table 2. Estimated withers heights of different species (cm)

Feature no. and type	*Cattle*			*Sheep*	*Goat*	*Horse*	*Dog*
	Cow	*Ox*	*Bull*				
Feature 1	102.9						
Pit 3	105.0						
Feature 1	105.8						
Feature 20/a	108.7						
Feature 1	109.2						
60/10–60/20	109.3						
Feature 37	109.3						
Trench 3	111.9						
Feature 37	115.1						
Feature 46	115.7						
Feature 40	115.9						
50/20–55/20	116.4						
Feature 1	116.7						
55/15–60/10		112.5					
Feature 1			105.4				
Feature 1			114.1				
Feature 40			116.6				
50/15–55/10			119.0				
2. modern-period rooms				57.8 (ewe)			
Feature 1				59.0			
Feature 54				61.0			
Feature 20				69.8 (ram)			
Feature 1				70.4			
Feature 53					60.0 (female)		
50/15–55/10					62.9 (female)		
Trench 3					84.3 (bock)		
Trench 3						152.3	
Feature 54						142.3	
Feature 1							53.7
Feature 1							55.8
Feature 1							57.2
Feature 1							64.0

Table 3. The age profiles of meat-purpose animals

Taxon	*Embryo+ neonatus*	%	*Juvenilis*	%	*Subadultus*	%	*Adultus*	%	*Maturus*	%	*Senilis*	%	*Non-identifiable*	%	*Total*
Cattle	34	0.45	42	0.5	560	7.5	100	1.33	4,575	61.3	41	0.5	2,122	28.4	7,474
Sheep	1	0.3			43	12.5	26	7.60	219	63.7	1	0.3	54	15.7	344
Goat					18	23.0	6	7.70	53	67.9			1	1.3	78
Caprine	3	0.7	8	1.8	41	9.1	37	8.10	139	30.7			225	49.6	453
Pig			1	1.8	11	20.0	11	20.0	23	41.8			9	16.4	55
Domestic hen			4	0.4	138	15.0	20	2.10	733	79.0	4	0.4	29	3.1	928
Red deer					2	5.0			35	87.5			3	7.5	40
Roe deer							3	9.70	25	80.6			3	9.7	31
Wild pig					1	12.5			7	87.5					8
Hare			1	4.0	3	12.0	4	16.0	16	64.0			1	4.0	25
Wild birds					3	16.7			14	77.8			1	5.5	18

Table 4. The anatomical distribution of remains of meat-purpose animals, according to Miklós Kretzoi's classification (Kretzoi 1968)

Skeletal parts	*Cattle*	*Caprine*	*Pig*	*Red deer*	*Roe deer*	*Wild pig*	*Hare*	*Domestic hen*
cornus	5	38						
neurocranium	97	24	7	2	1	2		13
viscerocranium	152	25	3					5
mandibula	347	61	2	1	7		1	
linguale	1	1						
dentes	91	13	2	1				
atlas	60	9						
axis	54	9						
Head total	**807**	**180**	**14**	**4**	**8**	**2**	**1**	**18**
vert. cervicalis	240	14						3
vert. thoracalis	239	14						12
vert. lumbalis	247	15					2	14
os sacrum	29	4						11
vert. caudalis	26	2						
sternum	1							33
clavicula								11
coracoideum								54
costa	1,720	126	4				1	53
Trunk total	**2,502**	**175**	**4**	**0**	**0**	**0**	**3**	**191**
scapula	302	38	4		1	1	1	42
humerus	379	71	6	3	3	3	9	101
radius	404	64	4	11	3		1	37
ulna	143	16	2	2			2	85
carpalia	81	1	2					
metacarpalia	314	54	2		4			16
Front limb total	**1,623**	**244**	**20**	**16**	**11**	**4**	**13**	**281**
pelvis	272	31	4	1		1	3	34
femur	323	53	5	2	1			127
patella	43	1						
tibia	423	83	4	3	2		4	166
fibula								4
calcaneus	139	17			1			
astragalus	155	7		1				
centrotarsale	77							
metatarsalia	429	69	2	4	4		1	106
Hind limb total	**1,861**	**261**	**15**	**11**	**8**	**1**	**8**	**437**
ph. proximalis	354	12	2	1	1	1		2
ph. media	161	2		3				
ph. distalis	159	1		2	2			
Phalanges total	**674**	**15**	**2**	**6**	**3**	**1**	**0**	**2**
Long bone	6							
Flat bone	1							
Non-identifiable								
Total NISP	**7,474**	**875**	**55**	**37**	**30**	**8**	**25**	**929**

Table 5. The anatomical distribution of remains of meat-purpose animals, according to Hans-Peter Uerpmann's meat quality categories

Skeletal parts	*Cattle*	*Caprine*	*Pig*	*Red deer*	*Roe deer*	*Wild pig*	*Hare*
atlas	60	9					
axis	54	9					
vert. cervicalis	240	14					
vert. thoracalis	239	14					
vert. lumbalis	247	15					2
os sacrum	29	4					
vert. caudalis	26	2					
sternum	1						
scapula	302	38	4		1	1	1
humerus	379	71	6	3	3	3	9
pelvis	272	31	4	1		1	3
femur	323	53	5	2	1		
Quality A meat total	**2,172**	**260**	**19**	**6**	**5**	**5**	**15**
frontale	49	7			1	1	
neurocranium	48	17	7	2		1	
mandibula	347	61	2	1	7		1
linguale	1	1					
costa	1720	126	4				1
radius	404	64	4	11	3		1
ulna	143	16	2	2			2
patella	43	1					
tibia	423	83	4	3	2		4
fibula							
Quality B meat total	**3,178**	**376**	**23**	**19**	**13**	**2**	**9**
cornus	5	38					
viscerocranium	115	13					
maxilla	37	12	3				
dentes	91	13	2	1			
carpalia	81	1	2				
metacarpalia	314	54	2		4		
ph. proximalis	354	12	2	1	1	1	
ph. media	161	2		3			
ph. distalis	159	1		2	2		
sesamoideum							
calcaneus	139	17			1		
astragalus	155	7		1			
centrotarsale	77						
metatarsalia	429	69	2	4	4		1
Quality C meat total	**2,117**	**239**	**13**	**12**	**12**	**1**	**1**
long bone	6						
flar bone	1						
Non-identifiable							
Total (A+B+C)	**7,474**	**875**	**55**	**37**	**30**	**8**	**25**

Numerous finds showed the symptoms of articular disease and dental anomalies, which tend to be related to the longevity of individuals. One of the premolars is completely missing from the right mandible shown in *Figure 2* representing a case of oligodontia. Spike-shaped exostoses identified on the proximal end of a cattle metatarsus also affected the articular surface *(Fig. 3)*. They may be considered as an early symptom of spavin, the ankylosis between tarsal bones.[12] A pair of proximal metacarpus fragments show advanced ankylosis of the small, almond-shaped vestigial 5th metacarpus onto the proximal end of the fused main 3rd–4th metacarpal bones *(Fig. 4)*. It is especially fortunate that these matching specimens could be recognized among the thousands of cattle remains. This anomaly is rare and the individual affected was large relative to others from the same site *(Fig. 5)*.

Figure 1. Perforated cattle radius (left: palmar view, right: dorsal view) (photograph by Erika Gál)

Figure 2. Oligodontia in the right lower jaw of cattle (photograph by Erika Gál)

Figure 3. Exostosis on a cattle metatarsal (left: dorsal view, right: proximal view) (photograph by Erika Gál)

Figure 4. A pair of metacarpus fragments showing the ankylosis of 5th metacarpal bones onto 3rd–4th metacarpus (palmar view) (photograph by Erika Gál)

12 Bartosiewicz et al. 1997.

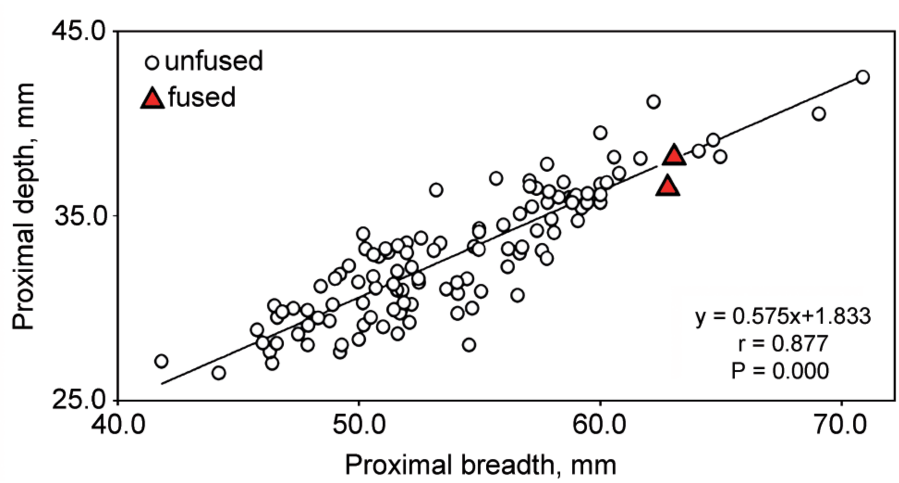


Figure 5. The size of the pair of large fused cattle metacarpal bones shown in *Figure 4* in relation to unfused specimens from the Barcs fort

Sheep and goat

Bones of sheep and goat (caprines) represent 8.9% of the assemblage. Although outnumbered by the remains of poultry, the remains of small ruminants were found in the second largest numbers among domestic mammals. The number of identifiable goat bones was only one-quarter of those representing sheep, a ratio characteristic for Ottoman-period Hungary.[13]

Mutton formed an important part not only of Turkish diets; it was popular throughout the Balkans, whence many of the mercenaries stationed at Barcs may have originated. While beef must have been a staple, the occasional consumption of sheep and goat was also important at the site.

Two types of sheep could be distinguished on the basis of cranial fragments. Horn cores of sheep were 115.0–200.0 mm long, robust, and of slightly twisted croissant-shape. Morphologically, they are reminiscent of the so-called prehistoric "copper sheep" *(Fig. 6)*. The same type was reported from the site of Székesfehérvár-Géza tér[14] and several other Ottoman-period settlements.[15] Horn cores of sheep were often cut off of the skull at Barcs. This may have been a regular practice during food preparation before the brain was extracted. Although horn sheaths may have been used for making combs and other objects, longitudinal cut marks characteristic of horn extraction are missing and no major accumulations of sheep horn cores were discovered either.[16] In addition to sheep with robust horns, another form, polled sheep, occurred as well. The place of the horn core of this animal is marked only by a minor protrusion of the frontal bone *(Fig. 7)*. So far, this latter form has only been found at one Ottoman-period site in Hungary, the Pasha's Palace in Buda.[17]

Long bones preserved in full length could be used in the estimation of withers heights.[18] These calculations resulted in values ranging between 57.8–70.4 cm. The mean value

13 Bartosiewicz 1999b.
14 Greenfield – Bartosiewicz 1992, 401, Fig. 2.
15 Vörös 2003, 359, Fig. 5/1.
16 Vörös 2003, 362.
17 Bökönyi 1974, 186, Fig. 62.
18 Teichert 1975.

Figure 6. Horn cores of "copper sheep" and goat, chopped with an axe or cleaver (photograph by Erika Gál)

Figure 7. Skull fragment of a hornless sheep (lateral view) (photograph by Erika Gál)

obtained for five individuals was only 63.5 cm (standard deviation=6.0 cm), which is close to the smallest known withers height recorded from the Ottoman period (62.2 cm).[19]

A study of measurements taken on all fragments, however, is indicative of a broad range of sheep sizes in the Barcs material. Recently, osteometric data from Ottoman-period assemblages from the Buda Castle area represented by the sites of the Buda Pasha's Palace, Teleki Palace, and Ganz utca[20] have been successfully compared to a group of 26 adult Shetland ewe skeletons representing a single contemporary flock.[21] Averages and standard deviations calculated by Simon J. M. Davis for the bone measurements of this primitive breed from Britain served as a background against which measurements of fragmentary Ottoman-period sheep bones from Hungary were pooled within the same histogram, regardless of their anatomical positions.[22] Using the measurable sheep bones from Barcs shows that measurements taken in the material from this palisade fort tend to very similarly exceed the mean size and narrow variability of present-day unimproved Shetland ewes *(Fig. 8)*. Some really large individuals

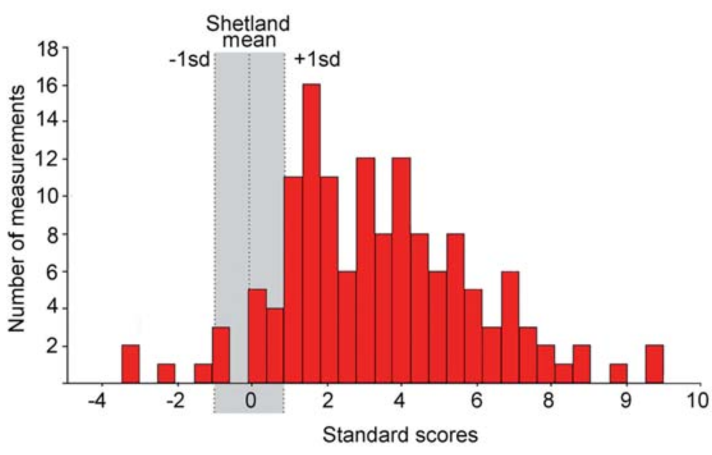


Figure 8. The distribution of Ottoman-period sheep bone measurements from Barcs in relation to the mean value and ±1 standard deviation of contemporary Shetland ewes

19 Vörös 2003, 357, Table 7.
20 Bökönyi 1974, 350; Daróczi-Szabó 2004, 161; Tóth et al. 2010, Fig. 8.
21 Davis 1996, 596, Table 2.
22 Tóth et al. 2010, Fig. 8.

Figure 9. Goat skull (lateral view) (photograph by Erika Gál)

from Barcs, presumably rams or wethers, are at a distance of over ten standard deviations from the mean value of Shetland sheep. The smallest, presumably young, are clustered at the other extreme of the size distribution range in this histogram. The rich meat of large, fattened castrates must have been highly valued, as were tender lambs, something Arab physicians considered close to perfection in terms of dietary value.[23]

Goat horn cores were rather long (118.0–199.0 mm), straight, and narrow of "sabre" shape, reminiscent of the so-called *prisca* type *(Fig. 9)*. This type was widespread in Hungary during the Ottoman period. Similarly to sheep, horn cores of goats were often cut off of the skull *(Fig. 6)*. Three fully preserved metapodia were available for estimating withers height, using the coefficients published by Zdislawa Schramm.[24] Two females were 60.0 and 62.9 cm tall at the withers, while a bock measured 84.3 cm *(Table 2)*.

The majority of sheep and goats were slaughtered as adults, possibly indicative of secondary exploitation for wool and milk. However, in comparison to the remains of calves, the proportion of lamb remains was twofold, while kids were represented with an even higher, threefold proportion. Since many of these bones originate from neonates and very young juveniles, some of the remains may be indicative of perinatal or juvenile mortality, attributable to poor keeping conditions, as these species were probably considered less valuable than cattle.

The slaughtering, butchery, and consumption of sheep and goat on location is indicated by the presence of bones from all body regions and the presence of remains associated with high-quality meat. Small and fragile skeletal parts (phalanges, ribs, etc.) were found in considerably smaller numbers than was the case with cattle *(Table 4)*. This may be related to the difference in body size that results in differential preservation. Small ruminants go through far less intensive butchery than cattle, and cut marks on their skeletal element, were observed only rarely. Their remains are more exposed to taphonomic loss already prior to deposition (e.g. scavenging by dogs, trampling, and natural erosion). Moreover, in the absence of sieving, small skeletal parts of sheep and goats are prone to recovery bias. However, this loss of information is somewhat tempered by the fact that the skeletal elements most affected are tiny bones of the basi- and autopodium of low dietary value. In the case of sheep and goats, A and B category bones representing edible tissue dominated *(Table 5)*. In spite of the aforementioned recovery bias, it is worth mentioning that the same pattern was observed in the case of cattle whose large bones may be considered representative.

23 Rosenberger 1999.
24 Schramm 1967.

Pig

The 55 pig remains recovered contributed minimally to the faunal assemblage (0.55% of NISP). This unambiguously shows that the overwhelming majority of the palisade fort's inhabitants avoided pork.

Historical and archaeological sources confirm that the fort of Barcs was staffed mostly by soldiers of Balkanic origin, who were partly Moslems. According to pay lists of the mercenaries stationed here (especially during the seventeenth century), many names are indicative of freshly converted Moslems.[25] It is therefore no surprise that bones of pig are virtually absent from the assemblage. Pork consumption in towns and castles generally decreased during the Ottoman period, and the ratio of pigs typically reaches only one-half or one-third of that of caprines. This, among other phenomena, indicates an economic and cultural shift in the occupied areas. In villages and monasteries, nevertheless, the popularity of pork remained comparable to that of mutton.[26] The nearby fort of Bajcsa is also worth mentioning: there, the number of pig bones significantly exceeded that of caprines, as the border fort was occupied by Christian forces, many of them of Germanic origin.[27]

Although the small sample of pig bones cannot be used in studying age distributions in detail, it is worth noting that the proportion between the remains of piglets and adult pigs was more-or-less equal. Similarly to small ruminants, skeletal elements representing great meat value dominated over small bones representing body regions poor in meat such as the feet *(Tables 3–5)*. No bones were available for the estimation of withers height in this small sub-assemblage. Marks of butchering and heat exposure were also rare on the few pig bones available for study.

Horse

The majority of the few (NISP=36) horse bones consisted of teeth, bones of the feet, and long bone fragments. These skeletal elements originated from at least three individuals. While horses must have been used extensively by the military, hippophagy was rare during this time period in Hungary.

Two long bones preserved in full length could be used in withers height estimations using the formulae developed by Ludwig Kiesewalter.[28] The third metacarpal bone recovered from Feature 54 yielded a withers height estimate of 142.3 cm. A complete radius found in Trench 3 belonged to a horse that measured approximately 152.3 cm at the withers. Both calculations, but especially the second one, suggests a particularly tall individual compared to other Ottoman-period data. Contemporaneous horses of similar sizes were found at Szolnok, Gyula, Kecskemét and Fonyód, while a small individual was identified from Ugod Castle.[29] Based on its slenderness index – calculated after Aleksandr Brauner[30] – the metacarpus of the smaller individual from Barcs originated from a moderately slender-legged horse.

25 Hegyi 2007, II: 1328, III: 1591–1594.
26 Vörös 2003, 353, Table 1.
27 Bartosiewicz 2002.
28 Kiesewalter 1888.
29 Vörös 2003, 360, Table 8.
30 Brauner 1916.

Dog

A relatively small sample of dog bones, though larger than that of horses, was brought to light (68 pieces). Several long bones were unearthed from Feature 1, which probably belong to one individual whose estimated withers height was 57.7 cm.[31] Compared to modern standards, this corresponds to the Hungarian pointer. Dog bones found in Feature 33 also come from the skeleton of a single individual. Even though the size of this dog was impossible to estimate, its heavily worn teeth along with the tissue lesions at the alveoli and the exostoses observed on bones that constitute the knee joint testify to old age *(Fig. 10)*.

In addition to the direct evidence of dog bones, dog gnawing marks on the bones of other species speak for the presence of dogs on the site. Only a small number of bones (157 pieces, 1.6%) were gnawed in the Barcs assemblage. This also suggests that dogs were rarely kept in the palisade fort, and this is one of the reasons why the number of excavated dog bones was low (besides, dogs were probably buried elsewhere when they died, and the few dog bones were only secondarily deposited in the kitchen garbage). Another indirect evidence suggesting that dogs and pigs were not kept in high numbers is the frequency of hen remains, a species whose bones can be destroyed by dogs or pigs scavenging at other sites.

Figure 10. Mandible, femur, and tibia fragments of an old dog. A bone tissue lesion was observed on the mandible, while there are exostoses on the femur and tibia (photograph by Erika Gál)

Domestic cat

Domestic cats are represented by the smallest group of remains among all domestic mammals. These 28 bones were also secondary deposits in the kitchen refuse. The bones come from at least three individuals of comparable sizes *(Fig. 11)*.

Since there is no method for the estimation of withers height in cats, size comparisons were made using the smallest breadth to greatest length proportions of humeri from Barcs, medieval Vác,[32] and medieval Haithabu in northern Germany.[33] Two bigger and one small group may be recognized in the diagram *(Fig. 11)*. The short and gracile bones grouping

31 Koudelka 1884.
32 Bartosiewicz 1995b, 152.
33 Johansson – Hüster 1987, 66–68.

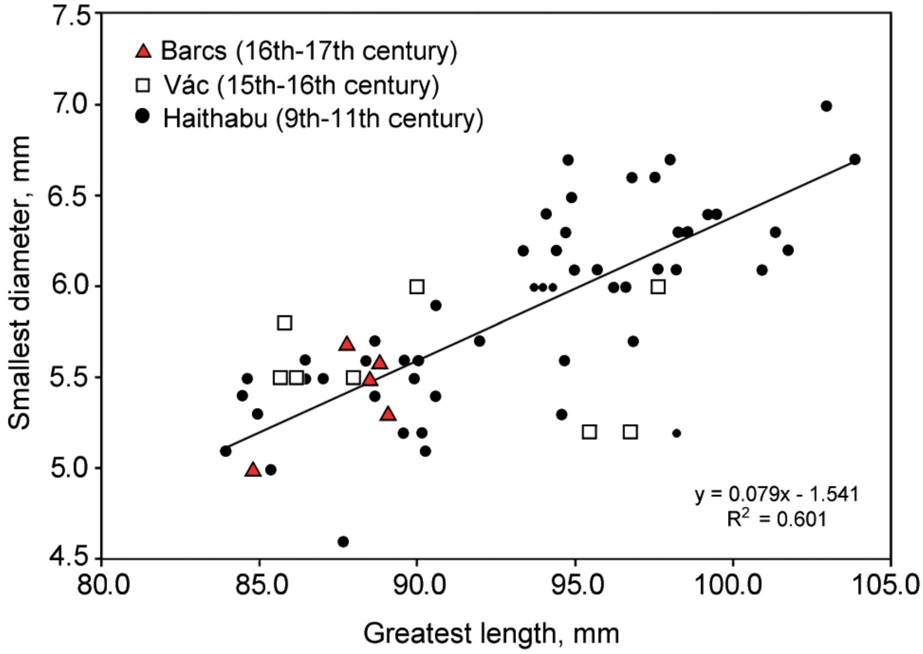


Figure 11. Size variability in cat humeri (mm). Linear trend line: Haithabu, based on ninth–eleventh-century finds

in the lower left corner represent females, while the large ones in the upper right corner are probably males. This also means that the individuals known from Barcs were probably females. Measurements in the lower right corner of the diagram, associated with cats from Germany and Vác, probably indicate that long and gracile bones probably represent another, rare cat phenotype. The linear trend line calculated from the most abundant dataset from Germany shows a close connection. The coefficient of determination (R^2=0.601) between the two values means a close, positive linear correlation (r=0.775).

Domestic hen

Poultry consumption was typical in towns of the Ottoman period, while their keeping was less important in castles and even less typical in villages.[34] Hen bones were abundant in the bone assemblage recently identified from Barcs, domestic hen became the second most frequently encountered species in the palisade fort with NISP=929 (9.5%; *Table 1*). In spite of this, the NISP value for domestic hen can hardly be compared to those of cattle or caprines due to differences in anatomy, taphonomy,[35] and economic utilization. An even higher ratio (22%) of domestic hen remains was only observed in the fifteenth–seventeenth-century assemblage of Solomon's Tower in Visegrád.[36]

However, over half of the hen bones brought to light at Barcs was unearthed from Feature 26, which yielded few remains of other species, and testifies to the role of poultry in meat consumption in a certain period. Feature 26 was located in the middle of the palisade fort, and remains of sixteenth-century buildings were brought to light in its vicinity. At the bottom

34 Vörös 2003, 353.
35 Bartosiewicz – Gál 2007, 42.
36 Bökönyi 1974, 429.

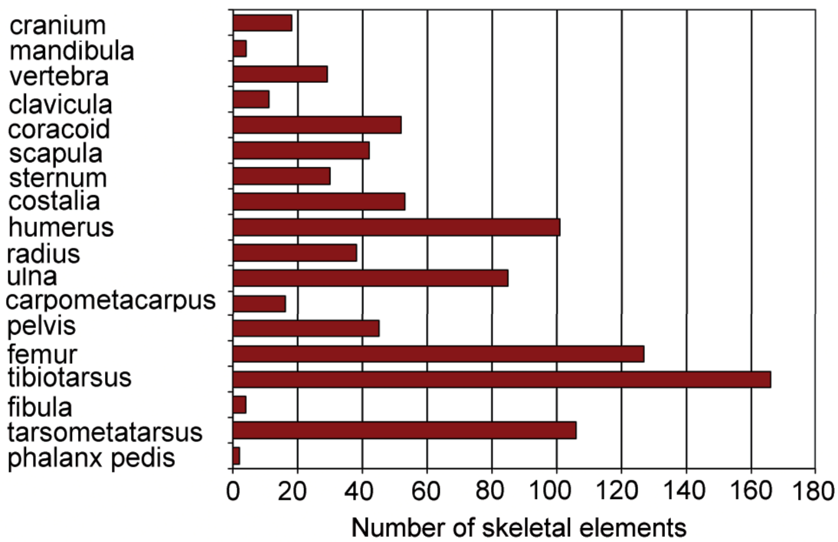


Figure 12. The anatomical distribution of domestic hen remains

of the 2 m deep pit, stove tiles and collapsed wall debris were found, which in all probability were deposited after the sixteenth-century destruction, when the rubble was cleared.[37] The minimum number of individuals calculated from the hen bones deposited here was 48. While cattle bones can be seen as evidence of military food provisioning and long-distance trade, the high number of hen bones is indicative of a local resource that, in principle, may have been used in some form of feasting. This high number and the good preservation of hen bones as well as the lack of gnawing marks suggest that poultry remains were deposited in garbage pits to which the few potential scavengers (dogs, cats, pigs) had limited access, and that these remains were buried quickly. Bird bones are much smaller and more fragile than those of domestic mammals, and at sites where scavengers had access to the food refuse, these bones were usually destroyed prior to deposition. From this point of view, the sixteenth-century assemblage of the late medieval manor at Székelyudvarhely (Odorheiu Secuiesc, Romania) is another interesting exception: there, a lot of fragile bird bones were preserved because food refuse was partly disposed of in the latrine, which guaranteed good preservation.[38]

The abundance of skull fragments, tarsometatarsals, and phalanges suggest that hens must have been killed on location. The most frequent body parts originate from meaty body regions (the thighs, "drumsticks", and forequarters; see *Table 4)*. The relatively small number of excavated mandibles, fibulae, and small bones (such as phalanges) may be explained by their smaller chances of both preservation and recovery when material is collected by hand only *(Fig. 12)*. In addition to the anatomical distribution of hen bones testifying to a practice that they were killed inside the palisade fort, poultry keeping within the fort's walls also seems a most likely possibility. Poultry need little space and scavenge on human refuse. In return, females may have been at hand to be exploited for eggs.

As for age, there are five times more bones from adult individuals than from juveniles *(Table 3)*. This, on the one hand, indicates that the purpose of poultry keeping was in part egg production and breeding, and that hens only occasionally contributed to the meat supply at the end of their lives as egg-producers. However, in some cases, medullary bone tissue was

37 Gyöngyi Kovács, personal communication.
38 Gál 2008.

observed in the long bones, proving that egg-laying hens were also killed and consumed off the egg-laying season.

Sexual dimorphism is present in this species and it is also evident in body size. Therefore, bone sizes in themselves are not sufficient to differentiate between "breeds" and types, but various forms need to be investigated within one sex. The tarsometatarsal bones of hens and roosters are easy to qualitatively differentiate on the basis of the spur present only in males. It is worth mentioning that in extreme cases, old age or hormonal disorders may result in spurs also growing in females,[39] but these are smaller and less developed than those of males, and the phenomenon itself is very rare. Another, more time-consuming method for separating the two sexes involves the examination of medullary bone tissue present in the medullary cavity of female long bones during the period which precedes egg-laying.[40]

Tarsometatarsal proportions shown in *Figure 13* reveal three different types of domestic hens consumed in the Barcs palisaded fort. The smallest type is represented by two hens and one rooster whose short and thick limbs differentiate them from the rest of the lot. The medium-sized type is represented mostly by hens and three roosters. The overwhelming dominance of females may be explained by egg production as well as the natural behavior of the species, which results in roosters posing a threat to each other and to the females as well if they increase in number. The largest size group is represented by two hens and four roosters among the tarsometatarsal bones. Calculations thus revealed three size groups, although the smallest and largest types are represented only by a few finds. Most bones come from the widespread medium-sized type also identified at Ugod,[41] Segesd,[42] and Bajcsa *(Fig. 13)*.

Keeping conditions, transportation as well as the natural rasorial behavior of hens sometimes result in traumas and other disease that are manifested on the bones. Such

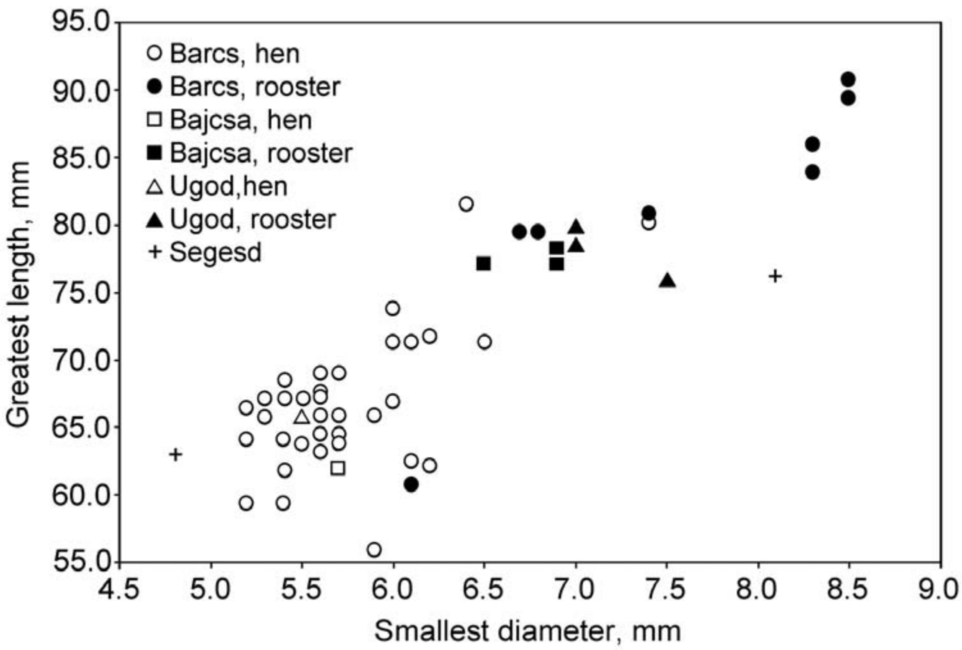


Figure 13. Greatest length/smallest breadth proportion of tarsometatarsals of both sexes in domestic hen

39 De Cupere et al. 2005, 1590, Fig. 2.
40 Gál 2006, 53, Fig. 3a-b.
41 Vörös 1988.
42 Bartosiewicz 1996, 208.

pathologically modified bones were found in the Barcs assemblage as well. *Figure 14* shows a case of necrosis (probably due to an inflammation of the pelvic joint) on the proximal epiphysis of a left femur and on the acetabulum of the left pelvis. Fractures healed with dislocation were observed each on a femur, a tarsometatarsus, and a sternum *(Fig. 15)*.

Figure 14. Post-inflammatory pathological bone tissue on the left pelvis and femur of a domestic hen (photograph by Erika Gál)

Figure 15. Fractures of a sternum, femur, and tarsometatarsus in domestic hen, healed with dislocation (photograph by Erika Gál)

Wild animals

Wild animals only occasionally contributed to the diet in the Barcs palisade fort, bones of game represent only 1.2% of this large assemblage. Most of these belong to mammals, red and roe deer, and hare respectively *(Fig. 16)*, indicative of both forests and open grassland environments in the vicinity of the site. Two red deer remains, however, are antler fragments recovered from workshop debris; it is therefore impossible to tell whether these animals were hunted or only shed antlers were collected. Exostoses on the distal end of the femur and the proximal end of the tibia of a roe deer suggest a chronic inflammation of the knee joint,

Figure 16. Metatarsal fragments of red and roe deer (dorsal view) (photograph by Erika Gál)

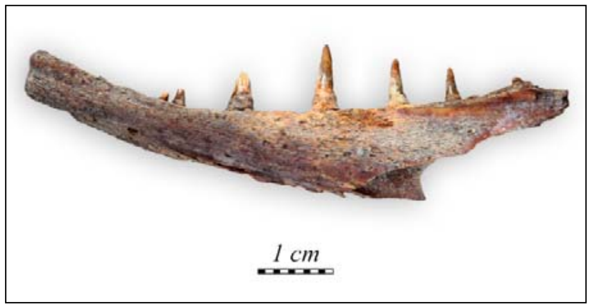


Figure 17. Dentale fragment of pike (photograph by Erika Gál)

which may have made this lame individual an easy target for opportunistic hunters.

Red deer, roe deer, and hare were sporadically represented wild mammals not only at Barcs *(Table 1)*, but at other Ottoman-period sites as well.[43] The small number of wild pig bones is probably connected to the avoidance of pork in general; wild pig must have been abundant in the swampy, floodplain forests along the Drava River. An exotic marine mammal, walrus, was represented by a worked piece of ivory.

Among the non-mammalian remains, bones of carp, pike *(Fig. 17)* and mallard are associated with the Drava River. Wild bird remains identified at Barcs show that fowling was occasionally practiced in these habitats since great cormorant and grey heron also inhabit floodplains. Geese and mallards have always been popular targets. The meat of cormorants and herons, however, is considered smelly by modern standards, as these birds prey on fish. Their skeletal elements found in Barcs, however, represent meaty body parts. Several wild fowl species, including water birds (pelican and purple heron), were also identified in the nearby Christian fort of Bajcsa.[44] High-status recipes in the cookbook translated from German in 1680 for Anna Bornemisza, wife of Michael Apafi, elected Prince of Transylvania, call for pelicans and herons, showing the difference between sixteenth–seventeenth-century and modern Western tastes.[45]

In the case of duck and goose bones, it is practically impossible to differentiate between the wild and the domestic forms. The sizes of well-preserved long bones, if compared to recent and subfossil finds, may help in making this distinction. There was no intact long bone of goose at Barcs; the measurements taken are equally typical of domestic goose and greylag goose. The duck bones brought to light from Features 23 and 40 correspond in size to

43 Vörös 2003, 353, Table 1.
44 Gál 2002.
45 Lakó (ed.) 1983, 140.

the mallard.[46] The remains of wild mammals and birds mostly represent adult individuals, similarly as in the case of domestic species *(Table 3)*.

Fish was probably relatively rarely consumed, although the small number of fish bones is probably also due to the lack of water-sieving. Bones of carp and pike are large enough to be seen with the naked eye and picked up during excavation. These remains show that the Drava River played some role in the palisade fort's food supply. The pike jaw (dentale) fragment shown in *Figure 14* measures 56.4 mm on its internal side, suggesting an estimated total body length of 564 mm.[47]

A single bone of pond turtle found in the large assemblage possibly originated from an Ottoman-period individual. However, it may also represent an intrusive animal that hibernated and died long after the settlement was abandoned.

CONCLUDING REMARKS

Previous excavations at Barcs already yielded almost 4,000 animal bones, sufficient for a preliminary analysis and comparisons.[48] This final summary reconfirmed some of those observations, but also helped refining the picture by revealing entirely new phenomena. NISP values of the most characteristic animal taxa summarized in *Table 6* differed between the two phases of this work in statistically significant terms. It is worth reviewing the main sources of difference.

Table 6. Differences in the representation of the main taxa identified in two phases of the evaluation work at Barcs (Chi^2=193.311, df=4, P=0.000)

NISP	*Before 1999*	*After 1999*	*Pooled assemblage*
Cattle	2,811	4,663	7,474
Caprine	442	433	875
Pig	34	21	55
Horse	8	28	36
Domestic hen	192	737	929

(1) The new results lend additional weight to the statement that the Ottoman-period animal bone material unearthed in the Barcs palisade fort consists mainly of food refuse. Animals not kept for meat were identified only in negligible numbers, and worked pieces of bone are also scarce. The anatomical distribution of the remains shows that animals slaughtered for meat were killed and dismembered within the fort. Scavenger damage is minimal. The finds are well-preserved and the high ratio of poultry bones suggests that food refuse was separately disposed of and buried relatively quickly.

(2) The overwhelming dominance of adult cattle in the pooled assemblage (76% of ageable cattle NISP) shows the importance of this species in local meat provisioning and the strategic trading position of this fort: the abundance in beef may be related to the periodical market supply provided by the southwestern herding route crossing the Drava River here. Thanks to the increase in assemblage size, the morphometry

46 Woelfle 1967, 156.
47 Bartosiewicz 1990.
48 Bartosiewicz 1999a.

of cattle finds could be analyzed. Horn conformation and withers height estimates suggests that these animals belonged to a short-horned, small type; the withers height of an ox and bulls seem especially low in comparison with other Ottoman-period data.

(3) Comparisons between Barcs and archaeozoological finds from the Ottoman-Turkish palisaded fort of Szekszárd-Palánk showed a dominance of bones from sheep and goats at the latter site.[49] New results from Barcs add further emphasis to this contrast, as recent research increased the contribution of caprine remains far less than those from cattle. Sheep included a hornless form, not widespread in Hungary at the time.

(4) Given the key significance of mutton in Moslem meat diets, it seems that relatively large and varied sheep were bred in Ottoman-period Hungary, a tendency also observed on sheep bones from eleventh–twelfth-century Moslem deposits in Portugal.[50] Assuming that size increase in that case reflected upgraded stocks, Simon J. M. Davis[51] explained this phenomenon with the pivotal role of mutton in Moslem diets.

(5) Moslem soldiers in the service of the Sublime Porte avoided pork, as is supported by the negligible number of pig bones whose percentual contribution also decreased relative to the preliminary results. Although the number of horse remains increased, the small set of horse bones is not indicative of horse flesh eating.

(6) Remarkable new results were brought by the analysis of domestic hen remains. Their numbers massively increased during recent identification work, largely at the expense of domestic mammals except for cattle. Plotting measurements from this considerable body of data allowed distinguishing between forms beyond simple sexual dimorphism. Equating the resulting size groups with "breeds" may sound far-fetched, but the concept of Ottoman-period poultry breeding is clearly illustrated by the presence of crested hens in the Buda area,[52] a form also known as *Gallina turcica* in contemporaneous Europe.[53]

(7) Remains of non-meat-purpose domesticates as well as of fish and game were found in small numbers. Bones of horses, dogs, and cats made up less than 1% of the whole assemblage, often in the form of disarticulated skeletons. Venison and the meat of aquatic birds were occasionally consumed.

Archaeological finds other than animal bones reveal a modest everyday life in the palisade fort without much luxury: only a few potsherds of Balkanic and Anatolian origin, rare fragments from China, a few iron knives with ornamented handles from Styria, and a few shards of glazed pottery indicate that the people inhabiting the place had sporadic access to special objects via long-distance trade or other movements.[54] A belt plaque made of walrus tusk, perhaps manufactured in Istanbul, is definitely one of the most interesting and most valuable pieces found at the site. It was probably brought here as a personal object.[55] This special piece is also discussed in an other chapter in this volume.

49 Bartosiewicz 1999a, 50, Fig. 2.
50 Davis 2008.
51 Davis 2008, 1001.
52 Gál et al. 2010.
53 Aldrovandi 1603.
54 Kovács – Rózsás 1996; 2010; Kovács 1998.
55 Gál – Kovács 2011.

REFERENCES

Aldrovandi 1603 — Aldrovandi, U.: *Ornithologiae: hoc est de avibus historiae. Liber decimusquartus*. Bononiae: Apud Franciscum de Franciscis senensem, 1603.

Bartosiewicz 1990 — Bartosiewicz, L.: Osteometrical studies on the skeleton of pike (*Esox lucius* L. 1758). *Aquacultura Hungarica* 6 (1990) 25–34.

Bartosiewicz 1995a — Bartosiewicz, L.: Camel remains from Hungary. In: *Archaeozoology of the Near East* II. Eds.: Buitenhuis, H. – Uerpmann, H.-P. Leiden: Backhuys Publishers, 1995, 119–125.

Bartosiewicz 1995b — Bartosiewicz, L.: *Animals in the urban landscape in the wake of the Middle Ages*. Oxford: Tempus Reparatum, 1995.

Bartosiewicz 1996 — Bartosiewicz, L.: Közép- és török kori állatmaradványok Segesdről (Medieval and Turkish Period animal bones from Segesd, Southwestern Hungary). *Somogyi Múzeumok Közleményei* 12 (1996) 183–222.

Bartosiewicz 1999a — Bartosiewicz, L.: Turkish Period bone finds and cattle trade in south-western Hungary. In: *Historia animalum ex ossibus*. Beiträge zur Paläoanatomie, Archäologie, Ägyptologie, Ethnologie und Geschichte der Tiermedizin. Eds.: Becker, C. – Manhart, H. – Peters, J. – Schibler, J. Rahden/Westf.: Verlag Marie Leidorf GmbH, 1999, 47–56.

Bartosiewicz 1999b — Bartosiewicz, L.: The role of sheep versus goat in meat consumption at archaeological sites. In: *Transhumant pastoralism in Southern Europe*. Eds.: Bartosiewicz, L. – Greenfield, H. J. Budapest: Archaeolingua, 1999, 47–60.

Bartosiewicz 2002 — Bartosiewicz, L.: A török kori Bajcsavár állatai. [Animals from the Turkish-period castle of Bajcsa]. In: *Weitschawar – Bajcsa-vár*. Ed.: Kovács, Gy. Zalaegerszeg: Zala Megyei Múzeumok Igazgatósága, 2002, 89–100, 242–245.

Bartosiewicz – Gál 2007 — Bartosiewicz, L. – Gál, E.: Sample size and taxonomic richness in mammalian and avian bone assemblages from archaeological sites. *Archeometriai Műhely* 2007:1 (2007) 37–44.

Bartosiewicz et al. 1997 — Bartosiewicz, L. – Demeure, R. – Mottet, I. – Van Neer, W. – Lentacker, A.: Magnetic resonance imaging in the study of spavin in recent and subfossil cattle. *Anthropozoologica* 25–26 (1997) 57–60.

Bökönyi 1974 — Bökönyi, S.: *History of domestic mammals in Central and Eastern Europe*. Budapest: Akadémiai Kiadó, 1974.

Brauner 1916 — Brauner, A.: *Materiali k poznaniju domashnickh zhivotnykh Rossii*. 1. *Loshad kurgannikh pogrebenij Tiraspolskogo uezda, Hersonskoj gubernii, Equus goschkewitschi, mihi*. Odessa: Zapiski Imperatorskogo Obshchestva Selskogo Hozjaistva Juzhnoj Rossii, 1916.

Daróczi-Szabó 2004 — Daróczi-Szabó, L.: Animal Bones as Indicators of Kosher Food Refuse from 14th-century AD Buda, Hungary. In: *Behaviour Behind Bones: The Zooarchaeology of Ritual, Religion, Status and Identity*. Eds.: Jones O'Day, S. – Van Neer, W. – Ervynck, A. Oxford: Oxbow Books, 2004, 252–261.

Davis 1996 — Davis, S. J. M.: Measurements of a Group of Adult Female Shetland Sheep Skeletons from a Single Flock: A Baseline for Zooarchaeologists. *Journal of Archaeological Science* 23 (1996) 593–612.

Davis 2008 — Davis, S. J. M.: Zooarchaeological Evidence for Moslem and Christian Improvements of Sheep and Cattle in Portugal. *Journal of Archaeological Science* 35 (2008) 991–1010.

De Cupere et al. 2005 — De Cupere, B. – Van Neer, W. – Monchot, H. – Rijmenants, E. – Udrescu, M. – Waelkens, M.: Ancient breeds of domestic fowl (*Gallus gallus* f. *domestica*) distinguished on the basis of traditional observations combined with mixture analysis. *Journal of Archaeological Science* 32 (2005) 1587–1597.

von den Driesch 1976 — von den Driesch, A.: *A guide to the measurements of animal bones from archaeological sites*. Peabody Museum Bulletins 1. Cambridge/Mass.: Peabody Museum of Archaeology and Ethnology, Harvard University, 1976.

Gál 2002 — Gál, E.: Madárleletek a bajcsai várból [Bird remains from the fort of Bajcsa]. In: *Weitschawar – Bajcsa-vár. Egy stájer erődítmény Magyarországon a 16. század második felében.* Ed.: Kovács Gy. Zalaegerszeg: Zala Megyei Múzeumok Igazgatósága, 2002, 101–105, 245.

Gál 2006 — Gál, E.: The role of archaeo-ornithology in the environmental and animal history studies. In: *Archaeological and Cultural Heritage Preservation. Within the Light of New Technologies. Selected papers from the joint Archaeolingua-EPOCH workshop, 27th September – 2nd October, 2004, Százhalombatta, Hungary*. Eds.: Jerem, E. – Mester, Zs. – Benczes, R. Budapest: Archaeolingua, 2006, 49–61.

Gál 2008 — Gál, E.: A székelykeresztúri késő középkori udvarház állatcsont leletei [Animal bone finds from the late medieval manor of Székelykeresztúr]. In: *Középkori udvarház és nemesség a Székelyföldön*. Eds. Benkő, E. – Székely, A. Budapest: Nap Kiadó, 2008, 301–355.

Gál et al. 2010 — Gál, E. – Csippán, P. – Daróczi-Szabó, L. – Daróczi-Szabó, M.: Evidence of the crested form of domestic hen (*Gallus gallus* f. *domestica*) from three post-medieval sites in Hungary. *Journal of Archaeological Science* 37 (2010) 1065–1072.

Gál – Kovács 2011 — Gál, E. – Kovács, Gy.: A walrus-tusk belt plaque from an Ottoman-Turkish castle at Barcs, Hungary. *Antiquity* 85:329 (2011) Project Gallery. http://antiquity.ac.uk/projgall/gal329/ (last accessed March 24, 2016).

GREENFIELD – BARTOSIEWICZ 1992 GREENFIELD, H. J. – BARTOSIEWICZ, L.: Zooarchaeology in Székesfehérvár: the Géza Square and Csók István Street sites. *Acta Archaeologica Academiae Scientiarum Hungaricae* 44 (1992) 389–413.

HEGYI 2007 HEGYI, K.: *A török hódoltság várai és várkatonasága* [The Castles and Garrisons of Ottoman Hungary] I–III. Budapest: História – MTA Történettudományi Intézete, 2007.

JOHANSSON – HÜSTER 1987 JOHANSSON, F. – HÜSTER, H.: *Untersuchungen an Skelettresten in Katzen aus Haithabu (Ausgrabung 1966–1969).* Berichte über die Ausgrabungen in Haithabu 24. Neumünster: Karl Wachholtz Verlag 1987.

KIESEWALTER 1888 KIESEWALTER, L.: *Skelettmessungen am Pferde als Beitrag zur theoretischen Grundlage der Beurteilungslehre des Pferdes.* PhD Thesis, Leipzig, 1888.

KOUDELKA 1884 KOUDELKA, F.: Das Verhältniss der Ossa longa zur Skeletthöhe bei den Säugertieren. *Verhandlungen des Naturforschenden Vereins* 24 (1884) 127–153.

KOVÁCS 1998 KOVÁCS, Gy.: A barcsi török palánkvár kerámialeletei (The Ceramic Finds from the Turkish Palisade Fort at Barcs). *Communicationes Archaeologicae Hungariae* (1998) 155–180.

KOVÁCS – RÓZSÁS 1996 KOVÁCS, Gy. – RÓZSÁS, M.: A barcsi török palánkvár (The Turkish Hoarding [palisaded] Castle of Barcs). *Somogyi Múzeumok Közleményei* 12 (1996) 163–182.

KOVÁCS – RÓZSÁS 2010 KOVÁCS, Gy – RÓZSÁS, M.: A barcsi török vár és környéke. Újabb kutatások (1999–2009) (The Ottoman-Turkish Castle at Barcs and its surroundings. New Research, 1999–2009). In: *A középkor és a kora újkor régészete Magyarországon / Archaeology of the Middle Ages and the Early Modern Period in Hungary* I–II. Eds.: Benkő, E. – Kovács, Gy. Budapest: MTA Régészeti Intézete, 2010, II: 621–642.

KRETZOI 1968 KRETZOI, M.: La répartition anatomique du matériel ostéologique selon les espeéces el les amas de déchets. In: *La station du paléolithique moyen d'Érd – Hongrie.* Eds.: Gábori-Csánk, V. – Kretzoi, M. Monumenta Historica Budapestinensia 3. Budapest: Akadémiai Kiadó, 1968, 230–244.

LAKÓ (ed.) 1983 *Bornemisza Anna szakácskönyve 1680-ból* [The Cookbook of Anna Bornemisza from 1680]. Ed.: Lakó, E. Budapest: Kriterion Könyvkiadó, 1983.

MATOLCSI 1970 MATOLCSI, J.: Historische Erforschung der Körpergrösse des Rindes auf Grund von ungarischen Knochenmaterial. *Zeitschrift für Tierzüchtung und Züchtungsbiologie* 87:2 (1970) 89–137.

NOBIS 1954 NOBIS, G.: Zur Kenntnis der ur- und frühgeschichtlichen Rinder Nord- und Mitteldeutschlands. *Zeitschrift für Tierzüchtung und Züchtungsbiologie* 63 (1954) 155–194.

PÁLFFY 2009 PÁLFFY, G.: *The Kingdom of Hungary and the Habsburg Monarchy in the Sixteenth Century.* East European Monographs No. DCCXXXV. New York: Columbia University Press, 2009.

Rosenberger 1999 — Rosenberger, B.: Arab Cuisine and its Contribution to European culture. In: *Food: A Culinary History from Antiquity to the Present*. Eds.: Flandrin, J.-L. – Montanari, M. New York: Columbia University Press, 1999, 207–223.

Rúzsás 1979 — Rúzsás, L.: Barcs a feudalizmus korában [Barcs in the feudal era]. In: *Barcs múltja és jelene*. Ed.: Rúzsás, L. Barcs: Barcsi Városi Tanács, 1979, 3–37.

Schramm 1967 — Schramm, Z.: Kości długie a wysokość w kłębie u kozy [Long bones and withers height in goats]. *Roczniki Wyższej Szkoły Rolniczej w Poznaniu* 36 (1967) 89–105.

Teichert 1975 — Teichert, M.: Osteologische Unterschungen zur Berechnung der Widerristhöhe bei Schafen. In: *Archeological studies*. Ed.: Clason, A. T. Amsterdam – New York: North Holland and American Elsevier, 1975, 51–69.

Tóth et al. 2010 — Tóth, A. J. – Daróczi-Szabó, L. – Kovács, Zs. E. – Gál, E. – Bartosiewicz, L.: In the Light of the Crescent Moon: Reconstructing Environment and Diet from an Ottoman-Period Deposit in Sixteenth to Seventeenth Century Hungary. In: *Integrating Zooarchaeology and Paleoethnobotany. A Consideration of Issues, Methods, and Cases*. Eds.: Van Derwarker, A. M. – Peres, T. M. New York – Dordrecht – Heidelberg – London: Springer, 2010, 245–286.

Uerpmann 1973 — Uerpmann, H.-P.: Animal bone finds and economic archaeology: A critical study of 'osteo-archaeological' method. *World Archaeology* 4:3 (1973) 307–322.

Vörös 1988 — Vörös, I.: Az ugodi vár középkori állatcsontmaradványai (Tierknochen aus dem Mittelalter in der Burg von Ugod). *Acta Musei Papensis* 1 (1988) 99–129.

Vörös 2003 — Vörös, I.: Sixteenth- and Seventeenth-century Animal Bone Finds in Hungary. In: *Archaeology of the Ottoman Period in Hungary*. Eds.: Gerelyes, I. – Kovács, Gy. Opuscula Hungarica 3. Budapest: Hungarian National Museum, 2003, 351–364.

Woelfle 1967 — Woelfle, E.: *Vergleichend morphologische Untersuchungen an Einzelknochen des postcranialen Skelettes in Mitteleuropa vorkommender Enten, Halbgänse und Säger.* Inaugural-Dissertation zur Erlangung der tierrmedizinischen Doktorwürde der Tierätztlichen Fakultät der Ludwig-Maximilians-Universität, München, 1967.

APPENDIX

Appendix 1: Skull and mandible measurements (mm), following the measurements given in von den Driesch 1976

Measurement no.	*Cranium*	*Mandibula*
	Capra hircus	*Felis catus*
1		61.2
2		58.0
3		54.3
4		51.1
5		18.4
6		
7		6.3
8		26.3
9		11.2
10		10.7
11		
26	77.7	
27	51.0	
28		
29	18.4	
30	18.0	
31		
32		
33	75.6	

Appendix 2: Bone measurements (mm), following the standard given in von den Driesch 1976. * – LA of the pelvis; ** – Lm of the coracoid of birds; *** – LG of the scapula of mammals, Bb of the coracoid, Dic of the scapula of birds; **** – BG of the scapula, BF of the coracoid

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
Cattle (*Bos taurus* Linnaeus, 1758)									
proc. cornualis	sin.		95.0	26.3	24.2				
proc. cornualis	dex.	cow	116.5	41.0	33.0				
proc. cornualis	sin.		137.5	46.2	42.5				
proc. cornualis	dex.			39.5	33.9				
proc. cornualis	sin.			43.5	36.5				
proc. cornualis	dex.			48.9	43.7				
atlas	sin.		82.5						
UM1-3 teeth	sin.		73.0						
LP2-M3 teeth			115.7						
LP2-M3 teeth			118.2						
LP2-M3 teeth			118.4						
LP2-M3 teeth	sin.		118.5						
LP2-M3 teeth			120.6						
LP2-M3 teeth			123.5						
LP2-M3 teeth			123.6						
LP2-M3 teeth			126.3						
LP2-M3 teeth			126.4						
LP2-M3 teeth			127.0						
LP2-M3 teeth			127.7						
LP2-M3 teeth			128.0						
LP2-M3 teeth	sin.		128.9						
LP2-M3 teeth	sin.		130.0						
LP2-M3 teeth			130.8						
LP2-M3 teeth			138.6						
LP2-M3 teeth			139.2						
LP2-M3 teeth			139.3						
LP2-M3 teeth			139.7						
LP2-M3 teeth			140.2						
LP2-M3 teeth	sin.		141.0						
LP2-4 teeth			40.3						
LP2-4 teeth			42.8						
LP2-4 teeth			43.6						
LP2-4 teeth			44.1						
LP2-4 teeth			45.3						
LP2-4 teeth			45.4						
LP2-4 teeth			45.8						
LP2-4 teeth			46.0						
LP2-4 teeth			47.0						
LP2-4 teeth			47.6						
LP2-4 teeth			47.8						
LP2-4 teeth			48.0						
LP2-4 teeth			49.6						
LP2-4 teeth			50.6						
LP2-4 teeth			51.2						
LP2-4 teeth			51.4						
LM1-3 teeth			74.1						
LM1-3 teeth			74.3						

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
LM1-3 teeth			74.6						
LM1-3 teeth			74.7						
LM1-3 teeth	sin.		74.8						
LM1-3 teeth			75.3						
LM1-3 teeth			75.4						
LM1-3 teeth			75.7						
LM1-3 teeth			75.8						
LM1-3 teeth			76.0						
LM1-3 teeth			76.3						
LM1-3 teeth			76.7						
LM1-3 teeth			77.1						
LM1-3 teeth			79.4						
LM1-3 teeth			79.6						
LM1-3 teeth	sin.		79.9						
LM1-3 teeth			80.7						
LM1-3 teeth	sin.		81.0						
LM1-3 teeth	sin.		81.4						
LM1-3 teeth			82.6						
LM1-3 teeth			82.8						
LM1-3 teeth	sin.		83.1						
LM1-3 teeth			83.5						
LM1-3 teeth	sin.		84.2						
LM1-3 teeth			85.1						
LM1-3 teeth			85.8						
LM1-3 teeth			88.0						
LM1-3 teeth			88.4						
LM1-3 teeth			90.3						
LM1-3 teeth			91.1						
LM1-3 teeth	sin.		91.2						
LM3 tooth	dex.		31.1	12.2					
LM3 tooth			31.2	14.9					
LM3 tooth	sin.		31.5	14.5					
LM3 tooth			31.6	13.4					
LM3 tooth	sin.		31.8	14.1					
LM3 tooth	sin.		32.0	12.1					
LM3 tooth	sin.		32.1	13.1					
LM3 tooth	sin.		32.2	12.8					
LM3 tooth	sin.		32.4	14.1					
LM3 tooth	dex.		32.8	11.9					
LM3 tooth	sin.		33.0	14.0					
LM3 tooth	dex.		33.1	12.2					
LM3 tooth	sin.		33.1	12.8					
LM3 tooth	sin.		33.2	12.5					
LM3 tooth	sin.		33.3	11.0					
LM3 tooth	sin.		33.3	12.0					
LM3 tooth	sin.		33.3	13.5					
LM3 tooth	dex.		33.3	13.8					
LM3 tooth	dex.		33.3	14.2					
LM3 tooth			33.4	12.3					
LM3 tooth			33.4	13.3					
LM3 tooth	sin.		33.4	14.8					

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
LM3 tooth	sin.		33.5	14.0					
LM3 tooth	sin.		33.8	12.1					
LM3 tooth	sin.		33.8	12.5					
LM3 tooth	sin.		33.8	14.8					
LM3 tooth	dex.		34.1	11.7					
LM3 tooth	sin.		34.1	14.8					
LM3 tooth	sin.		34.2	13.5					
LM3 tooth	sin.		34.2	16.1					
LM3 tooth	dex.		34.5	12.3					
LM3 tooth	sin.		34.7	12.5					
LM3 tooth	dex.		34.7	13.3					
LM3 tooth	sin.		35.0	13.2					
LM3 tooth	sin.		35.0	14.7					
LM3 tooth	sin.		35.0	15.0					
LM3 tooth	sin.		35.1	14.8					
LM3 tooth	dex.		35.2	13.9					
LM3 tooth	sin.		35.3	15.4					
LM3 tooth	sin.		35.5	14.2					
LM3 tooth	sin.		35.5	14.5					
LM3 tooth	sin.		35.8	15.5					
LM3 tooth	sin.		36.0	12.1					
LM3 tooth	sin.		36.0	13.0					
LM3 tooth	sin.		36.2	13.2					
LM3 tooth	dex.		36.2	14.5					
LM3 tooth			36.6	15.1					
LM3 tooth	dex.		36.9	13.0					
LM3 tooth	sin.		36.9	14.9					
LM3 tooth	dex.		37.2	16.0					
LM3 tooth	sin.		38.2	14.8					
LM3 tooth	sin.		38.8	14.0					
LM3 tooth	sin.		38.9	18.1					
LM3 tooth	dex.		41.3	15.1					
scapula	sin.					46.2		39.0	46.3
scapula	sin.					41.8		40.3	48.1
scapula	sin.							45.5	53.1
scapula	sin.							47.1	39.4
scapula	sin.					41.7		47.2	
scapula	sin.							47.4	36.5
scapula	sin.							47.5	35.7
scapula	sin.					40.6		47.7	40.0
scapula	sin.					48.8		49.2	41.4
scapula	sin.							51.0	44.5
scapula	sin.							51.1	42.0
scapula	sin.							51.4	41.7
scapula	dex.							51.9	42.4
scapula	dex.					46.6		52.0	39.5
scapula	sin.					42.5		52.5	39.5
scapula	dex.							52.5	54.8
scapula	sin.							52.6	45.2
scapula	sin.							52.7	42.8
scapula	dex.					43.0		54.1	41.0
scapula	dex.							54.3	43.3

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
scapula	sin.							54.6	46.0
scapula	dex.							54.6	49.0
scapula	sin.					43.2		55.0	39.5
scapula	sin.					55.4		55.7	39.4
scapula	dex.					43.0		55.8	41.5
scapula	sin.					50.6		56.2	42.1
scapula	dex.					58.3		56.2	44.6
scapula	dex.					54.0		56.3	41.5
scapula	sin.					41.5		57.5	40.0
scapula	dex.							57.7	47.2
scapula	dex.							58.0	50.5
scapula	sin.							58.4	44.8
scapula	sin.							59.5	47.5
humerus	dex.			96.0	77.6				
humerus	sin.			109.0					
humerus	dex.			111.2					
humerus	dex.			115.2	95.0				
humerus	sin.					34.5	45.3	69.3	66.5
humerus	sin.					38.8		72.1	69.7
humerus	sin.					41.2		82.0	82.8
humerus	sin.						64.0		
humerus	dex.							57.0	55.7
humerus	dex.							59.4	
humerus	dex.							59.8	59.1
humerus	sin.							60	58.6
humerus	sin.							60.0	56.2
humerus	sin.							60.3	63.5
humerus	sin.							61.5	58.9
humerus	dex.							61.6	67.0
humerus	sin.							62.0	57.4
humerus	sin.							62.1	
humerus	sin.							62.5	
humerus	sin.							62.5	60.5
humerus	dex.							62.5	58.6
humerus	dex.							62.6	
humerus	sin.							62.7	58.3
humerus	dex.							63.0	
humerus	sin.							63.4	
humerus	dex.							63.4	62.2
humerus	sin.							64.0	65.8
humerus	dex.							64.2	
humerus	sin.							65.0	
humerus	dex.							65.0	
humerus	dex.							65.3	60.3
humerus	dex.							66.2	63.7
humerus	sin.							66.6	70.4
humerus	dex.							66.8	68.5
humerus	dex.							67.0	60.8
humerus	sin.							67.4	60.2
humerus	sin.							67.8	
humerus	sin.							67.9	
humerus	sin.							68.0	67.5

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
humerus	sin.							68.0	61.0
humerus	dex.							68.0	66.4
humerus	dex.							68.1	
humerus	sin.							69.7	65.3
humerus	sin.							70.0	
humerus	sin.							70.4	67.5
humerus	sin.							70.6	
humerus	sin.							71.4	40.0
humerus	dex.							71.8	70.7
humerus	sin.							72.0	71.8
humerus	sin.							72.1	
humerus	sin.							72.2	70.7
humerus	dex.							72.7	
humerus	dex.							72.8	65.8
humerus	sin.							73.0	
humerus	dex.							73.0	
humerus	sin.							73.1	
humerus	sin.							73.6	64.4
humerus	sin.							73.6	61.7
humerus	dex.							74.0	72.3
humerus	sin.							74.2	
humerus	sin.							74.2	64.5
humerus	dex.							74.5	69.3
humerus	dex.							74.8	71.6
humerus	dex.							75.2	
humerus	dex.							75.4	73.5
humerus	dex.							76.0	
humerus	sin.							77.0	62.0
humerus	sin.							77.0	72.4
humerus	dex.							78.5	
humerus	dex.							80.8	72.9
humerus	dex.							80.8	
humerus	dex.							81.2	89.2
humerus	sin.							83.2	78.2
humerus	dex.							84.3	76.5
humerus	sin.							89.0	
humerus	sin.							93.8	
humerus	sin.							98.0	80.0
radius	sin.		255.0	69.3	35.2	34.3	18.9	60.0	39.7
radius	dex.			61.5	37.0				
radius	dex.			62.4	34.0				
radius	dex.			63.4	30.5				
radius	dex.			63.9	34.0	31.9	18.3		
radius	dex.			64.6	33.9				
radius	dex.			64.7	32.0				
radius	sin.			65.4	35.1				
radius	sin.			65.5	36.2				
radius	sin.			65.8	35.8				
radius	sin.			66.1	33.4				
radius	dex.			66.6	35.8				
radius	dex.			66.8	34.7				
radius	sin.			67.0	35.4				

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
radius	dex.			67.4	33.0				
radius	dex.			67.7	34.0				
radius	sin.			68.1	34.4				
radius	sin.			68.1	39.4				
radius	dex.			68.2	34.2				
radius	sin.			68.7	35.5				
radius	dex.			68.8	37.5				
radius	dex.			68.8					
radius	dex.			69.9	34.1				
radius	sin.			70.0	36.3				
radius	dex.			70.0	36.8				
radius	dex.			70.1	34.5			64.1	39.0
radius	sin.			70.3	38.0				
radius	dex.			70.5					
radius	dex.			70.6	34.9				
radius	dex.			70.7	37.0				
radius	sin.			71.0	36.5				
radius	dex.			71.1	35.6				
radius	dex.			71.2	35.2				
radius	sin.			71.2	37.3				
radius	dex.			71.7	36.0				
radius	sin.			72.0	40.2				
radius	sin.			72.4	38.9				
radius	sin.			72.4	40.1				
radius	dex.			72.8	37.3				
radius	sin.			73.1	38.4				
radius	sin.			73.2	39.4				
radius	sin.			73.3	38.9				
radius	dex.			73.7	37.5				
radius	dex.			74.0	40.0				
radius	sin.			74.1	39.0				
radius	dex.			74.2	38.7				
radius	sin.			74.3	39.6			62.5	42.4
radius	sin.			75.9	37.8				
radius	sin.			76.0	36.8				
radius	dex.			76.4	37.3				
radius	sin.			76.6	39.7				
radius	dex.			76.7	40.0				
radius	sin.			76.9	40.3				
radius	dex.			77.0	39.6				
radius	sin.			77.1	40.1				
radius	sin.			77.1					
radius	sin.			77.5	36.5				
radius	sin.			77.5	39.3				
radius	dex.			77.6					
radius	dex.			77.7	39.7				
radius	sin.			77.7	40.9				
radius	dex.			77.8	39.7				
radius	sin.			78.3	39.8				
radius	dex.			78.5	38.0				
radius	dex.			78.9	40.7				
radius	sin.			79.0	38.0				

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
radius	sin.			79.0	41.3				
radius	dex.			79.3	37.9				
radius	dex.			79.5	40.8				
radius	dex.			79.6	40.0			63.3	42.1
radius	dex.			80.0	42.2	43.7			
radius	sin.			80.2	39.0				
radius	dex.			80.3	41.4	40.9	23.9	71.4	44.5
radius	dex.			80.6	38.8				
radius	dex.			80.6	40.0				
radius	dex.			80.8	40.4				
radius	sin.			81.0	39.2				
radius	sin.			81.0	42.1				
radius	dex.			81.1	39.7				
radius	dex.			81.2	43.7				
radius	dex.			82.1	43.5				
radius	dex.			82.4	40.0				
radius	dex.			82.4	46.6				
radius	sin.			83.3	39.6				
radius	sin.			83.3	41.9				
radius	sin.			84.1	43.6				
radius	sin.			85.2	43.6			65.7	42.0
radius	dex.			86.0	47.0			75.4	49.7
radius	dex.			87.3	41.7				
radius	dex.			90.2	45.6			74.0	47.2
radius	dex.			90.6	45.5				
radius	dex.			94.2	47.7				
radius	dex.					34.2		61.1	39.0
radius	sin.					41.7		74.4	53.4
radius	dex.						59.6	43.5	
radius	sin.							55.8	40.0
radius	dex.							56.0	37.0
radius	dex.							58.1	40.8
radius	sin.							59.3	41.5
radius	sin.							59.5	42.2
radius	dex.							59.8	38.0
radius	sin.							60.2	39.8
radius	sin.							61.0	46.7
radius	sin.							61.1	40.6
radius	sin.							61.2	42.5
radius	dex.							61.6	42.3
radius	sin.							62.2	42.5
radius	sin.							62.5	45.5
radius	dex.							63.0	45.5
radius	dex.							63.6	42.6
radius	sin.							63.7	46.7
radius	sin.							63.8	42.6
radius	sin.							64.1	42.1
radius	sin.							64.6	42.6
radius	sin.							65.7	47.5
radius	sin.							66.2	41.1
radius	dex.							66.5	45.0
radius	sin.							66.5	43.3

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
radius	sin.							66.7	39.5
radius	sin.							67.2	
radius	dex.							67.3	44.0
radius	dex.							67.4	47.3
radius	dex.							68.0	43.3
radius	dex.							68.0	42.5
radius	dex.							68.3	47.0
radius	sin.							69.6	48.0
radius	dex.							70.1	44.2
radius	dex.							70.1	45.9
radius	dex.							71.6	49.5
radius	sin.							71.8	47.4
radius	dex.							71.9	42.6
radius	dex.							72.0	
radius	sin.							72.6	48.2
radius	sin.							72.7	50.8
radius	dex.							72.7	44.6
radius	sin.							73.1	41.0
radius	dex.							73.2	51.4
radius	dex.							73.3	46.8
radius	dex.							74.6	44.1
radius	sin.							75.5	53.0
radius	sin.							75.6	49.4
radius	dex.							75.6	50.8
radius	dex.							76.0	48.5
radius	sin.							76.0	53.0
radius	dex.							77.8	47.9
radius	dex.							79.6	
radius	dex.							87.2	60.4
ulna	dex.		81.3	50.5		42.6			
ulna	dex.		82.1	59.6	49.2				
ulna	sin.		104.1			53.1			
ulna	dex.		116.4	59.5					
metacarpus	dex.		73.3			12.1			
metacarpus	sin.		175.0	51.7	29.8		19.0	55.0	28.2
metacarpus	dex.		175.6	51.5	29.9		19.2	54.9	27.9
metacarpus	dex.		180.3	57.9	36.2		19.5	62.4	31.0
metacarpus	sin.		182.0	54.1	31.3	29.2	19.2	52.7	29.7
metacarpus	sin.		188.0	59.3	35.5				
metacarpus	dex.		193.0	53.5	31.4	27.3	18.6	51.9	28.8
metacarpus	sin.		193.5	49.2	31.5		20.1	51.1	28.0
metacarpus	sin.			33.0	18.2		12.0	31.1	
metacarpus	dex.			41.8	27.1				
metacarpus	sin.			44.2	26.5				
metacarpus	dex.			45.8	28.8				
metacarpus	dex.			46.0	28.1				
metacarpus	dex.			46.3	27.6				
metacarpus	dex.			46.4	27.0				
metacarpus	sin.			46.5	30.1	27.9			
metacarpus	dex.			46.6	28.1				
metacarpus	dex.			46.6	29.5				
metacarpus	sin.			46.8	29.8				

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
metacarpus	sin.			47.3	30.0				
metacarpus	sin.			47.5	28.6				
metacarpus	dex.			47.9	28.0				
metacarpus	sin.			47.9	29.1				
metacarpus	sin.			47.9	29.9				
metacarpus	dex.			48.3	29.5				
metacarpus	sin.			48.4	31.2				
metacarpus	sin.			48.8	29.3				
metacarpus	sin.			48.9	30.2				
metacarpus	sin.			49.0	31.6				
metacarpus	dex.			49.2	27.6				
metacarpus	sin.			49.2	31.8				
metacarpus	dex.			49.3	28.0				
metacarpus	dex.			49.6	32.3				
metacarpus	sin.			50.0	28.3				
metacarpus	sin.			50.0	31.4				
metacarpus	sin.			50.2	29.1				
metacarpus	dex.			50.2	30.3				
metacarpus	sin.			50.2	34.0				
metacarpus	sin.			50.3	33.2				
metacarpus	sin.			50.5	29.5				
metacarpus	sin.			50.6	31.7				
metacarpus	sin.			50.6	32.9				
metacarpus	sin.			50.7	31.1				
metacarpus	sin.			50.8	32.8				
metacarpus	dex.			51.0	29.0				
metacarpus	sin.			51.1	33.2				
metacarpus	dex.			51.2	33.0				
metacarpus	dex.			51.5	31.1				
metacarpus	dex.			51.6	28.6				
metacarpus	sin.			51.6	31.0				
metacarpus	sin.			51.6	32.0			58.0	30.0
metacarpus	sin.			51.6	33.4				
metacarpus	sin.			51.8	30.8				
metacarpus	sin.			51.8	31.0				
metacarpus	dex.			51.9	30.3				
metacarpus	sin.			52.0	33.0				
metacarpus	sin.			52.0	33.5				
metacarpus	sin.			52.1	29.2				
metacarpus	sin.			52.2	30.2				
metacarpus	dex.			52.2	32.2				
metacarpus	sin.			52.5	31.4				
metacarpus	sin.			52.5	31.6				
metacarpus	sin.			52.6	33.8				
metacarpus	sin.			53.1	33.1				
metacarpus	sin.			53.1	33.1				
metacarpus	sin.			53.2	36.4				
metacarpus	sin.			53.4	33.5				
metacarpus	dex.			54.1	29.7				
metacarpus	dex.			54.1	30.8				
metacarpus	sin.			54.5	31.6				
metacarpus	dex.			54.6	28.0				

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
metacarpus	sin.			54.7	30.0				
metacarpus	sin.			54.8	33.3				
metacarpus	sin.			55.0	33.2				
metacarpus	sin.			55.0	34.1				
metacarpus	sin.			55.0	34.1				
metacarpus	sin.			55.0	34.3				
metacarpus	sin.			55.1	30.9				
metacarpus	dex.			55.7	37.0				
metacarpus	sin.			56.0	34.5				
metacarpus	sin.			56.2	32.2				
metacarpus	dex.			56.2	33.2				
metacarpus	dex.			56.6	30.7			53.2	27.6
metacarpus	sin.			56.7	33.0				
metacarpus	dex.			56.7	35.1				
metacarpus	sin.			56.8	33.3				
metacarpus	sin.			57.1	36.6				
metacarpus	dex.			57.1	36.9				
metacarpus	sin.			57.2	35.5				
metacarpus	dex.			57.4	34.2				
metacarpus	sin.			57.4	36.5				
metacarpus	dex.			57.6	33.1				
metacarpus	sin.			57.8	32.7				
metacarpus	dex.			57.8	35.7				
metacarpus	dex.			57.8	37.8				
metacarpus	sin.			57.9					
metacarpus	dex.			58.0	34.8				
metacarpus	dex.			58.1	34.1				
metacarpus	sin.			58.3	36.0				
metacarpus	dex.			58.5	36.8				
metacarpus	sin.			58.7	36.0			56.1	28.8
metacarpus	dex.			58.9	36.0				
metacarpus	dex.			59.0	36.1				
metacarpus	dex.			59.1	34.7				
metacarpus	sin.			59.2	36.0				
metacarpus	sin.			59.5	36.2				
metacarpus	sin.			60.0	35.7				
metacarpus	sin.			60.0	36.1				
metacarpus	sin.			60.0	36.7				
metacarpus	sin.			60.0	39.5				
metacarpus	dex.			60.3	36.8				
metacarpus	dex.			60.6	38.2	38.4	24.0		
metacarpus	sin.			60.8	37.3				
metacarpus	sin.			61.7	38.1				
metacarpus	sin.			62.2	41.2				
metacarpus	dex.			62.8	37.0				
metacarpus	sin.			63.0	58.1				
metacarpus	dex.			64.1	38.5				
metacarpus	dex.			64.7	39.1				
metacarpus	sin.			65.0	38.2				
metacarpus	dex.			69.1	40.5				
metacarpus	sin.			73.9	42.5				
metacarpus	dex.				26.9				

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
phalanx prox. ant.			49.0	24.1		19.2		21.4	
phalanx prox. ant.			49.8	26.2		23.0		26.0	
phalanx prox. ant.			49.9	24.0		20.1		24.0	
phalanx prox. ant.			50.2	26.2		21.3		23.8	
phalanx prox. ant.			50.6	25.0		21.4		23.7	
phalanx prox. ant.			51.0	23.3		20.9		23.1	
phalanx prox. ant.			51.0	24.4		19.4		22.1	
phalanx prox. ant.			51.0	27.0		21.7		24.5	
phalanx prox. ant.			51.3	24.5		20.6		23.0	
phalanx prox. ant.			51.3	30.7		25.1		28.8	
phalanx prox. ant.			51.4	26.8		21.3		24.2	
phalanx prox. ant.			51.6	24.6		19.7		24.0	
phalanx prox. ant.			51.7	24.9		21.1		23.8	
phalanx prox. ant.			52.0	28.1		23.0		25.1	
phalanx prox. ant.			52.4	23.0		19.6		21.6	
phalanx prox. ant.			52.4	26.4		22.4		23.8	
phalanx prox. ant.			52.4	28.4		23.3		26.8	
phalanx prox. ant.			52.5	23.0		14.0		22.0	
phalanx prox. ant.			52.7	26.3		21.3		23.8	
phalanx prox. ant.			53.0	24.4		20.5		23.0	
phalanx prox. ant.			53.0	26.0		22.0		24.0	
phalanx prox. ant.			53.0	26.5		21.8		25.8	
phalanx prox. ant.			53.1	23.1		20.1		22.1	
phalanx prox. ant.			53.4	27.1		23.3		24.7	
phalanx prox. ant.			53.5	23.3		19.8		23.5	
phalanx prox. ant.			53.6	25.6		21.2		22.1	
phalanx prox. ant.			53.7	30.2		26.5		28.2	
phalanx prox. ant.			54.0					25.3	
phalanx prox. ant.			54.4	24.6		20.0		23.0	
phalanx prox. ant.			54.4	27.5		22.6		25.4	
phalanx prox. ant.			54.4	27.5		23.3		25.9	
phalanx prox. ant.			54.6	26.2		22.4		26.3	
phalanx prox. ant.			54.7	24.5		21.6		24.9	
phalanx prox. ant.			54.8	24.6		20.0		22.6	
phalanx prox. ant.			54.8	26.4		22.1		24.7	
phalanx prox. ant.			55.1	26.2		20.9		23.0	
phalanx prox. ant.			55.5	24.5		20.4		23.6	
phalanx prox. ant.			55.5	28.7		24.7		26.5	
phalanx prox. ant.			55.6	22.5		18.5		21.1	
phalanx prox. ant.			55.6	23.7		21.1.		22.2	
phalanx prox. ant.			55.7	23.1		20.0		21.7	
phalanx prox. ant.			56.0	28.2		22.7		26.0	
phalanx prox. ant.			56.1	24.0		18.8		22.4	
phalanx prox. ant.			56.1	25.4		20.3		22.6	
phalanx prox. ant.			56.1	26.6		21.9		23.1	
phalanx prox. ant.			56.1	27.0		23.3		24.1	
phalanx prox. ant.			56.3	31.0		24.7		28.0	
phalanx prox. ant.			56.4	26.0		21.2		25.4	
phalanx prox. ant.			56.5	23.7		20.2		21.7	
phalanx prox. ant.			56.5	24.8		19.5		20.9	
phalanx prox. ant.			56.5	27.4		22.8		27.5	
phalanx prox. ant.			56.6	23.9		20.6		24.1	

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
phalanx prox. ant.			56.7	27.2		23.0		25.2	
phalanx prox. ant.			57.0	23.8		19.4		23.5	
phalanx prox. ant.			57.0	24.5		20.5		21.7	
phalanx prox. ant.			57.0	26.9		21.7			
phalanx prox. ant.			57.1	23.3		19.6		23.3	
phalanx prox. ant.			57.1	28.3		23.3		25.7	
phalanx prox. ant.			57.1	31.3		25.4		28.5	
phalanx prox. ant.			57.2	24.8		21.6		24.3	
phalanx prox. ant.			57.3	32.7		27.1		29.0	
phalanx prox. ant.			57.4	28.7		23.1		26.5	
phalanx prox. ant.			57.5	23.1		19.9		23.4	
phalanx prox. ant.			57.7	31.1		24.6		28.5	
phalanx prox. ant.			58.0	29.6		27.1		27.9	
phalanx prox. ant.			58.1	23.5		21.0		22.8	
phalanx prox. ant.			58.1	28.7		23.5		26.8	
phalanx prox. ant.			58.3	23.1		20.2		22.4	
phalanx prox. ant.			58.4	25.0		22.0		24.9	
phalanx prox. ant.			58.5	24.6		20.4		24.5	
phalanx prox. ant.			58.7	28.9		22.9		25.2	
phalanx prox. ant.			58.8			21.9		23.6	
phalanx prox. ant.			60.4	26.8		23.1		24.8	
phalanx prox. ant.			60.7	21.8		17.6		19.9	
phalanx prox. ant.			60.8	27.1		22.1		27.1	
phalanx prox. ant.			61.0	27.6		23.5		30.3	
phalanx prox. ant.			61.3	25.3		22.4		24.6	
phalanx prox. ant.			61.4	27.2		23.7		27.7	
phalanx prox. ant.			61.8	33.0		27.7		30.5	
phalanx prox. ant.			62.8	29.5		22.5		25.4	
phalanx prox. ant.			63.4	29.8		24.8		28.5	
phalanx prox. ant.			63.8	27.1		23.4		24.8	
phalanx prox. ant.			65.7	28.7		23.9		27.8	
phalanx prox. ant.			65.8	29.3		26.0		28.3	
phalanx prox. ant.			66.0	28.5		23.6		28.5	
phalanx prox. ant.						23.9		24.8	
acetabulum	dex.		57.4						
acetabulum	sin.		59.5						
acetabulum	dex.		61.7						
acetabulum	sin.		61.7						
acetabulum	dex.		62.0						
acetabulum	dex.		64.0						
acetabulum	sin.		64.8						
acetabulum	sin.		65.2						
acetabulum	dex.		66.0						
acetabulum	sin.		71.1						
acetabulum	dex.		74.3						
acetabulum	sin.		76.7						
femur	sin.			98.4					
femur	dex.			100.4	38.0				
femur	dex.			101.9	52.9				
femur	sin.			120.4					
femur	sin.							79.0	100.6
femur	sin.							79.5	105.7

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
femur	dex.					28.7	33.8	80.7	102.4
femur	dex.							82.8	101.4
femur	sin.							84.5	101.0
femur	sin.							84.7	103.1
femur	sin.					36.6	40.3	85.9	
femur	dex.							91.1	
femur	dex.							92.1	117.2
femur	dex.							93.1	
femur	sin.							93.3	114.0
femur	sin.							96.0	118.0
femur	dex.							99.4	
femur	sin.							99.6	120.2
patella	dex.		49.3	41.0					
patella	sin.		50.8	43.1					
patella	sin.		51.5	37.4					
patella	sin.		52.8	45.0					
patella	sin.		53.0						
patella	sin.		53.4	44.6					
patella	sin.		54.9	44.2					
patella	dex.		55.4	40.7					
patella	sin.		55.5	45.5					
patella	sin.		55.6	45.6					
patella	sin.		55.7	45.1					
patella	dex.		56.1	43.0					
patella	dex.		57.2	45.0					
patella	dex.		58.1	44.3					
patella	sin.		58.7	47.0					
patella	dex.		59.0						
patella	sin.		59.7	46.8					
patella	sin.		60.0	48.9					
patella	sin.		60.3	42.7					
patella	sin.		60.7	48.6					
patella	dex.		61.2						
patella	sin.		61.4	45.0					
patella	sin.		61.4	51.0					
patella	sin.		61.6	51.3					
patella	sin.		62.3	57.5					
patella	dex.		63.8	52.5					
patella	dex.		73.2	60.0					
tibia	dex.			76.0	72.6				
tibia	dex.			76.2	78.7				
tibia	sin.			78.0	67.0				
tibia	sin.			79.6	68.5				
tibia	sin.			80.4	72.3				
tibia	sin.			81.8	76.5				
tibia	sin.			83.7	76.5				
tibia	sin.			84.0	77.5				
tibia	sin.			85.3					
tibia	dex.			85.6	79.2				
tibia	dex.			85.7	66.0				
tibia	sin.			87.3	74.6				
tibia	sin.			87.4					

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
tibia	sin.			87.8	77.4				
tibia	sin.			90.0	69.0				
tibia	dex.			90.3	87.5				
tibia	dex.			91.0	77.0				
tibia	sin.			91.3	74.0				
tibia	dex.			91.3	89.4				
tibia	sin.			91.6	79.0				
tibia	sin.			91.8	90.0				
tibia	dex.			92.5					
tibia	dex.			94.3	93.0				
tibia	sin.			94.6	89.4				
tibia	dex.			94.8	84.6			63.9	48.7
tibia	sin.			97.4	87.5			64.6	48.0
tibia	dex.			98.4	85.6				
tibia	sin.			98.8	88.4				
tibia	sin.			110.4	95.1				
tibia	dex.							49.5	38.8
tibia	sin.							49.6	37.5
tibia	dex.							50.4	37.0
tibia	dex.							50.5	38.4
tibia	dex.							50.7	36.6
tibia	dex.							51.1	37.5
tibia	sin.							51.5	39.7
tibia	dex.							51.7	35.2
tibia	sin.							51.7	37.8
tibia	dex.							51.7	39.7
tibia	sin.							51.8	38.7
tibia	dex.							51.9	38.9
tibia	dex.							52.0	36.8
tibia	sin.							52.0	42.4
tibia	dex.							52.2	35.2
tibia	sin.							52.2	35.8
tibia	dex.							52.2	36.8
tibia	dex.							52.2	37.3
tibia	sin.					30.8	20.0	52.2	39.4
tibia	sin.							52.3	39.6
tibia	dex.							52.6	37.7
tibia	dex.							52.7	41.3
tibia	sin.							52.9	42.3
tibia	dex.							53.0	38.6
tibia	sin.							53.0	39.1
tibia	sin.							53.0	39.7
tibia	sin.							53.2	
tibia	dex.							53.6	35.2
tibia	dex.							53.6	41.3
tibia	sin.							53.8	47.1
tibia	sin.							54.0	39.2
tibia	dex.							54.2	36.5
tibia	dex.							54.6	39.2
tibia	dex.							55.0	41.5
tibia	sin.							55.0	44.5
tibia	dex.							55.1	43.8

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
tibia	dex.							55.2	
tibia	dex.					34.0		55.3	43.6
tibia	dex.							55.5	46.9
tibia	sin.							56.0	45.0
tibia	dex.							56.0	45.3
tibia	dex.							56.1	44.2
tibia	sin.							56.4	42.8
tibia	dex.							56.5	44.0
tibia	sin.							56.5	44.0
tibia	sin.							56.6	41.8
tibia	sin.							56.8	44.0
tibia	dex.							57.0	45.0
tibia	dex.							57.1	42.1
tibia	sin.							57.3	43.3
tibia	sin.							57.3	44.6
tibia	dex.							57.5	42.4
tibia	sin.							57.5	43.2
tibia	sin.							57.5	44.2
tibia	sin.							57.6	37.7
tibia	sin.							57.7	42.8
tibia	sin.							57.8	39.8
tibia	sin.							58.0	45.0
tibia	sin.							58.2	44.3
tibia	sin.							58.4	39.3
tibia	sin.							58.4	40.6
tibia	dex.							58.6	42.6
tibia	sin.							58.9	41.9
tibia	dex.							59.1	44.2
tibia	dex.							59.2	31.8
tibia	dex.							59.2	44.5
tibia	dex.							59.3	42.6
tibia	sin.					37.1	26.2	59.3	44.7
tibia	dex.							59.4	43.5
tibia	dex.							59.4	46.7
tibia	dex.							59.4	47.3
tibia	sin.							59.5	45.0
tibia	dex.							59.6	42.0
tibia	dex.							60.0	43.3
tibia	dex.							60.0	43.6
tibia	sin.							60.2	44.5
tibia	dex.							60.5	42.2
tibia	sin.							60.5	49.0
tibia	sin.							61.0	43.9
tibia	sin.							61.0	45.6
tibia	sin.							61.0	47.0
tibia	dex.							61.1	46.0
tibia	dex.					37.5		61.4	47.6
tibia	sin.							61.5	41.5
tibia	sin.							61.6	44.0
tibia	dex.							62.0	46.0
tibia	dex.							62.0	48.6
tibia	sin.							62.1	46.1

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
tibia	sin.							62.5	41.1
tibia	sin.							62.6	44.8
tibia	dex.							62.7	46.3
tibia	sin.							63.0	39.2
tibia	dex.							63.0	50.0
tibia	sin.							63.1	45.3
tibia	dex.							63.7	44.5
tibia	dex.							65.0	48.7
tibia	sin.							65.4	50.3
tibia	dex.							65.6	54.4
tibia	dex.							66.7	49.9
tibia	sin.							73.1	46.1
tibia	sin.							79.6	54.1
astragalus	sin.		49.6	28.2	27.7			30.6	23.5
astragalus	dex.		51.5	48.7				33.1	27.5
astragalus	dex.		53.4	28.7	25.7			34.5	24.9
astragalus	sin.		54.1	30.2	29.1			34.5	23.7
astragalus	sin.		54.1	49.1					33.5
astragalus	sin.		54.4	30.1	24.8			35.0	25.0
astragalus	sin.		54.8					32.1	
astragalus	sin.		55.5	31.4	27.5			34.0	26.8
astragalus	sin.		55.5	31.6	31.4			35.0	26.2
astragalus	dex.		55.8	30.3	28.8			36.9	27.2
astragalus	dex.		55.9	31.0	29.8			37.3	25.0
astragalus	sin.		55.9						
astragalus	sin.		56.5					34.4	
astragalus	sin.		56.8	32.5	31.1			35.4	26.5
astragalus	dex.		57.0	30.9	32.9			36.5	27.8
astragalus	sin.		57.0	52.0					
astragalus	dex.		57.1	31.2				34.9	25.0
astragalus	dex.		57.2	31.0	30.8			36.6	25.5
astragalus	sin.		57.2	52.5				37.0	31.1
astragalus	dex.		57.6	31.7	27.1			35.7	26.1
astragalus	dex.		57.9	31.9	31.6			36.7	27.5
astragalus	dex.		58.0	31.9	27.6			37.1	27.2
astragalus	sin.		58.2	31.3	29.4			38.0	28.7
astragalus	sin.		58.2	31.5	31.3			35.8	27.6
astragalus			58.2	54.0				34.5	29.5
astragalus	sin.		58.3		30.3			39.1	28.6
astragalus	dex.		58.7	31.0	30.6			33.8	25.4
astragalus	dex.		59.0	33.0	32.8			37.9	28.7
astragalus	dex.		59.2	33.1	32.8			36.8	26.9
astragalus	dex.		59.2	33.5	33.9			39.0	29.2
astragalus	dex.		59.4	32.0	32.1			38.2	27.0
astragalus	sin.		59.4	32.5	30.9			35.0	25.3
astragalus	sin.		59.4	33.1	31.0			38.8	
astragalus	sin.		59.4	33.8	33.8			36.7	28.8
astragalus	dex.		59.4	53.1				37.1	33.2
astragalus	sin.		59.6	31.4	33.6			36.8	29.2
astragalus	dex.		59.7	54.1				36.9	
astragalus	sin.		59.8	32.5	32.0			34.8	26.0
astragalus	sin.		59.8	54.1				38.2	33.2

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
astragalus	dex.		59.9	54.1				36.9	32.5
astragalus	dex.		60.0	31.4	33.0			37.0	29.2
astragalus	sin.		60.0	37.0	37.0			40.0	31.0
astragalus	dex.		60.0		31.0			36.2	27.7
astragalus	dex.		60.0					38.5	29.7
astragalus	dex.		60.3	32.5	32.8				
astragalus	dex.		60.6	34.2	34.5			39.8	29.7
astragalus	sin.		60.8	34.8	30.5			39.7	30.4
astragalus	sin.		60.8	55.0				38.5	33.3
astragalus	sin.		61.0	33.1	34.3			40.3	29.3
astragalus	dex.		61.1	54.1				35.9	32.1
astragalus	dex.		61.3	33.5	33.5			37.2	27.3
astragalus	dex.		61.4	30.5	33.5			38.7	28.0
astragalus	sin.		61.4	33.7	29.0			38.4	27.9
astragalus	dex.		61.5	33.0	33.6			39.3	27.3
astragalus	sin.		61.7	34.2	33.5			37.2	28.2
astragalus	sin.		62.3						
astragalus	sin.		62.4	33.1	32.7		39.3	29.5	
astragalus	dex.		62.4	33.7	34.3			39.1	29.8
astragalus	sin.		62.4	34.4	35.4			41.1	29.1
astragalus	dex.		62.4	34.5	33.5			38.4	
astragalus	sin.		62.8	33.8	32.3			36.6	26.1
astragalus	dex.		62.8	35.6	31.8			42.0	31.4
astragalus	dex.		63.0	34.0	32.4			44.6	
astragalus	sin.		63.0	34.3					
astragalus	dex.		63.0	35.5	34.8			39.0	28.5
astragalus	sin.		63.1	34.3	34.5			39.4	29.1
astragalus	sin.		63.1	57.2				41.6	35.0
astragalus	sin.		63.2	34.6	35.4			41.5	30.0
astragalus	sin.		63.4	33.5	29.7			38.9	28.9
astragalus	dex.		63.8	34.0	37.3			40.0	30.6
astragalus	sin.		64.0	35.2	35.3			39.5	29.5
astragalus	sin.		64.0	58.9				42.0	34.0
astragalus			64.0					40.0	35.0
astragalus	dex.		64.2	34.1	30.9			41.5	27.7
astragalus	sin.		64.2	35.4	31.5			40.1	29.3
astragalus	dex.		64.2	58.5				41.1	36.2
astragalus	dex.		64.3		36.4			44.4	33.3
astragalus	sin.		64.6	34.9	30.4			41.5	29.2
astragalus	sin.		64.8	35.3	36.1			42.3	30.0
astragalus	dex.		64.9	35.1	32.5			39.2	29.7
astragalus	sin.		65.8	36.7	35.4			43.2	33.3
astragalus	dex.		66.0	37.8	38.6			45.4	32.5
astragalus	sin.		66.2	60.8				41.0	36.1
astragalus	dex.		66.5	35.8	36.5			43.2	31.8
astragalus	sin.		66.8	61.9				41.1	36.9
astragalus	sin.		67.4	35.4	36.2			40.9	30.1
astragalus	dex.		67.4	36.5	32.5			44.4	
astragalus	sin.		67.8						
astragalus	dex.		67.9	38.6	36.1			41.1	31.2
astragalus	dex.		68.1	37.4	38.2			41.2	33.3
astragalus	sin.		68.5	38.7	34.9			45.4	33.0

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
astragalus	dex.		69.3	37.7	32.9			42.4	32.0
astragalus	dex.		72.5	42.0	37.0			44.7	35.5
astragalus	dex.		78.1	73.2				52.5	41.9
calcaneus	dex.		104.2	36.2					
calcaneus	dex.		108.0	34.0					
calcaneus	dex.		110.2	41.0					
calcaneus	sin.		112.0	39.0					
calcaneus	sin.		112.1	35.0					
calcaneus	dex.		112.1	39.7					
calcaneus	sin.		112.8	40.2					
calcaneus	dex.		113.0	37.0					
calcaneus	dex.		113.5	37.5					
calcaneus	sin.		114.2	38.6					
calcaneus	sin.		114.7	36.8					
calcaneus	sin.		115.0	40.0					
calcaneus	sin.		115.0	40.3					
calcaneus	dex.		117.4	45.7					
calcaneus	sin.		117.4						
calcaneus	sin.		119.6	40.5					
calcaneus	sin.		120.0	41.8					
calcaneus	sin.		121.6	35.8					
calcaneus	dex.		122.3	41.7					
calcaneus	sin.		122.8	40.6					
calcaneus	sin.		123.0						
calcaneus	sin.		123.1	39.0					
calcaneus	sin.		123.3	42.3					
calcaneus	dex.		123.6	40.0					
calcaneus	sin.		124.8	35.7					
calcaneus	dex.		128.0	45.2					
calcaneus	dex.		129.1	44.2					
calcaneus	dex.		129.1						
calcaneus	sin.		129.3	43.5					
calcaneus	sin.		130.2						
calcaneus	sin.		130.4						
calcaneus	dex.		135.0						
calcaneus	sin.		135.4	41.5					
calcaneus	dex.		138.1	45.0					
calcaneus	dex.		138.3	50.0					
calcaneus	sin.		138.9	44.8					
calcaneus	dex.		139.8						
calcaneus	dex.		154.2	58.1					
centrotarsale	dex.			43.2					
centrotarsale	dex.			43.7					
centrotarsale	sin.			44.5					
centrotarsale	sin.			44.5					
centrotarsale	sin.			44.9					
centrotarsale	dex.			45.1					
centrotarsale	sin.			45.1					
centrotarsale	sin.			45.3					
centrotarsale	dex.			45.3					
centrotarsale	sin.			45.6					
centrotarsale	sin.			45.6					

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
centrotarsale	dex.			45.7					
centrotarsale	dex.			46.0					
centrotarsale	sin.			46.1					
centrotarsale	sin.			46.2					
centrotarsale	dex.			47.0					
centrotarsale	dex.			47.4					
centrotarsale	sin.			47.7					
centrotarsale	sin.			47.7					
centrotarsale	dex.			47.8					
centrotarsale	sin.			47.8					
centrotarsale	dex.			47.9					
centrotarsale	dex.			48.2					
centrotarsale	dex.			48.6					
centrotarsale	dex.			48.7					
centrotarsale	dex.			48.9					
centrotarsale	dex.			49.0					
centrotarsale	sin.			49.2					
centrotarsale	sin.			49.6					
centrotarsale	dex.			49.7					
centrotarsale	sin.			49.8					
centrotarsale	dex.			49.8					
centrotarsale	dex.			49.9					
centrotarsale	sin.			50.3					
centrotarsale	sin.			50.3					
centrotarsale	dex.			50.4					
centrotarsale	dex.			50.6					
centrotarsale	dex.			50.8					
centrotarsale	dex.			50.9					
centrotarsale	sin.			51.0					
centrotarsale	sin.			51.2					
centrotarsale	sin.			51.2					
centrotarsale	sin.			51.6					
centrotarsale	sin.			51.8					
centrotarsale	sin.			51.8					
centrotarsale	sin.			52.1					
centrotarsale	dex.			52.3					
centrotarsale	sin.			52.3					
centrotarsale	dex.			53.2					
centrotarsale	sin.			53.3					
centrotarsale	dex.			53.7					
centrotarsale	sin.			53.8					
centrotarsale	sin.			53.9					
centrotarsale	dex.			53.9					
centrotarsale	dex.			54.1					
centrotarsale	dex.			54.2					
centrotarsale	dex.			54.7					
centrotarsale	dex.			54.7					
centrotarsale	dex.			55.0					
centrotarsale	sin.			55.0					
centrotarsale	dex.			55.0					
centrotarsale	sin.			55.6					
centrotarsale	sin.			56.6					

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
centrotarsale	sin.			57.2					
centrotarsale	dex.			57.2					
centrotarsale	dex.			57.3					
centrotarsale	sin.			57.7					
centrotarsale	dex.			61.4					
metatarsus	sin.		187.5	47.9	43.1		21.5	56.1	30.0
metatarsus	dex.		193.1	35.5	36.2	21.5	21.1	44.2	26.1
metatarsus	sin.		197.0	37.8	39.2	23.2	22.0	46.6	27.4
metatarsus	dex.		204.0	40.3	39.1	20.6	21.1	46.0	26.9
metatarsus	dex.		205.0	38.5	22.5	20.5	45.4	24.6	
metatarsus	sin.		205.0	38.8	36.5	21.5	21.9	47.6	26.7
metatarsus	dex.		205.0	41.0	37.5	22.1	22.9	45.0	27.6
metatarsus	dex.		207.5	51.5	48.4	29.7	26.4	64.9	31.9
metatarsus	sin.		210.0	40.2	35.4	21.3	20.1	44.2	25.7
metatarsus	sin.		216.0	44.8	41.2	26.9	23.2	51.2	28.0
metatarsus	sin.		217.0	44.4	43.4	25.0	25.5	53.8	30.3
metatarsus	sin.		217.5	42.0	42.2	24.5	24.6	50.2	28.1
metatarsus	dex.			37.0	37.6				
metatarsus	dex.			37.6					
metatarsus	sin.			37.7	36.0				
metatarsus	dex.			38.2	37.5				
metatarsus	dex.			38.3	37.8				
metatarsus	dex.			39.1	38.4				
metatarsus	sin.			39.3	37.2				
metatarsus	sin.			39.3	38.6				
metatarsus	sin.			39.4	38.7				
metatarsus	sin.			39.4	38.7				
metatarsus	sin.			39.4	40.2				
metatarsus	dex.			39.5	37.5				
metatarsus	dex.			39.6	36.8				
metatarsus	dex.			39.6	38.7				
metatarsus	sin.			39.6	40.9				
metatarsus	dex.			39.8	37.3				
metatarsus	sin.			40.0	39.6				
metatarsus	sin.			40.4	38.5				
metatarsus	sin.			40.4	39.1				
metatarsus	sin.			40.5	37.6	24.1		55.6	30.9
metatarsus	dex.			40.6	39.4				
metatarsus	dex.			40.7	39.8				
metatarsus	sin.			40.8	39.0				
metatarsus	dex.			40.8	39.5				
metatarsus	sin.			40.8	40.9				
metatarsus	sin.			41.0	39.5				
metatarsus	dex.			41.3	40.3				
metatarsus	sin.			41.3	41.4				
metatarsus	dex.			41.3	42.0			50.4	28.4
metatarsus	dex.			41.5	37.1	23.3	21.0		
metatarsus	sin.			41.5	39.0				
metatarsus	sin.			41.5		23.8	21.8		
metatarsus	sin.			41.6	39.7				
metatarsus	dex.			41.7	39.5				
metatarsus	dex.			41.8	39.6				

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
metatarsus	sin.			41.9	41.4				
metatarsus	sin.			42.0	38.1				
metatarsus	dex.			42.0	40.2				
metatarsus	dex.			42.0	41.5				
metatarsus	sin.			42.1	41.4				
metatarsus	sin.			42.2	42.7				
metatarsus	dex.			42.3	41.5				
metatarsus	sin.			42.4	38.7				
metatarsus	sin.			42.4	42.2				
metatarsus	dex.			42.6	41.5				
metatarsus	sin.			42.8	36.0				
metatarsus	sin.			42.8	40.4				
metatarsus	dex.			42.9	41.3				
metatarsus	dex.			43.0	36.0				
metatarsus	sin.			43.1	40.7				
metatarsus	sin.			43.1	41.1				
metatarsus	sin.			43.2	38.5				
metatarsus	dex.			43.3	43.9				
metatarsus	sin.			43.4	39.2				
metatarsus	dex.			43.4	41.2				
metatarsus	sin.			43.5	43.1				
metatarsus	dex.			43.5	46.7				
metatarsus	sin.			43.8	42.8				
metatarsus	sin.			43.8	43.2				
metatarsus	sin.			44.0	42.8				
metatarsus	dex.			44.1	39.4				
metatarsus	sin.			44.2	44.1				
metatarsus	sin.			44.3	42.1				
metatarsus	sin.			44.5	42.2				
metatarsus	sin.			44.6	42.7				
metatarsus	dex.			44.7	42.7	25.0			
metatarsus	dex.			44.7	43.1				
metatarsus	sin.			44.8	43.9				
metatarsus	sin.			45.0	42.8				
metatarsus	dex.			45.0	43.8				
metatarsus	sin.			45.1	40.7				
metatarsus	sin.			45.3	44.6				
metatarsus	sin.			45.4	39.6				
metatarsus	sin.			45.5	42.9	26.4	23.7		
metatarsus	sin.			45.5	44.5				
metatarsus	sin.			45.6	42.1				
metatarsus	dex.			45.6	42.2				
metatarsus	dex.			45.7	42.8				
metatarsus	sin.			45.7	44.4				
metatarsus	sin.			45.7	45.1				
metatarsus	sin.			45.8	41.6				
metatarsus	sin.			45.8	42.1	25.6			
metatarsus	sin.			45.8	44.3				
metatarsus	dex.			45.9	43.4				
metatarsus	sin.			46.1	40.6				
metatarsus	sin.			46.1	45.0				
metatarsus	dex.			46.2	36.1				

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
metatarsus	dex.			46.2	43.8				
metatarsus	dex.			46.3	40.0				
metatarsus	dex.			46.5	41.0				
metatarsus	dex.			46.5	41.6				
metatarsus	sin.			46.5	43.1				
metatarsus	dex.			46.5	43.3				
metatarsus	sin.			46.6	42.0				
metatarsus	sin.			46.6	42.7				
metatarsus	dex.			47.0	44.0			55.1	30.5
metatarsus	sin.			47.0	45.1				
metatarsus	dex.			47.1	44.0				
metatarsus	dex.			47.1	45.4	24.7			
metatarsus	dex.			47.1					
metatarsus	sin.			47.4	44.5				
metatarsus	dex.			47.5	45.6				
metatarsus	dex.			47.7	44.4				
metatarsus	sin.			47.9	44.9				
metatarsus	sin.			48.0	44.3				
metatarsus	sin.			48.2	44.6				
metatarsus	dex.			48.2	46.4				
metatarsus	sin.			48.3	42.5			53.9	29.7
metatarsus	dex.			48.3	44.5				
metatarsus	dex.			48.4	45.0				
metatarsus	dex.			48.5	43.4				
metatarsus	sin.			48.5	43.7				
metatarsus	dex.			48.5	48.0				
metatarsus	sin.			48.6	44.6				
metatarsus	sin.			48.9	40.7				
metatarsus	sin.			48.9	45.1				
metatarsus	dex.			48.9	45.9				
metatarsus	dex.			49.2	42.8				
metatarsus	sin.			49.2	45.1				
metatarsus	dex.			49.4	46.5				
metatarsus	dex.			49.4	48.1				
metatarsus	sin.			49.5	44.0				
metatarsus	dex.			49.6	48.3				
metatarsus	sin.			49.7	46.2				
metatarsus	dex.			50.2	30.0				
metatarsus	dex.			50.2	46.1				
metatarsus	dex.			50.2	50.0				
metatarsus	sin.			50.3	47.4				
metatarsus	dex.			50.4	46.7				
metatarsus	dex.			50.8	47.1				
metatarsus	sin.			51.2	46.2				
metatarsus	sin.			51.4	46.4				
metatarsus	dex.			52.2	48.5				
metatarsus	dex.			52.2	52.0				
metatarsus	sin.			53.3	48.9				
metatarsus	sin.			59.1	38.1				
metatarsus	sin.							41.9	24.3
metatarsus	dex.							43.0	24.7
metatarsus	sin.							43.2	25.7

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
metatarsus	sin.							43.3	25.7
metatarsus	dex.							43.3	27.6
metatarsus	dex.							44.4	24.8
metatarsus	sin.							44.4	26.7
metatarsus	dex.							44.5	24.7
metatarsus	dex.							44.7	27.0
metatarsus	dex.							44.8	26.3
metatarsus	dex.							44.8	27.1
metatarsus	dex.							45.0	24.3
metatarsus	dex.							45.2	25.3
metatarsus	dex.							45.2	26.6
metatarsus	sin.							45.3	25.3
metatarsus	dex.							45.4	26.9
metatarsus	dex.							45.4	27.1
metatarsus	sin.							45.6	23.9
metatarsus	dex.							45.6	27.0
metatarsus	dex.							46.0	26.8
metatarsus	dex.							46.1	26.5
metatarsus	dex.							46.2	26.2
metatarsus	dex.							46.2	
metatarsus	dex.							46.4	27.2
metatarsus	dex.							46.6	27.7
metatarsus	sin.							46.6	27.8
metatarsus	dex.							47.0	28.6
metatarsus	sin.							47.7	26.8
metatarsus	dex.							47.7	27.0
metatarsus	dex.							47.9	27.5
metatarsus	sin.							47.9	27.8
metatarsus	sin.							48.0	27.0
metatarsus	sin.							48.3	26.6
metatarsus	dex.							48.3	26.9
metatarsus	sin.							48.8	26.0
metatarsus	dex.							49.0	26.2
metatarsus	sin.							49.0	27.7
metatarsus	dex.							49.2	27.4
metatarsus	sin.							49.2	27.8
metatarsus	sin.							49.3	28.6
metatarsus	sin.							49.6	28.1
metatarsus	sin.							49.7	29.0
metatarsus	sin.							50.5	27.9
metatarsus	sin.							50.8	27.7
metatarsus	dex.							51.2	27.5
metatarsus	dex.							51.3	28.7
metatarsus	dex.							51.4	29.9
metatarsus	dex.							51.9	28.5
metatarsus	sin.							52.4	30.2
metatarsus	sin.							52.7	29.4
metatarsus	dex.							53.0	29.1
metatarsus	sin.							53.1	29.5
metatarsus	dex.							53.3	28.9
metatarsus	dex.							53.4	28.7
metatarsus	dex.							53.6	30.0

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
metatarsus	dex.							53.8	30.4
metatarsus	sin.							54.2	31.2
metatarsus	sin.							55.0	32.0
metatarsus	sin.							55.3	28.7
metatarsus	dex.							55.7	29.0
metatarsus	sin.							55.8	30.3
metatarsus	sin.							56.1	29.3
metatarsus	dex.					28.2	22.5	56.5	31.4
metatarsus	sin.							56.8	32.7
metatarsus	dex.							57.3	31.7
metatarsus	dex.							57.7	32.1
metatarsus	dex.							59.2	33.1
metatarsus	sin.							59.5	30.5
metatarsus	sin.							63.3	31.7
metatarsus	dex.							66.9	31.1
phalanx prox. post.			48.2	22.5		18.2		21.8	
phalanx prox. post.			49.7	24.0		21.2		23.1	
phalanx prox. post.			50.2	23.6		20.0		22.4	
phalanx prox. post.			50.4	27.4		22.3		25.6	
phalanx prox. post.			50.5	24.7		20.2		22.5	
phalanx prox. post.			50.6	26.8		22.0		24.1	
phalanx prox. post.			51.0	23.5		19.6		23.7	
phalanx prox. post.			52.2	27.5		22.1		25.2	
phalanx prox. post.			52.5	26.8		20.8		23.0	
phalanx prox. post.			52.7	24.2		19.4		22.4	
phalanx prox. post.			52.7	25.0		22.2		23.6	
phalanx prox. post.			53.1	23.3		20.5		23.3	
phalanx prox. post.			53.1	25.1		21.7		23.6	
phalanx prox. post.			53.5	31.2		26.6		28.4	
phalanx prox. post.			53.8	26.3		20.9		22.7	
phalanx prox. post.			54.0	31.2		26.3		28.3	
phalanx prox. post.			54.1	28.9		24.2		27.5	
phalanx prox. post.			54.6	24.5		19.2		24.0	
phalanx prox. post.			54.7	24.5		19.7		25.4	
phalanx prox. post.			54.9	24.5		20.7		22.8	
phalanx prox. post.			54.9	31.2		27.0		27.1	
phalanx prox. post.			55.0	26.4		21.1		25.0	
phalanx prox. post.			55.0	27.0		20.1		24.0	
phalanx prox. post.			55.3	24.8		22.4		23.2	
phalanx prox. post.			55.3	30.9		24.7		28.0	
phalanx prox. post.			55.4	24.5		20.0		21.5	
phalanx prox. post.			55.5	32.1		25.0		28.1	
phalanx prox. post.			55.6	25.1		19.8		21.3	
phalanx prox. post.			56.0	23.6		20.3		24.0	
phalanx prox. post.			56.0	24.8		21.9		23.6	
phalanx prox. post.			56.0	25.2		21.5		23.6	
phalanx prox. post.			56.4	30.7		26.6		28.1	
phalanx prox. post.			56.5	30.0		25.4		29.0	
phalanx prox. post.			56.7	28.3		24.3		27.0	
phalanx prox. post.			56.7	30.7		25.5		29.6	
phalanx prox. post.			57.0	32.2		27.4		29.5	
phalanx prox. post.			57.3	24.8		21.2		23.1	

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
phalanx prox. post.			57.4	32.3		26.0		28.8	
phalanx prox. post.			57.5	26.0		21.4		24.5	
phalanx prox. post.			57.5	26.2		21.2		24.3	
phalanx prox. post.			57.5	27.0		22.0		24.7	
phalanx prox. post.			57.6	24.3		19.5		24.1	
phalanx prox. post.			57.7	31.2		26.8		28.7	
phalanx prox. post.			58.0	27.7		21.2		25.6	
phalanx prox. post.			58.0			23.5		26.5	
phalanx prox. post.			58.2	30.7		26.5		30.2	
phalanx prox. post.			58.2						
phalanx prox. post.			58.3	23.5		19.0		23.3	
phalanx prox. post.			58.5	29.0		23.3		26.3	
phalanx prox. post.			58.5	31.7		25.7		25.7	
phalanx prox. post.			58.9	24.3		21.1		24.5	
phalanx prox. post.			58.9	28.4		24.3		25.7	
phalanx prox. post.			59.2	26.1		24.1		28.9	
phalanx prox. post.			59.4	27.1		22.8		25.7	
phalanx prox. post.			59.6	30.1		23.3		26.1	
phalanx prox. post.			59.6	31.4		27.6		30.6	
phalanx prox. post.			59.6						
phalanx prox. post.			60.3	28.4		22.4		25.7	
phalanx prox. post.			60.3	33.5		28.9		30.0	
phalanx prox. post.			60.4	31.9		26.7		28.0	
phalanx prox. post.			60.6	27.3		23.6		25.9	
phalanx prox. post.			60.8	28.3		25.5		28.3	
phalanx prox. post.			61.6	26.4		22.7		25.8	
phalanx prox. post.			62.1	29.4		24.5			
phalanx prox. post.			62.2	28.9		25.1		27.0	
phalanx prox. post.			62.2			27.2		30.7	
phalanx prox. post.			62.8	30.3		25.4		27.0	
phalanx prox. post.			62.9	30.2		25.0		27.4	
phalanx prox. post.			63.2	29.6		22.9		28.2	
phalanx prox. post.			63.7	25.5		21.9		26.7	
phalanx prox. post.			64.6	30.6		26.5		28.3	
phalanx prox. post.			65.0	30.3		27.8		28.2	
phalanx prox. post.			66.2	32.0		25.7		31.2	
phalanx prox. post.			69.0	32.7		26.1		29.6	
phalanx prox. post.			69.4	30.7		27.1		30.3	
phalanx prox. post.			69.5	30.2		25.7		29.8	
phalanx prox. post.				32.3		26.6		30.5	
phalanx media			32.1	22.7		16.7		18.3	
phalanx media			33.8	24.1		18.2		20.1	
phalanx media			34.0	23.6		18.1		20.1	
phalanx media			34.1	23.4		18.4		19.3	
phalanx media			34.3	24.6		19.6		21.5	
phalanx media			34.3	26.3		20.3		21.3	
phalanx media			34.3	27.4		21.5		23.2	
phalanx media			34.9	23.9		18.2		20.3	
phalanx media			34.9	27.0		21.7		23.3	
phalanx media			35.0	25.0		20.6		22.8	
phalanx media			35.1	23.7		18.3		19.2	
phalanx media			35.5	22.9		17.6			

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
phalanx media			35.6	23.6		18.2		19.8	
phalanx media			35.6	24.4		19.7		20.6	
phalanx media			35.7	26.5		20.4		21.4	
phalanx media			35.8	26.0		20.4		21.4	
phalanx media			36.2	27.0		20.0		22.2	
phalanx media			36.5	30.0		23.6		24.9	
phalanx media			36.6	24.7		19.2		21.1	
phalanx media			36.6	25.0		19.8		20.4	
phalanx media			36.6	26.0		19.7		19.2	
phalanx media			36.9	23.4		17.4		19.3	
phalanx media			37.0			18.6		20.1	
phalanx media			37.1	30.6		24.0		25.5	
phalanx media			37.2	24.3		18.7		20.6	
phalanx media			37.2	25.7		20.4		20.3	
phalanx media			37.2	26.0		20.3		22.8	
phalanx media			37.2	27.8		21.6		24.3	
phalanx media			37.3	25.5		18.7		19.6	
phalanx media			37.4	31.3		23.1		26.6	
phalanx media			37.6	24.6		19.0		21.7	
phalanx media			37.6	27.3		21.2		24.2	
phalanx media			37.7	23.8		18.0			
phalanx media			37.7	25.9		21.3			
phalanx media			37.8	25.6		20.3		21.6	
phalanx media			38.0						
phalanx media			38.1	26.9		20.1		21.0	
phalanx media			38.1	27.6		21.2		24.3	
phalanx media			38.3	24.3		19.4		20.7	
phalanx media			38.3	28.6		23.1		23.8	
phalanx media			38.4	26.0		20.3		21.4	
phalanx media			38.4	30.5		23.5		24.8	
phalanx media			38.7	27.0		20.3		22.3	
phalanx media			38.8	23.4		18.3		18.8	
phalanx media			38.8	26.0		20.0		19.5	
phalanx media			39.0	25.6		19.4		20.6	
phalanx media			39.0	26.7		19.0		21.0	
phalanx media			39.0	27.2		23.0		24.2	
phalanx media			39.0	28.9		23.2		25.4	
phalanx media			39.0	31.5		23.3		25.9	
phalanx media			39.1	30.0		25.2		24.8	
phalanx media			39.2	25.3		19.5		21.2	
phalanx media			39.3	28.8		21.2		23.1	
phalanx media			39.5	26.8		20.1		23.3	
phalanx media			39.5	30.0		24.2		25.0	
phalanx media			39.5	30.2		24.0		24.9	
phalanx media			39.5	31.4		24.8			
phalanx media			39.7	27.0		21.0		23.0	
phalanx media			40.0	31.4		23.5		24.0	
phalanx media			40.1	28.9		23.4		23.9	
phalanx media			40.3	29.8		22.4		25.0	
phalanx media			40.5	28.7		23.0		24.1	
phalanx media			40.5	28.8		23.1		23.6	
phalanx media			40.5	29.1		22.2		23.7	

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
phalanx media			40.5	30.7		24.7		24.7	
phalanx media			40.6	26.2		20.5		20.7	
phalanx media			40.6	27.4		23.0			
phalanx media			40.7	30.1		22.2		23.2	
phalanx media			40.8	30.0		22.1		25.4	
phalanx media			41.0	26.5		21.0		22.6	
phalanx media			41.0	28.0		21.7		24.1	
phalanx media			41.1	32.1		22.8		26.0	
phalanx media			41.4	31.1		23.5		25.0	
phalanx media			41.4	31.3		25.6		26.4	
phalanx media			41.6	29.3		22.0		23.3	
phalanx media			41.6	30.8		23.1		23.9	
phalanx media			41.7	28.4		22.6		24.6	
phalanx media			41.8	29.4		23.6		25.9	
phalanx media			41.9	26.9		23.0		24.0	
phalanx media			42.3	29.5		23.3		25.3	
phalanx media			42.4	30.2		24.0		23.5	
phalanx media			42.5	30.7		23.0		24.0	
phalanx media			42.6	31.2		24.8		25.1	
phalanx media			42.9	31.1		24.8		27.8	
phalanx media			43.2	29.8		21.5		24.0	
phalanx media			43.8	30.1		23.7		25.2	
phalanx media			44.1	29.0		22.8		24.2	
phalanx media			45.0	31.2		24.3		25.9	
phalanx media			45.2	29.0		21.7		23.5	
phalanx media			45.4	29.3		21.8		24.6	
phalanx media			46.0	31.4		25.7		26.6	
phalanx media			46.2	35.0		27.7		29.8	
phalanx media			46.6	33.1		26.2		27.6	
phalanx media			47.0	33.9		26.9		30.7	
phalanx media			47.1	33.9		26.5		29.5	
phalanx media			47.6	31.6		23.2		25.2	
phalanx media			48.5	33.3		26.3		29.1	
phalanx media			49.7	33.2		26.2		28.1	
phalanx media			50.0	31.7		25.5		27.0	
phalanx media			83.7	68.4				28.7	
phalanx dist.			48.5	40.4		15.3			
phalanx dist.			54.1						
phalanx dist.			55.2	50.1		15.0			
phalanx dist.			55.4	41.4		18.3			
phalanx dist.			55.4	46.5		18.9			
phalanx dist.			55.8						
phalanx dist.			56.0						
phalanx dist.			56.0						
phalanx dist.			56.3						
phalanx dist.			56.8						
phalanx dist.			57.0	46.7		19.6			
phalanx dist.			57.1						
phalanx dist.			57.1						
phalanx dist.			57.7	46.7		19.6			
phalanx dist.			58.0						
phalanx dist.			58.3	49.1		18.5			

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
phalanx dist.			58.5						
phalanx dist.			58.8	46.4		18.4			
phalanx dist.			59.1	44.1		18.0			
phalanx dist.			59.2	47.3		19.4			
phalanx dist.			59.2	48.2		18.5			
phalanx dist.			59.2						
phalanx dist.			59.6	49.5		19.3			
phalanx dist.			60.0	45.0		18.2			
phalanx dist.			60.0	46.6		19.0			
phalanx dist.			60.0	47.8		20.0			
phalanx dist.			60.1	46.5		19.5			
phalanx dist.			60.2						
phalanx dist.			60.2						
phalanx dist.			60.3	42.8		20.4			
phalanx dist.			60.3						
phalanx dist.			60.5	46.4		18.7			
phalanx dist.			60.6	49.4		21.6			
phalanx dist.			61.3	48.7		22.6			
phalanx dist.			61.4	48.0		20.9			
phalanx dist.			61.5						
phalanx dist.			61.7	45.4		19.4			
phalanx dist.			62.0						
phalanx dist.			62.3	45.2		20.5			
phalanx dist.			62.4	47.0		20.0			
phalanx dist.			62.5	43.6		19.4			
phalanx dist.			62.6	48.8		20.4			
phalanx dist.			62.8	49.6		19.5			
phalanx dist.			63.2	47.3		21.0			
phalanx dist.			63.2	47.6		25.7			
phalanx dist.			63.2						
phalanx dist.			63.3	50.6		18.5			
phalanx dist.			64.2	48.2		20.5			
phalanx dist.			64.3	48.6		21.0			
phalanx dist.			64.8	54.5		24.6			
phalanx dist.			64.9	47.2		20.8			
phalanx dist.			65.0	53.6		25.8			
phalanx dist.			65.2						
phalanx dist.			65.2						
phalanx dist.			65.3	47.4		20.1			
phalanx dist.			65.4	48.7		20.5			
phalanx dist.			65.5	53.7		22.0			
phalanx dist.			65.6	53.4		24.7			
phalanx dist.			65.6						
phalanx dist.			65.9	52.8		22.6			
phalanx dist.			66.0	51.6		23.6			
phalanx dist.			66.0	52.3		21.1			
phalanx dist.			66.3	49.1		20.3			
phalanx dist.			66.6	49.6		21.0			
phalanx dist.			66.6	53.9		22.5			
phalanx dist.			66.8	54.6		24.8			
phalanx dist.			67.1						
phalanx dist.			67.2						

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
phalanx dist.			67.5	49.3		23.5			
phalanx dist.			67.5						
phalanx dist.			67.8						
phalanx dist.			67.9	54.5		24.3			
phalanx dist.			68.0						
phalanx dist.			68.3	56.1		23.9			
phalanx dist.			68.7						
phalanx dist.			69.0	57.0		25.0			
phalanx dist.			69.4	51.4		23.7			
phalanx dist.			69.6	57.4		24.3			
phalanx dist.			69.7	55.0		23.0			
phalanx dist.			70.2	53.4		25.7			
phalanx dist.			70.7	52.6		23.3			
phalanx dist.			70.7	53.8		27.7			
phalanx dist.			71.2	51.8		22.8			
phalanx dist.			71.2						
phalanx dist.			71.7	57.0		22.4			
phalanx dist.			72.0	52.4		24.8			
phalanx dist.			72.1	54.0		24.6			
phalanx dist.			73.0						
phalanx dist.			73.5	51.5		21.8			
phalanx dist.			73.5	53.0		26.0			
phalanx dist.			73.6	53.4		27.0			
phalanx dist.			73.8	52.9		26.3			
phalanx dist.			74.1	56.7		27.5			
phalanx dist.			74.4	53.1		23.8			
phalanx dist.			74.4	55.1		25.4			
phalanx dist.			74.5	54.9		26.4			
phalanx dist.			75.4	56.8		22.4			
phalanx dist.			75.8	56.4		28.0			
phalanx dist.			75.9	53.8		23.4			
phalanx dist.			76.1						
phalanx dist.			76.2	56.0		22.0			
phalanx dist.			77.0	55.2		22.3			
phalanx dist.			78.0	62.0		25.6			
phalanx dist.			78.3	58.8		24.2			
phalanx dist.			78.7	60.8		30.9			
phalanx dist.			79.2						
phalanx dist.			79.5	60.0		29.2			
phalanx dist.			79.6	57.3		25.6			
phalanx dist.			79.8	57.0		27.1			
phalanx dist.			79.8	60.7		25.1			
phalanx dist.			80.3						
phalanx dist.			80.8	61.0		25.6			
phalanx dist.			82.4	62.1		26.2			
phalanx dist.			82.8						
phalanx dist.			83.1	63.1		24.7			
phalanx dist.			85.0						
phalanx dist.			88.1	62.1		31.8			
phalanx dist.			89.0						
phalanx dist.			90.6	61.4		26.7			
phalanx dist.			94.9	70.2		31.2			

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
Sheep (*Ovis aries* Linnaeus, 1758)									
proc. cornualis	sin.		115.0	40.9	24.3				
proc. cornualis	sin.		120.0	35.2	22.7				
proc. cornualis	dex.		182.0						
proc. cornualis	dex.		185.0						
proc. cornualis	dex.		200.0	38.6	23.0				
proc. cornualis	dex.			37.3	26.6				
proc. cornualis				39.7	24.1				
proc. cornualis	sin.			40.0	24.5				
proc. cornualis	dex.			51.5					
proc. cornualis	sin.			53.2	32.1				
atlas	sin.		50.3	66.5					
axis			54.5						
axis			46.8						
LP2-M3 teeth	dex.		68.2						
LP2-M3 teeth			70.6						
LP2-M3 teeth			75.4						
LP2-4 teeth			23.2						
LM1-3 teeth			46.0						
LM1-3 teeth			49.6						
LM1-3 teeth			50.9						
LM3 teeth			22.8	8.0					
LM3 teeth	dex.		23.1	8.0					
LM3 teeth	dex.		25.0	8.9					
scapula	sin.					20.0		29.5	20.8
scapula	dex.					20.9		31.1	19.2
scapula	dex.					24.5		38.3	25.2
humerus	dex.			32.0	40.0				
humerus	dex.			32.9	41.5				
humerus	sin.			36.8	46.1				
humerus	dex.			40.2	44.8				
humerus	sin.			40.9	45.1				
humerus	dex.			43.2	46.5				
humerus	dex.							28.2	25.0
humerus	sin.							28.7	26.9
humerus	dex.							29.4	26.1
humerus	sin.							29.6	25.1
humerus	sin.							30.1	26.3
humerus	sin.							30.2	25.8
humerus	dex.							30.5	25.0
humerus	sin.							31.6	26.5
humerus	dex.							31.8	25.3
humerus	dex.							32.1	27.0
humerus	sin.							32.2	27.0
humerus	dex.							32.5	26.6
humerus	sin.							32.7	29.8
humerus	dex.							33.1	29.2
humerus	dex.							33.4	30.0
humerus	dex.							33.6	29.1
humerus	dex.							33.9	28.3
humerus	sin.							34.2	29.5
humerus	dex.							34.3	

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
humerus	dex.							35.2	30.9
humerus	dex.							37.4	31.1
radius	dex.			29.2	15.5				
radius	sin.			29.2	16.5				
radius	sin.			30.8	15.4	16.8			
radius	dex.			31.3					
radius	dex.			32.1	17.5				
radius	sin.			32.2	16.7				
radius	dex.			32.5	16.0				
radius	sin.			32.6	17.1				
radius	sin.			32.8	16.7				
radius	sin.			34.2	17.2				
radius	sin.			34.5	17.6				
radius	sin.			34.8	17.4				
radius	dex.			36.9	19.0				
radius	sin.				16.2	8.6		30.2	20.4
radius	sin.							31.2	21.1
radius	dex.							32.9	23.0
radius	sin.							32.9	24.0
radius	sin.							34.0	22.1
metacarpus	dex.		121.8	22.1	16.5		8.4	25.6	16.0
metacarpus	dex.		126.0			13.2		24.9	
metacarpus	dex.	ram	144.3	27.5	17.8	16.9	11.4		17.9
metacarpus	sin.			23.0	15.0				
metacarpus	dex.			24.2	17.1				
metacarpus	dex.			24.2	18.2				
metacarpus	sin.			28.5	19.7				
metacarpus	sin.			28.8	20.7				
metacarpus	sin.			29.0	20.7				
metacarpus	sin.						10.0	21.1	18.2
metacarpus	dex.							25.8	17.1
metacarpus	sin.							25.8	17.7
metacarpus	sin.							26.2	13.4
metacarpus	sin.							26.2	18.3
metacarpus	sin.							27.0	18.7
metacarpus	dex.							28.9	18.9
metacarpus	sin.							30.6	18.3
femur	dex.			44.1					
femur	dex.			47.4	25.5				
femur	sin.			47.5	26.9				
femur	dex.							39.1	49.0
femur	sin.							40.0	45.2
femur	sin.							41.5	50.5
femur	sin.							45.6	40.0
femur	dex.							48.5	60.0
patella	dex.		21.6	13.9					
tibia	sin.			43.0	43.2				
tibia	sin.			46.4	48.7				
tibia	sin.							21.9	18.1
tibia	dex.							24.3	19.7
tibia	sin.							25.1	20.5
tibia	dex.							25.3	21.6

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
tibia	sin.							26.0	21.0
tibia	sin.						11.5	26.0	21.5
tibia	sin.					16.2		26.3	21.0
tibia	sin.							26.8	19.5
tibia	dex.					14.9	12.4	26.8	20.7
tibia	dex.							26.9	21.3
tibia	sin.							27.4	22.5
tibia	sin.							28.1	24.1
tibia	dex.							28.2	23.0
tibia	dex.							28.9	21.0
tibia	dex.							29.0	23.5
tibia	sin.							29.4	23.1
tibia	sin.							29.4	23.5
tibia	sin.							29.9	21.0
tibia	dex.							31.8	24.1
astragalus	sin.		28.0	23.9				18.0	15.2
astragalus	dex.		29.9	27.9				19.6	17.0
astragalus	sin.		30.2	28.1				19.8	17.1
astragalus	sin.		33.6	18.6	18.7			21.3	16.0
astragalus	sin.		36.0	20.5	20.1			23.5	17.7
calcaneus	sin.		53.2	19.6					
calcaneus	dex.		61.1					24.1	22.0
calcaneus	sin.		63.0					21.8	25.0
calcaneus	dex.		63.2						
calcaneus	sin.		63.5	21.8					
calcaneus	dex.		64.2	20.6					
calcaneus	sin.		64.3	21.4					
calcaneus	sin.		65.8	22.2					
metatarsus	sin.	ewe	128.2	20.1	19.4	11.4	9.6	24.0	15.1
metatarsus	sin.		156.0	23.0	23.1		10.4	25.2	17.5
metatarsus	sin.			20.3	20.5			25.9	16.9
metatarsus	sin.			21.0	20.2				
metatarsus	sin.			21.1	18.9				
metatarsus	sin.			21.1	20.6				
metatarsus	sin.			21.6	21.1				
metatarsus	sin.			22.0	21.9				
metatarsus	dex.			22.1	20.7	14.0	12.0		
metatarsus	sin.			22.1	21.8				
metatarsus	dex.			22.6	22.6				
metatarsus	dex.			24.8	23.4				
metatarsus	sin.			25.3	24.2				
metatarsus	dex.						11.1	23.2	16.2
metatarsus	sin.							24.0	16.2
metatarsus	sin.						10.0	24.0	16.7
metatarsus	sin.							25.8	16.9
metatarsus	sin.						11.1	26.2	17.0
metatarsus	sin.						11.6	27.1	17.5
metatarsus	sin.					14.8	12.8	27.6	17.9
phalanx prox.			40.0	12.6		10.9		11.7	
Goat (*Capra hircus* Linnaeus, 1758)									
proc. cornualis	dex.		118.0						
proc. cornualis			142.0	31.4	21.7				

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
proc. cornualis	sin.		199.0	36.2	23.0				
proc. cornualis	dex.			31.5	18.7				
proc. cornualis	sin.			35.1	23.3				
proc. cornualis	sin.			36.2	20.0				
proc. cornualis	dex.			36.6	24.4				
LP2-M3 teeth			67.5						
LP2-M3 teeth			69.4						
LP2-4 teeth			23.0						
LP2-4 teeth			23.4						
LM1-3 teeth			44.0						
LM1-3 teeth			44.6						
atlas			49.5	60.8					
atlas				68.5					
humerus	sin.							30.1	26.6
humerus	sin.							30.5	29.2
humerus	dex.							31.6	28.1
radius	sin.			31.6	16.4				
radius	dex.			32.6	17.6				
radius	dex.			35.4	17.7				
radius	sin.							33.0	22.2
metacarpus	dex.		109.4	24.1	17.3	16.1	9.2	27.9	16.8
metacarpus	sin.	male	146.0	26.6	17.9	17.1	12.0	28.7	18.2
metacarpus	dex.			23.4	20.3				
metacarpus	dex.			25.0	17.1		9.9		
metacarpus	sin.			25.2	18.1		11.1	29.0	15.8
metacarpus	dex.			27.3	20.0	15.4	10.4		
metacarpus	sin.							27.8	17.2
metacarpus	sin.							28.5	15.0
tibia	dex.							24.1	19.2
astragalus	dex.		32.3	18.0	19.2			21.3	16.1
astragalus	sin.		33.3	18.8	20.0			23.3	17.5
metatarsus	sin.	female	112.4	20.5	18.6	12.3	11.7	26.2	15.9
metatarsus	dex.	male	157.8	22.8	22.6	13.4	12.6	18.1	
metatarsus	sin.			21.0	20.9				
metatarsus	dex.			21.6	22.2				
metatarsus	sin.			22.1	21.9				
metatarsus	dex.			22.2	22.1		11.1	27.0	16.0
metatarsus	dex.			23.0	23.5	13.0	11.4		
metatarsus	sin.			24.0	21.6				
Pig (*Sus domesticus* Erxleben, 1777)									
UM1-3 teeth	sin.		61.2						
UM1-3 teeth	sin.		65.1						
UM3 tooth	sin.		28.2	17.9					
UM3 tooth	sin.		33.2	16.9					
LM3 tooth	sin.		29.1	16.0					
LM3 tooth	sin.		37.0	16.0					
scapula	dex.					22.9		23.1	22.6
scapula	sin.					24.1		37.0	25.8
humerus	sin.							32.7	26.7
humerus	sin.					14.2	22.1	37.2	37.0
humerus	dex.					16.2	21.0	39.1	37.5
humerus	dex.					19.0	25.3	42.0	39.8

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
radius	sin.			26.0	17.5	13.5	9.2		
radius	dex.			31.1	20.4	19.5	11.1		
femur	sin.			56.1	32.0				
femur	sin.							41.1	53.0
femur	dex.							44.8	57.1
tibia	dex.							29.9	26.5
Horse (*Equus caballus* Linnaeus, 1758)									
humerus	sin.					29.2	37.3	68.6	73.5
humerus	dex.					39.7	45.9	79.5	89.0
humerus	dex.							89.8	
radius	sin.		351.0	79.5	46.3	38.4	29.5	76.2	47.8
radius	sin.							72.8	39.8
os carpale III	dex.			40.5					
metacarpus	dex.		227.0	49.8	33.6	34.5	21.0	48.3	37.2
metacarpus	dex.			19.2	14.3				
os tarsale III	sin.			42.4					
astragalus	dex.		59.7	60.2	56.5				
Dog (*Canis familiaris* Linnaeus, 1758)									
humerus	sin.		190.0	32.0	46.0	13.0	15.0	35.0	31.5
radius	dex.		173.2	19.0	12.5	12.5	6.5	25.0	14.0
tibia	dex.		184.0	34.0	37.0	12.0	12.0	23.0	18.0
tibia	dex.		196.0	33.5	37.0	13.0	12.5	24.0	18.5
fibula	sin.		175.4						
Domestic cat (*Felis catus* Linnaeus, 1758)									
humerus	sin.		84.8	13.4	16.4	5.0	6.0	15.1	8.2
humerus	dex.		87.9	18.2	15.4	5.7	6.7	16.2	9.9
humerus	sin.		88.4	14.2	17.0	5.5	6.8	15.6	9.1
humerus	dex.		88.7	14.4	17.4	5.6	6.8	15.9	9.2
humerus	sin.		89.1	14.2	16.8	5.3	6.6	15.8	8.7
humerus	dex.					5.1	6.1	14.8	8.3
radius	dex.		88.5	7.7	5.8	4.7	3.2	12.1	6.8
radius	sin.		92.1	7.4	5.5	4.9	2.9	11.0	6.4
radius	sin.		95.2	8.8	5.9	5.4	3.1	12.3	7.5
ulna	dex.		14.1						
ilium	sin.		88.2						
femur	sin.		95.9	17.9	9.0	7.3	6.5	15.9	15.3
femur	dex.		96.0	18.0	8.7	7.7	7.6	16.3	
tibia	sin.			16.1	16.9				
tibia	dex.							12.5	8.5
tibia	sin.							14.1	8.3
tibia	sin.							14.1	9.5
Domestic hen (*Gallus domesticus* Linnaeus, 1758)									
coracoideum	sin.		45.1	43.2		3.8		13.2	10.7
coracoideum	sin.		46.3	44.5		4.3		13.0	10.5
coracoideum	dex.		46.4	44.2		4.2		12.7	9.9
coracoideum	dex.		46.7	44.7		4.1		12.0	9.6
coracoideum	sin.		47.0	45.2		4.0		12.2	9.8
coracoideum	dex.		47.7	45.6		4.8		13.7	10.2
coracoideum	sin.		48.0	45.7		4.1		11.5	9.6
coracoideum	sin.		48.5			4.2		12.0	9.2
coracoideum	dex.		48.8	46.3		4.2			10.7
coracoideum	sin.		48.8	46.7		4.1		11.8	9.4

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
coracoideum	sin.		48.9	46.2		4.8		14.1	11.1
coracoideum	sin.		49.0	46.4		4.5		12.8	10.3
coracoideum	dex.		49.3	46.6		4.6		12.6	10.8
coracoideum	sin.		49.5	47.1		4.9		13.4	11.8
coracoideum	sin.		49.5	47.1		4.1		12.7	10.0
coracoideum	sin.		49.5	47.3		4.0		12.3	10.6
coracoideum	dex.		49.8	49.7		4.0			10.9
coracoideum	sin.		50.6			4.1		11.9	10.4
coracoideum	dex.		50.8	49.7		4.4		12.7	10.0
coracoideum	dex.		51.1	48.8		4.5		13.2	11.5
coracoideum	sin.		51.3	48.8		4.6		12.1	10.2
coracoideum	sin.		51.4	49.7		4.5		12.8	10.4
coracoideum	dex.		51.8	48.6		4.9		14.6	11.9
coracoideum	sin.		51.8	48.7		5.0			12.0
coracoideum	dex.		52.0	50.3		5.1		13.1	11.4
coracoideum	dex.		52.1	49.6		4.7		13.3	10.3
coracoideum	sin.		52.2	50.2		5.4		13.4	11.5
coracoideum	dex.		52.4	50.3		4.7		14.3	11.5
coracoideum	sin.		52.6	50.3		5.0		14.0	10.7
coracoideum	sin.		52.6	50.4		4.8		14.6	11.6
coracoideum	sin.		54.0	51.7		4.5		13.2	11.4
coracoideum	dex.		54.5	52.4		4.7		15.0	12.3
coracoideum	dex.		54.9	52.6		4.7		15.6	12.3
coracoideum	sin.		56.6	54.1		5.8			13.0
coracoideum	dex.		57.7	55.7		5.2		14.2	11.8
coracoideum	dex.		58.8			5.5			
coracoideum	sin.	rooster	59.3	56.0		6.2		17.0	15.7
coracoideum	dex.	rooster	60.6	57.5		5.8		16.8	13.8
coracoideum	sin.		61.5	59.5		5.8			
scapula	dex.		60.0			4.0		10.3	
scapula	sin.		60.1			4.4		10.9	
scapula	dex.		61.0			4.2		10.3	
scapula	dex.		61.3			4.5		10.7	
scapula	dex.		62.7			4.2		11.2	
scapula	sin.		63.0			5.1		11.1	
scapula	sin.		63.2			4.5		10.9	
scapula	sin.		63.3			4.3		10.7	
scapula	dex.		63.4			4.8		11.0	
scapula	sin.		64.6			4.3		10.6	
scapula	dex.		64.7			5.2		11.2	
scapula	sin.		65.0			4.8		11.4	
scapula	dex.		65.2			4.4		11.0	
scapula	dex.		66.3			4.2		10.7	
scapula	sin.		66.6			4.9		12.1	
scapula	dex.		67.0			5.3		12.4	
scapula	dex.		67.0			5.3		12.4	
scapula	dex.		67.6			4.6		11.0	
scapula	dex.		67.7			5.2		11.4	
scapula	sin.		69.0			5.1		11.6	
scapula	dex.		69.3			5.2		11.6	
scapula	sin.		70.0			4.8		11.2	
scapula	sin.		74.9			6.2		13.0	

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
scapula	sin.	rooster	78.2			5.7		13.3	
scapula	dex.	rooster	78.8					13.5	
scapula	sin.					4.5		10.0	
scapula	dex.					4.0		10.1	
scapula	sin.					4.2		10.3	
scapula	dex.					4.8		11.1	
scapula	sin.					4.2		11.3	
scapula	sin.					5.0		11.4	
scapula	dex.					5.0		11.5	
scapula	sin.					5.2		12.2	
scapula	sin.					5.3		12.2	
scapula	dex.					6.0		12.8	
sternum			100	75.0					
sternum			103.8	78.2					
sternum			127.0						
humerus	sin.		58.9	16.1		5.8			7.1
humerus	dex.		60.5	17.1		6.1			7.7
humerus	sin.		60.8	17.0		6.1			7.3
humerus	sin.		61.1	18.3		6.3			7.6
humerus	sin.		61.5	17.3		6.0			7.5
humerus	dex.		61.8	17.7		6.6			7.7
humerus	sin.		61.9	17.6		6.2			7.5
humerus	dex.		62.0	18.3		6.4			7.7
humerus	sin.		62.2	18.2		6.5			8.0
humerus	dex.		62.3	17.1		6.2			7.3
humerus	dex.		62.4	18.3		6.7			7.7
humerus	dex.		62.5	18.0		6.2			7.2
humerus	sin.		62.6	17.8		5.9			7.2
humerus	sin.		62.6	18.4		6.5			7.6
humerus	dex.		63.0	16.3		5.9			6.9
humerus	sin.		63.0	17.8		5.9			7.2
humerus	sin.		63.2	17.2		6.1			7.2
humerus	dex.		63.2	18.4		6.5			7.5
humerus	dex.		63.3	18.5		6.0			7.7
humerus	sin.		63.7	18.4		6.4			7.7
humerus	sin.		63.8	18.4		6.0			8.1
humerus	sin.		64.0	17.5		6.2			7.5
humerus	sin.		64.1	17.7		5.8			7.5
humerus	sin.		64.1	18.1		6.3			7.1
humerus	dex.		64.2	17.7		5.9			7.4
humerus	dex.		64.2	18.0		6.5			7.6
humerus	dex.		64.6	18.3		6.2			7.5
humerus	sin.		65.1	17.5		6.2			7.3
humerus	sin.		65.1	18.1		6.4			7.8
humerus	sin.		65.2	18.7		6.6			
humerus	dex.		65.4	18.6		7.1			8.0
humerus	sin.		65.5	18.6		6.9		13.7	8.3
humerus	dex.		65.7	19.3		6.3		14.6	8.0
humerus	sin.		65.8	18.6		6.6		13.8	8.0
humerus	dex.		66.1	17.7		6.5		13.4	7.5
humerus	sin.		66.1	19.6		6.5		14.8	8.1
humerus	dex.		66.3	18.3		6.3		13.8	7.6

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
humerus	sin.		66.5	17.9		6.2		13.7	7.4
humerus	sin.		66.5	18.4		6.4		13.7	7.4
humerus	sin.		66.6	18.8		7.0		14.4	8.0
humerus	dex.		67.8	19.1		7.2		15.0	7.8
humerus	sin.		67.8	19.1		7.3		14.7	7.7
humerus	dex.		69.2	19.6		6.6		14.7	8.4
humerus	sin.		69.7	19.7		6.3		14.6	8.8
humerus	sin.		70.0	20.0		7.5		14.5	8.0
humerus	sin.		71.5	19.2		6.9		15.9	9.1
humerus	dex.		71.5	20.0		7.3		15.0	8.4
humerus	dex.		71.9	18.1		6.7		14.9	8.1
humerus	sin.		72.0	19.1		7.2			
humerus	sin.		72.1	20.2		7.1		15.4	8.4
humerus	sin.		72.4			7.0			
humerus	sin.		74.1	20.9		7.5		15.9	9.1
humerus	dex.		74.4	21.1		7.7		16.1	8.8
humerus	sin.		74.4	21.4		7.3		16.0	8.4
humerus	dex.		74.5	21.5		7.4		15.6	9.0
humerus	sin.		74.9	21.4		7.5		15.9	9.2
humerus	sin.		75.1	21.3		7.8		16.2	9.5
humerus	sin.	rooster	78.0	22.3		7.4		16.7	9.4
humerus	dex.	rooster	79.9	23.0		7.4		17.7	9.8
humerus	sin.	rooster	80.3	23.1		7.3		17.8	9.9
humerus	sin.			16.4					
humerus	dex.			19.1					
humerus	dex.			19.3					
humerus	sin.			20.0					
humerus	dex.			20.3		7.7			
humerus	dex.			20.4					
humerus	dex.			20.5					
humerus	sin.			20.8					
humerus	sin.					5.8		13.4	7.2
humerus	sin.					6.3		13.5	7.5
humerus	dex.					6.6		15.0	8.2
humerus	sin.							14.5	8.3
humerus	sin.							14.8	8.5
radius	dex.		48.2						
radius	sin.		50.2						
radius	sin.		53.7			2.8		6.0	
radius	sin.		53.9			2.6		5.8	
radius	dex.		53.9			2.8		5.8	
radius	dex.		55.2			2.6		6.1	
radius	sin.		55.3			2.5		6.1	
radius	sin.		55.8			2.6		5.7	
radius	sin.		56.2			2.5		6.1	
radius	sin.		56.4			2.8		6.1	
radius	dex.		56.4			2.7		6.1	
radius	dex.		57.7			2.4		6.2	
radius	sin.		58.0			2.6		6.1	
radius	dex.		58.4			2.7		6.1	
radius	sin.		58.9						
radius	sin.		59.0			2.8			

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
radius	sin.		59.1			2.9		6.1	
radius	dex.		59.3			2.8		6.3	
radius	dex.		59.7			2.8		6.5	
radius	sin.		60.0			2.7		6.5	
radius	sin.		60.3			3.0		6.6	
radius	dex.		60.5			3.3		6.8	
radius	dex.		63.6						
radius	dex.		64.1			2.8		6.7	
radius	sin.		64.2			2.8		6.7	
radius	sin.		64.5						
radius	dex.		65.2						
radius	dex.		67.8			3.1		7.3	
radius	dex.					2.6		5.6	
ulna	dex.		57.8	7.4	10.6	3.8		8.3	6.0
ulna	sin.		59.9						
ulna	dex.		60.0	7.9	11.4	3.8		8.3	6.5
ulna	sin.		60.0	8.5	11.5	3.7		8.5	6.4
ulna	sin.		60.0						
ulna	sin.		60.1						
ulna	dex.		60.4	8.2	11.6	3.8		8.8	6.8
ulna	sin.		60.5	8.5	11.5	3.9		8.5	6.6
ulna	sin.		61.0	8.1	11.9	3.6		8.6	6.0
ulna	sin.		61.6	8.4	12.3	3.8		8.8	6.6
ulna	dex.		61.8	7.5		3.5		8.6	6.4
ulna	dex.		61.9	7.5	11.6	3.8		8.6	6.6
ulna	dex.		61.9	8.0	11.2	3.5		8.5	6.3
ulna	sin.		61.9	8.4	11.4	3.7		8.5	6.4
ulna	dex.		62.2	8.1	12.2	3.9		8.7	6.7
ulna	dex.		62.7	8.6	11.9	3.8		8.5	6.6
ulna	sin.		63.0						
ulna	dex.		63.1	7.7	11.8	3.6		8.7	6.6
ulna	sin.		63.1						
ulna	sin.		63.2	8.3	12.1	3.7		8.7	6.6
ulna	sin.		63.2	8.5	11.9	3.6		8.9	6.6
ulna	sin.		63.2						
ulna	sin.		63.3	8.8	12.2	4.5		9.1	6.6
ulna	sin.		64.2						
ulna	dex.		64.3	7.7	11.4	3.6		8.6	6.1
ulna	sin.		64.3	8.3	11.9	4.0		8.8	6.5
ulna	sin.		64.4	8.1	11.8	3.7		8.8	6.1
ulna	sin.		64.5	8.2	12.0	3.9		8.8	6.7
ulna	sin.		64.5						
ulna	dex.		64.8	7.9	12.0	3.9		8.7	6.7
ulna	sin.		65.1						
ulna	dex.		65.6	8.8	12.2	3.9		9.4	6.4
ulna	sin.		65.7	8.9	12.0	4.3		9.1	6.7
ulna	dex.		66.0	9.3	13.6	4.0		9.9	7.3
ulna	sin.		66.2	8.8	12.2	4.3		9.2	6.8
ulna	sin.		66.3	9.4	12.9	4.0		9.4	6.5
ulna	dex.		66.4	7.9	10.6	4.0		9.2	7.2
ulna	dex.		66.5	8.6	12.4	4.5		9.4	6.9
ulna	dex.		66.6	8.8	12.6	3.8		9.2	6.7

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
ulna	sin.		66.9						
ulna	sin.		67.1	8.8	13.0	3.8		9.4	6.9
ulna	dex.		67.2	8.1	12.7	4.1		9.3	6.8
ulna	sin.		68.7						
ulna	sin.		69.2						
ulna	sin.		70.0						
ulna	dex.		70.6	8.4	13.3	4.2		9.9	6.9
ulna	sin.		70.9	9.3	13.4	4.1		10.2	6.7
ulna	sin.		71.1						
ulna	sin.		71.2						
ulna	dex.		71.8	9.6	13.1	3.9		10.0	7.2
ulna	sin.		73.4	9.8	14.1	4.4		10.0	7.8
ulna	sin.		73.7	8.9	13.4	4.9		10.2	7.4
ulna	sin.		74.3						
ulna	sin.		75.2						
ulna	dex.		76.5	9.1	15.1	4.5		10.4	8.1
ulna	sin.	rooster	76.9	10.0	15.3	4.6		10.8	8.4
ulna	sin.		78.2	10.2	15.6	5.0		11.0	8.4
ulna	sin.		78.2						
ulna	sin.		78.8						
ulna	sin.		79.0						
ulna	sin.		85.3	11.4	14.1	5.8		11.8	8.4
ulna	dex.			7.9	11.2	3.5			
ulna	dex.			7.9	11.9	3.6			
ulna	dex.			8.7	13.1	3.8			
carpometacarpus	dex.		32.0	10.3				6.3	
carpometacarpus	sin.		32.3	10.4				7.4	
carpometacarpus	sin.		33.8	10.8				6.6	
carpometacarpus	dex.		33.9	10.3				6.3	
carpometacarpus	sin.		35.1	10.8				7.1	
carpometacarpus	dex.		35.1	10.9				7.0	
carpometacarpus	dex.		35.8	11.3				7.5	
carpometacarpus	sin.		36.0	11.5				7.3	
carpometacarpus	sin.		36.2	11.8				7.3	
carpometacarpus	sin.		36.3	11.1				7.3	
carpometacarpus	dex.		36.3	11.4				7.0	
carpometacarpus	dex.		36.3	11.8				7.3	
carpometacarpus	sin.		37.0	11.6	5.8	8.8		7.1	3.9
carpometacarpus	sin.		41.1	12.5	6.1	9.7		8.2	4.6
carpometacarpus	sin.							8.0	4.6
pelvis			101.3	109.2					
femur	dex.		60.8						
femur	sin.		61.2						
femur	sin.		66.2			5.6		12.6	9.8
femur	dex.		67.5	14.0	9.4	6.0		13.8	11.1
femur	sin.		67.7	14.1	9.4	6.3		13.2	11.1
femur	sin.		68.0	13.3	8.9	6.0		13.4	11.0
femur	dex.		68.0	13.8	9.0	6.1		13.4	11.0
femur	sin.		68.0	63.0	14.2	9.2	6.3	13.3	10.7
femur	sin.		68.6	14.3	9.3	6.2		12.9	11.2
femur	sin.		69.0	13.1	8.8	5.0	5.0	13.1	10.2
femur	dex.		69.0	13.6	9.4	6.2		12.9	11.4

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
femur	sin.		69.0	14.8	10.6	6.0		14.2	12.0
femur	sin.		69.1	14.2	9.6	6.5		13.4	10.8
femur	dex.		69.3	13.7	9.5	6.1		12.9	11.0
femur	dex.		69.4	14.2	9.4	6.1		13.2	11.0
femur	sin.		69.4	14.7	9.8	5.6		14.3	11.0
femur	dex.		69.6	14.2	10.2	6.8		13.2	10.4
femur	dex.		69.8	13.5	9.0	5.3	5.1	13.3	10.4
femur	dex.		69.8	14.3	9.1	6.0		13.3	11.4
femur	sin.		70.2	14.2	9.7	6.2		13.4	11.4
femur	dex.		70.2	14.5	10.0	6.0		13.3	10.5
femur	sin.		70.4	14.4	9.3	6.1		14.1	12.4
femur	sin.		70.5	14.1	9.9	6.2		13.8	11.8
femur	sin.		70.6	14.8	9.5	6.3		14.6	12.1
femur	dex.		70.7	14.6	9.6	5.9		13.9	12.0
femur	dex.		70.7	14.8	9.7	6.4		13.7	11.8
femur	dex.		70.9	14.3	9.8	6.2			
femur	sin.		71.2	14.0	9.6	5.9		13.3	11.5
femur	dex.		71.2	14.4	9.7	6.1		12.9	11.5
femur	dex.		71.4	14.9	10.3	5.9		13.2	10.5
femur	sin.		72.1	15.2	9.7	6.1		14.2	12.2
femur	sin.		72.1	15.3	9.8	6.1		13.7	11.4
femur	sin.		72.5	15.2	9.4	6.9	6.1	14.2	12.1
femur	dex.		72.5	15.3	10.0	6.2		14.1	12.4
femur	sin.		73.3	14.8	9.7	6.4		13.8	11.6
femur	sin.		73.5	14.5	9.3	6.2		14.3	11.3
femur	dex.		73.6	14.8	10.0	6.1		14.0	11.4
femur	dex.		73.7	15.1	10.5	6.3		14.1	12.0
femur	sin.		73.8	68.3	14.4	9.9	6.3	13.9	12.4
femur	sin.		74.0	14.6	9.7	6.3		15.3	12.7
femur	dex.		74.9	14.8	10.1	6.6		13.5	10.9
femur	dex.		75.0	15.8	10.4	6.9	6.0	15.2	12.4
femur	sin.		75.1	14.0	7.9	7.5		14.9	11.2
femur	sin.		75.3	14.6	9.9	6.7		14.3	11.7
femur	dex.		75.3	16.4	11.1	7.1		16.1	13.0
femur	dex.		75.4	15.8	10.4	6.6		15.0	12.1
femur	dex.		75.5	16.4	11.4	6.4		15.1	13.0
femur	sin.		75.6	16.3	10.7	7.0		15.9	13.2
femur	sin.		75.8	16.2	10.5	7.3	6.4	16.0	13.1
femur	sin.		76.1	16.1	10.4	7.1	6.2	15.8	12.9
femur	sin.		76.2	16.1	11.1	6.5		15.7	13.3
femur	dex.		76.6	15.6	10.2	7.0	6.1	15.8	12.5
femur	dex.		77.0	15.8	10.5	7.1	6.3	16.0	12.9
femur	dex.		77.1	14.7	9.9	6.9			
femur	dex.		78.3	15.6	11.5	7.2		15.3	12.9
femur	dex.		79.1	17.4	11.6	7.7		18.4	13.5
femur	dex.		81.0	16.4	10.7	7.1		14.8	12.0
femur	sin.		81.8	16.2	11.5	7.1		16.2	12.8
femur	sin.	rooster	82.0	17.1	11.3	6.8		15.5	13.1
femur	sin.		82.4	17.5	13.0	7.7		17.0	14.2
femur	dex.		82.6	16.7	12.2	7.8		16.4	13.8
femur	dex.		82.9	17.3	12.3	7.4		17.2	14.0
femur	dex.		83.1	16.6	11.0	8.1			

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
femur	dex.		85.3	17.0	12.1	7.6		16.8	13.6
femur	sin.	rooster	88.6	19.2	12.5	7.7		17.8	15.7
femur	dex.	rooster	91.0	19.2	13.5	8.7		18.6	14.9
femur	sin.	rooster	91.1	19.5	13.3	8.7		18.8	15.2
femur	dex.			12.3	8.4				
femur	dex.			14.0	10.2				
femur	sin.			14.2	10.0				
femur	dex.			14.4	9.7	6.4			
femur	dex.			14.4	10.0	6.3			
femur	sin.			15.0	11.0	6.8	5.9		
femur	dex.			15.8	11.5	7.2	6.2		
femur	dex.			16.0	10.8				
femur	sin.			16.2	11.2				
femur	sin.			16.4	9.6	6.4		14.2	13.0
femur	dex.				14.7	10.8		13.7	11.8
femur	dex.					5.7		13.8	10.9
femur	dex.					6.5		14.0	11.2
femur	sin.					6.6		15.0	12.4
femur	sin.					6.7		14.1	11.3
femur	dex.					7.1		15.6	13.3
femur	dex.						6.2	14.5	12.3
femur	sin.							10.1	8.9
femur	sin.							10.2	9.1
femur	dex.							11.4	9.8
femur	dex.							12.0	10.0
femur	sin.							15.6	12.3
femur	sin.							15.9	12.5
tibiotarsus	dex.		92.0	16.4		5.5		10.1	10.1
tibiotarsus	dex.		92.1	17.7		4.7		9.6	10.8
tibiotarsus	sin.		92.8	17.6		5.1		9.4	10.5
tibiotarsus	dex.		93.1	17.6		5.0		9.2	10.4
tibiotarsus	sin.		93.4	17.4		5.3		10.3	10.0
tibiotarsus	dex.		93.4	17.4		5.5		10.2	10.3
tibiotarsus	dex.		93.4	17.9		5.1		10.0	10.9
tibiotarsus	dex.		93.7	17.0		6.0		10.4	10.2
tibiotarsus	sin.		93.8	17.4		5.3		10.1	10.3
tibiotarsus	sin.		94.6	18.0		4.9		10.0	9.7
tibiotarsus	sin.		94.7	17.3		5.0		9.6	10.5
tibiotarsus	sin.		95.3	18.1		5.6		10.3	10.1
tibiotarsus	dex.		95.3	18.4		5.7		10.1	10.8
tibiotarsus	sin.		95.5	17.1		5.2		10.2	10.1
tibiotarsus	dex.		95.6	17.3		5.2		10.0	10.3
tibiotarsus	dex.		95.6	17.4		4.7		9.3	10.5
tibiotarsus	dex.		96.0	17.4		5.1		10.4	10.3
tibiotarsus	dex.		96.1	18.0		5.1		10.0	10.3
tibiotarsus	dex.		96.2	18.9		5.4		10.1	10.9
tibiotarsus	sin.		96.4	19.5		5.6		10.1	10.9
tibiotarsus	sin.		96.5	17.7		5.7		10.1	10.2
tibiotarsus	sin.		97.0	16.8		5.0		10.2	10.2
tibiotarsus	dex.		97.2						
tibiotarsus	dex.		97.3	18.1		5.1		10.1	11.2
tibiotarsus	sin.		97.8	19.3		5.5		10.6	11.1

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
tibiotarsus	dex.		98.2	16.3	18.1	4.8	4.2	10.2	9.6
tibiotarsus	dex.		98.2	18.6		5.5		10.2	11.1
tibiotarsus	dex.		98.6	16.0		5.1		10.0	
tibiotarsus	dex.		98.6	18.6		5.3		9.7	11.0
tibiotarsus	sin.		98.7	15.6	14.1	4.3	3.8	10.3	11.1
tibiotarsus	sin.		98.7	16.0	17.2	4.8	4.0	10.0	11.3
tibiotarsus	dex.		98.7	18.4		5.4		9.6	10.6
tibiotarsus	sin.		98.9	18.6		5.6		9.9	10.9
tibiotarsus	sin.		99.5	18.5		5.3		10.0	10.6
tibiotarsus	dex.		100.0	19.2		5.3		10.5	10.5
tibiotarsus	sin.		100.2	19.1		5.4		10.8	10.5
tibiotarsus	dex.		100.4	18.6		5.5		10.1	10.2
tibiotarsus	sin.		100.8	18.6		5.9		10.2	10.1
tibiotarsus	sin.		100.9	18.9		5.4		10.4	11.1
tibiotarsus	sin.		101.0	19.5		5.6		10.2	
tibiotarsus	dex.		101.3	19.5		5.7		10.3	10.9
tibiotarsus	sin.		101.5	17.2		5.4		9.7	10.5
tibiotarsus	dex.		101.5	18.8		5.5		10.6	11.1
tibiotarsus	dex.		101.8	18.0		5.8		10.3	
tibiotarsus	sin.		102.1	17.3		5.5		10.9	10.9
tibiotarsus	sin.		102.4	18.5		5.4		10.9	11.4
tibiotarsus	sin.		102.8	18.2		5.2		10.2	10.5
tibiotarsus	dex.		104.1	19.2		6.2		10.2	
tibiotarsus	dex.		104.5	19.0		5.5		10.3	11.0
tibiotarsus	sin.		105.3	21.0		5.7		11.2	11.8
tibiotarsus	sin.		105.4	19.9		6.2		11.7	11.4
tibiotarsus	dex.		105.8	19.7		5.9		11.6	11.5
tibiotarsus	dex.		106.8	15.5	16.0	6.5	4.3	11.5	12.1
tibiotarsus	sin.		107.2	18.7		5.8		11.1	10.8
tibiotarsus	sin.		107.2	21.0		5.8		11.2	12.1
tibiotarsus	dex.		107.5	17.8		5.1		9.8	10.9
tibiotarsus	sin.		108.2	16.9	17.2	6.1	4.5	10.5	12.1
tibiotarsus	sin.		109.1	18.0	17.2	6.1	4.9	10.0	12.0
tibiotarsus	sin.		110.0	17.0	17.4	6.3	5.0	10.7	12.5
tibiotarsus	sin.		113.4	22.4		6.5		12.0	
tibiotarsus	sin.		114.1	15.5	17.2			11.5	12.1
tibiotarsus	sin.		114.1	16.8	19.1	5.2	5.0	11.9	12.0
tibiotarsus	sin.		114.1	19.9	21.2	6.2	5.0	12.0	12.8
tibiotarsus	sin.		114.2	19.2	20.1	5.1	4.9	11.8	12.0
tibiotarsus	sin.		114.8	19.3	21.4	6.2	5.1	12.1	12.6
tibiotarsus	dex.		115.5	21.1		6.5		11.2	11.4
tibiotarsus	sin.		115.5	21.5		6.6		11.5	12.3
tibiotarsus	dex.		117.8	28.5	20.9	6.0	4.8	13.0	12.9
tibiotarsus	dex.		118.2	29.2	21.5	6.2	5.1	12.9	13.1
tibiotarsus	dex.		118.8			6.8		10.7	12.3
tibiotarsus	dex.	rooster	119.2	20.6		7.0		12.0	12.9
tibiotarsus	dex.		120.4	22.1		6.6		12.1	12.3
tibiotarsus	dex.		121.1	19.3	17.8	6.8	5.1	12.1	13.5
tibiotarsus	dex.		122.3	19.6	18.0	7.0	5.3	12.3	13.8
tibiotarsus	dex.	rooster	124.5	25.2		7.8		12.9	13.8
tibiotarsus	dex.	rooster	125.7	24.4		6.8		13.6	14.5
tibiotarsus	sin.	rooster	125.9	24.5		7.0		13.8	14.1

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
tibiotarsus	dex.	rooster	129.8	25.7		7.2		12.5	14.1
tibiotarsus	sin.	rooster	130.0	25.9		7.3		13.0	14.3
tibiotarsus	dex.		105.5	20.9		5.6		10.7	12.1
tibiotarsus	sin.			16.0	17.5				
tibiotarsus	sin.			17.9					
tibiotarsus	dex.			17.9					
tibiotarsus	sin.			18.1					
tibiotarsus	sin.			18.2		5.7			
tibiotarsus	dex.			18.6		5.9			
tibiotarsus	sin.			19.0					
tibiotarsus	dex.	hen		22.7					
tibiotarsus	sin.					4.9		9.9	10.7
tibiotarsus	sin.					5.1		10.1	11.0
tibiotarsus	dex.					5.1		10.4	11.1
tibiotarsus	sin.					5.2		10.3	10.9
tibiotarsus	dex.					5.9		10.9	11.3
tibiotarsus	dex.					5.9		12.9	13.1
tibiotarsus	dex.					6.0		11.1	12.1
tibiotarsus	dex.					6.2		12.7	12.0
tibiotarsus	sin.	rooster				6.3		12.3	12.4
tibiotarsus	sin.					6.4		11.5	11.8
tibiotarsus	sin.					6.6	12.6	13.0	
tibiotarsus	dex.	hen				6.6		11.7	12.3
tibiotarsus	sin.							12.2	12.1
tibiotarsus	sin.					5.5	4.4	11.3	11.6
tibiotarsus	sin.					6.3	5.1	11.0	11.3
tibiotarsus	sin.					6.5	5.2	11.1	11.9
tibiotarsus	sin.							1.0	13.0
tibiotarsus	sin.							9.2	9.4
tibiotarsus	sin.							10.0	10.2
tibiotarsus	sin.							13.0	13.0
tarsometatarsus	sin.	hen	56.0	12.3	9.6	5.9		12.1	8.0
tarsometatarsus	sin.	hen	59.3	11.2		5.4		11.2	7.8
tarsometatarsus	dex.	hen	59.4	11.5		5.2		11.6	8.4
tarsometatarsus	sin.	hen	60.6	11.5	10.4	5.5		11.5	8.9
tarsometatarsus	dex.	rooster	61.0	11.7	10.7	6.1		11.6	9.3
tarsometatarsus	dex.	hen	61.8	11.5		5.4			
tarsometatarsus	sin.	hen	62.2	11.5		6.2		11.6	8.5
tarsometatarsus	dex.	hen	62.6	11.2		6.1		11.7	8.4
tarsometatarsus	sin.	hen	63.4	11.6		5.6		11.9	8.8
tarsometatarsus	dex.	hen	63.6	11.5	11.6	5.7		12.1	8.9
tarsometatarsus	sin.	hen	63.8	11.1		5.5		11.5	8.9
tarsometatarsus	sin.	hen	64.0	11.3	10.7	5.2		11.0	8.4
tarsometatarsus	dex.	hen	64.0	11.6	11.0	5.2		12.0	8.7
tarsometatarsus	sin.	hen	64.1	12.0	11.3	5.4		11.8	8.5
tarsometatarsus	dex.	hen	64.7	10.9		5.7		11.7	9.2
tarsometatarsus	sin.	hen	65.1	12.0	11.0	5.6		12.2	7.6
tarsometatarsus	dex.		65.2	12.2		5.7		12.5	8.9
tarsometatarsus	dex.	hen	65.6	11.2		5.3		12.1	8.3
tarsometatarsus	dex.	hen	65.7	11.7		5.7		11.9	9.0
tarsometatarsus	sin.	hen	65.9	11.4	11.7	5.5			
tarsometatarsus	dex.	hen	66.0	11.5		5.9		13.2	9.1

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
tarsometatarsus	sin.	hen	66.1	11.8		5.6		12.6	9.1
tarsometatarsus	sin.	hen	66.5	11.6	11.8	5.3		11.9	8.1
tarsometatarsus	sin.	hen	66.6	11.2	11.2	5.2		11.7	8.4
tarsometatarsus	sin.	hen	66.9	11.1	11.1	5.5		11.6	8.3
tarsometatarsus	sin.	hen	67.0	12.0	11.5	6.0		12.3	9.5
tarsometatarsus	dex.	hen	67.1	11.3	11.1	5.3		11.8	8.9
tarsometatarsus	sin.	hen	67.1	12.0		5.6		12.5	8.9
tarsometatarsus	dex.	hen	67.1	12.3		5.4		12.6	9.2
tarsometatarsus	dex.	hen	67.7	11.3		5.6		11.9	10.0
tarsometatarsus	sin.	hen	68.1	12.6	11.0	5.4		12.7	9.9
tarsometatarsus	sin.	hen	68.8	11.9	11.6	5.7		12.1	9.0
tarsometatarsus	dex.	hen	68.9	12.0	11.2	5.6		12.1	9.0
tarsometatarsus	dex.	hen	69.0	12.1	11.1	5.6		12.3	9.0
tarsometatarsus	dex.	hen	71.3	14.8		6.0		13.5	10.1
tarsometatarsus	sin.	hen	71.3	15.0		6.1		12.8	9.1
tarsometatarsus	sin.	hen	71.4	13.9		6.5		13.6	9.9
tarsometatarsus	dex.	hen	71.8	14.8		6.2		13.2	10.1
tarsometatarsus	sin.	hen	71.8			6.0		13.0	8.5
tarsometatarsus	dex.	hen	72.0	11.5	11.1	5.2	2.5	12.5	8.4
tarsometatarsus	dex.	hen	72.0			5.3	2.5	12.5	8.2
tarsometatarsus	dex.	hen	72.1	11.9	11.5	5.6	2.8	12.6	8.1
tarsometatarsus	dex.	hen	72.2			5.8	3.5	12.7	9.0
tarsometatarsus	sin.	hen	72.3	11.6	11.5	6.0	3.7	12.5	8.9
tarsometatarsus	sin.	hen	72.5	11.7	11.7	6.2	3.8	13.0	9.1
tarsometatarsus	sin.	hen	73.7	13.0	13.5	6.0		13.2	9.8
tarsometatarsus	sin	rooster	74.5	13.0	13.3	6.2		13.0	10.4
tarsometatarsus	sin.	hen	75.0	13.0	12.8	6.9	4.0	13.0	9.7
tarsometatarsus	sin.	hen	75.1	13.2	13.1	7.0	4.1	13.2	9.8
tarsometatarsus	dex.	hen	75.3			6.4	3.6	13.0	9.8
tarsometatarsus	sin.	rooster	75.8						
tarsometatarsus	sin.	rooster	76.0	14.3	12.5	7.9	3.3		
tarsometatarsus	sin.	hen	76.2	13.1	13.0	6.8	3.7	13.2	9.0
tarsometatarsus	sin.	rooster	77.8						
tarsometatarsus	sin.	rooster	78.5	14.9	12.5	7.8	3.2	13.2	9.5
tarsometatarsus	sin.	rooster	79.0	15.0	12.5	8.0	3.6	14.0	10.0
tarsometatarsus	sin.	rooster	79.2	15.0	12.9	8.0	3.5	13.8	10.8
tarsometatarsus	sin.	rooster	79.4	13.6		6.8		13.8	10.8
tarsometatarsus	dex.	rooster	79.5	13.3		6.7		13.7	10.6
tarsometatarsus	sin.	rooster	80.0	15.1	12.9	8.0	3.6	13.6	10.0
tarsometatarsus	sin.	hen	80.3	14.7	14.8	7.4		15.0	11.1
tarsometatarsus	dex.	rooster	80.9	14.5		7.4		15.1	11.2
tarsometatarsus	dex.	hen	81.6	13.4	12.2	6.4		14.7	8.9
tarsometatarsus	dex.	hen	81.6	13.5	13.6	6.4		14.5	10.6
tarsometatarsus	sin.	rooster	82.7	13.9	13.1	6.4		14.5	9.6
tarsometatarsus	dex.	rooster	83.2	13.6	12.8	6.6		15.4	9.8
tarsometatarsus	dex.	hen	83.8	14.0	13.3	7.0		17.3	10.1
tarsometatarsus	sin.	rooster	83.9	16.0	15.2	8.3		16.0	12.5
tarsometatarsus	dex.	rooster	86.0	15.7	15.0	8.3		16.1	11.8
tarsometatarsus	sin.	rooster	89.9	16.5	16.5	8.5		16.3	11.4
tarsometatarsus	dex.	rooster	90.3	15.5	15.4	8.5		16.2	11.5
tarsometatarsus	sin.	hen		12.1		6.1			
tarsometatarsus	dex.	rooster		14.0	12.6	8.0			

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
tarsometatarsus	sin.	hen				5.6		12.2	8.5
tarsometatarsus	sin.	hen				5.6		12.5	9.0
tarsometatarsus		hen					3.7	13.4	9.3
tarsometatarsus	sin.	hen						12.5	8.4
tarsometatarsus		hen						12.6	8.5
tarsometatarsus	sin.	hen						13.0	8.7
Red deer (*Cervus elaphus* Linnaeus, 1758)									
cornus		workshop debitage	51.2						
LM3 tooth	dex.		35.0	15.1					
humerus	dex.		264.2	60.0	87.0	29.0	36.1	57.0	57.0
humerus	sin.							52.7	53.2
radius	sin.							53.1	39.1
radius	sin.							53.6	38.6
radius	dex.							54.1	38.3
femur	sin.							51.5	37.2
metatarsus	dex.			35.4	38.0	21.8			
metatarsus	dex.			41.6					
metatarsus	sin.					24.5	23.4	42.3	29.3
metatarsus	sin.							49.0	30.4
phalanx prox. ant.			47.3	21.3		16.6		17.3	
phalanx dist.			55.2						
Roe deer (*Capreolus capreolus* Linnaeus 1758)									
LI4 teeth-P2			33.3						
LP2-M3 teeth			65.2						
LP2-M3 teeth			70.2						
LP2-4 teeth			26.9						
LP2-4 teeth			27						
LM1-3 teeth			37.9						
LM1-3 teeth			40.1						
LM3 tooth			15.3	7.4					
scapula	sin.					11.8	18.4	22.4	23.5
radius	dex.			25.2	14.4	15.3	10.4		
radius	sin.			28.2	17.0				
metacarpus	sin.		174.5			13.2	9.3	22.3	14.7
metacarpus	sin.		180.0	24.0	17.6	14.9	10.2	23.5	15.4
metatarsus	dex.							25.1	16.8
phalanx prox. post.	dex.		40.3	12.1		8.1		10.5	
phalanx dist.			59.0	44.8	18.4				
phalanx dist.				44.5	18.7				
Brown hare (*Lepus europaeus* Pallas, 1778)									
humerus	sin.		111.0	22.2	17.0	6.4	7.2	14.1	10.4
humerus	dex.		111.8	20.8	18.0	6.9	6.3	12.5	10.0
humerus	sin.			22.0	17.5				
humerus	sin.					5.6		13.2	9.5
humerus	dex.					7.1		12.2	10.2
humerus	sin.					8.6		21.5	15.5
metatarsus	sin.		59.1	5.9	9.6	4.6	4.1	6.9	5.5
pelvis	dex.		15.0						
tibia	dex.			22.5	22.4				

Skeletal element	*Side*	*Comment*	*GL**	*Bp***	*Dp*	*SC*	*SD*	*Bd****	*Dd*****
Cormorant (*Phalacrocorax carbo* Linnaeus, 1758)									
humerus	sin.			24.1		8.4			
Grey heron (*Ardea cinerea* Linnaeus, 1758)									
oracoideum	dex.		69.5						22.7
Mallard (*Anas platyrhynchos* Linnaeus, 1758)									
femur	dex.		53.1	13.4	9.2	5.6		12.7	10.1
femur	dex.		53.5	13.4	9.2	5.9		12.6	10.0
Pike (*Esox lucius* Linnaeus, 1758)									
dentale	sin.		56.4						

"per sylvam et per lacus nimios" ("across a forest and a multitude of lakes") is how a pilgrim travelling to the Holy Land in the eleventh century described his crossing across the Drava River. Reading the Ottoman-period travelogues written some six hundred years later, it seems that the Drava region had changed little during the centuries. The extensive woodlands and marshy areas of the contemporary landscape still preserve some of the characteristics of the past environment.

The interdisciplinary research project entitled "Studies on Settlement Archaeology and Environmental History in Southern Transdanubia, 1300–1700" aimed at exploring this landscape, its changes, and the impact of the region's communities on this land during the medieval and Ottoman period. As a border area, the Drava district, selected for more detailed studies within the region, was relatively undisturbed by intensive construction work in the Modern Age, and it was, therefore, a place where new directions for investigations could be formulated.

The present volume offers a summary of the environmental history and the findings of the natural scientific analyses of this interdisciplinary research program. Although earthenware, bones, and soil samples were examined in the analyses, the focus of our research was always on human beings and their activities. The aim was to uncover the kinds of settlements they lived in, the kinds of artifacts they used, the kinds of food they ate, and the kind of environment they lived in, as well as the kind of responses they gave to the environmental challenges they faced.

The archaeological findings of the project – part of which have already been published in preliminary reports – will appear in a subsequent volume.