ASCENT OF QUATERNARY GEOLOGICAL, ENVIRONMENTAL HISTORICAL AND GEOARCHEOLOGICAL RESEARCH AND EDUCATION AT THE DEPARTMENT OF GEOLOGY AND PALEONTOLOGY, UNIVERSITY OF SZEGED, HUNGARY FOREWORD TO THE SPECIAL EDITION OF ARCHEOMETRIAI MŰHELY•

A NEGYEDIDŐSZAKI GEOLÓGIA, KÖRNYEZETTÖRTÉNET ÉS RÉGÉSZETI GEOLÓGIA OKTATÁSÁNAK ÉS KUTATÁSÁNAK FELEMELKEDÉSE A SZEGEDI FÖLDTANI ÉS ŐSLÉNYTANI TANSZÉKEN – BEVEZETŐ GONDOLATOK A KÖTETHEZ

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„1. To everything there is a season, and a time to every purpose under the heaven”.
„5. A time to cast away stones, and a time to gather stones together;”
King James Version: Ecclesiastes Chapter 3
„1. Mindennek rendelt ideje van, és ideje van az ég alatt minden akaratnak.”
„5. Ideje van a kövek elhányásának és ideje a kövek egybegyűjtésének”
Prédikátorok könyve, 3. fejezet (Károli Gáspár fordítása)

Abstract

The 2019 closing volume of Archeometriai Műhely co-edited by the Department of Geology and Paleontology, University of Szeged, Hungary is dedicated to its centennial re-establishment in 1921. After the Trianon treaty, the university moved to Szeged from Kolozsvár (Cluj-Napoca, Romania). Professors and faculty members of the old geology departments were to build up a new scientific line of research and education in Earth Sciences of the Carpathian Basin while keeping the Kolozsvár traditions as well. Following the path outlined by the founding fathers of the new school, the past 20 years witnessed a significant development under the umbrella of a new faculty and head of department. New instruments, laboratory facilities have been acquired and new labs established, thanks to the generous support of various research grants. Numerous papers have been published in prestigious international journals and books all related to research done in the field of Quaternary geology, environmental history and geoarcheology. Thanks to the interim scientific developments and the newly established international connections and emerging collaborations results of research are continuously published in D1, Q1 journals. In addition, the department is hosting a significant number of international PhD students as well. The initial focus of research was constrained to the wider surroundings of the Carpathian Basin and recently has been complemented by works addressing questions on global scale. This opening to the international community in research and education will be the major focus of the next 5-7 years which will also witness the time of necessary changes in leadership at the department expressed in the order of authors of the foreword as well.

Kivonat

Az Archeometriai Műhely 2019 évi záró számát a Szegedi Tudományegyetem Földtani és Őslénytani Tanszéke jegyzi. A tanszék jövőre lesz 100 éves: Jogelődünk a trianoni döntés értelmében 1921-ben költözött Kolozsvárról Szegedre és fogalmazta újra önmagát, tudományos küldetését és kezdett bele a Kárpát-medence kutatását középpontba helyező tudományos megközelítés kialakításába. Az elmúlt 20 év során az alapító okiratokkal és az alapító egyéniségek elképzeléseivel teljesen összhangban lévő új tanszékvezetéssel az eddig elért eredményekhez

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képest jelentős előrelépést hajtottunk végre. Új laboratóriumokat alakítottunk ki, új műszereket szereztünk be sikeres pályázataink nyomán, és nemzetközi, hazai szinten vezető lapokban, átfogó könyvekben folyamatosan publikálni kezdtük főként a negyedidőszaki földtan és őslénytan, környezettörténet, és régészeti geológia területén elért eredményeinket. A tanszéki belső fejlődés és a külső nemzetközi kapcsolatok nyomán elértük, hogy folyamatosan a világ vezető lapjaiban publikálhatunk, jelentős számú hazai és nemzetközi PhD hallgatóval rendelkezünk, és nemzetközi kutatási projektekbe kezdhettünk. Kutatásaink ennek nyomán előbb a Kárpát-medence tágabb térségére terjedtek ki, legújabban pedig már globális negyedidőszaki, környezettörténeti és geoarcheológiai kérdéskörökkel is foglalkozhattunk. A tanszékünkön lassan már 100 éve kialakított analitikus földtani és őslénytani tudományos iskola nemzetközi szintűvé válása jellemezi, előre láthatóan, az elkövetkező 5 éves időszakot is. Ebben az új szakaszban, legkésőbb 3-4 év múlva kerül sor a tanszékvezetésben egy újabb, az élet/az idő diktálta váltásra, amely már itt az összefoglaló cikkünk szerzői sorrendjében is megnyilvánul.

KEYWORDS: QUATERNARY GEOLOGY, PALEONTOLOGY, ENVIRONMENTAL HISTORY, GEOARCHAEOLOGY, HERITAGE SCIENCE AND NEW PERSPECTIVES

KULCSSZAVAK: NEGYEDIDŐSZAKI FÖLDTAN, NEGYEDIDŐSZAKI PALEONTOLÓGIA, KÖRNYEZETTÖRTÉNET, RÉGÉSZETI GEOLÓGIA, ÖRÖKSÉGVÉDELEM ÉS ÚJ PERSPEKTÍVÁK

The current volume of Archeometriai Műhely (2019/3) was compiled and co-edited by the Department of Geology and Paleontology, University of Szeged, Hungary. It is dedicated to the centennial re-establishment of the Department in 1921. In this foreword an attempt is made to overview the recent significant scientific achievements and technical developments of the past 20 years under the direction of the current leadership. The start was not without problems due to a major debt in the budget putting the department to the edge of survival 20 years ago. Changes in the leadership from 2000 onwards, partly dictated by temporal necessities, introduced new lines and perspectives in education and research, which was a last minute rescue belt to the department. It must be acknowledged, that possibilities have always been constrained by availability of funding and collective research and education aims of the institute hosting the department. Knowing these constraints, the new leadership of the department devised a long-term development plan with optimistic aims of ascending research and education of Quaternary geology, environmental history and geoarcheology to an international level placing the department in a leading role in the field. The present volume hosting papers written by members of the department as well as researchers, whose work is connected somehow is a demonstration of the outcome of these efforts.

The planned changes were perfectly in line with the ideas, work established by the founding declaration of the new department as well as the first professors. István Miháltz, the founding professor of the department as well as József Sümeghy, the first successful PhD candidate later becoming a leading senior research fellow in Hungarian Quaternary geology set excellent examples. The initial focus of research in the re-established Department of Geology was addressing questions of Quaternary sedimentological, paleo-environmental and geological evolution of the Great Hungarian Plain basin. This has been extended to the area of geoarcheological research and multidisciplinary studies of archeological sites under the leadership of István Miháltz (1935). These were complemented by a new line of research fields due to newly established collaboration with researchers from the field of ecology, botany. Quaternary malacology (1935), anthracology (1936), palynology (1944), microfacies analysis using thin-sections (from 1952) are on the list. These fields were put into focus again from 2000 using new methodologies, know-how and instrumentation with aims to putting works into the streamline of international scientific research and education in the referred fields. Csanád Bálint, a Szeged born archeologist, member of the Hungarian Academy of Sciences has made a significant contribution to the development of the new laboratories and instrumentation of the department providing funding from an NKFP research grant brought to fruition by the collaboration of our department and the Institute of Archeology, HAS.

In addition, continuous applications for research funding and successful accomplishment of numerous projects, the adoption of absolute chronologies based on ^{14}C and other dating methods in Quaternary geological research provided a background to the continuous flow of publication of research results in internationally acknowledged, primary journals. These were especially prominent following the referred changes. The number of SCI, WOS indexed publications written by members of the department have significantly increased since 2000 (88 SCI, 32 additional international papers). In the period between 1921 and 2000 these numbers were lower (ca. 12-15) with most papers published in Hungary in English, German, French enabling the attainment of high international interests of contemporary geological research. Similar changes are notable in terms of the number of published monographs and book chapters from 2000 onwards (16 monographs, book chapters in international (25) and Hungarian (182) volumes, most of them in

English, 22 popular scientific publications, 34 proceedings, 67 Hungarian journal papers). These works received citations in 4600 international, more than 1000 Hungarian papers, monographs and book chapters in addition to 365 citations in PhD and academic doctoral theses. Due to these major improvements, the department is proudly hosting 7 Hungarian and 3 international PhD students during this academic year. The past 20 years also hosted 15 successful PhD defences, 107 graduate and undergraduate theses defences, and 15 National Student Scientific Competition contributions. A new post-graduate program has also been established in Geoarcheology for the first time in Hungary. 12 students of archeology has successfully gained degrees in the program so far. Members of the department has actively engaged in popular scientific outreach with 21 appearances in national and regional TV and radio programs (Mindentudás Egyeteme, Mindenki Akadémiája, Alma Mater, Science Cafe, Sciesta, Dugonics Fraternity). Short documentaries were made on geoarcheological, archeomalacological research, evolution of Lake Balaton, the landscape evolution of the Hortobágy, the reintroduction of wild horses and its archeobotanical, archeozoological aspects, as well as the geological evolution of a unique site with strong ties to the city of Szeged hosting a Paleolithic camp: Szeged-Öthalom (Five Hills). All these significant achievements granted us a possibility to sum up the results in the present special volume.

Besides successes, we also had some failures marked by the rejection of numerous carefully prepared high quality grant proposals due to technical and science political issues, conflicting interests with newly established research groups, laboratories leading to a ca. 10-year period of lack of funding in basic scientific research. Nevertheless, work has relentlessly continued reaching phase 5 planned originally. New collaborations have been established with Chinese, Estonian, Croatian, Polish, Turkish, American, Australian, New Zealand colleagues enabling us to participate in, and hand in international research grant proposals and publish our results in D1 and Q1 journals. This expansion to the web of global scientific research is to be the major focus of the following years. The next 5-7 years will also witness the time of necessary changes in leadership at the department expressed in the order of authors of the foreword as well. The new leadership will take on the role of carrying on the heritage and achievements made so far. Some aims include the introduction of English language education and reinforcement of the position of the department in international Quaternary geological, environmental historical, geoarcheological research. These efforts are all straight-line outcome of our centennial heritage.

Now is also the time to address the achievements of our distinguished retired professors who worked to maintain the original goals set by the founding fathers. The oldest member of the department Prof. emeritus Béla Molnár former HoD, age 85, Associate Professor Dr. Miklós Szónoky age 80 and Associate Professor Dr. János Geiger turning 66 and retiring this year are all necessary to be mentioned. Last December a special workshop was dedicated to their achievements. This occasion also allowed us to greet a friend and fellow paleontologist Ferenc Wanek (age 75) from the University of Kolozsvár, Transylvania, who has always been an active contributor to our work. The internationally acknowledged Quaternary malacologist, paleoecologist late Prof. Endre Krolopp was also an important member of the department often greeted. In 2014 a workshop was dedicated to the life and achievements of our founding professor István Miháltz. This is how the continuity between older, active and potentially future members of the department is established and maintained putting into existence of what is stated in the slogan adopted: '*Sine praeteritis futura nulla - there is no future without the past.'*

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REFUTING IDEAS BASED ON SMALL BATCH OF DATA: MALACOTHERMOMETRY AID IN THE RECONSTRUCTION OF MEAN JULY PALEO-TEMPERATURES IN THE CARPATHIAN BASIN FOR THE LAST GLACIAL OF THE PLEISTOCENE•

TÖBB TERMÉSZETTUDOMÁNYI ADATOT ÉS KEVESEBB MÍTOSZT – MALAKOHŐMÉRŐ MÓDSZERREL REKONSTRUÁLT EGYKORI JÚLIUSI HŐMÉRSÉKLETI ADATOK A JÉGKOR UTOLSÓ LÖSZKÉPZŐDÉSI PERIÓDUSÁBAN KIFEJLŐDÖTT VALÓDI SZÁRAZFÖLDI KÖRNYEZETRE VONATKOZÓAN A KÁRPÁT-MEDENCÉBEN

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Abstract

There are several ways in which terrestrial molluscs can be used to capture or model the former paleo-temperatures. The most frequently used approaches are based on the utilization of the dominance values of the cold-loving and thermophilous species for the separation of relatively milder and colder periods. In other approaches, the abundance of the cold-loving forms is used to capture the short-term stadials. These previously mentioned approaches rely on the presumption that the fluctuations observable in the specimen number or percentages of cold-loving or thermophilous forms is related to the fluctuations of the paleo-temperature. On the other hand, the terrestrial mollusc faunas are also well-suited for capturing climate changes for the past 100 000 years utilizing their modern distribution patterns, similarly to insects, vertebrates and paleobotanical data. In this paper we present an updated version of the paleo-climatological, paleo-ecological model prepared by Sümegi (1989), and referred to as the malaco-thermometer method. The model uses the recent distribution, composition as well as dominance values of the individual species for the reconstruction of the paleo-temperatures. The original method has been successfully applied to numerous radiocarbon-dated localities within the Carpathian Basin. In some works, hypothetical paleo-temperature curves based on the original model has been presented. However, there is one important deviation from the previously mentioned methods, namely that the activation temperatures for the terrestrial gastropods were captured not as the recorded mean July paleo-temperatures of the growth season in the center of distribution, but rather those recorded along the rims. Applications of the updated method and results gained via its utilization are presented.

Kivonat

A szárazföldi Mollusca *faunát többféleképpen használhatjuk fel az egykori hőmérsékleti viszonyok modellezésére. Legelterjedtebben a hidegkedvelő és enyhébb éghajlatot igénylő fajok dominanciáját használják fel a relatíve hidegebb és enyhébb szakaszok elkülönítésére. Ismeretesek olyan módszerek is ahol a hidegkedvelő malakofauna abundanciáját használták fel rövidebb ideig tartó stadiális szakaszok rekonstruálására. Mindegyik módszer azzal számol, hogy az enyhébb éghajlatot kedvelő, vagy a hidegkedvelő faunaelemek egyedszámának, vagy százalékos arányának változása összefüggésben van az egykori hőmérséklet változásaival. Ugyanakkor a recens elterjedései alapján a bogármaradványokhoz, a gerinces adatokhoz és a paleobotanikai adatokhoz hasonlóan a szárazföldi csiga fajok is jól felhasználhatók az utolsó százezer év éghajlati változásainak rekonstruálásában. Az egyes szárazföldi csiga fajok recens elterjedése, a fauna összetétele, dominanciaviszonyai alapján készített, nemzetközi szinten is újnak számító paleoklimatológiai rekonstrukciós modellt, az ún. "malako-hőmérő"-t Sümegi (1989) készítette. Ezzel a módszerével korábban már több, radiokarbon adatokkal datált kárpát-medencei lelőhely őshőmérsékleti körülményeit rekonstruáltuk, sőt némely tanulmány már hipotetikus őshőmérsékleti görbéket is felrajzolt ezen módszer alapján. Ugyanakkor a különböző, az előbb felsorolt bio-indikációs csoportokhoz képest jelentős eltérés, hogy a malako-hőmérő esetében az egyes* Mollusca *fajok*

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hőmérsékleti aktivitási tartományát nem az elterjedés centrumában mért júliusi középhőmérséklettel jellemeztük, hanem az elterjedés perifériáin mérhető tenyészidőszak hőmérsékletekkel próbáltuk lehatárolni. A jelen tanulmány a módszer egy továbbfejlesztett változatának alkalmazását mutatja be.

KEYWORDS: LATE QUATERNARY, LANDSNAIL, PALEOCLIMATOLOGY, MALACO-THERMOMETER, UPPER PALEOLITHIC

KULCSSZAVAK: NEGYEDIDŐSZAK VÉGE, SZÁRAZFÖLDI CSIGÁK, PALEOKLIMATOLÓGIA, MALAKOHŐMÉRŐ, FELSŐ PALEOLITIKUM

Introduction

The major aim of the present paper is to give an overview of the different paleoclimatic conditions and their alterations within the area of the Carpathian Basin during the Last Glacial (Alpean stratigraphy - Würmian Glacial: Spötl et al. 2019; Marine Isotope Stage or marine oxygen-isotope stages, or oxygen isotope stages (OIS): MIS4, MIS3, MIS2 levels: Antoine et al. 2009; Jullien et al. 2009; Johnsen et al. 2001; Rassmussen et al. 2006, 2008, 2014) primarily for the terminal part of it, via the paleo-climatological evaluation of the mollusc faunas retrieved from the loess-covered areas of NE Hungary, and their comparison with similar faunas from other Hungarian localities, primarily of Southern Hungary. I also intend to discuss the effects these factors posed on the Upper Paleolithic human communities. Furthermore, I would like to present a new stratigraphic system for the above mentioned period, which is based on the newly gained results of my work, and though congruent with the past findings, it provides a better resolution and in certain aspects carries new attributes as well. In order to accomplish the task of successfully capturing the most complex, wide-ranging view of the former paleoecology, several new methods, or at least new in the field of Quaternary mollusc studies (Krolopp 1961, 1965a, b, c, 1966, 1967, 1973, 1977, 1983, 2003; Krolopp & Sümegi 1995; Ložek 1964, 1990, 2001; Alexandrowicz 1988; Rousseau, 1990, 1991, 2001; Rousseau & Kukla 1994; Rousseau & Wu 1997; Rousseu et al. 1992, 1994, 1998, 2000; Magnin 1993; Alexandrowicz 2014; Wu et al. 2018) have been introduced into my work, ranging from biometric analysis to complex statistical evaluations. The well-known malaco-thermometric method, postulated in my university doctoral thesis in 1989 (Sümegi 1989), have been upgraded with the help of recent findings (Sümegi 1996, 2005, 2007). This upgraded version and a comparison with other paleo-climatological methods and approaches is also presented in this paper.

The model uses the recent distribution, composition as well as dominance values of the individual species for the reconstruction of the paleo-temperatures. This method has been successfully applied to numerous radiocarbon-dated localities within the Carpathian Basin (Sümegi et al. 1991; Szöőr et al. 1991a, b; Hertelendi et al. 1992; Sümegi & Krolopp 2002). Krolopp (2003) went even further to set up hypothetical paleo-temperature curves based on this model. However, the method has not been described scientifically so far, except for a PhD thesis (Sümegi 1989).

There are several ways in which the molluscs can be used to capture or model the former paleo-temperatures. The most frequently used approaches are based on the utilization of the dominance values of the cold-loving and thermophilous species for the separation of relatively milder and colder periods (Krolopp 1967, 1973, 1983; Magnin 1993). In other approaches, the abundance of the cold-loving forms is used to capture the short-term stadials (Sümegi et al. 1991; Nyilas & Sümegi 1991). These previously mentioned approaches rely on the presumption that the fluctuations observable in the specimen number or percentages of cold-loving or thermophilous forms is related to the fluctuations of the paleo-temperature (Magnin 1993). But is this truly the case?

Evans (1972), Rousseau et al. (1991a, b) and Davies (2008) noted that alterations in the dominant values are not only dependant exclusively on, thus mark temperature changes but are also a factor of several other parameters like humidity, the composition of the vegetation, changes in the number of predators preying upon molluscs or those of the parasites, plus the quality of the habitat seen in substrate composition, carbonate content, pH (Arnason & Grant 1976; Müller et al. 2005; Horsák et al. 2007; Sulikowska-Drozd & Horsák 2007; Sulikowska-Drozd et al. 2013).

These latter two can be excluded in case of the loess layers having a neutral pH and relatively large carbonate content. Conversely, several research on the recent mollusc faunas implemented by Fröming (1954), Ant (1963), Sólymos & Nagy (1997), Sólymos & Sümegi (1999) pointed out that such parameters as humidity, air temperature, and light intensity are the most influential factors in the activity potential of molluscs (Arnason & Grant 1976; Abdel - Rehim 1987; Magnin 1993; Staikou 1999). From several ecological studies it also seems apparent (Ant 1963) that the environmental components have mosaic-like scattered distribution in areas studded with woodlands, woodland margins and bushes (Arnason & Grant1976; Martin & Sommer 2004; Horsák et al. 2007; Sulikowska-Drozd & Horsák 2007). This pattern is also observable in the mollusc faunas adapting to these conditions. Consequently, it is very hard to accurately capture the true ecological requirements of woodlands species in contrast to open area dwellers, due to the significant differences in the micro and mesoclimatic conditions in a woodland (Arnason & Grant 1976; Sümegi 1989, 1996, 2005, 2007; Martin & Sommer 2004; Horsák et al. 2007; Sulikowska-Drozd & Horsák 2007; Sulikowska-Drozd et al. 2013).

Taking an account of all these results, initially those taxa were chosen for the purpose of paleo-temperature reconstruction which were steppe, at the most forest-steppe dwellers, because there is only a slight chance for the presence of actual differences between the light intensities or humidities of these habitats. Plus there are no significant deviations between the micro- and regional climate here (Arnason & Grant 1976; Sümegi 1989, 1996, 2005, 2007; Sümegi et al. 2001).

From the ecological studies of the recent faunas it seems also quite apparent (Owen & Bengtson 1972; Arnason & Grant 1976; Domokos 1995), that there are considerable deviations between the temperatures required for mollusc activation (movement, feeding etc.), and perishing (Domokos1982). Furthermore, it is also obvious that the individual molluscs are active only in a certain part of the year, the so-called growth season and hibernate during the periods with unfavorable conditions- too arid or too cold (Owen & Bengtson 1972; Arnason & Grant 1976; Domokos 1982, 1995; Sümegi 1989, 1996, 2005, 2007; Sümegi et al. 1991; Müller et al. 2005; Sulikowska-Drozd et al. 2013).

Thus, the detailed investigations of molluscs can yield information regarding the environmental conditions of the growth or active season alone (Arnason & Grant 1976; Owen & Bengtson 1972; Müller et al. 2005; Sulikowska-Drozd & Horsák 2007; Sulikowska-Drozd et al. 2013). When all these parameters are noted, we are facing a less wide temperature spectrum, in which molluscs tend to live, move, feed etc. actively (Sümegi 1989). This interval can be regarded as the activation interval of terrestrial gastropods. The tolerance of the mollusc species studied so far tended to follow a normal distribution (Domokos & Fűköh 1984, 1986; Sólymos et al. 2002; Domokos & Sólymos 2013; Domokos et al. 2014). Thus, we have every reason to believe that the activation temperature curves, embedding the ranges of unfavorable conditions as well, will be characterized by similar shapes (Sümegi 1989, 1996, 2005, 2007; Sümegi et al. 1991).

The activation temperatures of the individual mollusc species is determined from the recent distribution of the forms under study and the measured temperatures of the growth season recorded at mesoclimatic stations (Sümegi 1989, 1996, 2005, 2007; Sümegi et al. 1991). This is, however, rather problematic in several ways (Sümegi 1989, 1996, 2005, 2007; Sümegi et al. 1991). First of all, it is the microclimatic parameters that primarily influence the activation of terrestrial molluscs, and mainly that of the air temperatures recorded 1-2 cm above the ground (Arnason & Grant 1976; Abdel-Rehim 1987; Nyilas & Sümegi 1987; Sümegi et al. 1991; Sólymos1996; Sólymos & Nagy 1997; Sólymos & Sümegi 1999). Thus the temperatures recorded at the mesoclimatic stations at a height of 2 m above the ground are only distantly correlated with the actual activation temperatures of the mollusc species, following only perhaps a similar trend (Arnason & Grant 1976; Sümegi 1989, 1996, 2005, 2007). This can only be changed by recording the microclimatic parameters along with numerous other factors like humidity and light intensity during investigations on the recent faunas (Sümegi 1989, 1996, 2005, 2007; Sümegi et al. 1991). These measurements, presently going on and likely to continue in the fitotron (or more precisely in the malacotron: Sümegi 1989, 1996, 2005, 2007) will hopefully help us to make our model more accurate and realistic (Sümegi 1989, 1996, 2005, 2007; Sümegi et al. 1991).

On the other hand, the terrestrial mollusc faunas are also well-suited (Sümegi 1989, 1996, 2005, 2007) for capturing climate changes for the past 100,000 years utilizing their modern distribution patterns, similarly to insects (Coope 1975, 2002; Coope et al. 1971; Ashworth 1996, 2001), vertebrates (Hokr 1951; Kretzoi 1957, 1977; Kordos 1977, 1981, 1987) and paleobotanical data (Skoflek 1990; Heusser 1973; Iversen 1944; Járainé-Komlódi 1966, 1968, 1969, 1987; Magyari 2002; Magyari et al. 2001).

The theory behind the method

There is one important deviation from the previously mentioned methods, namely that the activation temperatures for the terrestrial gastropods were captured not as the recorded mean July temperatures of the growth season in the center of distribution, but rather those recorded along the rims (Sümegi 1989, 1996, 2005, 2007; Sümegi et al. 1991). What does this exactly mean?

Table 1.: The activation temperatures as well as the mean or optimal values of these for the mollusks used in the "malacothermometer model"

1. táblázat: A malakohőmérő modellben szereplő csigák átlagos és optimális aktivitási hőmérsékleti értékei

The mollusc species used in the malaco-thermometer model	The assumed activation temperature ranges calculated from the modern distributions	The mean or optimal value of the activation temperatures taken to signify the former mean July paleotemperatures
Succinea oblonga	13-19 °C	16 °C
Columella edentula	10-20 °C	15 °C
Columella columella	5-15 °C	10 °C
Vertigo genesii	5-15 °C	10 °C
Vertigo modesta	5-15 °C	10 °C
Pupilla muscorum	10-22 °C	16 °C
Pupilla triplicata	16-24 °C	20 °C
Pupilla sterri	5.5-16.5 °C	11 °C
Vallonia costata	10-24 °C	17 °C
Vallonia tenuilabris	4-14 °C	9 °C
Granaria frumentum	17-26 °C	21.5 °C
Clausilia dubia	12-20 °C	16 °C
Punctum pygmaeum	9-22 °C	15 °C
Vitrea crystallina	11-21 °C	16 °C
Trichia hispida	10-20 °C	15 °C
Cepaea vindobonensis	18-26 °C	22 °C

In case of a species with a relatively extensive distribution area, say from the Mediterranean up to the highest boreal latitudes (e.g.: *Pupilla muscorum*), the optimal temperature used in our model derived from not the center of this taxon's distribution, but the mean July temperature recorded in the northern boreal peripheries were considered, while in case of the Mediterranean the more humid fall and winter temperatures were used (Sümegi 1989, 1996, 2005, 2007 Sümegi et al. 1991). In case of the Mediterranean, humidity acts as a limiting factor on terrestrial gastropods, especially during the hot and dry summer days. However, during the more humid fall and winter days, the temperature becomes the main factor influencing the activation of these molluscs, with humidity losing importance as a limiting factor of activation. This way the temperature tolerance ranges of terrestrial species characterized with an extensive distribution area and considered to be eurythermic (Meijer 1985; Kuijper 1985) can be more precisely captured (Sümegi 1989).

Initially, the activation temperatures for the hottest month (July) of the growth season were determined for 8 species (Sümegi 1989, 1996, 2005, 2007). This was later on extended to 16 species to meet the requests of fellow researchers (Sümegi 1996, 2005, 2007). Among these, there are forms with highly different distributional areas, characterized by activation temperatures in different ranges as well (**Table 1.**).

In case of cold-resistant (Chlachula 1991; Chlachula et al. 2004; Rousseau & Puisségur 1999; Rousseau et al. 1992; Moine et al. 2005) *Succinea oblonga*, the 13 ºC minimal activation temperature values were observable in the distribution margins of the species at Scotland (Kerney & Cameron 1979; Kerney et al. 1983), Finland (Routio & Valta 2011) and Western Siberia (Welter-Schultes 2012). Here the temperature acts as a limiting factor during the relatively intensively humid growth season. The maximum value of 19 ºC comes from the scattered southern distribution margins, like the Hungarian wetlands (Bába 1989).

The activation temperature ranges of the Northern Asian (Meng 2009; Meng & Hoffmann 2009; Horsak et al. 2010, 2015), xeromontane, cold-loving (Rousseau 1986, 1989) *Vallonia tenuilabris* were set up on the basis of personal encounters gained in the Altai Mts. as part of an expedition in 1989 (Sümegi 1996, 2005, 2007; Sümegi et al. 1991). This species appears from an altitude of 2100 – 2200 m to the height of the Alpine tundra, shrub and grasslands located at 3000 - 3500 m ASL (Meng 2009; Meng & Hoffmann 2009; Horsak et al. 2010, 2015) forming a glacial refugia (Bennett et al. 1991; Willis et al. 2000; Stewart & Lister 2001; Stewart et al. 2010; Rull 2010; Keppel et al. 2012; Horsák et al. 2015). The activation range of *V. tenulabris* is completely different from that of *Succinea oblonga* and tends to be congruent with the periodic fluctuations observable in the abundance and dominance rates of the two species in the Hungarian loess profiles (Sümegi 1989, 1996, 2005, 2007; Sümegi et al. 1991).

The highest activation temperatures were recorded for *Pupilla muscorum*, which is by no means surprising, as this species inhabits a region extending from the tundra down to the Mediterranean (Kerney et al. 1983; Welter-Schultes 2012). According to the available data for fossil and modern populations, the morphological plasticity of *Pupilla muscorum*is supposed to be the result of ecophenotypical adaptations to varying environmental and climatic conditions (Rousseau & Laurin, 1984; Rousseau 1997).

Pupilla triplicata is known to invade areas in Central and Southern Europe (Sólymos 2008; Horsák et al. 2013; Balashov & Kryvokhyzha 2015; Georgiev & Stoycheva 2010), which are characterized by mean July temperatures below 20 ºC (Carpathians, foothills of the Alps,). However, it has only a scattered distribution restricted to the southern, drier and warmer slopes with a carbonate rich bedrock in these regions (Georgiev & Stoycheva 2010). The cold-loving *Pupilla sterri* goes up as high as 2700–2800 m ASL in the mountains (Soós 1943; Klemm 1974; Bába 1980; Myšák 2009; Duda et al. 2018).

The species *Columella columella* tends to have a similar distribution, but this form goes even higher up to the kingdom of ice and snow to a height of 2900-3000 m ASL (Klemm 1974; Kerney et al. 1983; Ložek 1990; Juřičková & Ložek 2008). Thus its presence indicates colder mean July temperature values than the ones marked by *Pupilla sterri*.

The gastropod *Columella columella* is a typical Arcto-Alpine element (Kerney et al. 1980; Ložek 1990; Juřičková & Ložek 2008), appearing during the most important cooling periods of the Pleistocene (Rousseau 1990; Rousseau et al. 1990) and has an Arctic- Subarctic distribution today (Klemm 1974; Kerney et al. 1983; Meng et al. 2011). Though the distributions of *C. columella* and *C. edentula* partially overlap, they tend to complement each other both vertically and horizontally in the montane regions (Kerney et al. 1983; Limondin‑Lozouet & Antoine 2001; Hausdorf 2006; Meng et al. 2011).

Similar changes are observable in the dominance values of the two taxa in the Hungarian Pleistocene profiles, where they tend to overlap each other but their dominances are contrasting (Krolopp 1973, 1983; Krolopp & Sümegi 1995; Sümegi 1989, 1996, 2005, 2007; Sümegi & Krolopp 1995, 2002, 2006). Similar trends are observable in case of the species *Trichia hispida*, *Succinea oblonga*, *C. edentula*, *Clausilia dubia*, *Vitrea crystallina* (Wäreborn 1970; Kappes et al. 2006; Horsák et al. 2007; Davies 2008; Szybiak et al. 2009; Sólymos et al. 2009; Pilate 2009).

The Arcto-Alpine *Vertigo genesii, Vertigo modesta* and *Columella columella* has similar characteristics (Frest & Dickson 1986; Hausdorf & Henning 2003; Alexandrowicz & Rudzka 2006; Hájek et al. 2011; Schenková & Horsák 2013; Krolopp 1973, 1983; Krolopp & Sümegi 1993; Sümegi 1989, 1996, 2005, 2007) (**Table 1.**). The ecological requirements of these taxa, and their temperature tolerance as well as ranges of activation temperatures are more ore less the same.

The Southern-South-eastern European *Cepaea vindobonensis* and *Granaria frumentum* require different temperature conditions (Currey & Cain 1968; Jones 1973; Cameron 1992; Magnin 1993; Welter-Schultes 2012; Dvořáková & Horsák 2012) marking milder climatic periods. Their indicative temperatures seem to be well-correlated with the results of recent microclimatic research (Domokos 1982; Fűköh & Domokos 1984, 1986; Magni 1993; Sólymos & Sümegi 1999). Similar trends are observable in case of the widely-distributed *Vallonia costata* and *Punctum pygmaeum* (Kerney et al. 1983; Baur 1987; Magni 1993; Welter-Schultes 2012; Hettenbergerová et al. 2013).

Conversely, the reconstructed activation temperatures of the extensive *Clausilia dubia* and *Vitrea crystallina* (Wäreborn 1970; Kappes et al. 2006; Horsák et al. 2007; Davies 2008; Szybiak et al. 2009; Sólymos et al. 2009; Pilate 2009) requiring lush vegetation cover are rather sketchy and entered into the original list of species on the request of my former supervisor Endre Krolopp in 1996 (Sümegi 1996). The error comes from the presently observable high difference between the microclimatic and mesoclimatic parameters characterizing the habitats inhabited by these forms, yielding a significant uncertainty in the model of paleo-temperature reconstruction (Wäreborn 1970; Kappes et al. 2006; Horsák et al. 2007; Davies

2008; Szybiak et al. 2009; Sólymos et al. 2009; Pilate 2009).

The reliable introduction of these taxa into the model would require detailed documentation of their ecological requirements among field and lab conditions. For the calculation of the mean July paleo-temperatures the mean values of the activation temperature ranges of the individual taxa (**Table 2.**) have been utilized along with their abundance values (Sümegi 1989, 1996). A similar formula was used in paleobotanical studies for such purposes (Skoflek 1977, 1990).

Table 2.: Classification of July paleotemperature according to malacothermometer method (Sümegi 1989, 1996)

2. táblázat: Az egykori júliusi középhőmérséklet meghatározása malakohőmérő módszerével (Sümegi 1989, 1996)

$$T = \frac{\sum_{I=1}^{N} A_i T_i}{\sum_{I=1}^{N} A_i}$$

A_i = The abundance of a given i species in the sample

T_i = The optimum temperature of a given i species in the sample

N = Number of species used for the estamination

T = Estaminated July paleotemperature (°C)

Modelling the relationship of the Upper Paleolithic communities and the environment of the Carpathian Basin during the Upper Würmian (terminal phase of MIS3 and MIS2)

The first radiocarbon-dated chronological unit represents a period between 35,000–25,000 cal BP years. This unit was correlated by the Denekamp interstadial (West 1984; Lisá et al. 2018) located at the boundary of the Middle and Upper Pleniglacial in Western Europe (Zagwijn 1961, 1974), and between the SPECMAP 2 and 3 isotopic stages (Shakleton 1977; Shakleton & Opdyke 1973; Shakleton et al. 1983, 1984; Imbrie et al. 1984; Rudimann et al. 1986) and the terminal phase of MIS3 and MIS2 stage (Svensson et al. 2006; Rassmussen et al. 2006, 2008, 2014). This paleosol horizon dated into this period can be correlated with the Stillfried B paleosol (Fink 1954; Valentine & Dalrymple 1976; Velichko 1990; Szöőr et al. 1991; Zöller et al. 1994; Terhorst et al. 2011, 2014; Peticzka et al. 2010). According to the available malacological data, this period can be divided into two parts. The older phase between 35,000 – 30,000 cal BP years was characterized by milder and more humid conditions (Krolopp & Sümegi 1992, 1995; Sümegi 2011).

For this time period we could infer mean July paleo-temperatures ranging around 19-20 °C in the southern parts of the Carpathian Basin, 18 °C in the central parts of the Great Hungarian Plains, and 17 °C in the Northern Mid-Mountains and the southern foothills of the Northern Carpathians, respectively (Sümegi & Krolopp 1995, 2002; Sümegi et al. 2000, 2002). This NE-SW trend observable in the distribution of the temperature values is congruent with the differences observable between the individual parts of the country even today; i.e. a 2-3 °C difference between the northern and southern parts (Réthly 1937, 1948; Bacsó et al. 1953; Bacsó 1959; Péczely 1998; Szelepcsény et al. 2014, 2016). Furthermore, we had only minimal deviations from the modern temperature values here being in the range of 2-3 °C implying the presence of very mild conditions between 35,000–30,000 cal BP years.

According to our paleobotanical data, a mixed-leaved taiga dominated by spruce must have emerged in the area of the Northern Mid-Mountains and its foothills during this time. It might be important to know in reconstruction of the surrounding environment of the Upper Paleolithic hunters, that several *Picea* charcoal remains studied by Edina Rudner (Willis et al. 2000; Rudner & Sümegi 2001) have been recovered from the Upper Paleolithic sites and loess section themselves (Bodrogkeresztúr, Henye-tető Upper Palaeolithic horizon in fossil soil layer: 26 318 ± 365 BP = 29661-31090 cal BP years (2σ range – calibration: Reimer et al. 2014); Megyaszó, Szeles-tető, loess section, fossil soil horizon: 27, 070 ± 680 BP = 29 700-32 607 (2σ range); Püspökhatvan – Diós, Öregszőlő, Upper Palaeolithic horizon in fossil soil layer: 27, 700 ± 300 BP = 31 046-32 361 (2σ range); Hont-Parassa III/Orgonás, loess section, fossil soil horizon: 27, 350 ± 610 BP = 30 276-32 902 (2σ range).

All these data from archaeological sites seem to underlie that the earliest Gravettian hunting groups appearing during an interstadial at the end of the Middle Würmian (Gáboriné-Csánk 1980; T. Dobosi 2000) or at the terminal phase of MIS3, Dansgaard-Oschger (D-O) or Greenland (GI) interstadial 05 and 04 horizons (Bond et al. 1992, 1993, 1999) which evolved together (Sümegi et al. 2019) some places in the Carpathian Basin. The Carpathian Basin must have populated spruce open woodlands (open parkland type) containing thermos-mesophilous arboreal elements (*Carpinus* – hornbeam, *Salix* – willow, *Alnus* – alder, *Betula* – birch, *Pinus sylvestris* – Norway pine and possibly *Corylus* – hazelnut, *Tilia* – elm, *Quercus* – oak) as well (Sümegi et al. 1999, 2013a, 2016). Sporadic changes in the dominance of shade-loving mollusc species, as well as the scattered charcoal remains forming major spots refer to the presence of a

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variegated mixed taiga woodland containing steppe elements (forest steppe or open parkland: Sümegi et al. 2012, 2016). The differences in exposure between the slopes might have contributed to the emergence of minor spots (local level: Sümegi et al. 2012), characterized by warmer conditions harboring thermo-mesophilous arboreal elements within the spruce open parkland (local refugia: Willis et al. 1995; micro-environmental oases: Willis et al. 2000). A modern analogy of this spruce open woodland can be found in the Altai Mts. where a mixed spruce woodland of loose stands can be found at lower elevations containing such elements as Norway pine, alder, willow and oak (*Quercus mongoliensis*) (Sümegi 1996, 2005, 2007; Sümegi et al. 1999, 2013a). According to the data of Stieber (1967) and Rudner & Sümegi (2001) this spruce open woodland (open parkland type) can be traced within the Carpathian Basin as far as the Transdanubian Mid-mountains, turning gradually into forest steppes dominated by Norway pine and birch in the southern parts of Transdanubia and the Danube-Tisza Interfluve.

While the area of the Hajdúság in the Tiszántúl harbored thermo-mesophilous steppe elements at the same time (Sümegi 1989; Szöőr et al. 1991a, b; Hertelendi et al. 1992). Finally, the areas of the Hortobágy, Nagykunság, and Körös – Maros Interfluve were characterized by floodplain areas studded by alkaline steppes (Sümegi et al. 2013b). These open vegetation areas were studded by gallery forests running along the watercourses, and were characterized by hydromorphic, black earth and alkaline soils, parallel with the podzolic soils of the Northern Mid-Mountains (Sümegi, 1996, 2005). The area of the Danube-Tisza Interfluve was characterized by wind-blown sand deposition and movement as well as the development of soils under a highly special forest steppe vegetation composed of dominantly Norway pines and birches. The southern parts of Transdanubia were covered by evenly distributed woodlands, and clear signs referring for the closure of the arboreal vegetation could have been found in the former fauna and flora there. To my mind (Sümegi 1995, 1996, 2005, 2007), a major environmental boundary must have emerged in the center of the Carpathian Basin dividing it into two parts characterized by different evolutionary histories of the vegetation. These regional differences follow the same trends as observable today, only the composition of the vegetation was different from the modern one. These differences between this former vegetation characterized by a dominance of pines at 35,000 – 30000 BP years, and the modern vegetation characterized by a dominance of deciduous trees must be attributed to the shorter growth periods and the cooler winter temperatures during the interstadial. Nevertheless, it's rather surprising that the Gravettian sites of this period are restricted to the spruce open parklands of the Northern Mid-Mountains (Sümegi, 2014; Sümegi et al. 2016).

Several researchers, primarily geographers (Tarnocai & Schweitzer 1998; Fábián et al. 1998, 2000; Kovács et al. 2007; Obreht et al. 2019) have questioned the reliability of our July paleo-temperature reconstructions considering them too high. They have also debated our data referring to the presence of thermo-mesophilous arboreal elements in the vegetation, especially that of *Carpinus* (hornbeam) along with the presence of two biogeographical units, despite the fact that several archeologists have noted the presence of two climatic-economic units within this relatively closed system of the Carpathian Basin during the Upper Paleolithic, based on archeological results (Gáboriné Csánk 1980 p. 217).

In order to put an end on these debates, we have attempted to compare our vegetation, malacological, vertebrata and paleo-environmental data (Jánossy 1979, 1986; Járainé-Komlódi 2000; Willis et al. 2000; Sümegi 2005) with those of the neighboring areas to disprove the hypothesis according to which the Carpathian Basin was nothing else but an alternation of cold and warm desert conditions during the stadials and interstadials of the Würmian (Tarnocai & Schweitzer 1998; Fábián et al. 1998, 2000; Kovács et al. 2007; Obreht et al. 2019).

According to malacological data from thickest loess profiles in the Carpathian Basin, a cold phase developed in the Carpathian Basin between 30,000 and 29,000 cal BP years. This stadial phase had relatively low July mean temperatures around $15\pm1\ ^{o}C$ (Sümegi et al. 2019). Based on the distribution data of molluscs (Sümegi et al. 2019) low growing season and low winter temperatures (between $-6^{o}C$ and $-17\ ^{o}C$) as well as low annual temperatures prevailed (between +5 °C to +7 °C) in this phase.

After this rapid cold stage a new temperate (interstadial) phase formed between 29,000 and 25,000 / 24,500 cal BP years. It was characterized by 17-18 °C July paleo-temperatures and drier conditions (Sümegi 1989, 1996, 2005, 2007, 2014). This period is characterized by the reappearance of the SSE European xero-termophilous temperate grassland dweller *Granaria frumentum* along with other steppe dwelling elements. The composition of land snail faunas and indicator elements refers to the emergence of dry summer seasons with high continentality in the Carpathian Basin.

The next paleo-climatological - malacological horizon started from 25,000/24,500 cal BP years. *Granaria frumentum* disappeared, the dominance of the thermophilous species declined and some cold-resistant and cryophilous species, such as tundra-like environment favorable Boreo-Alpine

Columella columella and N-Asian xeromontan *Vallonia tenuilabris* occurred in this horizon. The dominance of the mesophilous species increased. A cold climatic phase developed and typical loess fauna formed in the analyzed region.

But the fauna composition of this zone was not homogenous. On the other hand, according to the findings of the sedimentological (Pécsi 1975, 1977, 1993), malacological (Sümegi 1989, 1996, 2005; Sümegi & Krolopp 1995, 2002), anthracological (Rudner & Sümegi 2001), and palynological investigations of the Upper Würmian (MIS2) profiles in the Carpathian Basin (Sümegi et al. 1999, 2013; Magyari 2002; Magyari et al. 1999) the loess formation was not continuous in this area during the Upper Würmian or the Upper Pleniglacial as in Western Europe (West 1984). But this strong cooling phase was interrupted by several alternating short warming and cooling, lasting for some hundred or some thousand years (micro-interstadial) which slowed down loess accumulation in the area.

The first micro-interstadial was recorded at 23,000 cal BP years, and was characterized by an increase in mesophilous land snails. The southern areas of the Carpathian Basin witnessed an expansion of the thermophilous elements of the mollusk fauna during this time (*Granaria frumentum*), while the waterbank areas were populated by eurytpic, hygrophilous, shade-loving forms requiring larger vegetation cover and inhabiting the modern boreal woodlands as well (*Clausilia dubia, Perofratella bidenetata, Arianta arbustorum, Discus ruderatus*). Conversely, the shade-loving elements have undergone an increase in the south-western parts of the basin (*Orcula dolium, Vitrea crystallina*).

These paleo-environmental data imply the survival of the formerly existing mosaic-patterning in the environment (and the flora) during this time, leading to the emergence of mixed, extinct floral and faunal associations. However, a characteristic increase in the dominance of the mesophilous, forest steppe dweller *Vallonia costata* is clearly observable in the majority of the profiles for this time (*Vallonia costata* zonula: Sümegi 1989).These short dominance changes of the different ecological tolerant species suggest that some dynamic climatic changes developed in the analyzed area during the beginning phase of the MIS2. The malaco-thermometer data showed the July paleo-temperature changed around 17^{o}C in this horizon.

After 23,000 cal BP all the thermophilous species disappeared, but the dominance of the cold-resistant and cryophilous species increased until 18,000 / 17,000 cal BP years. According to the malaco-thermometer data, July paleo-temperatures ranged between 11–14 ^{o}C in this cold phase representing the Last Glacial Maximum. A large number of woodland-dwellers, such as *Orcula dolium*, *Discus ruderatus* turn up in the malacofauna around 21,000 cal BP years. According to the dominance values and distributions of *Punctum pygmaeum* along with other woodland dwellers and elements preferring larger vegetation cover (*Orcula dolium, Discus ruderatus, Mastus venerabilis, Semilimax semilimax, S. kotulai, Vitrina pellucida, Vestia turgida, Arianta arbostrum*), extensive closed woodlands and gallery forests as well as forest-steppes must have developed in the southern parts of Transdanubia and the Great Hungarian Plains, along the major water courses and in certain parts of the mid-mountains in the Carpathian Basin during this (Dunazug Mts., Tokaj Mts.).

This paleo-ecological state resembles mostly to the mosaic-like vegetation of the taiga - forest steppe border zone in Southern Siberia (Sümegi 1989, 1996, 2005, 2007; Sümegi et al. 1999, 2012, 2013a, b). According to the general distribution of the elements preferring larger vegetation cover this time, the northward expansion of woodlands must have started off from the woodland refugia of the Northern Balkans, as well as the southern parts of the Great Hungarian Plains. On the other hand, the presence of forest covered regions inferred for the areas of the mid-mountains during this paleo-ecological horizon refer to the existence of woodland refugia within the Carpathian Basin as well during the end of the Pleistocene, (one of such refugia could have been identified in the Kereszt Hill of the Tokaj Mts. region: Sümegi 2005) or Bükk Mountain (Sümegi & Náfrádi 2015), from where the woodland elements could have started their expansion to other areas during times with favorable ecological conditions.

According to the appearance of *Orcula dolium*, *Discus ruderatus* and the dominance maximum of *Punctum pygmaeum, Clausilia dubia*, *Vitrina pellucida*, and *Vitrea crystallina* in the fauna a relatively milder climate must have emerged in this horizon, characterized by mean July paleo-temperatures ranging about 15±1 ^{o}C.

After 21,000 cal BP years the fauna composition changed very dynamically. The dominance of the mesophilous species decline, cold-resistant and cryophilous species such as *Trichia hispida, Columella columella, Vallonia tenuilabris, and Pupilla sterri* dominated again in this horizon. The July paleo-temperature decreased and stabilized between 11-14 ^{o}C. Cold – humid growing seasons developed in this climatic phase and a mosaic-like vegetation harboring tundra, scrub and boreal elements emerged in the Carpathian Basin.

The molluscs tend to react rather sensitively to environmental changes appearing at a micro or local scale. Thus via observing the transformations in the mollusc fauna, we can get a better view of the former environmental changes at a higher resolution compared to the one we get by studying the more mobile vertebrate elements of the fauna, enabling the detection of even small-scale changes (Kretzoi 1977). According to our findings, the classical so-called Dokuchaev zonation of the soils and the vegetation was not present in the area of the Carpathian Basin not even during the time of loess formation, hampering the utilization of the Northern European boreal taiga areas as modern analogies of this region. However, via the analysis of the mollusc fauna, we could have justified the presence of a climatic interface in the center of the Carpathian basin assumed by Kretzoi (1977) as well on the basis of the distribution patterns observable in the former vertebrate fauna.

Between 18,000–16,000 cal BP years, the thermophilous species re-occurred and the dominance of the cryophilous species declined. Cold-resistant and mesophilous steppe dwelling elements prevailed in this interstadial horizon. A relatively milder climate must have emerged between 18,000 and 16,000 cal BP years, characterized by mean July paleo-temperatures around 15 ± 1 ^{o}C

This previously mentioned persistence was characteristic to the interface of the major climatic zones, observable in the north-south and east-west trending of the continuous transformations of the flora and the fauna equally present during both the stadials and interstadials. Since it was only the absolute values of the temperature and the humidity that underwent a change, the general trends at a macro-scale were preserved in all cases. Via the observable changes in the paleo-temperature, colder and milder climatic phases corresponding to cycles of 1500/1000-5000 years could have been identified.

These climatic fluctuations had considerable effects on the Upper Paleolithic communities (Gábori & Gábori 1957; T. Dobosi & Vörös 1986, 1987). These smaller scale changes of some ten kys fundamentally determined the composition and migration of the animal herds upon which these humans preyed. Nevertheless, it might be also interesting to know how the mosaic-pattern influenced these Upper Paleolithic groups. In order to address this problem, the distribution of the individual environmental components was compared with that of the Upper Paleolithic sites. The necessary data for this work derived from various archeological papers on the one hand (T. Dobosi 1967, 1975, 1989, 1992, 1994, 1996, 2000; T. Dobosi & Simán 1996; T. Dobosi & Vörös 1986, 1987; T. Dobosi et al. 1983, 1988; Gábori & Gáboriné Csánk 1957; Gábori 1954, 1955, 1968, 1969, 1980, 1981, 1984; Gáboriné Csánk 1978, 1980, 1984; Banner 1936; Vértes 1964/1965, 1965, 1966) as well as our personal paleo-environmental database created via the study of the loess profiles. A comparison of these results was plausible either with the help of radiocarbon dates, or via making direct paleo-environmental observations at the excavation sites themselves.

After this afforestation stage, another cold maximum must have developed in the basin corresponding to the last significant appearance of the cold-loving elements (*Columella columella, Pupilla sterri, Vallonia tenuilabris*). This stadial horizon dated to the end of the Upper Würmian and the beginning of the Late Glacial can be observed in almost every Hungarian loess profiles (Sümegi 1988). According to the results of detailed chronological and paleontological studies (Sümegi 1988) this zone termed as the *Pupilla sterri* zonula (16,000–14,000 cal BP years) must correspond to the oldest Dryas stage of the palynological studies.

After this cold peak, the cold-loving elements underwent a gradual retreat then finally completely disappeared from the Hungarian loess deposits, and there was a dominance peak of the cold-resistant, hygrophilous elements (*Succinea oblonga, Columella edentula, Vertigo parcedentata, Trichia hispida*) around 14,000-12,000 cal BP years (Sümegi 1989). These latter taxa appeared in mass volumes in the profiles, sometimes representing even 90% of the total fauna as well. Based on the malacofauna composition a transition climatic and environmental phase developed during the last loess forming period.

Summary

MIS3 stage

According to the findings of complex radiocarbon dated malacological studies implemented on 27 loess/paleosol profiles in Hungary, the period dated between 35,000 and 10,000 cal BP years were characterized by cyclic climatic oscillations (**Fig. 1.**).

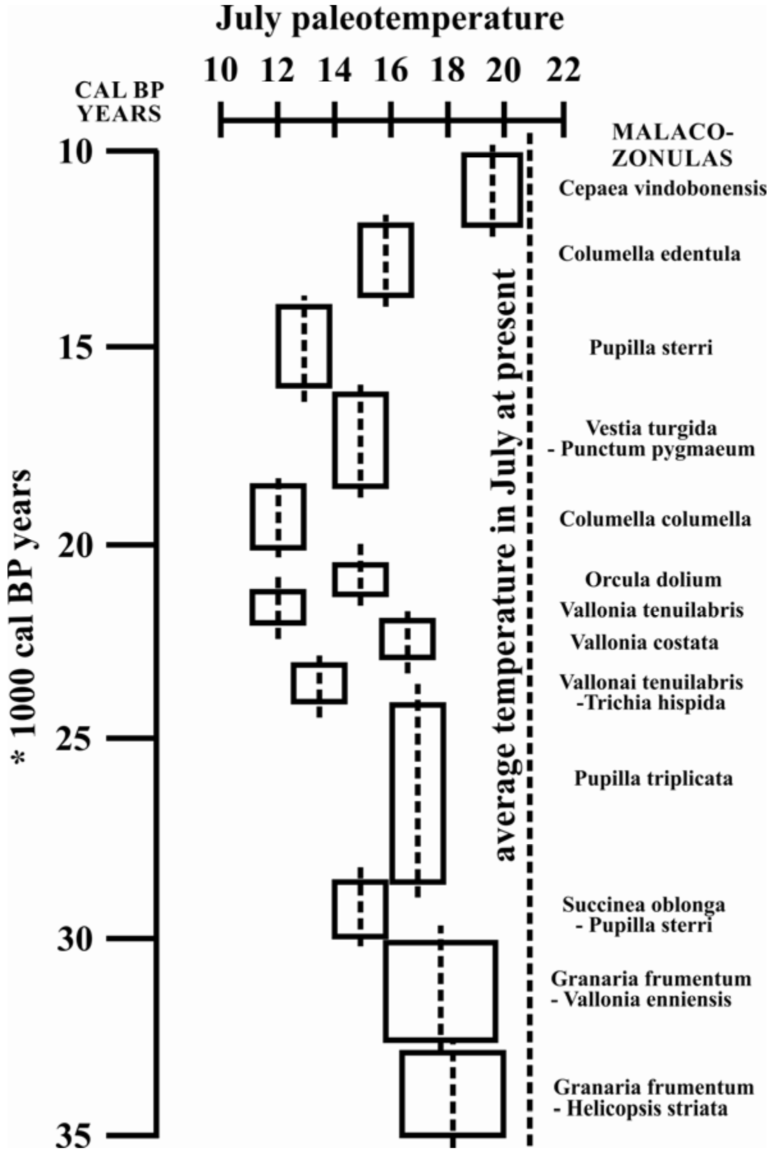

Fig. 1.:

Malacothermometer reconstructed July paletemperature changes from 35,000 cal BP to 10,000 cal BP years in the Carpathian basin

dashed line: average July paleotemperature value,

boxes: maximum and minimum values of July paleo-temperature

1. ábra:

A malakohőmérő módszerével rekonstruált júliusi középhőméséklet változásai 10 000 és 35 000 cal BP évek között a Kárpát-medencében

szaggatott vonal: átlagos júliusi középhőmérséklet,

négyzetek oldalai: minimum és maximum értékek

The interstadials correlate well with the Dansgaard – Oeschger (DO) interstadials 8, 7, 6, 5, 4, 3, 2 (Bond et al. 1992, 1993, 1999) seen in the Greenland ice core oxygen isotope records. The start of the intervening cold phases on the other hand correlate with Heinrich events 1, 2, 3, 4 and the LGM (Bond et al. 1999; Cacho et al. 1999; Voelker et al. 1998; Voelker 2002; Antoine et al. 2001; Rousseau et al. 2002; Daniau et al. 2007; Wohlfarth et al. 2008; Veres et al. 2010). These data overall confirm that millennial scale climate variability during second half of the MIS3 and MIS2 stages (Svensson et al. 2006; Rassmussen et al. 2006, 2008, 2014) had profound effect on the terrestrial ecosystems in the continental interior of SE Europe leading to the expansion of mixed boreal forest steppes in the interstadials. Conversely, the ecotone of cold steppe, taiga and tundra mosaics underwent an expansion during the stadial phases (Sümegi 2005, 2011; Sümegi et al. 2012).

The first radiocarbon-dated chronological and paleo-climatological unit determined from the inferred paleoclimatic changes dates between 35,000 – 29,000 cal BP years. This phase was characterized by milder and more humid conditions (Krolopp & Sümegi, 1992, 1995; Sümegi 2011).For this time interval according to malaco-thermometer method (Sümegi, 1989, 1996, 2005, 2007) we could infer mean July paleo-temperatures ranging around 19-20 °C in the southern parts of the Carpathian Basin, 18 °C in the central parts of the Great Hungarian Plains, and 17 °C in the Northern Mid-Mountains and the southern foothills of the Northern Carpathians, respectively (Sümegi & Krolopp 1995, 2002; Sümegi et al. 2000, 2002). Based on the occurrence of indicator snail species, a mixed taiga-steppe vegetation developed with mean January temperatures ranging between -3 °C and -10 °C and annual temperatures between +6 °C and +9 °C. The earliest Gravettian hunters appeared during this interstadial phase in the Carpathian Basin.

According to malacological data from thickest loess profiles in the Carpathian Basin, a short but intense cold phase formed 30,000 and 29,000 cal BP years in the Carpathian Basin. During this stadial, the otherwise relatively low July mean temperatures further decreased. Mean July paleo-temperatures were around 15 $\pm$ 1 ^{o}C in this phase (Sümegi et al. 2019). Based on mollusc distribution data (Sümegi et al. 2019) low growing season and low winter temperatures (between -7 ^{o}C and -17 ^{o}C) prevailed. In addition, annual temperatures were likewise very low (between +5 °C to +7 °C).

The next interstadial phase representing the period between 29,000 - 25,000/24,500 calBP years was characterized by higher July paleo-temperatures (16-17 °C) and drier conditions (Sümegi 1989, 1996, 2005, 2007, 2014) in the Carpathian Basin. This paleo-ecological horizon was classified as the *Pupilla triplicata* zonula which is rich in burnt charcoal fragments (Sümegi 2014). This burnt horizon is overlain by loess again. However, the loess and the underlying paleosol tend to be interfingered marking the significance of cyclically fluctuating bioactivities during the initiation of dust accumulation.

MIS2 stage

The next paleo-climatological - malacological horizon started from 25,000/24, 500 cal BP years. The dominance of the thermophilous species declined and some cold-resistant and cryophilous species like the Boreo-Alpin *Columella columella* and N-Asian xeromontane *Vallonia tenuilabris* occurred. The dominance of mesophilous species increased. A cold climatic phase developed and typical loess fauna formed in the analyzed region.

Yet the fauna of MIS2 was far from being homogenous. Therefore this strong cooling phase was interrupted by several alternating short warming and cooling, lasting for some hundred or some thousand years (microinterstadial) which slowed down dust accumulation in the area. The first microinterstadial was recorded at 23,000 cal BP years, and was characterized by an increase in mesophilous land snails. The southern areas of the Carpathian Basin witnessed an expansion of the thermophilous elements of the mollusc fauna during this time. Conversely, the shade-loving elements have undergone an increase in the south-western parts of the basin (*Orcula dolium, Vitrea crystallina*). These paleo-environmental data imply the survival of the formerly existing mosaic-patterning in the environment, leading to the emergence of mixed, extinct floral and faunal associations. However, a characteristic increase in the dominance of the mesophilous, forest steppe dweller *Vallonia costata* is clearly observable in the majority of the profiles for this time (*Vallonia costata* zonula: Sümegi 1989). Mean July paleo-temperatures changed to 17 ^{o}C $\pm$ 1 ^{o}C in this short interstadial.

After 23,000 cal BP years the fauna composition changed very dynamically. The dominance of the mesophilous species decline, cold-resistant and cryophilous species such as *Trichia hispida, Columella columella, Vallonia tenuilabris, and Pupilla sterri* dominate this horizon and Boreo-Alpine elements such as *Vertigo genesii*, *Vertigo parcedentata* (Pokryszko 1993; Van Helsdingen 1996; Hausdorf 2006; White et al. 2008; Meng 2008) occur. The July paleo-temperature decreased and stabilized between 11-14 ^{o}C in the Carpathian Basin. Cold – humid growth seasons developed and a mosaic of tundra, tundra-like vegetation spots, cold steppes, shrublands with scattered stands of arboreal vegetation emerged.

The second relative temperate phase formed around 21,000 cal BP years. According to the appearance of *Orcula dolium*, *Discus ruderatus* and the dominance maximum of *Punctum pygmaeum, Clausilia dubia*, *Vitrina pellucida*, and *Vitrea crystallina* in the fauna a relatively milder climate must have emerged in this horizon, characterized by mean July paleo-temperatures ranging about 15±1 ^{o}C.

After 21,000 cal BP years, the fauna composition changed very dynamically again. There is a decline in mesophilous species with dominance of cold-resistant and cryophilous species (*Trichia hispida, Columella columella, Vallonia tenuilabris, Pupilla sterri*) until 18,000 cal BP years. Boreo-Alpine elements (*Vertigo genesii*, *Vertigo parcedentata*) (Pokryszko 1993; Van Helsdingen 1996; Hausdorf 2006; White et al. 2008; Meng 2008) also reappear in the fauna. July paleo-temperatures decreased and stabilized between 11-14 ^{o}C. Cold – humid growth seasons developed in this climatic phase.

Between 18,000 – 16,000 cal BP years there is a decline in cryophilous species accompanied by the reoccurrence of thermophilous species. The dominant forms in this interstadial horizon are cold-resistant and mesophilous steppe like environment dwelling elements. These include the Central European montane shade-loving species like *Vestia turgida, Cochlodina cerata, Semilimax semilimax, Semilimax kotulai, Cochlodina laminata*. The composition of the mollusc fauna indicates the emergence of a relatively milder climate with mean July paleo-temperatures ranging around 15±1 ^{o}C.

After this afforestation stage another cold maximum must have developed in the basin corresponding to the last significant appearance of the cold-loving elements (*Columella columella, Pupilla sterri, Vallonia tenuilabris* and *Vertigo pseudosubstiata*). This stadial horizon dated to the end of the Upper Würmian and the beginning of the Late Glacial (around 16,000-13, 500 cal BP years) can be observed in almost every Hungarian loess profiles (Sümegi et al. 1991). Based on detailed chronological and paleontological studies (Sümegi et al. 1991; Szöőr et al. 1991), this zone was termed as the *Pupilla sterri* zonula. There was a decrease in July paleo-temperatures to stable values between 12-14 ^{o}C.

After this cold peak, the cold-loving elements underwent a gradual retreat then finally completely disappeared from the Hungarian loess deposits. There is a dominance peak of the cold-resistant, hygrophilous elements (*Succinea oblonga, Columella edentula, Trichia hispida*) around 13500-12000 BP (Sümegi 1989). These latter taxa appeared in mass volumes in the profiles, sometimes representing even 90% of the total fauna as well. This period is characterized by somewhat milder and more humid conditions. It also marks the last appearance of the loess fauna (*Columella edentula* zonula).The composition of the mollusc fauna indicates the emergence of relatively milder climate with mean July paleo-temperatures around 15 ± 1 ^{o}C.

After 12,000 BP, cold-loving elements (*Columella columella, Vallonia tenuilabris*) completely disappear from the central part of the Carpathian Basin. Afterwards there is a decrease in the proportions of cold-resistant forms as well (between 11,000-9,000 BP years), retreating back into the colder refugia of the basin (e.g. Bátorliget). On the other hand, the steppe-forest steppe dwellers start to expand (*Cepaea vindobonensis* zonula) gradually becoming dominant elements of the fauna (Sümegi 1989). According to this transformation in the mollusc fauna, colder loess steppes and mixed taiga woodlands, characterized by mean July paleo-temperatures between 12-16 °C were gradually overtaken by milder temperate forest steppes containing steppe and deciduous woodland elements (mean July paleo-temperatures 16-22 °C). All this led to the cessation of loess formation in the basin between 12,000-10,000 cal BP years. Cessation of loess formation in the Carpathian Basin was coeval with the disappearance of the periglacial environmental conditions (Willis et al. 1995).

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PALEOENVIRONMENTAL RECONSTRUCTION OF THE ALSÓNYÉK-BÁTASZÉK STARČEVO SITE USING ARCHEOMALACOLOGICAL DATA•

ALSÓNYÉK-BÁTASZÉK STARČEVO LELŐHELY ŐSKÖRNYEZETI REKONSTRUKCIÓJA ARCHEOMALAKOLÓGIAI ADATOK ALAPJÁN

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Abstract

From 2006 rescue excavations near Bátaszék SW Hungary revealed the presence of numerous archeological features dated to the Neolithic. This work presents the findings of archeomalacological investigations implemented at the Department of Geology and Paleontology, University of Szeged on samples from Starčevo feature. These studies included the taxonomic determination of the recovered mollusk taxa, size distribution analysis as well as geochemical analysis of freshwater shells. The studied material yielded 1382 individuals of 18 taxa (11 freshwater snails, 4 mussels and 3 terrestrial snails). Most of the examined freshwater species are characterized by a preference for moving-water conditions, while a smaller proportion was preferring standing water or temporary moving water conditions. Based on our findings, a more versatile use of the floodplain characterized by dominantly moving-water conditions may signal increased flooding preceding the time of site abandonment similarly to coeval Körös culture sites in the Middle Tisza region.

Kivonat

A Tolna megyei Bátaszék határában a 2006-tól a megelőző ásatások során több, a neolit korhoz is kapcsolható kultúra maradványait tárták fel. A Starčevo kultúra malakológiai leletanyaga a Szegedi Tudományegyetem Földtani és Őslénytani tanszékén került feldolgozásra. A vizsgálatok magukba foglalták a kagyló és csigahéjak taxonómiai meghatározását, a magassági és szélességi értékek meghatározását, méreteloszlásvizsgálatot és geokémiai vizsgálatot. Az 1382 mintából 18 fajt sikerült azonosítani, melyből három volt szárazföldi csigafaj, 11 vízi csigafaj és 4 kagylófaj. A vizsgált édesvízi fajok nagy többsége áramló környezethez, míg a kisebb hányaduk a lassú áramlókörnyezhez vagy az állóvízhez köthető fajok voltak. Az archeomalakológiai és héjgeokémiai eredmények alapján kijelenthető, hogy mai dunai viszonyokhoz képest a begyűjtés egy eltérő hidrodinamikai rendszerben történhetett. A kapott eredmények alapján kijelenthető, hogy a Starčevo-telep felhagyását megelőzően a környező árteret döntően mozgóvízi körülmények jellemezték, mely intenzívebb áradásokra utalhat. Hasonló változások voltak megfigyelhetőek a Tisza vidékén levő ugyanolyan korú Körös lelőhelyeken is.

KEYWORDS: MOLLUSKS, NEOLITHIC, STARČEVO CULTURE, PALEOENVIRONMENT RECONSTRUCTION

KULCSSZAVAK: PUHATESTŰEK, NEOLITIKUM, STARČEVO-KULTÚRA, KÖRNYEZETI REKONSTRUKCIÓ

Introduction

The region of the Carpathian Basin was occupied by three Neolithic cultural groups - Körös, Starčevo, Criş - from the 6th millennia BC. This is an important phase in human history, as this period witnessed one of the largest economic and cultural transformations, the spread of agriculture, which replaced the former hunting-gathering lifestyle (Kalicz 1990).

One of the main advantages of agriculture is the stable produce, but in periods of crisis, when there is crop failure or the output is not enough, alternative food sources are also included in subsistence like fish or shellfish. Multivariable archeomalacological studies can help us identify the role of these secondary resources in subsistence with potential underlying causes (Gulyás 2011; Gulyás and Sümegi 2012). This study presents the results of such investigations at one of the Early Neolithic sites in the Mid-Danube valley near Bátaszék, SW Hungary.

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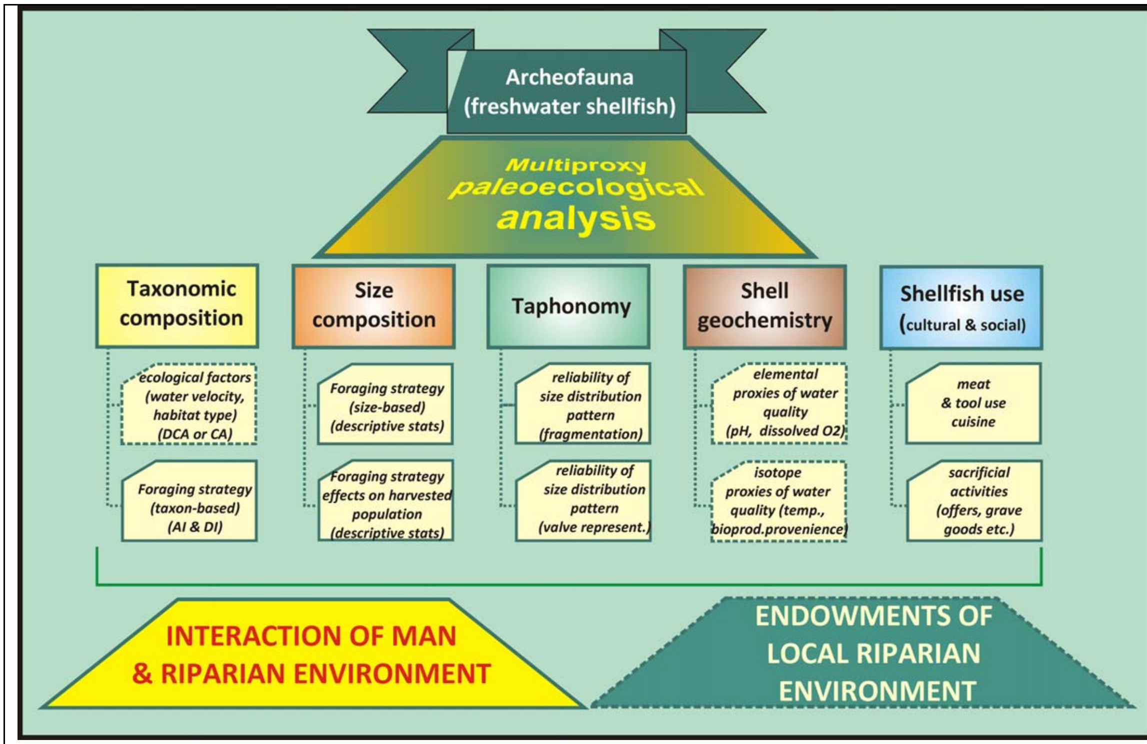

Fig. 1.: The steps of multiproxy paleoecological analysis (Gulyás & Sümegi 2011)
1. ábra: A többtényezős paleoökológiai elemzés lépései

Study area

The studied shells came to light from the south-east area of an excavation site found near Bátaszék: Bátaszék-Mérnökségi Telep. The city Alsónyék, Bátaszék located in Tolna country, SW Hungary, in the Tolnai-Sárköz micro-region. A substantial part of the surface is covered with the Pannonian/Holocene muddy substrate of Danube. (Dövényi 2010). Before the river regulations most of the area was part of the floodplain of the Danube and its small tributaries.

Archeological excavations lasted from 2006 to 2009. The entire site has an estimated extension of ca. 80 hectares, of which only ca. 25 hectares (254.417 m^2) have been systematically excavated (Osztás et al. 2016: p. 18). The number of excavated features was 15,443, from which 10.191 are from the Neolithic. In our study site excavations began in 2008. Here out of the 2.911 features 2.401 was Neolithic. Besides the 72.470 ceramic fragment and 30.914 animal bones (Osztás et al. 2016: p. 18) 25 human remains have been encountered dated to this period (Köhler 2015: p. 4).

Starčevo culture

Representatives of the Starčevo culture occupied the region of Transdanubia south of Lake Balaton from the 6th millennia BC. The coeval Körös and Criş cultures are found east of the Danube. The Starčevo culture created the first burned pottery in Transdanubia. Our studied settlements are found on a long ridge of larger streams and rivers. With time agriculture (einkorn wheat, emmer wheat, barley) and animal husbandry (cattle, sheep, goat, pig) got continually bigger emphasis. In the middle of the 6th millennia the emergence of the Central European Linear Pottery culture (LBK) in the Carpathian Basin led to the disappearance of the Starčevo culture. (Kalicz 1990)

Material and methods

In this study we followed the multiproxy paleoecological analysis (**Fig. 1.**) presented in Gulyás (2011) and Gulyás & Sümegi (2011, 2012a) for freshwater shells with a slight change. This enabled us to compare our results with those of other studied coeval sites. The purpose of the analysis is to highlight human environment interactions in riparian environments as well as the importance of second-line food resources.

The first step is the identification of taxonomic composition, if possible, at the species level. This is followed by the determination of minimum number of individuals (MNI) (Grayson 1978). This is then used to calculate the relative abundances of the identified taxa for each sample (Cannon 2001). Shannon diversity index (1949) provides information on taxon-specific foraging (Gulyás & Sümegi 2012a; Peet 1974). Higher diversity means the inclusion of more taxa in the harvested fauna; i.e. species with low economic value.

By applying correspondence analysis to a taxon abundance data matrix, with taxa in columns and samples in rows it is possible to investigate the complex taxonomical composition of the samples considering the environmental demand of the individual species as well (Gulyás & Sümegi 2012a). In this method the sample number and the individual numbers matrix can be described as a multi-dimensional space, which is transformed into a "theoretical ecological space", into a reduced one-dimensional space. In this space each species occupies a point corresponding to its ecological demands. Eigenvalues from each axis are interpreted as a background variable, which presents how the frequency of species with different ecological demands varies in the local ecological space.

The next step involves the description of size. Shell height and width was recorded on valves of mussels belonging to the group of *Unionidae* and freshwater snails of the *Viviparidea* family. Using univariate statistical descriptors (average, median, variance, skewness, kurtosis, range) we can get an overview of the age and size distribution of the fauna; in other words the demographic composition (Gulyás & Sümegi 2012a).

The following investigation involves detection of any signs of alteration of the shells carrying information on the utilization. Ash-brown shells indicate roasting before consumption.

Geochemical investigations provide information on the bioproductivity and volume changes of waterbodies of the surrounding freshwater habitats from which the mollusks derive. Because of their filtrating lifestyle, shellfish integrate trace elements into their shells in the same concentration as in their environment (Ravera et al. 2003; Gulyás & Sümegi 2012a). There is a strong correlation between the measured manganese concentrations and bioproductivity (Langlet et al. 2006). Green-algae are able to include manganese in large quantities in their bodies (Sunda & Huntsman 1985), which is released after their death into the water. However, a high degree of bioproduction requires a large amount of oxygen consumption, therefore, the higher manganese content in the shells indicates smaller dissolved oxygen content. Due to the significant use of oxygen, the reduction of iron and manganese lowers the pH of the water (Richardson et al. 1988). Since the water solubility of Fe^{2+}, Co^{2+} and Zn^{2+} is highly pH dependent (Stumm & Morgan 1996), we can get an understanding of the changes in the pH conditions of the water based on concentration values recorded in our shells. Geochemical investigations have been performed on a total of 69 specimens, of which 33 (24 pcs *Unio crassus*, 9 pcs *Unio tumidus*) originated from Sample 27, 10 from Sample 2 (10 pcs *Viviparus acerosus*). In addition 26 specimens (8-8 pcs *Unio crassus* and *Unio tumidus*, 10 pcs *Viviparus acerosus*) derive from the modern Danube near Baja (Nagy 2018). Manganese, iron and zinc content of the shells were determined after wet digestion using the flame AAS technique (Perkin Elmer A10 AAS). To determine if the individuals came from one or more places, a Kruskal-Wallis test on the results was implemented.

Results

A total of 14 samples were investigated containing 1382 pcs (Tab. 1) of identifiable individuals. The samples were taken from a refuse pit, object 1.107. From the identified 18 taxa *Viviparus acerosus* (BOURGUIGNAT 1862) (686 pcs) was the most frequent followed by *Unio crassus* (PHILIPSSON 1788) with 225 pieces and *Unio tumidus* (PHILIPSON 1788) with 151 shells (Nagy 2018: 27-46. p.). 9 samples were dominated moving-water species, while in five samples the dominance of stagnant water or slowly moving-water species was typical.

It is already apparent from these data, the environs around the site were constantly changing, and different aquatic environments were targeted. The results of correspondence analysis also led to similar conclusions (**Fig. 2.**). Note that sample 27/3 is separated from other samples because of the small number of individuals. On **Fig. 2**. Axis 1 must represent stream velocity, while Axis 2 substrate type. Positive eigenvalues on Axis 1 correspond to higher velocities. Positive values on Axis 2 represent sandy substrates.

Table 1.: List of the identified species (Nagy 2018) (NISP: Number of the identified specimens, MNI: Minimum number of individuals)

1 táblázat: Azonosított fajok listája (NISP: teljes felismert példányszám, MNI: legkisebb becsült egyedszám)

Paleoecological group	Név	NISP	MNI	Dominance	Dominance of the paleoeocological groups
Terrestrial species	*Chondrula tridens* (MÜLLER 1774)	12	12	0.99%	2.56%
	Cepaea vindobonensis (PFEIFFER 1828)	6	6	0.50%	
	Granaria frumentum (DRAPARNAUD 1801)	13	13	1.07%	
Ditch species	*Anodonta cygnea* (LINNAEUS 1758)	4	4	0.33%	21.29%
	Anisus spirorbis (LINNAEUS 1758)	1	1	0.08%	
	Bithynia tentaculata (LINNAEUS 1758)	8	8	0.66%	
	Lymnaea stagnalis (LINNAEUS 1758)	51	51	4.21%	
	Planorbarius corneus (LINNAEUS 1758)	21	21	1.73%	
	Planorbis planorbis (LINNAEUS 1758)	1	1	0.08%	
	Stagnicola palustris (MÜLLER 1774)	18	18	1.49%	
	Unio pictorum (LINNAEUS 1758)	55	33	2.72%	
	Unio tumidus (PHILIPSON 1788)	151	95	7.84%	
	Valvata cristata (MÜLLER 1774)	15	15	1.24%	
	Valvata piscinalis (MÜLLER 1774)	11	11	0.91%	
Reophyllic species	*Lithoglyphus naticoides* (PFEIFFER 1828)	58	58	4.79%	76.16%
	Unio crassus (PHILIPSSON 1788)	225	133	10.97%	
	Viviparus acerosus (BOURGUIGNAT 1862)	686	686	56.60%	
	Viviparus contectus (MILLET 1813)	46	46	3.80%	
Total		1382	1212	100%	100%

Manganese concentrations in most of the *Unio crassus* shells from Sample 27 varied between 100 and 250 ppm. Similar values are reported by Bába et al. (2002) from modern Tisza specimens and Ravera et al. (2003) from specimens of an Italian lake. It must be noted though that these measurements were made on a shell of a different taxa. Measurements on samples from the Körös sites of Ecsegfalva 23B, Tiszapüspöki and Nagykörű-Gyümölcsös (Gulyás 2011) were done on representatives of the same taxa as ours, and values are comparable. (**Table 2.**) Low manganese concentrations indicate a lower rate of bioproduction, higher dissolved oxygen levels of the waterbodies found on the floodplain; i.e. higher freshwater supply with a higher water velocity. This also implies the presence of a highly unstable riparian environment, where water supply and flow conditions changed continuously (Gulyás & Sümegi 2012b). According to the Kruskal-Wallis test on the measured values, the samples must derive from the same habitat (P=0.35387, P=0.225343 without recent samples).

Concentrations of zinc in *Unio crassus* shells yielded similar results to those of the sites listed above. However, the standard deviation is very high here. It may also indicate that the individuals derive from a habitat where pH conditions are very diverse (Gulyás & Sümegi 2012b). Kruskal-Wallis test shows a significant difference between the samples (P=0.000605231; without recent samples P=0.00323383), so the collection may have targeted different habitats. Concentrations of zinc in *Unio crassus* shells yielded similar results to those of the other sites listed above. However, the standard deviation is very high here. It may also indicate that the individuals derive from a habitat where pH conditions are very diverse (Gulyás & Sümegi 2012b). Kruskal-Wallis test shows a significant difference between the samples (P=0.000605231; without recent samples P=0.00323383), so the collection may have targeted different habitats.

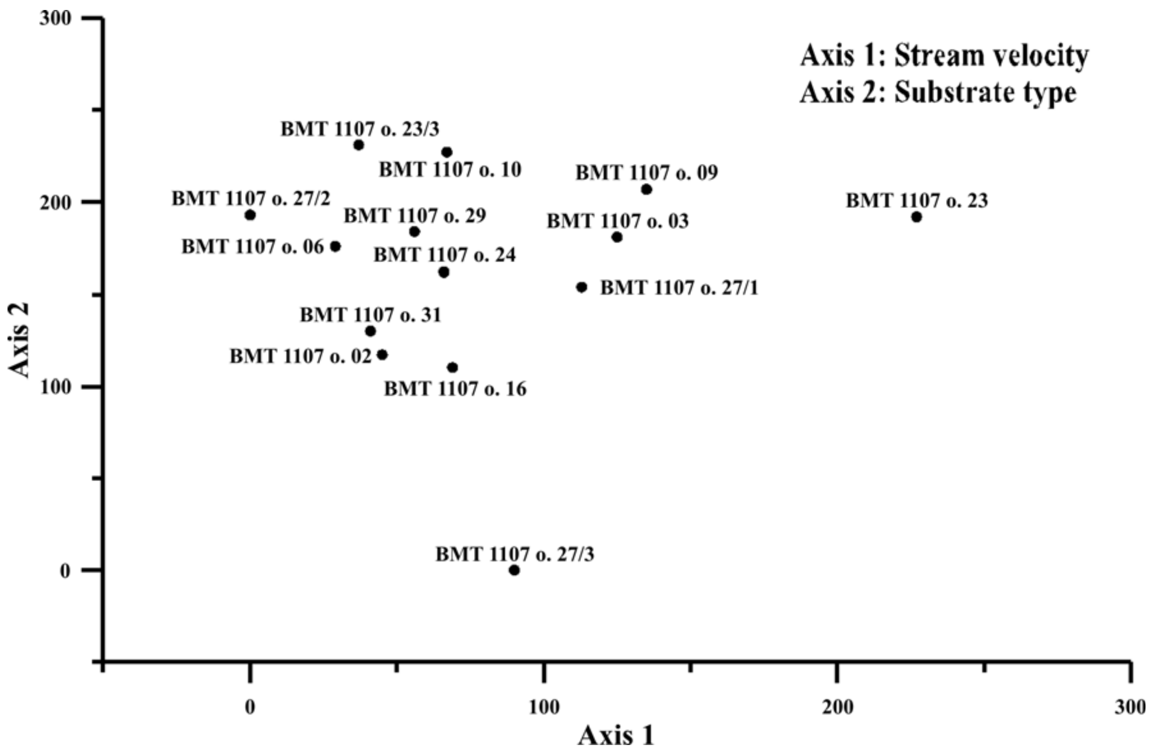

Fig. 2.: Results of the correspondence analysis (Nagy 2018)

2. ábra: A korrespondencia analízis eredménye

Table 2.: Mn and Zn concentration in mussels (U.c.: *Unio crassus,* U.t.: *Unio tumidus*, U.p. *Unio pictorum*) (after Nagy 2018, edited)

2. táblázat: Kagylók Mn és Zn koncentrációi (U.c.: *Unio crassus*, U.t.: *Unio tumidus*, U.p. *Unio pictoru*m)

	Sample 27 Nagy 2018: p. 51	Bába et al. 2002: p. 44	Ravera et al. 2003: p. 65	Ecsegfalva 23B Gulyás 2011: p. 52-53	Tiszapüspöki Gulyás 2011: p. 60-61	Nagykörű-Gyümölcsös Gulyás 2011: p. 69-70
Mn	U.c.: 214.4 ppm U.t.: 236.6 ppm	U. t.: 226 ppm; U. p.: 166 ppm	U.p.: 220 ppm	U.c.: 216 ppm	U.c.: 110-320 ppm	U.c.: 157-370 ppm
Zn	U. c.: 18.6 ppm U. t.: 17.2 ppm	U.t.: 11.17 ppm; U. p.: 26.25 ppm	U.p.: 19 ppm	U.c.: 17-21 ppm	U.c.: 12-13 ppm	U.c.: 15-35 ppm

In the case of *Unio tumidus*, the manganese content is slightly higher than that of *Unio crassus*. This may indicate a lower oxygen supply and a stable environment. These values are similar to measured data from Hungary and Europe. According to the Kruskal-Wallis test (P=0.196703; P=0.45198 considering the recent samples) there is no significant difference, so they come from the same habitat.

The standard deviation of the measured zinc content is very high indicating large-scale changes of the pH of the habitat. According to the Kruskal-Wallis test (P=0.0152741; without recent samples P= 0.020134), the collection of individuals could have happened from different habitats. The values are similar to the data from other sites in Hungary and Europe.

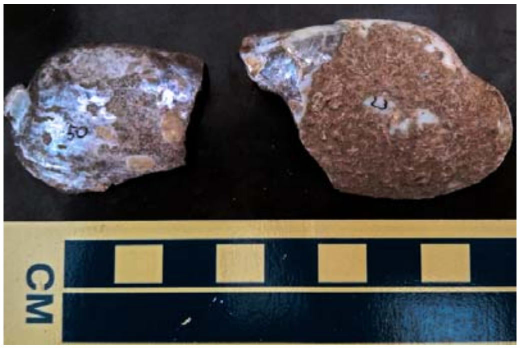

Fig. 3.: Scorched mussel shells (Nagy 2018, edited)

3. ábra: Megperzselődött kagylóhéjak

The low manganese content of the *Viviparus acerosus* shells from Sample 2 (average 56.3 ppm) indicates good oxygen supply and rapid water movement. Recent specimens yielded higher values (average 80.4 ppm), i.e. the two environments were different based on the manganese content, which is also supported by the Kruskal-Wallis test (P= 0.000155268). The amount of zinc in the archaeological specimens ranges on a wide scale (17-29 ppm), which may refer to the large-scale changes of pH. According to the results of the Kruskal-Wallis test, (P=0.272493) the samples must derive from similar habitats.

Some of the shells were ash-brown displaying signs of burning (**Fig. 3.**) (samples 6 and 24). This may imply roasting before consumption. Alternatively, mussel meat could have been used as fodder too (Fűköh 2007, Sümegi et al. 2011).

Conclusion

Based on our findings it is possible to distinguish a period characterized by a higher water velocity, high freshwater supply when mollusks were collected from the drainage channels (**Fig. 4.**).

After this period of intensified flooding more stable conditions emerged when the collection occurred in larger puddles and small ponds (Nagy 2018).

Studies at sites of similar age (Gulyás 2011; Gulyás & Sümegi 2012b) show a similar picture. Flooding and tranquil periods also changed around the Tisza settlements. The area of Bátaszék-Mérnöki Telep was abandoned during the late 6th millennium BC. The following settlement of the LBK-Culture (Linearbandkeramik or Linear Pottery Culture) is recorded after a ca. 160-310-year gap (Bánffy et al. 2016).

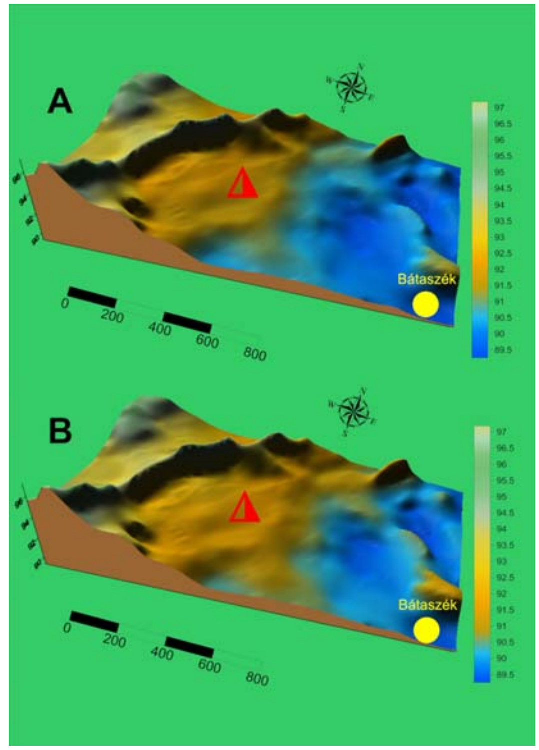

Fig. 4.: The environs of the excavation site (triangle) during floods (A) and after floods (B) (after Nagy 2018, edited)

4. ábra: A feltárás (háromszög) környéke árvizek idején (A) és az árvízek levonolása után (B)

Based on our findings, a more versatile use of the floodplain characterized by dominantly moving-water conditions may signal increased flooding preceding the time of site abandonment. Nevertheless, more data is needed to justify this assumption.

Acknowledgements

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A LANDSCAPE HISTORICAL OVERVIEW OF THE TWO TÖRÖK-HALOM KURGANS IN KÉTEGYHÁZA, HUNGARY•

A KÉTEGYHÁZI KÉT TÖRÖK-HALOM TÁJTÖRTÉNETI VÁZLATA

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Abstract

In the area of the Körös-Maros National Park called Kígyósi-puszta, the two kurgans – both called Török-halom (means "Turkish mound") – rising in the grassland near Kétegyháza are the two largest members of a kurgan field consisting of more than one hundred mounds. The kurgans were built by the local community of the semi-nomadic Yamnaya Entity of eastern origin at the end of the Copper Age (3000–2700 BC). Saline pastures and marshes surround the two mounds, but there is a relatively rich variety of Pannonic loess meadow steppe vegetation with regionally valuable plant species on the surface of the northern one. During the centuries, their surface did not escape disturbances (treasure hunting, permanent establishment of a land surveying point). Between the two mounds, a boundary ditch of Late Medieval origin is still preserved. The northern Török-halom kurgan is still relatively intact, but the southern has been demolished by the local cooperative for its material. The removal of the soil of the mound was preceded by an archaeological rescue excavation in 1967, when the foundation burial of the kurgan and three other burials were discovered. After the removal, only a small piece of the north-western part of the mound was left, but it had original vegetation. In 2011, the Körös-Maros National Park Directorate rebuilt the southern Török-halom involving significant earthworks as a landscape rehabilitation project, and planted loess vegetation on its surface.

Kivonat

A Körös-Maros Nemzeti Park Kígyósi-puszta területi egységén, a kétegyházi pusztán emelkedő két – mindkettő egyaránt a Török-halom nevet viselő – kurgán az itt található, több mint száz halomból álló halommező két legnagyobb tagja. A kurgánokat a keleti eredetű, nomád/félnomád Jamnaja-entitás helyi közössége emelte a rézkor végén (3000–2700 BC). A halom párt alapvetően szikes legelők és mocsarak veszik körül, az északi halom felszínén azonban aránylag fajgazdag, löszpusztagyep karakterű növényzet található, regionálisan értékes növényfajokkal. Az évszázadok alatt a kurgán felszínét a bolygatások sem kerülték el (kincskeresés, földmérési alappont állandósítása). A két halom között részleteiben megmaradt késő középkori eredetű határárok húzódik. Az északi Török-halom ma is viszonylagos épségben áll, a délit viszont a helyi termelőszövetkezet anyagnyerés céljából elhordta. Az elhordást 1967-ben régészeti ásatás (leletmentés) előzte meg, amely során a kurgán alaptemetkezését és további három sírt tártak fel benne. Az elhordást követően a halomnak csak az északnyugati lábrészéből maradt meg egy kis darab, mely azonban eredeti növényzetét megtartotta. A Körös-Maros Nemzeti Park Igazgatóság a déli Török-halmot nagy földmunkákkal járó, táj-rehabilitációs célú beruházással 2011-ben újraépítette, felszínére a löszvegetációra jellemző növényfajokat telepített.

KEYWORDS: YAMNAYA ENTITY, KURGAN (BURIAL MOUND), LANDSCAPE HISTORY, LANDSCAPE ECOLOGY, GREAT HUNGARIAN PLAIN, KÉTEGYHÁZA

KULCSSZAVAK: JAMNAJA-ENTITÁS, KURGÁN (HALOMSÍR), TÁJTÖRTÉNET, TÁJÖKOLÓGIA, ALFÖLD, KÉTEGYHÁZA

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Introduction

The thousands of burial mounds (kurgans) are the heritage of the so-called Yamnaya Group, who arrived in multiple waves to the Carpathian Basin – to the eastern part of River Tisza (Tiszántúl region), to the Danube-Tisza Interfluve and the Transylvanian Maros River Valley – between the Middle Copper Age and the beginning of the Bronze Age. These barrows still stand high in the plain, even if in a somewhat damaged state and diminished numbers. These animal breeding, nomadic pastoral groups of eastern origin raised these mounds for burial purposes, with a sacral function (Ecsedy 1979; Dani & Horváth 2012; Bede 2016).

These mounds are highly important from archaeological, paleoecological and cultural heritage perspectives, and are salient cultural element of the landscape. Through detailed and complex studies they provide information not only on the life history, archaeological heritage and customs of the people buried inside them, but also on the environment, the ancient flora and fauna, and the geological formations that existed at the time of their construction (Tóth 2011; Deák et al. 2016; Deák 2018; Tóth et al. 2018).

The present study attempts to outline the landscape historical aspects of a pair of mounds and to analyse the collected data at a historical level. In order to achieve this, archival documents, maps and photographs were used.

Material and methods

The prehistoric kurgans of the Tiszántúl region (east of the River Tisza) are barrows raised by the communities of the East European Yamnaya entity in the Late Copper Age/Early Bronze Age (3600–2700 BC) for burial and sacrificial (sacred) purposes (Ecsedy 1979; Dani & Horváth 2012).

The object of our study is a very characteristic pair of kurgans in the Great Hungarian Plain, located in the northern vicinity of Kétegyháza settlement and both of them bearing the name Török-halom. They exhibit both unique and general traits with regard to their external characteristics (location, character, and form), their structure and vegetation.

The kurgans of the discussed double mound bear the name Török-halom both together and separately. For this reason, we use consistently the terms northern and southern to differentiate them. Since the (landscape) history of the northern kurgan – and also its vegetation – has been relatively continuous and free of major formal changes and disturbances, we attempt to provide a complete picture of its natural state. The southern, larger kurgan became the victim of the greediness of the local cooperative: in the 1960s and 1970s the mound was virtually completely removed (only small, peripheral parts remained intact). Between 1966 and 1968, it was cut through during an archaeological excavation and its burials were unearthed (Ecsedy 1979, 21–23; Bede 2016, 83–84). In 2011, the Körös-Maros National Park Directorate rebuilt the kurgan as part of a large-scale project (Nagy 2012). Therefore, in the case of the southern mound, we focus primarily on its formal changes.

During the analysis, we primarily used handmade (M.1–3; M.5–8) and later printed maps (M.4; M.9–17) for the sake of completeness. In addition, local historical and natural scientific literature, the available aerial photographs (Fentről.hu; Military History Map Collection; Google Earth) and manuscripts (e.g. FÖMI; MNM RégAd XVIII. 282/1967) were also included in the study. Photographs from different decades show well the changes in the shape or vegetation of the mounds, or, on the contrary, recorded permanence (such as the border position).

Geomorphological conditions

"Today, the whole area of our village is plain, only here and there are some smaller hills. In the past, rain and floods grooved this vast plain, or small creeks from the nearby rivers meandered here, and then gradually transformed into lakes, mud, swamps and marshes" – as pastor Iosif Ioan Ardelean, the historian of Kétegyháza village described the landscape at the end of the 19th century (Ardelean 1986, 89).

The number of kurgans in the core area of the Kígyósi-puszta of the Körös-Maros National Park is 75. Although it touches the administrative area of other settlements as well, the kurgan field is usually connected to Kétegyháza village, as the highest number and density of mounds and mound groups can be found in the northern vicinity of Kétegyháza (Bede 2016, 82–84).

The landscape itself, which is outstanding from the point of view of natural protection as well, is varied and sometimes quite mosaic-like (**Fig. 1.**). Parallel ancient channels of the river Maros (Vizes-völgy, Apáti-ér, Szabadkai-ér, Nagy-Csattogó, Hajdú-völgy) cut through the terrain, with larger ridges and Pleistocene remnant surfaces between them (Gazdag 1960; Rónai & Fehérvári 1960; Rakonczai 1986a). In the central area of the plain, there are large salinized grasslands and marshes (alluvial basins), smaller loess meadow steppe fragments, in the periphery scattered arable lands, forests and smaller grasslands (Rakonczai 1986b; Kertész 2005; Kertész 2006).

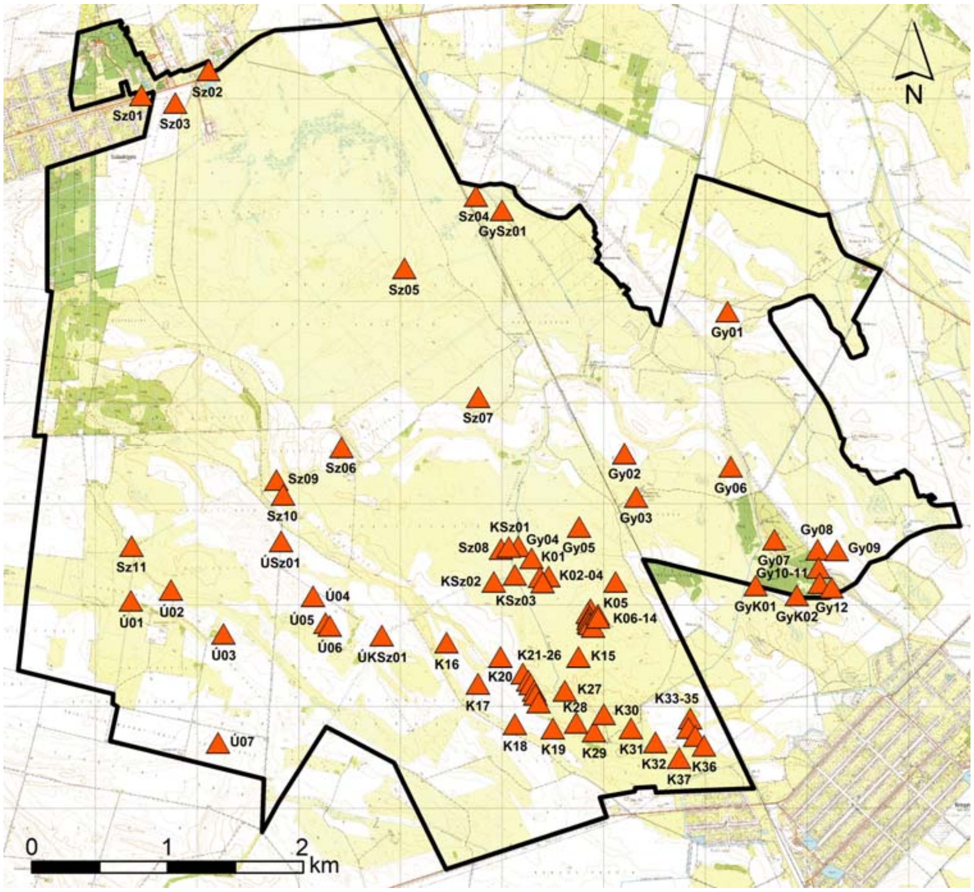

Fig. 1.: The Kígyós-puszta area, part of the Körös-Maros National Park with the kurgans surveyed by Á. Bede (based on Bede 2016)

1. ábra: A Körös-Maros Nemzeti Park Kígyós-puszta területe a Bede Á. által felmért halmokkal (Bede 2016 nyomán)

Natural geological and geomorphological conditions must have played a crucial role in the selection and construction of the kurgan field (Dövényi et al. 1977). The mounds are usually lined up along the banks of former riverbeds and on the ridges that accompany them.

In addition to the highest mounds – the two Török-halom (**Fig. 2.**) and the Hegyes-halom – a number of medium-sized or lower kurgans were also raised in the area. On both the western and eastern side of the Szabadkígyós-Kétegyháza railway there are two groups of very small barrows. They could remain relatively intact because due to the poor quality of the saline soil, they were probably never ploughed, or they had only a very small amount of disturbance. The 18^{th}-19^{th}-century military, manor and cadastral maps indicate several mounds of the kurgan field, and regularly mark the mounds at border points (M. 1–8). This landscape has been intensively cultivated since the first half of the 18^{th} century, following re-settlement after the Turkish rule, and the extension of arable land has grown continuously, which has left a permanent mark on many mounds.

Archaeological aspects

The significance of the mounds in the vicinity of Kétegyháza, Gyula, Szabadkígyós and Újkígyós is outstanding because they can be found here in densities and clusters that we do not experience elsewhere in the Maros-Körös Interfluve. In total, more than one hundred mounds have been registered in this relatively small (4,779 ha), but well-defined area. Perhaps it was a clan or tribal burial ground, a sacral centre for the people of the Pit Grave Kurgans, who lived here more than five thousand years ago (Bede 2016, 82).

The abundance – in a regional comparison – of (temporary) surface waters in the region may have contributed to the unusual density of the mounds, which may be connected to the lifestyle and landscape use of the communities living here.

Fig. 2.: The two Török-halom kurgans on the saline grassland in Kétegyháza, 1967 (photo by Gy. Gazdapusztai; MNM RégAd XVIII. 282/1967; Ecsedy 1979, 72, Pl. 4.1)

2. ábra: A déli és az északi Török-halom a kétegyházi szikes legelőn 1967-ben (Gazdapusztai Gy. felvétele; MNM RégAd XVIII. 282/1967; Ecsedy 1979, 72, Pl. 4.1)

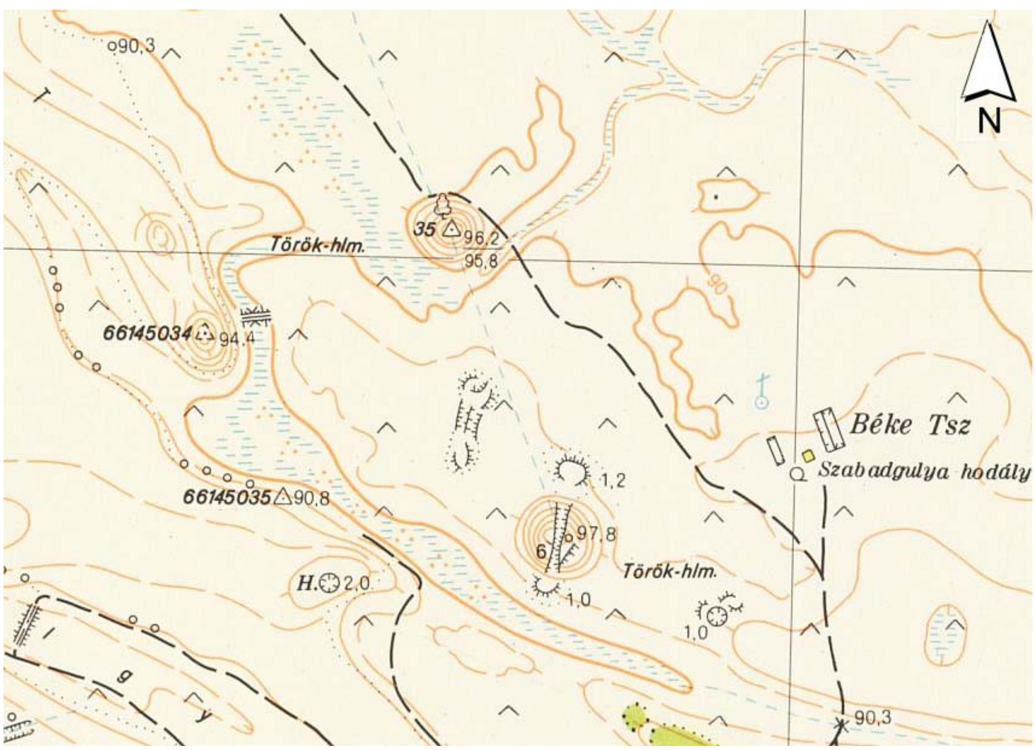

Fig. 3.: The northern and the cut southern Török-halom kurgans in 1969–1971 (M.13). Scale of original map 1:10,000

3. ábra: Az északi és az átvágott déli Török-halom 1969–1971-ben (M.13). Eredeti térkép méretaránya 1:10 000

In 1966–1968, Gyula Gazdapusztai excavated 17 burials in 11 kurgans near Kétegyháza, and the results were later published by István Ecsedy (Gazdapusztai 1966; Gazdapusztai 1967; Gazdapusztai 1968; Ecsedy 1979, 20–33). The Holocene palaeosoils under, and the material of the kurgans contained the artefacts of the Middle Copper Age Bodrogkeresztúr and Boleráz Cultures; the communities of later times (Scythians, Sarmatians) also buried into the mounds, and some central tombs were robbed during the Migration Period (Ecsedy 1973; Ecsedy 1979, 20–33). It is typical of the excavation methods of the time that several mounds could be excavated only at the price of being fully or partially destroyed, and many kurgans still bear the traces of the archaeological research fifty years ago (their central part is dug up, cut longitudinally, and the earth is still placed on the sides). Unfortunately, the removed soil was never reburied in any of the cases. The reconstruction of these mounds would require a targeted program with the help of a project grant.

The largest mound of the kurgan field is the southern Török-halom, which was almost completely destroyed by the local cooperative in the 1960s to fill up the streets in the centre of the village, leaving only a small part of its western periphery. Thanks to the excavation, we know its structure well: the barrow was the burial place of the Late Copper Age/Early Bronze Age people of the Pit Grave Kurgans containing four burials, raised in three different, consecutive periods (3000–2700 Cal BC). The timber framed burial chamber of the central burial, as well as the imprints of mats, furs and textiles in it, could be observed; a pair of silver hair rings, a necklace of animal teeth, an amulet, and red ochre paint containing iron oxide used for the ceremony were among the grave goods of the deceased, who had been buried with raised legs (Ecsedy 1979, 21–23; Horváth 2011, 92; Dani & Horváth 2012, 76).

The two Török-halom kurgans in the landscape

The northern kurgan

The main morphometric data of the northern Török-halom left in its original state are as follows. Central coordinates: WGS84 46°33’01.44” (46.550407) N, 21°08’31.44” (21.142058) E (Google Earth), EOV 810,618, 136,155 (EOTR 38-424; M.14); relative height: 5 m; absolute (altitude) height: 96.1 m; diameters: 58 m and 52 m. Perimeter: 218 m. Floor area: 3,670 m^2.

19th-21st-century printed maps also show the mound with its altitude above the Adriatic, and from 1953 the Baltic Sea. These are in chronological order: 53.1 fathom (100.7 m) (M.5), 97 m (M.5), 52.1 fathom (98.8 m) (M.6–8), 98 m (M.4; M.10), 96.2 m (M.11; M.15), 96.2/95.8 m (M.12), 95.9 m (M.14), 96.6 m (M.16–17). Toponym on maps: Török-hlm. (M.13–14; M.16–17).

The entire surface of the Török-halom is registered as grassland (pasture) with regard to type of exploitation. Topographical lot numbers: 0213/2, 0223/12. Interestingly, the dividing line between the two parcels is still the same as the late Medieval settlement boundary.

The third-rank triangulation base point on the top (plateau) of the mound was made permanent in 1981; its official number: 38-4234 (FÖMI). Due to lack of maintenance, it has been slightly damaged by now, the central vertical concrete element is loosened, but the square-shaped concrete cover is firmly fixed. The installation of such a base point – especially in the case of smaller mounds – can cause more serious damages, as the central part of the mound is dug up 1.5–2 m deep and 1–1.5 m wide and is then reburied.

Its name probably derives from the once well-known folk tradition that the mounds of the Great Hungarian Plain were human creations, raised during the Turkish rule, and according to legends, they were typically sentry points, messaging places, resting places, or burial sites. After the Turkish period, it was self-evident for the people – often of foreign origin – who had returned to the depopulated plain to link the already existing mounds to the Turkish world (Krupa 1981, 75).

It was probably a Late Medieval (16th-17th century), old border point, later a county border point between Kétegyháza village (Blazovich 1996, 159–160) and Kakucs territory (Blazovich 1996, 145–146), and between Békés and Arad Counties. (It is another Kakucs settlement, not the village which exists today in Pest County.) Since 1950 it belongs entirely to the administrative area of Kétegyháza. There was probably a boundary hill on the top (M.2; M.5–8), which is no longer present today.

The first (1783), the second (1860), the third military surveys (1884), the cadastral map of 1884, the 1884 census and the 1943 topographic map show it with Lehmann type hachures or in outline (M.1; M.3–5; M.7–9). In the 1884 cadastre map and in the military maps of 1950, 1955, 1982, 1991 and 2002 it is indicated as an elevation point (M.6; M.10–11; M.15–17), while in the 1969 and 1980 1:10,000 maps show detailed contours (M.13–14). Each map consistently displays it as on grassland.

In the 1960s and 1970s, a tree was standing on the top of the mound (**Fig. 2-3.**; Dövényi et al. 1977, 9. kép; M.13–14). Apart from this, it was probably always covered by dry grassland, with a loess meadow steppe character, although due to the use and intensive exploitation of the area, both the vegetation and the shape of the mound could have been affected by various disturbances (traces of diggings, foxholes, etc.). Although the barrow itself was probably never ploughed, the geomorphologic prominent parts of its immediate surroundings (loess hills) were already cultivated or used as a settlement in the Copper Age (Bodrogkeresztúr Culture), and later cultivation was expanded into even larger areas (e.g. by the Scythians, Celts, Sarmatians, Late Medieval Hungarians; based on data of Ecsedy 1979).

Even today, it is a huge, imposing mound of regular shape, impressive size and fundamentally intact structure, dominating the landscape in the plain grassland (**Fig. 4.**). This is the largest of the mounds preserved in their original state, and still in good condition today (**Fig. 5.**). All around it, the traces of a deeper area can be followed, from which the material of the mound was extracted in the Late Copper Age (these areas are now partly filled, typically marshy, swamp habitats) (**Fig. 6-7.**).

The bottom of the kurgan is eroded around the perimeter, and alkaline benches are forming. On its sides, there are traces of mild disturbances, such as a small scoop on its eastern slope (perhaps traces of the pit of a former treasure hunter or a foxhole/badger sett). The top of the kurgan is flat, suggesting that it was cut off in later periods.

A clearly marked boundary ditch and a rampart raised from the earth of the ditch runs from the south and from the north to the periphery of the kurgan, but it does not continue in the central part of the mound. The ditch and the rampart are most likely to have been built in the 17th-18th century; it has outstanding landscape value due to its historical connections. Unfortunately, in the 1970s, a drainage channel, now called Kígyósi-főcsatorna (or Kétegyházi-árapasztó) was dug in the other parts of the ditch (M.14).

The loess vegetation of the Török-halom, now surrounded by saline grassland, is not considered to be of outstanding naturalness (Medovarszky 2010), due to the hundreds of years of exploitation (grazing) and other disturbances, yet it can be considered to be rich in plant species. Most of the prehistoric monument is covered by generalist loess meadow steppe species and less ruderal weeds, but some species do occur that have floristic or nature conservation value; for example *Ranunculus illyricus*, *Rosa rubiginosa* s.l., *Ononis spinosiformis* subsp. *semihircina*, *Stachys germanica* and *Carthamus lanatus.*

Its surface – and vegetation – do not require any special nature conservation interventions, but over the long term moderate grazing or mowing and, possibly intermittently and partially, burning should be solved (there has been no stable, established practice over the past decades, but forward-looking initiatives have been taken by the local nature conservation ranger).

Fig. 4.: The northern Török-halom kurgan in 2017 (photo by Á. Bede)

4. ábra: Az északi Török-halom 2017-ben (Bede Á. felvétele)

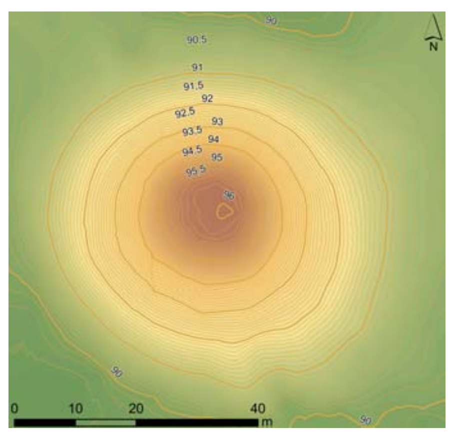

Fig. 5.: Contour surveying map of the northern Török-halom kurgan

5. ábra: Az északi Török-halom szint-vonalas felmérése

Fig. 6.: An aerial photo of the two Török-halom kurgans in 1962, between the mounds with Medieval border ditch (Fentről.hu)

6. ábra: A két Török-halom 1962-es légifotója, közöttük a középkori eredetű határárokkal (Fentről.hu)

Fig. 7.: An orthophoto of the northern Török-halom kurgan in 2011 (FÖMI)

7. ábra: Az északi Török-halom ortofotója 2011-ből (FÖMI)

The southern kurgan

In general, the overall picture of the northern mound is also valid for the southern one. The surface of this kurgan also evolved in a dry grassland environment over the past five thousand years, their archaeological aspects are also common, and their form and appearance were similar. Therefore, we are going to focus only on those significant and unique features that are fundamentally different in the (landscape) history of the two mounds.

The main morphometric data of the southern Török-halom kurgan before its destruction. Central coordinates: WGS84 46°32'51.32" (46.547241) N, 21°8'35.74" (21.143524) E (Google Earth), EOV 810,731, 135,839 (EOTR 38-442; M.14); relative height: 6.7 m. Absolute (altitude) height: 98.5 m (M.11–12), 97.8 m (M.13). Diameters: 74 m and 64 m. Perimeter: 220 m. Floor area: 3,770 m. Toponym on map: Török-hlm. (M.14).

A useful contour-map of its original shape was made in 1966 by Gyula Gazdapusztai and József Tóth (**Fig. 8.**; Gazdapusztai & Tóth 1966; MNM RégAd XVIII. 282/1967; Ecsedy 1979, 21, Fig. 8). In the course of the excavation in 1967, the centre of the kurgan was completely cut through, and its cross-section and the thickness of its layers were published by István Ecsedy (**Fig. 9.**; Ecsedy 1979, 24, Fig. 13–14).

The (rescue) excavation took place because the cooperative of Kétegyháza began to carry away the material of the kurgan to fill up the streets of the village; its south-eastern side had already been disturbed (**Fig. 8., 10.**). An aerial photo taken in 1962 already shows the destruction (Fentről.hu), but in 1953 it was not yet visible (Military History Map Collection, L-34-55-A-d). In the course of the excavation, the high-performance machines took out hundreds of cubic meters of earth from the central part of the kurgan within a few weeks, cutting a thick strip into its centre (**Fig. 3.**). For years after the documented archaeological work, the locals had been carrying away the earth from the mound (**Fig. 11.**), until it disappeared almost completely. In the spring of 2011, there was still a 1.2-meter-high "in situ" piece on its western periphery, with dugouts and smaller piles of earth in the central part of the mound (**Fig. 12.**). Despite its almost complete destruction, the outline of its location was still visible, with only a few *Elaeagnus angustifolia* trees standing on it.

After the excavation and destruction – and even today – the Late Medieval boundary ditch between the two mounds (**Fig. 6.**), which separated the administrative areas of Kétegyháza village and Kakucs territory ("puszta") until 1947 (Németh 2002, 81), is easily discernible. However, just to the south of the mound the line of the ditch becomes uncertain.

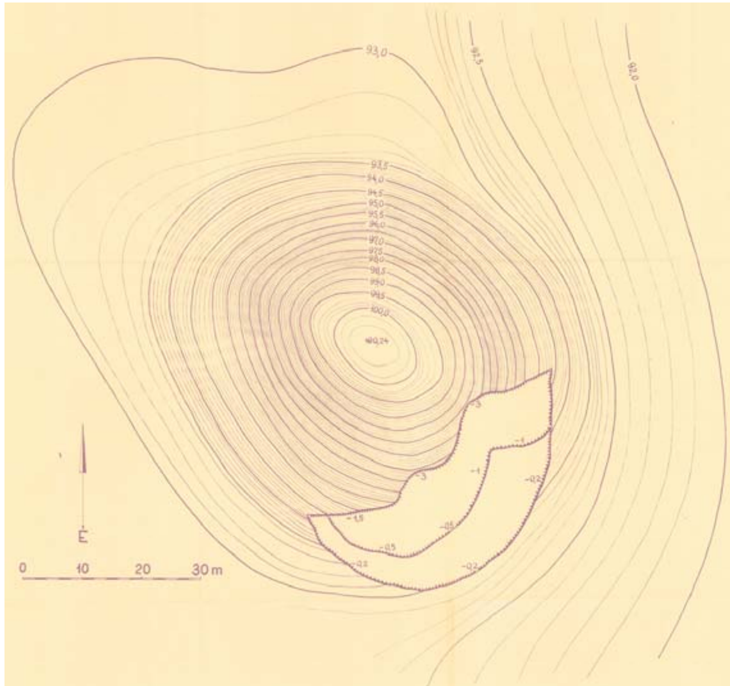

Fig. 8.: Original contour surveying map of the southern Török-halom kurgan in 1966 (MNM RégAd XVIII. 282/1967)

8. ábra: A déli Török-halom eredeti szintvonalas felmérése 1966-ból (MNM RégAd XVIII. 282/1967)

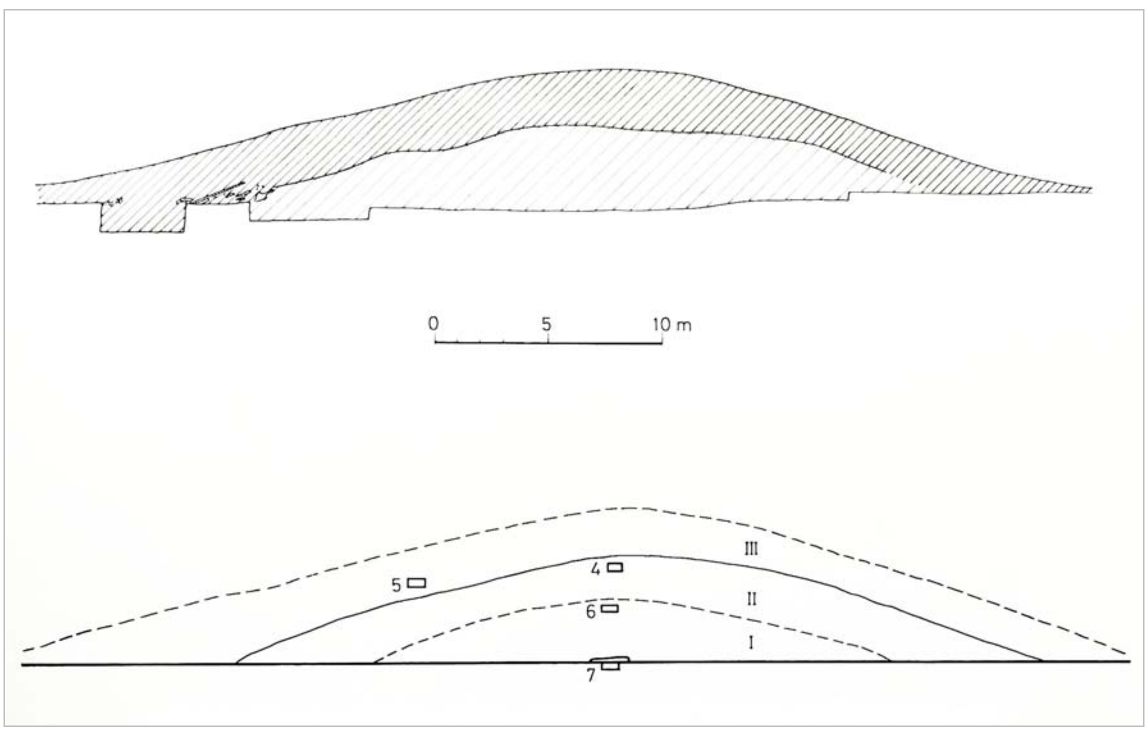

Fig. 9.: The cross-sectional profile interpretation of the excavated southern Török-halom kurgan (Ecsedy 1979, 24, Fig. 13–14)

9. ábra: A feltárt déli Török-halom értelmezett keresztmetszeti szelvényrajzai (Ecsedy 1979, 24, Fig. 13–14)

Fig. 10.: The injured southern Török-halom kurgan before the archaeological excavation in 1967 (photo by I. Ecsedy; MTA RégInt, Photographs 10.231)

10. ábra: A megbontott déli Török-halom a régészeti feltárás előtt, 1967-ben (Ecsedy I. felvétele; MTA RégInt Fotótára 10.231)

Fig. 11.: The damaged southern Török-halom kurgan in the 1970s (Dövényi et al. 1977, Fig. 7)

11. ábra: A déli Török-halom torzója az 1970-es évek első felében (Dövényi et al. 1977, 7. kép)

Fig. 12.: The site of the destroyed southern Török-halom kurgan with original bottom parts on the right side of the picture (photo by Á. Bede, 2011)

12. ábra: Az elhordott déli Török-halom helye, a kép jobb oldalán „in situ" lábi részekkel (Bede Á. felvétele, 2011)

Fig. 13.: The rebuilt southern Török-halom kurgan in 2011, Autumn (photo by B. Forgách)

13. ábra: A frissen újraépített déli Török-halom 2011 őszén (Forgách B. felvétele)

The rebuilding of the southern kurgan was part of the regional habitat conservation and restoration concept of the Körös-Maros National Park Directorate, and was completed in July-August 2011 after a long planning phase (**Fig. 13.**; Nagy 2012, 99–100). To this end, the shape and morphological character of the northern Török-halom were used, adapted to the dimensions of the former mound. Although the survey of the original mound from 1966 was available (Gazdapusztai & Tóth 1966; MNM RégAd XVIII. 282/1967; Ecsedy 1979, 21, Fig. 8), this source was unfortunately not known by the designers and was not taken into account. Unfortunately, during the construction, the "in situ" periphery was covered with earth in a large area, thus not only the last remains of the original point were destroyed, but a part of the residual loess vegetation was also lost.

Originally, the southern kurgan could have vegetation similar to that of the northern one (Medovarszky 2010; Nagy 2012, 97–98). We can deduce this primarily from the small loess grassland patch on the preserved part at the periphery of the mound. After the reconstruction, the experts of the national park tried to reconstruct the natural habitat by using rescued turf and sowing indigenous species on the surface of the kurgan (Nagy 2012, 100–101). From the loess surface of the original destroyed mound, 6 pieces of turf blocks (approx. 1.5×3 meters and 40 cm deep) covered with loess meadow steppe vegetation were picked up by the workers of the Körös-Maros National Park Directorate with construction machinery before the rebuilding. The turf blocks were put in a nearby place during the work, and at the end of the reconstruction these blocks were take back to the surface of the rebuilt cylinder at the same distances, 1-2 meters above the bottom of the kurgan. In addition, two bags of hand-picked seeds of *Agropyron cristatum* (from the Gödény-halom kurgan near Békésszentandrás) were sprinkled on the mound body by the staff of the national park in the same year. They also sowed seeds collected from the Tompapusztai-löszgyep loess meadow steppe grassland near Battonya, the colonization of some species (*Linum austriacum*, *Teucrium chamaedrys*, *Onobrychis arenaria*, and *Salvia nemorosa*) were surely successful (Judit Sallainé Kapocsi's written communication).

Discussion

Typically, landscape historical studies are carried out on a smaller or larger, but mostly well-defined landscape, region, or larger scale landscape, as their historical aspects can be grasped well and the trends of change can be consistently described (Molnár & Biró 2011; Molnár & Biró 2017). However, in our opinion, it is worth examining the historical changes of the landscape at a smaller scale as well, even through features of smaller sizes. These include point or line like features of anthropogenic origin, raised in archaeological periods, such as tells, mounds, ramparts and fortified settlements. Their micro-level research or large-scale comparative investigation and comparison with other archaeological sites can also produce important results (Saláta et al. 2017).

In the Tiszántúl region, pairs of kurgans (double mounds) are quite frequent. The pair typically consists of a larger and a much smaller mound, or two mounds of approximately the same size (Bede 2016, 36–37). In our case, we can speak of two impressive, large kurgans surrounded by smaller mounds in rows and groups. The southern Török-halom was larger (higher and wider), but the size of the northern one was not far behind.

Despite the difficulties outlined, the reconstruction work of the southern Török-halom mound has a great importance, since previously a kurgan of this size had never been rebuilt (we are not aware of a similar case). According to the goals of the national park – with the aim of landscape rehabilitation – other, smaller, damaged mounds will also be restored.

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Abbreviations

ARCHIVES OF BÉKÉS COUNTY: Archives of Békés County (A Magyar Nemzeti Levéltár Békés Megyei Levéltára), Gyula.

MILITARY HISTORY MAP COLLECTION: *Museum of Military History, Military History Map Collection* (Hadtörténeti Intézet és Múzeum Hadtörténeti Térképtára), Budapest.

MOL: National Archives of Hungary (Magyar Nemzeti Levéltár Országos Levéltára), Budapest.

MNM RégAd: Archaeological Repository of Hungarian National Museum (Magyar Nemzeti Múzeum Régészeti Adattára), Budapest.

MTA RégInt: Hungarian Academy of Sciences, Research Centre for the Humanities, Institute of Archaeology (Magyar Tudományos Akadémia, Bölcsészettudományi Kutatóközpont Régészeti Intézete), Budapest.

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GOOGLE EARTH: Google Earth Pro online GIS application. https://www.google.hu/intl/hu/earth December 31, 2018.

Maps

M.1: First military surveying map. 1783. 1:28,800. C. XXII. S. XVIII (Military History Map Collection; published: Első katonai felmérés 2004).

M.2: “Hydrographia depressae Regionis fluviatilis Crisiorum, Magni, Albi, Nigri, Velocis, Parvi, Fl. Berettyó”. 68 sections. 1822. 1:36,000. Mátyás Huszár (MOL S 80. Körösök 39).

M.3: Second military surveying map. 1860. 1:28,800. S. 58. C. XLI. (Military History Map Collection; published: Második katonai felmérés 2005).

M.4: Third military surveying map. 1884. 1:25,000. 5366/4 (Military History Map Collection; published: Harmadik katonai felmérés 2007).

M.5: “KÉTEGYHÁZA / nagy község / felvételi előrajzai / 1884”. 1:2,880. Manó Kerausch, Antal Witlaczil (MOL S 79. 202/5. 5. page).

M.6: “KÉTEGYHÁZA / nagyközség / Békés megyében / 1884”. 1:2,880. Manó Kerausch (MOL S 78. 49. box, Kétegyháza, 5. page).

M.7: Cadastral map of Kétegyháza. 1:2,880. 1884 (published: Békés megye 2009).

M.8: "ELEK II. RÉSZ / vagyis / Bánkut, Eperjes és Kakucs / pusztaadóközség / Arad megyében / 1885.". 1:2,880. Mihály Schatteles, Vilmos Kutscher (Archives of Békés County BmK 44/44.; published: Békés megye 2009).

M.9: Military map. 1943. 1:50,000. 5366 K (Military History Map Collection; published: Magyarország topográfiai térképe 2008).

M.10: Military map. 1950. 1:25,000. L-34-55-A-d (Military History Map Collection).

M.11: Military map. 1955. 1:25,000. L-34-55-A-d (Military History Map Collection).

M.12: Military map. 1965. 1:50,000. L-34-55-A (Military History Map Collection).

M.13: Military map. 1969–1971. 1:10,000. 710-141 (Military History Map Collection).

M.14: Unified National Cartography System (Egységes Országos Térképrendszer, EOTR). 1980. 38-424 (FÖMI).

M.15: Military map. 1982–1983. 1:25,000. L-34-55-A-d (Military History Map Collection).

M.16: Military map. 1991. 1:25,000. L-34-55-A-d (Military History Map Collection).

M.17: Military map. 2002. 1:50,000. L-34-55 (Military History Map Collection).

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PRELIMINARY DATA OF THE GEOARCHAEOLOGICAL ANALYSES ON THE VESSZŐS-HALOM (MOUND) AT PUSZTASZER•

PUSZTASZER, VESSZŐS-HALOM GEOARCHEOLÓGIAI VIZSGÁLATÁNAK ELŐZETES EREDMÉNYEI

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Abstract

Mineralogical, geological and paleontological analyses of archaeological tools and features have started already in the 18th century. These sporadic investigations were followed by systematic geological analysis from the middle of the 19th century. Following the proposals of Flóris Rómer archaeologist at this time in Hungary in the 1860s, geoarchaeological research started at first by the analysis of obsidian stone tools and later by the analysis of kurgans. By the magnetic susceptibility and complex sedimentological analysis of Vesszős-halom (Pusztaszer/Ópusztaszer), we were able to separate three different phases of accumulation of the analysed kurgan. It was also possible to prove the formation of the bedrock and soils that cover the surface of kurgan (Vesszős-halom – Vesszős Mound). Furthermore, the former environment of the kurgan could have been reconstructed by using the results of pollen and malacological analyses.

Kivonat

A régészeti tárgyak és régészeti objektumok ásványtani, kőzettani, geológiai és őslénytani elemzése már a XVIII. században elkezdődött. Ezeket a szórványos analíziseket a régészeti objektumok rendszeres geológiai vizsgálata követte a XIX. század közepétől. Ezek a vizsgálatok Rómer Flóris régész javaslatára hazánkban is ebben az időszakban – az 1860-as években – indultak meg. Az emberi tevékenység nyomán kialakított pozitív geológiai formák közül a pusztaszeri/ópusztaszeri Vesszős-halom (kurgán) elemzését mutattuk be. A Vesszős-halom fúrásszelvényéből kiemelt minták mágneses szuszceptibilitásának és szervesanyag tartalmának elemzésével sikerült a kurgánok három felhalmozási szakaszát és a fekü, valamint a kurgánok felszínét borító talajképződmények fejlődési körülményeinek különbözőségeit elkülöníteni. Továbbá a kurgán területének egykori környezetét is rekonstruálhattuk az üledék malakológiai anyagának és pollentartalmának felhasználásával.

KEYWORDS: GEOARCHEOLOGY, STRATIGRAPHY, VESSZŐS-HALOM (MOUND), SEDIMENTOLOGY, MAGNETIC SUSCEPTIBILITY

KULCSSZAVAK: GEOARCHEOLÓGIA, RÉTEGTAN, VESSZŐS-HALOM, SZEDIMENTOLÓGIA, MÁGNESES SZUSZCEPTIBILITÁS

Introduction

At the request of the Dunatáj Értékeiért Nonprofit Közhasznú Zrt., Vesszős-halom (central identifier: 20825, 33570 EOV), which is situated near the settlements of Pusztaszer and Ópusztaszer (**Fig. 1.**) a borehole was drilled at its highest point, on October 25, 2018. At the top of the Vesszős-halom a concrete cartographic elevation point is placed (**Fig. 2.**). This point provides an immense advantage in the determination of the mound's altitude and position however it limited the available surface (which is needed for the drilling), on the top of the mound. A significant part of the kurgan's surface is covered by *Robinia pseudoacacia* and *Lycium barbarum*.

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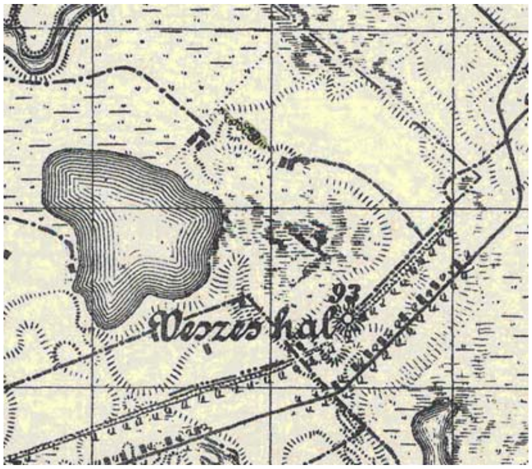

Fig. 1.: Vesszős-halom (mound) can be found on theboundary zone between Pusztaszer and Ópusztaszer villages'areas on the topographic map of Hungary in the period of the II[nd] World War

1. ábra: Vesszős-halom elhelyezkedése Pusztaszer és Ópusztaszer községek határán a második világháborús magyar topográfiai katonai térképen

The latter was completely removed by a team of the Dunatáj Értékeiért Nonprofit Public Limited Liability Company when the drilling had started.

The 15 cm large-diameter spiral-machine drilling was required to provide the appropriate amount of sample material for the implementation of sedimentological, geochemical and radiocarbon analyses. The drilling was successful and the kurgan was fully explored to a depth of 600 cm up to the eolian sand followed by fluvial sand below. Samples were taken from every 10 cm therefore 60 samples were analyzed for the measuring of magnetic susceptibility, organic matter, carbonate and inorganic matter content, grain composition, and for the malacological and pollen analysis.

Material and methods

After the macroscopic description, our samples were taken out from the profile following the protocol which was established for geoarchaeological researches of kurgans (Sümegi et al. 2015a). International loose sediment categories (Troels-Smith, 1955) were used for macroscopic layer description, and sediment colour was determined by the Munsell Color Chart (Soil Color Company, 1994) (**Table 1.**). The geoarchaeological protocol was created between 1988 and 1999 (Sümegi 1988, 1992, 1993, 1994-1999) and officially was accepted in 2002 (Sümegi 2001, 2002; Sümegi & Szilágyi 2011; Sümegi et al., 2015a; Szilágyi et al., 2013, 2018).

2. ábra: A Vesszős-halom tetején kialakított nagy motoros fúrás 2018. október 25-én

Fig. 2.: The motor drilling process on the top of the Vesszős mound on 25 October 2018

The total length of the drill is 600 centimetres and the core recovery was almost perfect (99.8%). The 600 cm long borehole was sampled by monotonous sampling (Birks & Birks 1980) at every 10 cm, and a total of 60 samples were included in sedimentological, magnetic susceptibility, and loss on ignition analyzes.

During the measurement of magnetic susceptibility the magnetizable element content of the sediment was measured. Air-dry and powdered samples prepared for loss on ignition procedure were used for this method. For the measurements, a mobile (suitable for laboratory and field measurements) instrument, called Bartington MS2 Magnetic Susceptibility Meter was used at 2. 7 MHz (Dearing, 1994; Sümegi et al. 2015a). The minimum required amount of material for measuring was available for each sample. Three measurements were performed on each sample and the resulting values were averaged according to the former established practice (Sümegi et al. 2015a).

For the determination of the organic matter and carbonate content Dean's loss on ignition (LOI) method was applied (Dean, 1974). The 60 samples were powdered in a porcelain percussion mortar after drying at 65 °C for 24 hours. The weights of the crucibles were weighed to an accuracy of 0.0000 g. Then 3 g of sample weighed to an accuracy of 0.0001 g and, after firing at 550 °C. The weight loss was measured and the organic matter content was calculated. Then, after firing the same samples at 900 °C, the weight loss measured again and carbonate content was calculated.

The sedimentological analysis was implemented by using a 42-channel Laser Sedigraphy instrument, Easy Laser Particle Sizer 2.0, which detects 42 granular fractions at the same time, after proper sample preparation (Sümegi et al. 2015b).

Table 1. : The sequence of the core and its sediment description from the Vesszős-halom (mound) at Pusztaszer/Ópusztaszer

1. táblázat: A pusztaszeri – ópusztaszeri Vesszős-halom fúrásszelvényének rétegsora és leírása

cm	Troels-Smith categories	Munsell Colors	Soil genetics categories
0-20	Sh2As2	10 YR 2/2	Classic Chernozem A horizon
20-40	Sh1Lc1As2	10 YR 3/2	Classic Chernozem B horizon
40–120	Sh1As1Ag1Ga1	10 YR 3/1	Black-brown coloured, accumulated anthroposol, third layer of construction
120-240	Sh1As2Ag1	10 YR 3/1	Black-brown coloured, accumulated anthroposol, second layer of construction
240-370	Sh1As3	10 YR 3/1	Black-brown coloured, accumulated anthroposol, first layer of construction
370–400	Sh2As2	10 YR 2/2	Classic Chernozem A horizon with hydromorphic charachteristics (ferroustraces and nodules)
400-430	Sh1Lc1As2	10 YR 4/2-4/3	Classic Chernozem B horizon with hydromorphic charachteristics (ferroustraces and nodules)
430-490	Lc1Ag2As1	10 YR 5/6	Yellowish-brown loess level, the parent material of the original soil, which had envolved during the Pleistocene
490-570	Ga3Lc1	10 YR 7/6	Grayish-yellow wind-blown sand level consist of calcareous fine sand and coarse sand
570-600	Ga4	10 YR 7/4	Yellowish-gray calcareous fluvial sand level mostly consisted of splintery grains of quartz

The grain size distribution was defined according to the scale used in the international and Hungarian literature of geoarchaeological analyses (Sümegi, 1988, 1992, 1998, 2002, 2003a, 2004a, b, 2005).

Conventional extraction of pollen samples did not yield results; therefore, according to the method of extraction used in international geoarchaeology, 200 g of wet sediment was used for extraction (Zhou et al. 1999). The minimum pollen number per sample was set at 300 pollen grains to taking into consideration in the studies of Maher (1972), Sümegi et al. (1999), Magyari et al. (2001). The sample was considered pollen sterile when pollen and spore numbers were below 80 pieces per sample (Sümegi et al. 1999). 300-300 pieces of pollen grains were found in each sample.

A total of 60 samples (approximately 600 g wet weight per sample) were involved in the malacological analysis from the 600 cm long profile. Samples were flushed through a 0.8 mm sieve and the remaining snail shells were selected and determined. All samples contained malacological material, although not a statistically significant amount (Krolopp 1961).

Results

Macroscopic layer description

The top of the borehole is a classical chernozem soil formed on the surface of the kurgan, with the A horizon (upper 20 cm), followed by the B horizon (20-40 cm) (**Table 1.**) with carbonate accumulation zone (carbonate mycelium).

The constructed layers of the kurgan can be found below A and B horizons of the surface chernozem soil. Based on field macroscopic analysis, it was evident that the pyramidal body of the kurgan was not the result of single accumulation, but due to the changes in characteristics and texture of the sediment layers, approximately three construction phases can be identified. The third layer (between 120 and 40 cm) is the bedrock of the chernozem on the surface, consisting of a disturbed, anthropogenic soil material, layered with lenses and sediment strips, mainly from the bedrock. Within this horizon, crumbly structured soil can be found, similar to the chernozem of the surface. Of course, macroscopic observations do not allow for this to be sure but the magnetic susceptibility results of previous researches could help to resolve this issue (Sümegi et al. 2015a). Below the third layer the second level of the kurgan is located (120-240 cm). The accumulated soil is a finely laminated, subordinately consisted of the material of the bedrock mixed with the material of the former soil. Below the second construction layer, the first layer is between 240 and 370 cm. The first construction layer consisted entirely of chernozem-like soil with high organic matter content with hydromorphic features (**Table 1.**).

The original undisturbed chernozem soil can be found below the first construction layer (between 400-430 cm), which was developing at the beginning of the Holocene. It can be characterized with a black-brown coloured A horizon and a cinnamon-coloured B horizon (**Table 1.**), with characteristic features of a hydromorphic meadow soil, according to the classical Hungarian soil classification (Stefanovits 1963, 1972). The transitional characteristic of this soil level is well illustrated by the presence of both crumby and polyhedron textural elements (meadow and chernozem soil, which is why the Hungarian soil terminology created the term "meadow chernozem" for this soil type. (Stefanovits 1963, 1972).

Below the chernozem-like but hydromorphic level, based on its clay content, low carbonate content and macroscopic characteristics, loess sediment was deposited at the top of the sandy layers. This sedimentary layer (between 430 and 490 cm) forms the parent material of the buried soil under the kurgan.

Beneath the aleurite-rich loess sediment, a well-sorted layer of laminated fine sand extends (between 490 and 580 cm) with rounded quartz grains. Although rounded grains are typically microcraterial, the shape of the grains still preserves the fluvial origin and as a result of this and following geological surveys of the area (Molnár 2015), we assume that this windblown sand suffered only from local eolian reaccumulation processes. Windblown sand contains significant amounts of carbonate, primarily calcite, and formed by the reaccumulation of fluvial sediments of the former Danube.

A calcareous fluvial sand layer appeared at the bottom of the borehole, which was mostly consisted of splintered fractured, stepped surfaced quartz grains. This layer is also can be connected with the Danube sediment due to its development and relatively high carbonate content (Molnár 2015).

Magnetic susceptibility result

The magnetic susceptibility measurements were performed three times on each sample, and the mean of the three measurements was taken as the measured value. The magnetic susceptibility results on the 10^{-6} $m^3 \cdot kg^{-1}$ scale showed significant changes from bedrock to the surface soil.

Magnetic susceptibility (MS) values ranged from 1.07 to 1.18 at the level of the recent soil, and based on the values, the process of soil development affected the area that was observed macroscopically (40 cm from the surface).

The magnetic susceptibility values of the kurgan's soil under the recent chernozem soil showed strongly fluctuating values and were hardly different from those of the topsoil. As a result, the conditions of the formation of chernozem and the conditions and genetic type of the accumulated soil below, could not be different.

Based on the changes, three magnetic susceptibility phases can be determined and based on previous studies (Sümegi et al. 2015a), which phases are the three construction layers of the kurgan. The first layer is characterized by homogeneously high MS values. It extends from the modern surface to a former open soil surface between 120-140 cm.

The second level is characterized by fluctuations in MS values between 120 and 240 cm. It cannot be excluded, that the construction occurred at short intervals at this stage, but based on the values, they were more likely to carry the flushed soil back to the surface of the kurgan during this phase of construction.

Tampering of the mound may have occurred at that time, and it cannot be ruled out that a new burial chamber was formed (Ecsedy 1973, 1979), which caused the fluctuation of the MS values. Several subtypes of soil (hydromorphic soil, chernozem) were likely mixed in that level, but dominantly hydromorphic soil type (meadow chernozem) may have constituted the major part of the earth pyramid.

An undisturbed buried soil layer can be found beneath the construction layers (between 370-400 cm), where magnetic susceptibility values were still above 1, but then decrease below 1, which shows us the B horizon of this soil. The sediments were not affected by soiling processes below this horizon, based on the low MS values.

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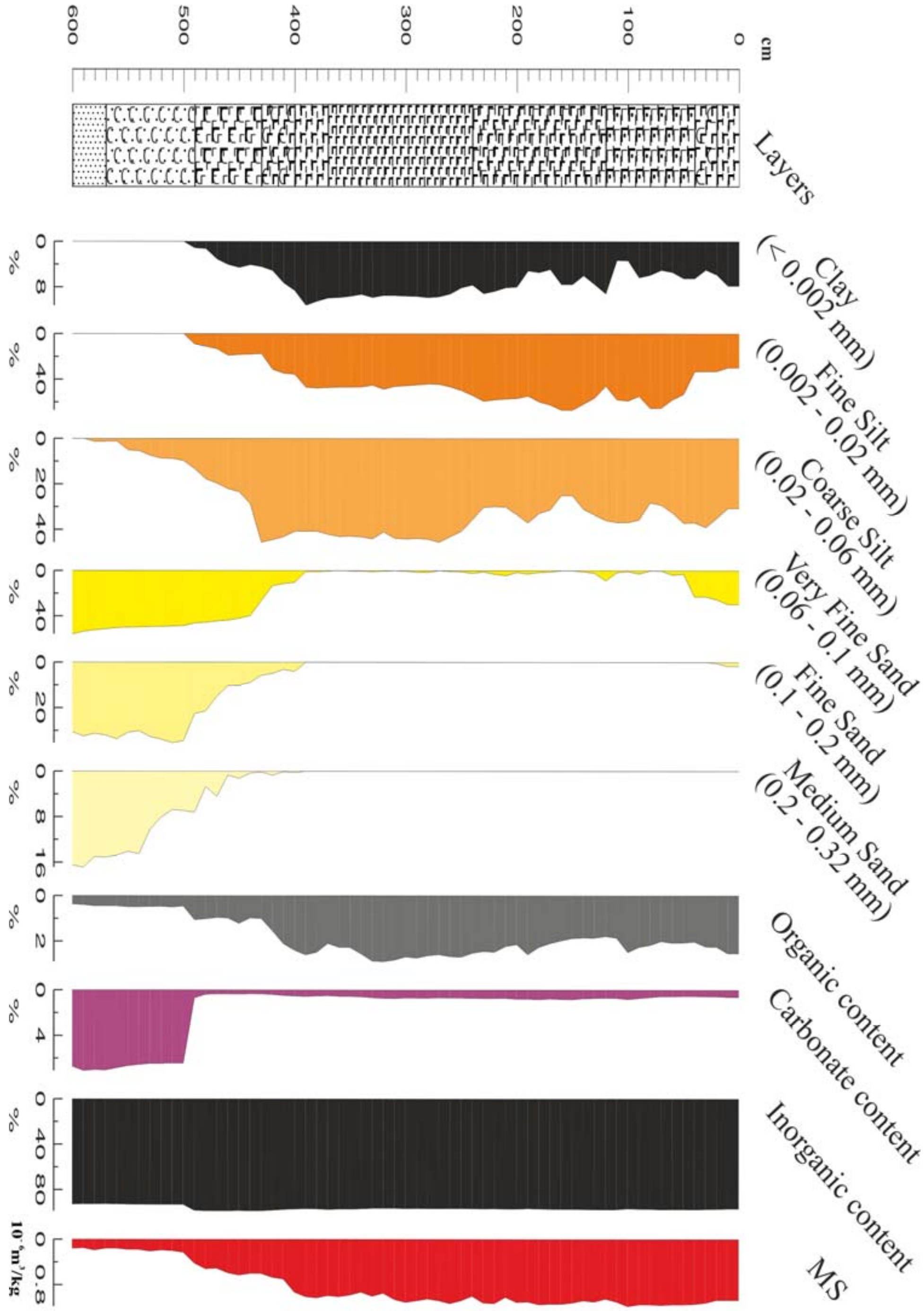

Fig. 3.: The results of the georchaeological analyses of the core sediment sequence of the Vesszős-halom (mound). The core sequence was drawn using Psimpoll programme (Bennett, 1992, 2005) within Troels-Smith's soft sediment categories (Troels-Smith, 1955) and granulometical, loss on ignitation (LOI) and magnetic susceptibility data

3. ábra: A régészeti geológiai vizsgálatok eredményei a pusztaszeri/ópusztaszeri Vesszős-halmi fúrás rétegsorán. A rétegsor Psimpoll számítógépes programmal (Bennett, 1992, 2005) generáltuk, Troels-Smith (1955) üledékes kategóriákat, szemcseösszetételi, izzítási

As a result, based on our previous data (Sümegi et al. 2015a) and the magnetic susceptibility values of the recent soil formed on the surface of the Vesszős-halom, three earlier soil formation levels have been established below the accumulated soil levels (the body of the kurgan). At least three phases are can be considered in the formation of the Pusztaszer - Ópusztaszer Vesszős-halom. Based on the MS values, the bedrock, the paleosoil horizon, as well as the levels of the accumulated soil material can be separated.

Organic matter, carbonate content and inorganic matter results

The organic matter content is greatly characteristic in the Vesszős-halom borehole. Taking into account

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the evolution of the chernozem soil and the near-surface accumulation of organic matter, 5 of organic matter content maximum could be detected in the profile.

The first organic matter maximum is related to the buried soil, the meadow chernozem horizon with hydromorphic effects (380-410 cm). Below this, the bedrock levels (loess sediment, eolian sand, fluvial sand) can only be characterized by organic matter content below 1%. After a peak of 2.5% organic matter, a protracted and slowly decreasing maximum occurred between 340 and 240 cm (**Fig. 3.**). This level is difficult to interpret in terms of natural sedimentological and soiling processes. On the other hand, considering the human impacts due to the distribution of the organic matter content, that layer can be originated from the subsoil (**Fig. 3.**).

A characteristic organic matter maximum and a decreasing can be observed (between 180 and 240 cm) on the surface of the first layer of the kurgan, similar to the buried soil. As a result, it can be assumed that there was a break in the construction of the first phase between 370 and 240 cm. During this pause, a new chernozem soil developed on the surface of the former pyramid with relatively rich organic matter content. This soil formation resulted high organic matter in the A horizon (between 180 and 190 cm), which a relatively reduced in B horizon (between 190 and 240 cm). Based on these organic matter data, the first accumulation level was between 370 and 180 cm. A similar change could be detected between 90 and 120 cm based on the change in organic matter content, and as a result, similar soil formation can be assumed in this horizon. Based on the change in organic matter content, a new accumulation level was developed between 180/190 cm and 90 cm.

A smaller peak appeared on the surface and then a decrease occurred. This change is related to the basic trends of chernozem soils; the near-surface accumulation of organic matter. Similarly, to the magnetic susceptibility values, three construction layers can be assumed in the kurgan above the buried soil, but the organic matter content has resulted in between 370-180 cm, 180-90 cm, and from 90 cm to the surface. Although there are slight differences in depth between these two methods even so changes in organic matter content (**Fig. 3.**) support the results of magnetic susceptibility measurements (**Fig. 3.**): Thus, the results of the investigations of both methods can be assumed to be three construction levels of the Vesszős-halom.

The distribution of the carbonate content shows a fairly clear distribution. Significant carbonate content was found only in the bedrock (6.43-7.10%), but no notable carbonate content could be detected in the loess sediment neither in the paleosoil (**Fig. 3.**). The soil of the entire kurgan may have contained minimal carbonate because the most of it may have been leached towards the bedrock.

Only part of the bedrock was cemented with carbonate (by the migration of the rainwater to deeper layers from the surface) which was located at the fluctuation level of groundwater (Molnár 2015). Even the loess horizon became carbonate-free during the leaching process, but below the loess, the grains of the windblown and fluvial sand were poorly cemented by the precipitated carbonate. This post-genetic process of the carbonate transfer (so-called "Braunization" process: Sümegi 2003b), was reached such a degree that it was partially solved the shells of molluscs, although most of them remained specifiable. The leaching process was driven by the organic matter content and type of the subsoil (with hydromorphic marks) that formed the entire kurgan. The organic matter content of the accumulated earth pyramid, the organic matter content of the soils formed on the former surfaces of the kurgan during the pause of construction and the rainwater on the surface of the kurgan may have created the calcareous water conditions which soluted the low carbonate content of the soil (Chu et al. 2012), and also transformed the shells in it to pseudomorphoses (Keresztúri et al. 2015).

The organic matter and carbonate content values were used as the basis for the calculation of the inorganic content (**Fig. 3.**). Because of the extremely high carbonate content of the sand layers, as a result of the leaching-precipitation processes, the lowest values of inorganic material content was found there. The relative richness in organic matter but low carbonate content the changes of the inorganic content in the soil of the Vesszős-halom are exactly the opposite of the organic matter content. Thus, the change in inorganic content (which is not independent of the change in organic matter due to calculation from loss on ignition (Dean 1974) can be expected to have several accumulation stages following the changes in the dominance (%) of the inorganic content in the subsoil (**Fig. 3.**). Wave-like changes in the content of inorganic materials can be the result of at least three but possibly four construction levels. Unfortunately, there has been no real interpretation of the inorganic content of sediment samples extracted from the accumulated levels of kurgans. The approaches so far (Barczi et al. 2012) are impractical from a sedimentological point of view and the values given (Barczi et al. 2012, p. 31. Fig. 5.) are probably based on erroneous data or are more likely based on poor LOI measurements or miscalculation.

Table 2a: Arbor Pollen dominance from pollen analytical samples from core sequence of the Vesszős-halom (mound)

2a táblázat: A Vesszős-halomban pollenanalitikai szempontból feltárt minták fásszárú (AP) pollenanyaga (dominancia – százalékos arány)

cm	*Pinus sylvestris*	*Fagus*	*Carpinus*	*Quercus*	*Salix*	*Tilia*	*Ulmus*	**AP summa**
	%	**%**	**%**	**%**	**%**	**%**	**%**	**%**
330-340	6.32	0.29	0.29	2.59	3.16	0.00	0.00	**12.64**
340-350	6.76	0.29	0.29	2.35	3.53	0.00	0.00	**13.24**
350-360	7.02	0.29	0.29	2.63	3.22	0.00	0.00	**13.45**
360-370	6.00	0.29	0.29	3.14	3.71	0.00	0.00	**13.14**
370-380	6.13	0.28	0.28	3.34	4.18	0.28	0.84	**15.32**

Table 2b: Arbor Pollen dominance from pollen analytical samples from core sequence of the Vesszős-halom (mound)

2b táblázat: A Vesszős-halomban pollenanalitikai szempontból feltárt minták lágyszárú (NAP) pollenanyaga (dominancia – százalékos arány)

cm	*Achillea type*	*Artemisia*	*Cerealia*	*Chenopodiaceae*	*Compositae*	*Plantago lanceolata*	*Poaceae*	*Polygonum aviculare*	*Stachys*	*Taraxacum*	*Verbascum*	NAP	SUMMA
	%	%	%	%	%	%	%	%	%	%	%	%	%
330-340	2.30	5.46	0.57	4.02	0.86	0.57	68.68	0.57	3.16	0.86	0.57	87.36	100.00
340-350	2.35	5.29	0.59	3.53	0.59	0.29	72.06	0.59	0.00	0.88	0.59	86.76	100.00
350-360	2.63	4.09	0.58	4.97	0.58	0.29	71.35	0.29	0.29	0.88	0.58	86.55	100.00
360-370	2.29	3.43	0.57	3.14	0.57	0.29	74.57	0.29	0.29	0.86	0.57	86.86	100.00
370-380	2.23	2.23	0.56	2.23	0.84	0.56	74.93	0.28	0.28	0.28	0.56	84.68	100.00

None of the hundreds of our LOI analyses performed on a kurgan (Barczi et al. 2012, p. 31. Fig. 5.) showed any outstanding organic matter content (Barczi et al. 2012, p. 31: Fig. 5.) which is claimed in the article's given figure. These misrepresentations also indicate that a comprehensive geoarchaeological analysis of the kurgans would be extremely important for comparisons for all profiles.

Results of pollen analysis

By our commitment, 5 samples were extracted to pollen analysis. We focused on the pollen content of the buried soil samples and the lower samples of the first accumulation level, which formed on the surface of this soil. All samples contained statistically significant pollen material (higher than 300 pieces) (**Tables 2a** and **2b**) and as a result, the vegetation background of the buried soil and the first accumulation level were reconstructed.

It has to be noted, that the kurgan is not a pond- or marsh-like sedimentary basin, but a cyclically wetting and drying surface where groundwater has only a limited effect (Sümegi, 2002) so only the organic matter, clay content and the moisture of the soil determines the pollen retention capacity of this sediment.

The proportion of arboreal pollens (AP) were below 20% (**Table 2a**). Based on the AP: NAP ratios of the works of Allen et al. (2000), Behre (1981, 1986), Elenga et al. (2000), Magyari et al. (2010), Prentice et al. (1996), Prentice and Webb (1998), Tarasov et al. (1998, 2000) the area was transformed into a moderate belt steppe before the construction of the kurgan at the beginning of the Holocene. The pollen material of the buried soil and the sediment of the first accumulation level represents the vegetation only on a local scale which was a few hectares of steppe-like area.

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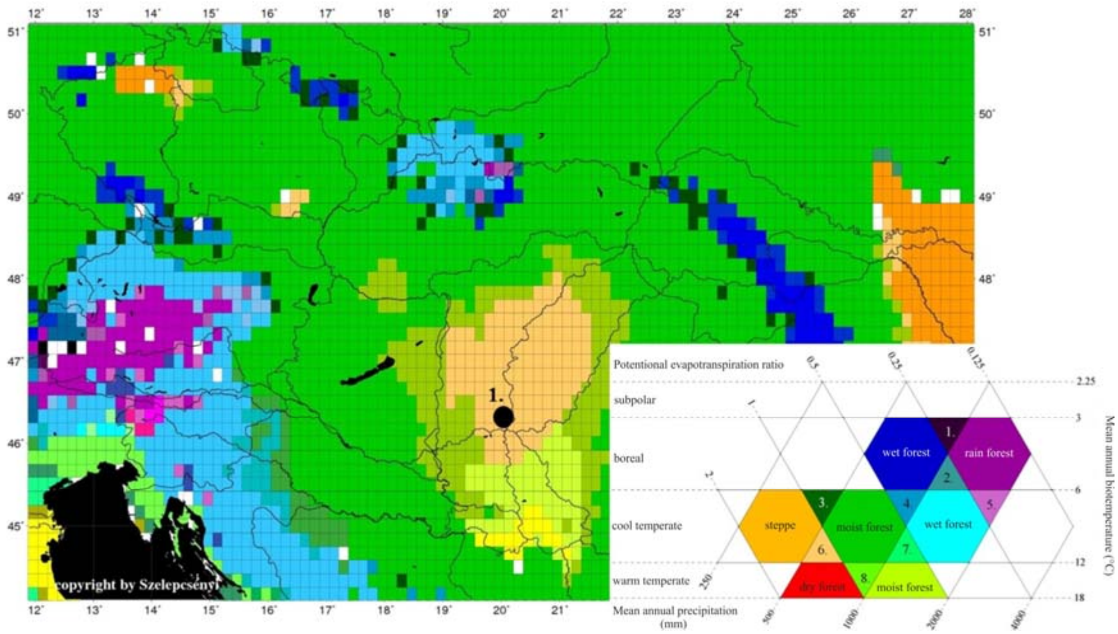

Fig. 4.: Spatial distribution of the modified Holdridge life zones on the map and the figure caption of the map

4. ábra: A Kárpát-medence továbbfejlesztett Holdridge bioklimatológiai rendszere térképen és a térkép magyarázója (Szelepcsényi et al. 2015 és 2016)

The purpose of the paleo-vegetation reconstruction works mentioned above, are connected to the vegetation zones of the Eastern European Plain but based on the results of earlier and present bioclimatic analyses (Borhidi 1961, Szelepcsényi et al., 2014, 2018) there are no zones in the Carpathian Basin but we can expect the development of landscape vegetation and strong basin effect (**Fig. 4.**) (Sümegi et al. 2018; Törőcsik et al. 2018). Thus, in our view the reality of the paleo-vegetational units based on the pollen results of the Eastern European Plain severely limited in the Carpathian Basin (Sümegi et al., 2018).

At the same time, pollen layers of temperate belt trees (*Fagus, Carpinus, Quercus, Ulmus* and *Tilia*) were found in both the buried soil and in the earth pyramid. The high proportion of pine pollens caused by pollen contamination. Based on pollen composition during the period of the formation of the kurgan, temperate belt steppes were subdivided into mosaic patches with hardwood gallery forests predominantly adjacent to the riverside. The main elements of that were the *Quercus*, *Ulmus* and *Tilia* (**Tables 2a** and **2b**). On the other hand, *Fagus* and *Carpinus* pollens appeared alongside the *Quercus* in the material of the kurgan which means that the formation of the kurgan can be reckoned from the end of the Copper Age in the second half of the Holocene.

In our opinion, the temperate forest-steppe developed during the Holocene where the woody vegetation was mainly provided by the hardwood gallery forests accompanying the watercourses. During the development of the kurgan, the arboreal vegetation changed, the beech and the hornbeam appeared in the local woody vegetation and as a result a cooler and rainy climate phase can be expected. The herbaceous vegetation was homogeneous with the absolute dominance of grasses (*Poaceae* = *Gramineae*), with a high proportion of *Artemisia* and *Chenopodiaceae* at the Holocene levels.

In the soil horizon developed before the construction of the kurgan and also in the kurgan's material, weeds appeared which indicating animal husbandry, and human digestion (*Polygonum aviculare*, *Stachys*, *Taraxacum*, *Verbascum*, *Plantago lanceolata, Compositae*). The human effect is further clarified by the presence of cereals (*Cerealia)* at this level. As a result, human impacts on forest-steppe vegetation with minimal tree and shrub growth should be considered before and during the construction of the kurgan.

Results of malacological analysis

Samples taken from every 10 cm were flushed through a 0.8 mm sieve and the remaining snail shells were selected and determined according to the malacological protocol developed by Krolopp (1961). A total of 60 samples were processed from the 600 cm borehole and the amount of one sample in the wet weight was approximately 500 g. A total of 268 specimens of 13 species were found in the material. Due to the insignificant number of individuals, the malacological material could not be statistically evaluated.

Table 3a: Mollusca fauna from core sequence of the Vesszős-halom (mound) 1 (individuals)
3a táblázat: A Vesszős-halomban feltárt minták malakológiai (darabszám) anyaga 1

cm	Aquatic species					Terrestrial species								**SUMMA**
	Lymnaea truncatula	*Planorbis planorbis*	*Planorbarius corneus*	*Anisus spirobis*	*Pisidium*	*Succinea oblonga*	*Chondrula tridens*	*Helicopsis striata*	*Pupilla muscorum*	*Vallonia costata*	*Vallonia pulchella*	*Cepaea vindobonensis*	*Helix pomatia*	
	pcs	**pcs**	**pcs**	**pcs**	**pcs**	**pcs**	**pcs**	**pcs**	**pcs**	**pcs**	**pcs**	**pcs**	**pcs**	**pcs**
10	0	0	0	0	0	0	0	0	0	2	1	1	0	**3**
20	0	0	0	0	0	0	0	0	0	2	2	0	0	**4**
30	0	0	0	0	0	0	0	0	0	1	2	0	0	**3**
40	0	0	0	0	0	0	0	0	0	2	1	0	0	**3**
50	0	0	0	0	0	0	0	0	0	2	1	0	0	**3**
60	0	0	0	0	0	0	0	0	0	2	1	0	0	**3**
70	0	0	0	0	0	0	0	0	0	2	2	0	1	**5**
80	0	0	0	0	0	0	0	0	0	2	2	0	0	**4**
90	0	0	0	0	0	0	0	0	1	1	2	0	1	**5**
100	0	0	0	0	0	0	0	1	1	2	1	0	0	**5**
110	0	0	0	0	0	0	0	0	1	2	1	1	1	**6**
120	0	0	0	0	0	0	0	1	1	2	1	0	0	**5**
130	0	0	0	0	0	0	0	0	1	1	2	1	1	**6**
140	0	0	0	0	0	0	0	0	1	2	1	0	0	**4**
150	0	0	0	0	0	0	0	0	1	2	1	1	1	**6**
160	0	0	0	0	0	0	0	0	0	1	1	0	0	**2**
170	0	0	0	0	0	0	0	0	0	2	1	0	0	**3**
180	0	0	0	0	0	0	0	0	0	1	1	0	0	**2**
190	0	0	0	0	0	0	0	0	1	0	1	0	0	**2**
200	0	0	0	0	0	0	0	0	1	1	1	1	0	**4**
210	0	0	0	0	0	0	0	0	0	0	0	1	0	**1**
220	0	0	0	0	0	0	1	0	0	1	0	0	0	**2**
230	0	0	0	0	0	0	1	0	0	0	1	0	0	**2**
240	0	0	0	0	0	0	1	0	1	1	1	1	1	**6**
250	0	0	0	0	0	0	1	0	0	0	1	0	0	**2**
260	0	0	0	0	0	0	1	0	0	0	1	0	0	**2**
270	0	0	0	0	0	0	1	0	0	1	1	0	0	**3**
280	0	0	0	0	0	0	1	0	0	1	1	0	0	**3**
290	0	0	0	0	0	0	1	0	0	1	1	0	0	**3**
300	0	0	0	0	0	0	1	0	0	1	1	0	0	**3**

Table 3b: Mollusca fauna from core sequence of the Vesszős-halom (mound) 2 (individuals)
3b táblázat: A Vesszős-halomban feltárt minták malakológiai (darabszám) anyaga 2

cm	Aquatic species					Terrestrial species								SUMMA
	Lymnaea truncatula	*Planorbis planorbis*	*Planorbarius corneus*	*Anisus spirobis*	*Pisidium*	*Succinea oblonga*	*Chondrula tridens*	*Helicopsis striata*	*Pupilla muscorum*	*Vallonia costata*	*Vallonia pulchella*	*Cepaea vindobonensis*	*Helix pomatia*	
	pcs	**pcs**	**pcs**	**pcs**	**pcs**	**pcs**	**pcs**	**pcs**	**pcs**	**pcs**	**pcs**	**pcs**	**pcs**	**pcs**
310	0	0	0	0	0	0	1	0	0	0	1	1	0	**3**
320	0	0	0	0	0	0	0	0	0	2	2	0	0	**4**
330	0	0	0	0	0	0	0	0	0	1	2	0	0	**3**
340	0	0	0	0	0	0	0	0	0	2	1	0	0	**3**
350	0	0	0	0	0	0	0	0	0	2	1	0	0	**3**
360	0	0	0	0	0	0	0	0	0	2	1	0	0	**3**
370	0	0	0	0	1	1	0	0	0	2	2	0	1	**7**
380	0	0	0	0	1	1	0	0	0	2	2	0	0	**6**
390	0	0	0	0	0	0	0	0	1	1	2	0	1	**5**
400	0	0	0	0	0	0	0	1	1	2	1	0	0	**5**
410	0	0	0	0	0	0	0	0	1	2	1	1	1	**6**
420	0	0	0	0	0	0	0	1	1	2	1	0	0	**5**
430	0	0	0	0	0	0	0	0	1	1	2	1	1	**6**
440	0	0	0	0	0	0	0	0	1	2	1	0	0	**4**
450	0	0	0	0	0	0	0	0	1	2	1	1	1	**6**
460	0	0	0	0	0	0	1	0	0	1	1	0	0	**3**
470	0	0	0	2	0	0	1	0	0	2	1	0	0	**6**
480	0	1	0	2	0	0	1	0	0	1	1	0	0	**5**
490	1	0	1	2	0	0	1	0	1	0	3	0	0	**8**
500	0	0	0	0	0	0	0	1	1	1	1	1	0	**5**
510	0	0	0	0	0	0	0	3	0	0	0	0	0	**3**
520	0	0	0	0	0	0	0	4	0	0	0	0	0	**4**
530	0	0	0	0	0	0	0	3	0	0	0	0	0	**3**
540	0	0	0	0	0	0	0	4	0	0	0	0	0	**4**
550	0	0	0	0	0	0	0	4	0	0	0	0	0	**4**
560	0	0	0	0	0	0	0	3	0	0	0	0	0	**3**
570	0	0	0	1	0	0	1	2	0	0	0	0	0	**4**
580	0	0	0	1	0	0	2	3	0	0	0	0	0	**6**
590	2	2	2	4	3	1	0	0	0	0	0	0	0	**14**
600	1	1	1	6	9	4	0	0	0	0	0	0	0	**22**

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Aquatic species such as *Succinea oblonga* which is typical of wet meadows were derived exclusively from river sand in the bedrock.

Although the number of Mollusca fauna is stayed below the statistically significant level, however, due to its very good environmental indicator species, the fauna can be used to plot the pre-kurgan glacial, early Holocene level and the environment of the accumulated soil. A relatively large number of species, including *Pisidium, Lymnaea truncatula, Anisus spirorbis* with relatively variable water cover and occasionally parched or puddle environment was found from the lower part of the profile. Snails representing the more stable water cover (*Planorbarius corneus* and *Planorbis planorbis)* were found only in Pleistocene river sediments. The presence of aquatic Mollusca species in the bedrock of the profile indicates a strong water effect on the formation of the bedrock, the floodplain. At the same time, the presence of species that prefer periodic water cover in the subsoil of the kurgan is indicative of seasonal water effects at soil development. These malacological data also support the hydromorphic (water-like) character of the developed early-Holocene soil.

Also, the presence of terrestrial, steppe (*Pupilla muscorum*), forest-steppe (*Vallonia costata, Cepaea vindobonensis, Helicopsis striata, Helix pomatia*) but also wet meadows and waterfront elements (*Succinea oblonga, Vallonia pulchella*) reflects more significant vegetation cover (reeds, sedges, rushes, willows). Land snails indicate a series of so-called "hydroseries"; the formation of a surface which becomes cyclically wetter and drier during the formation of the subsoil. In the first layer of the kurgan's body above the Early-Holocene paleosoil, the same fauna was found so the first layer is derived from the application of the hydromorphic (meadow chernozem) soil. This is partly due to the environmental conditions formed during the construction breaks and to the carbonate rearrangement and partly to the formation of the so-called 2-3% organic layer of organic matter that flows downward in the earth's pyramid, material. As a result of this combination, a slightly acidic environment was evident in the body and led to the dissolution of the Mollusca shells and carbonate rearrangement. This is probably the result of the carbonate concretions and the dissolution of the carbonate veins and the shells.

In the part from the surface to 370 cm, only terrestrial snails were found. All snail species found from the upper 120 cm layer of kurgan are characteristics of dry steppe and forest-steppe (**Tables 3a** and **3b**). As a result, the snail fauna also indicates a dry ecological island after the construction of the kurgan with open vegetation on the mound and the formation of the meadow soil. It cannot be excluded that the uppermost kurgan body deposition which was also sedimentologically different from the underside of the kurgan body, originated from previously deposited layers by carrying back the eroded soil material time by time to the top of the former mound.

It should be noted here that elements considered by Hungarian malacologists (Deli et al. 2012) to be species of forest-steppe in the Great Plain environment do not follow forest steppes consisting of forest and open vegetation mosaics as described by botanists; based on measurements of the ecological tolerance of some terrestrial snail species (Ant 1963). That is, forest-steppe or more specifically species (*Vallonia costata, Cepaea vindobonensis, Helix pomatia*) on the high grass steppe with high shade vegetation settle under the influence of stable shading without the need for a large number of border vegetation or scattered trees. Thus, based on the malacofauna detected at the highest level of the kurgan the mosaic-like development and open vegetation covering can be inferred rather than the presence of ecotone vegetation or trees.

Results of grain size distribution analysis

The most significant feature of the sedimentological analysis compared to the kurgans of Békés and Hortobágy (Sümegi, 1988, 1992, 2002, 2004a; Sümegi et al. 2015a, 2016; Sümegi & Szilágyi, 2011; Szilágyi et al. 2013, 2018), that the clay content (grains<0.002 mm in diameter) was subordinated in the Vesszős-halom (**Fig. 3.**). The clay content in the kurgan varied between 4-10%, but higher in the paleosoil level. In parallel, the proportion of fine aleurite (0.002-0.02 mm) became dominant (29% to 68%), as we have reconstructed in case of kurgans formed on floodplain loess-like sediments (Sümegi et al. 2015a).

At the same time, the proportion of coarse aleurite (0.02-0.06 mm) and fine sand (0.06-0.1 mm) was also very significant both in the kurgan's body and in the buried soil (**Fig. 3.**). In the kurgan's body it ranges from 25 to 45%, while in the buried soil it is 47-48%.

Coarse-grained aleurite enrichments may have been formed because of the heterogeneity of the accumulated soil material and grain migration in the body of the kurgan. It is also having a significant proportion in the bedrock and become the dominant fraction there. This grain-size composition is typical of Pleistocene sediments and it can be assumed that the bedrock under the kurgan was formed at the end of the Pleistocene.

A layer of fine sand (with a low proportion of coarse aleurite) stretched beneath the loess level (490-570 cm) and it passed through with continuous transition to the fluvial sand layer.

There was a stronger difference between the two sand-rich layers in the proportion of middle sand, which increases in the lowermost layer of sand. There was also a significant difference in the shape of the grains, as quartz grains characterized by stepped surfaces predominated in the fluvial layer, while in the overlying sand layer microcraterial surfaced sand grains became dominant. This characteristic is typical of locally redeposited eolian sand, which accumulates on the surfaces of fluvial sand (Sümegi, 1993). As a result, the windblown sand formed by local eolian accumulation from the fluvial sand below, based on its stratigraphic position at the end of the Ice Age.

Summary of the geoarchaeological survey of the kurgan

A large-diameter (15 cm) drill was made on the Vesszős-halom reached 6 meters depth to the Pleistocene bedrock. Radiocarbon, magnetic susceptibility, particle size, organic matter, carbonate, inorganic matter content (based on loss on ignition method), pollen analytical and malacological investigations were performed on the samples of the profile. The results of the analyses are summarized based on the exposed layers (**Fig. 3.**).

The level extended from 570 to 600 cm, consisted of a fluvial originated fine sandy layer also contained a significant amount of medium sand. Also, this level is where the most significant species-rich aquatic fauna was found. According to geological investigations (Molnár, 2015), this river sand layer is connected to the active river branch of the Pleistocene Danube sediment and this is confirmed by the significant carbonate content of the sediment. The value of MS was also clearly subordinated to this level.

Sand layer, which is between 490 and 570 cm, has developed from the river sand layer with local eolian accumulation. The layer contained carbonated fine sand with drought-tolerant *Chondrula tridens* and *Helicopsis striata*, which recently live in sandy areas. These molluscs indicate a particularly mild but dry environment during the formation of the eolian sand. The value of MS was also low at this level.

Even at the end of the Ice Age, post-genetically modified loessy sediment was deposited in the form of coarse aleurite with considerable clay and carbonate content. This layer subsequently became carbonate-free with only the carbonate content of the shells in it (**Fig. 3.**). Carbonate migration to the lower horizon may have been caused by fluctuating groundwater but may also has been triggered by rainwater leaking from above after the construction of the relatively high organic matter contented kurgan. The MS value of this level has already increased compared to the deeper levels (Figure 3).

The subsoil of the kurgan (level A at 370-400 cm and level B at 400-430) was still actively developing in the years of 4400-4600 BC. The soil is characterized by significant organic matter content (2-3%), carbonate-exemption, high clay content fine-coarse aleurite which already has a significant magnetic susceptibility value (**Fig. 3.**). Terrestrial steppe species (*Pupilla muscorum, Vallonia costata, Vallonia pulchella, Cepaea vindobonensis, Helix pomatia*) have been found in that layer.

Based on the composition of the fauna, a species-rich, high grass steppe dominated the studied area at the time of soil formation which certainly evolved at the end of the Neolithic, the beginning of the Copper Age (4600-4400 BC). Based on pollen analysis, a grassy steppe has developed in the area which may has formed a few acres of mosaic. Trees may have appeared at deeper areas with higher groundwater levels outside a radius of about 500 meters, based on their subordinated proportion. In the wider environment we can reconstruct a species-rich forest-steppe with mosaic structure and in the local environment; we can reconstruct a grass steppe at the time of the formation of the soil. As a result of the pollen analysis (weeds, cereals have found), human beings certainly had an effect on the pollen composition by grazing and cultivation activities. That human disturbance has primarily occurred in this area during the final phase of soil formation, and also during the construction of the kurgan.

The earthy pyramid (kurgan) is formed from 370 cm to the surface, in which we could separate three different levels based on changes in MS grain composition and organic matter content. These resulted in three large accumulation levels and three stages. The stages may have followed each other with a few lifetimes and in the second phase, and it is assumed that the body constructed in the first phase was disturbed. It cannot be excluded that a new burial chamber was created but during the drilling, neither the basic pit grave nor the supposed tomb in the kurgan was detected and no bone was recovered from the profile. This may also has been caused by significant dissolution processes in the kurgan's body.

The layer of the first phase consisted entirely of chernozem soil with hydromorphic marks and with high organic matter content. The level of the second stage could be formed between 120 and 240 cm. The accumulated soil is a finely laminated, subordinately consisted of the material of the bedrock mixed with the material of the former soil. The third stage (between 120 and 40 cm) forms the bedrock of surface chernozem, a level of human-disturbed, layered lenses and sediment strips mainly from the subsoil but sometimes from the bedrock including windblown sand. Within this horizon, a crumbly textured chernozem soil appeared.

According to the pollen analysis, grassland vegetation (sometimes with cereal field) dominated the area at the time of the formation of soil and beginning of the construction. Only terrestrial, steppe snail species were found in the kurgan's body but almost all of its shells were partially dissolved and carbonate pseudomorphoses were also found. Based on this, significant carbonate dissolution may have occurred in the earthy pyramid containing significant organic matter. Based on the presence of terrestrial snails, steppe environment dominated the kurgan and its surroundings throughout the time of the construction phases.

Based on the radiocarbon analyses carried out so far, the kurgan's earth pyramid may have been formed during the Late Copper to Early Bronze Age (Szilágyi et al. 2018). With the construction of the kurgan, a dry morphological and biogeographical island, a special geomorphological mosaic was created in the area. The surest sign of this is the classical chernozem soil, formed on the surface of the kurgan, on the material of the accumulated buried soil (and sometimes of the bedrock). In addition to geoarchaeological researches, we can also reconstruct the dynamic changes of the kurgan's environment over the last 5000 years, along with archaeological, archaeometrical analyses and historical data in the area. Vesszős-halom still exists in a rapidly changing landscape where human influences have intensified due to the use of mechanization and chemicals. For these reasons, active protection of the mound and careful conservation measures (such as we control the vegetation of the mound surface) are required to save this monument of approximate 5000 years of cultural history for the younger generations.

The borehole profile, complemented by radiocarbon data currently under investigation, will provide an excellent complex geoarchaeological data set for the author's legally protected, continuously expanding research at the Department of Geology and Paleontology, University of Szeged, which include Central Asian and Eastern European kurgans and burial mounds.

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DISTRIBUTION AND MOVEMENT OF WATER–SOLUBLE GEOCHEMICAL ELEMENTS IN A PEAT BOG DURING ENVIRONMENTAL CHANGES AND HUMAN IMPACTS IN THE EASTERN CARPATHIANS IN ROMANIA•

EGY TŐZEGLÁP VÍZOLDHATÓ GEOKÉMIAI ELEMEINEK ELOSZLÁSA ÉS MOZGÁSA A KÖRNYEZETI VÁLTOZÁSOK ÉS EMBERI HATÁSOK TÜKRÉBEN, A KELETI-KÁRPÁTOKBAN

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Abstract

This paper presents the result of geochemical analysis of the peat bog at Homoródszentpál Kerek-tó (Round Lake). The bog is situated in Homoród Hills of the Eastern Carpathians in Romania. The primary objective of this study was to analyse the water–soluble geochemical composition of a 7500 year long peat record and compared previous sedimentological and pollen analytical data. The selected water–soluble elements (Fe, Mn, Ca, Mg, Na and K) concentrations were determined using flame AAS. The 560 cm long sedimentary core consists of an upper lake and a lower marsh phase, which show different geochemical characteristics. The elemental distribution describes the paleoenvironmental and palaeohydrological changes and indicates different evolution stages of the bog system. Through our results, water–soluble Fe and Mn could be linked to the mineral component of the sediment while the Ca shows biophilic origin. The Na, K and Mg show affinity both to the organic and inorganic material.

Kivonat

Kutatásunkban a homoródszentpáli Kerek–tó tőzegláp geokémiai vizsgálatának eredményeit mutatjuk be. A láp a Keleti-Kárpátokban a Homoródi-dombságban található, Romániában. A tanulmány elsődleges célja a 7500 éves tőzegrétegsor vízoldható elemtartalom meghatározása volt, valamint a korábbi szedimentológiai és pollen elemzési adatokkal való összehasonlítása. A kiválasztott vízoldható elemek (Fe, Mn, Ca, Mg, Na, K) koncentrációját AAS atom abszorpciós spektroszkópiával határoztuk meg. Az 560 cm hosszú üledékes mag egy felső tavi és egy alsó lápi fázisból áll, melyek eltérő geokémiai jellemzőket mutatnak. Az elemek eloszlása leírja a paleokörnyezeti változásokat és megmutatja a láp különböző fejlődési szakaszát. Eredményeink szerint a vízben oldódó Fe és Mn az üledék ásványi anyagával mutat kapcsolatot, míg a Ca biofil eredetet mutat. A Na, K és Mg kapcsolatot mutat mind a szerves, mind a szervetlen anyaggal.

KEYWORDS: PEAT BOG, WATER–SOLUBLE ELEMENTS, ATOMIC ABSORPTION SPECTROMETRY, PALEOENVIRONMENT.

KULCSSZAVAK: TŐZEGLÁP, VÍZOLDHATÓ ELEMEK, ATOM ABSZORPCIÓS SPEKTROMETRIA, PALEOKÖRNYEZET.

Introduction

Peat and lake sediments which accumulated in situ are important paleoenvironmental archives (Mackareth 1965).

The peat records are appropriate for reconstructing the palaeoclimatic, paleoenvironmental and paleo-ecological changes (Blytt 1876; Sernander 1892), These changes could be reconstructed using many different methods, for instance radiocarbon dating, pollen and macrofossil analysis, testate amoebae, geochemical and isotope analysis.

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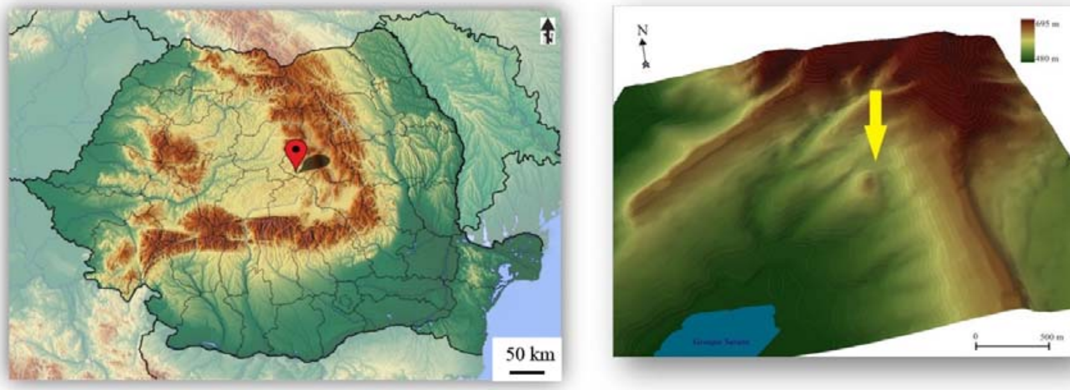

Fig. 1.: Relief map of Romania within the studied site (Round Lake at Sântpaul) and the location of core site on the 3D map

1. ábra: Románia domborzati térképe a vizsgálati helyszínnel (Kerek–tó, Homoródszentpál) és a fúrás helyszíne a 3D–s domborzati modellen

The Round Lake peat sequence formed between 7500 cal BP and the 16th century (depth of sediment: ca. 560–104 cm), when as a result of increased human activities the basing was gradually infilled. During the 19th century a fishing pond was created by damming (Tapody 2016; Tapody et al. 2018).

In this paper, we compared the previously published results of sedimentological and palinological investigations (Tapody et al. 2018 with the new geochemical results).

The aim of this study is to understand and present the geochemical behaviour of the analysed elements in peat deposits, and define the interaction between chemical changes and environmental, climatic and hydrological changes.

The site studied

The Round Lake (latitude 46°11′56.24″N and longitude 25°25′00.37″E) is a dried-out lake situated on the south-western foothills of the Hargita Mountains of the Eastern Carpathians in Romania (**Fig. 1.**).

The average elevation of the lake is 547 m a.s.l. and the surface is 2–3 hectares. The basin of the lake developed as a result of down-slope mass wasting promoted by thawing permafrost during the Late Glacial/Postglacial transition (Vandenberghe et al. 2014; Ruszkiczay–Rüdiger & Kern 2016; Tapody 2016; Tapody et al. 2018). The bedrock consists of Tertiary silty clay layers at the bottom overlain by Late Tertiary – Quaternary volcanic tuff and tuffite (Szakács & Seghedi 1995; Pécskay et al. 1995). The sampled core is 560 cm long and did not reach the bottom of the bog. The core sequence represents ca. 7500 years (Tapody et al. 2018). The lower 460 cm of the sequence is represented by various peat layers, and the overlying top 100 cm of the sequence is represented by sediments of the pond created at the end of the Middle Ages (Tapody et al. 2018).

The Carpathians are a transitional area between continental climates and the oceanic ones from east to the west, as well as between boreal climates in the north and Mediterranean climates in the south. Precipitation in the Eastern Carpathians ranges from 1,400 to 1,600 mm/year. These general characteristics vary in terms of radiation and the circulation of air masses, and are directly reflected in plant associations and soils, and consequently indirectly reflected in all the natural components of the mountainous environment (UNEP, 2007; JRC, 2010).

Materials and Methods

560 cm–long undisturbed core was taken by Russian peat corer from the centre of the former lake in June 2015. The sediment core was extracted by a 5–cm–diameter sealed liner tube and it was sub-sampled at 2–4 cm intervals for palaeobotanical, sedimentological, geochemical analysis. The main lithostratigraphic features of the core were described using Troels–Smith (1955) system, as the method developed for unconsolidated sediments.

This study is focused on the geochemical characteristics of the lake. The sedimentological and radiocarbon and palynological methodology and results are described in detail in Tapody et al. (2018).

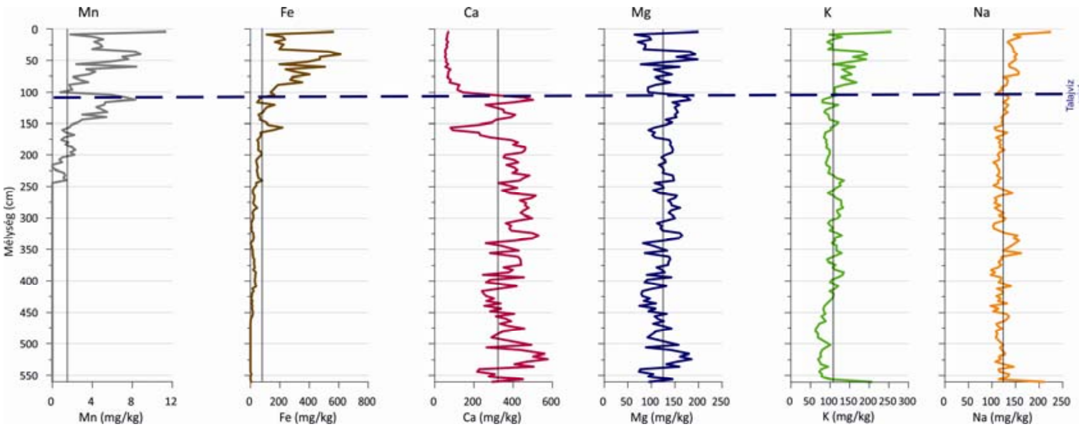

Fig. 2.: The concentration of water–soluble elements in the peat core and the water table. The black line represents the mean value.

2. ábra: A vízoldható elemtartalom a rétegsorban, megjelölt talajvízszinttel. A fekete vonal az átlagot jelöli.

Table 1.: Sedimentological description of the core profile of Round Lake

1. táblázat: A Kerek-tó fúrómagjának szedimentológiai leírása

Depth (cm)	**Troel-Smith category**	**Lithostratigraphy**
0-102	Lc1As3	Greyish red calcareous silty clay lake sediment
102-198	Lc1Th1As2	Dark brown calcareous silty clay with limonite precipitates
198-254	Th2Lc1As1	Blackish brown mixed reed and sedge peat with calcareous silty clay
254-260	Th3Lc1	Blackish brown mixed reed and sedge peat with carbonate rich silt
260-284	Th2Lc1As1	Blackish brown mixed reed and sedge peat with calcareous silty clay
284-290	Th3As1	Grey-black mixed reed and sedge peat with clay
290-292	Th2Lc1As1	Blackish brown mixed reed and sedge peat with calcareous silty clay
292-320	Th3As1	Grey-black mixed reed and sedge peat with clay
320-362	Tb3As1	Deep-red *Sphagnum* peat mixed with clay
362-366	Th2Lc1As1	Blackish brown mixed reed and sedge peat with calcareous silty clay
366-382	Th3Lc1	Deep-red mixed reed and sedge peat with calcareous silty clay
382-392	Th2Lc1As1	Blackish brown mixed reed and sedge peat with calcareous silty clay
392-510	Th3As1	Deep-red mixed reed and sedge peat with clay
510-530	Tb3As1	Dark brown *Sphagnum* peat mixed with clay
530-560	Th3As1	Deep-red mixed reed and sedge peat with clay

Table 2.: Water–soluble elements mean concentration (mg/kg) in the Round Lake whole section, compare to the lake and the bog phase.

2. táblázat: Vízoldható elemek átlag koncentrációi a teljes Kerek-tó szelvényében összehasonlítva a tavi és a lápi fázissal.

	Total section 0-560 cm	Lake phase 0-100 cm	Bog phase 100-560 cm
Mn	1.51	4.58	0.81
Fe	83.43	304.04	33.74
Mg	125.41	120.63	126.48
Ca	319.67	74.04	374.99
Na	125.06	143.45	120.92
K	108.13	139.30	101.11

The core for geochemical was sub-sampled at 4 cm intervals. Applied method was the first step of the five–step extraction–digestion method by Dániel (2004). The water–extractions of the unseparated samples gave information about the water–soluble elements from weathered minerals (like carbonates and salts), precipitates and ions bound slightly onto the mineral surface (Dániel, 2004). The distributions of concentrations of Mn, Fe, Ca, Mg, Na and K could indicate the changes in the bog conditions which describe the paleoenvironmental and palaeohydrological changes.

Samples were grounded and air-dried at 105 °C for 24 hours. 100 ml double–distilled water was added to 1.0 g sample. The samples were shaken for 6 hours at 160 rpm. The resulting suspension was filtered and diluted to 50 ml. 1 ml 65% (m/m) HNO3 was added for storage (Dániel 2004). Element concentrations were determined by flame AAS (Perkin–Elmer 100) using conventional standards of known concentrations.

Statistical analysis was performed by using SPSS 25.0 statistical software package and we used Spearman rho correlation coefficient.

Results

Stratigraphy of the Round Lake sediment

The sediments of the Round Lake could be divided into 3 main zones. The first zone from the surface to 100 cm depth is a lake sediment phase which a result of silt up in the Medieval Age. The second zone is a transition phase the lake sediment with mixed reed and sedge remains. The third zone between 198 cm and 560 cm is composed of mixed peat. This zone dominantly consists of reed and sedge peat, but Sphagnum peat is also present in two sections (320–362 cm and 510–530 cm). When the core was pulled out, the compression closed the hole, so the core did not reach the underlying bedrock. (**Table 1.**).

Elemental composition

The whole core section is characterised by various peat accumulation and inorganic sediment deposition. These changes can be observed in the content of water–soluble elements (**Fig. 2.**). In the case of the studied elements, it can be observed that they behave differently in both the lake (0–100 cm) and the bog phases (100–560 cm). The accumulation depends on various conditions, but overall, the lake phase have higher mean Mn, Fe Na, K and lower Ca and Mg concentrations which is the reverse of the bog phase (**Table 2.**).

In the correlation matrix of the whole section of the Round lake seen in **Table 3.** A strong positive correlation between Fe–Mn, Ca–Mg, Fe–Ash yield and Mn–Ash yield, and strong negative correlation between Ca–Fe, Ca–Ash yield. Furthermore, the correlation matrix for the lake and the bog phases were examined separately (**Table 4., Table 5.**). It can be clearly seen that in the lake phase Mg shows a strong correlation with Fe and Mn, while it has a negative correlation with Ca, meanwhile in the correlation matrix of the bog phase is similar to the whole section correlation matrix.

The distribution of Fe and Mn concentrations has similar trends along the whole section. From the surface to 104 cm is the first sedimentation layer which is a calcareous silty clay lake sediment. In this section, all analysed elements except the calcium showing high concentrations near the surface. There are three significant Mn and Fe peaks well correlated with each other. From 160 cm downward the amount of the two elements decreases.

The trends of Na and K contents are similar in the bog phase, and they show small fluctuation along the section. The higher K and N contents are recorded in the upper 104 cm (**Table 2.**). Significant peaks are detected between 36–83 cm, which is similar to Fe, Mn and Mg peaks. High Na concentrations were also recorded at depths 256–260 cm, 334–366 cm and 532–536 cm. These peaks overlap with higher plant–containing lithologic layers (Th3Lc1, Tb3As1, Th3As1) and layer boundaries.

The Ca and Mg concentrations from the base of the core to 112 cm have similar distributions. At the depth of 112 cm, the Ca concentration sharply decreased and remains at low values in the whole upper section of the core. Unlike Ca, the content Mg in the upper section is correlated with Fe and Mn distribution.

Table 3.: Spearman's rank correlation coefficient matrix between the concentration of analysed elements and ash yield in total section. **Correlation is significant at the 0.01 level (2–tailed). *Correlation is significant at the 0.05 level (2–tailed).

3. táblázat: Spearman–féle rangkorrelációs koefficiens mátrix az elemkoncentrációk és a hamutartalom között a Kerek tó teljes szelvényében. ** a korreláció szignifikáns 0.01 szintnél, * a korreláció szignifikáns 0,05 szintnél.

	Mn	Fe	Mg	Ca	Na	K
Fe	0.86**					
Mg	0.23**	0.15				
Ca	-0.47**	-0.48**	0.57**			
Na	0.42**	0.32**	0.13	-0.30**		
K	0.23**	0.51**	0.18*	-0.21*	0.28**	
Ash y.	0.82**	0.94**	0.08	-0.49**	0.29**	0.53**

Table 4.: Spearman's rank correlation coefficient matrix between the concentration of analysed elements and ash yield lake phase. **Correlation is significant at the 0.01 level (2–tailed). *Correlation is significant at the 0.05 level (2–tailed).

4. táblázat: Spearman–féle rangkorrelációs koefficiens mátrix az elemkoncentrációk és a hamutartalom között a tavi fázisban ** a korreláció szignifikáns 0,01 szintnél, * a korreláció szignifikáns 0,05 szintnél.

	Mn	Fe	Mg	Ca	Na	K
Fe	0.79**					
Mg	0.61**	0.91**				
Ca	-0.75**	-0.50*	-0.26			
Na	0.62**	0.56**	0.43*	-0.45*		
K	0.52**	0.86**	0.96**	-0.15	0.40*	
Ash y.	0.52**	0.16	-0.10	-0.77**	0.29	-0.15

Table 5.: Spearman's rank correlation coefficient matrix between the concentration of analysed elements and ash yield bog phase. **Correlation is significant at the 0.01 level (2–tailed). *Correlation is significant at the 0.05 level (2–tailed).

5. táblázat: Spearman–féle rangkorrelációs koefficiens mátrix az elemkoncentrációk és a hamutartalom között a lápi fázisban ** a korreláció szignifikáns 0,01 szintnél, * a korreláció szignifikáns 0,05 szintnél.

	Mn	Fe	Mg	Ca	Na	K
Fe	0.79**					
Mg	0.35**	0.29**				
Ca	-0.08	-0.05	0.81**			
Na	0.12	-0.02	0.22*	0.07		
K	-0.08	0.33**	0.13	0.12	0.03	
Ash y.	0.73**	0.91**	0.26**	-0.06	-0.06	0.41**

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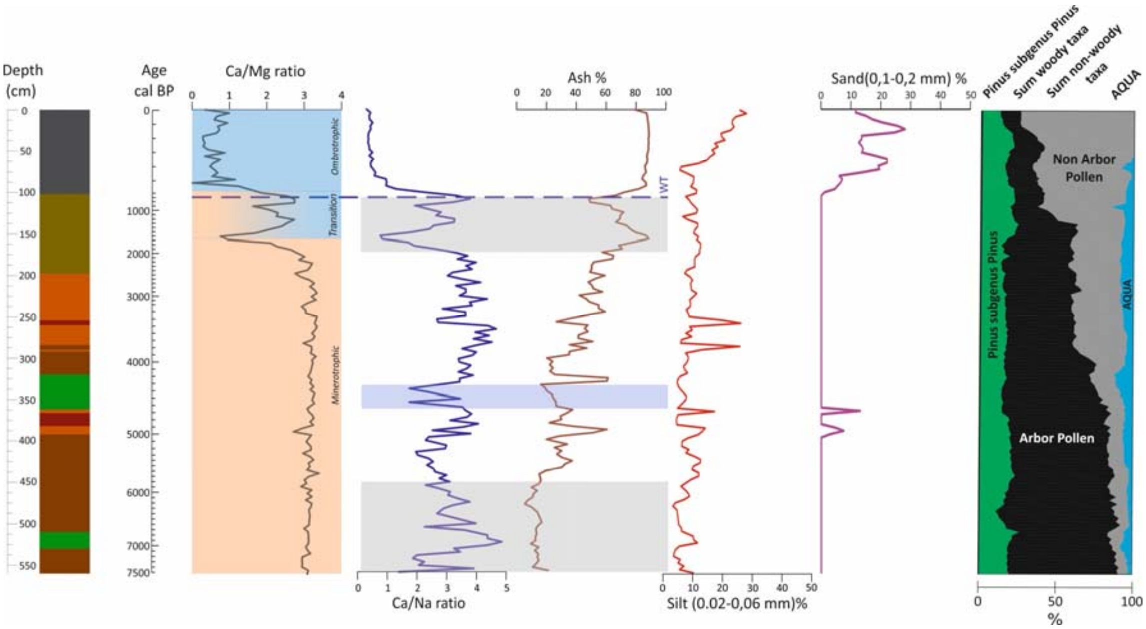

Fig. 3.: Comparable representation of the Ca/Mg ratio, Ca/Na ratio, Ash% content, coarse silt and fine sand content and a summarised pollen data from Tapody et al. (2018).

3. ábra: Összehasonlító ábra a Ca/Mg arány, Ca/Na arány, Hamu % tartalom, durva kőzetliszt %, finom homok % és az összesített pollen ábrával Tapody et al. (2018)-ból átvéve.

Discussion

The analysed concentration of elements show a significant change between the peat-land and the lake phase at about 104 cm, as well as at the time of the sampling (May 2015) the water table was at 104 cm.

The Fe and Mn are lithogenic elements, but their content depends on the environmental factors that control post–depositional processes (Schittek et al. 2015, Muller et al. 2006, 2008), which affected just the upper part of the section. Therefore, the concentration of water–soluble Mn and Fe are well correlated with the ash content (**Fig. 3.**). This section is a silty clay lake phase which derived from the weathering of mineral sediments. Both elements under anaerobic condition are mobile and accumulate above the water level (Damman 1978; Shittek et al. 2015).

In the previous studies (Mackereth 1966; Engström & Wright, 1984; Dániel 2004) it is elaborated that the contents of Na, K, Mg can indicate both chemical and physical weathering of soil in the past. The higher K contents in the uppermost section indicate intensive erosion and significant peaks correlate with Mn and Fe peaks that could originate from the feldspars in inorganic sediment (Mackareth 1966). The highest Na values are detected in the purest plant–based peat (mixed sedge and reed peat) where the Na accumulating species could fix the Na and K ions (Kustár et al. 2016.; Braun et al. 1993; Beeton, 1965).

The Ca and Mg concentration trend is similar in the bog phase and different in the lake phase. Ca is a well–known biophilic element (Gorham et al. 2005). For adequate growth in plants is normally around 0.5% shoot dry matter (Batty & Younger, 2004). There is a clear similarity between the Ca concentration and the Arbor pollen concentrations, which could derive from the deciduous tree fallen leaves. The Arbor pollen concentration sharply decreased, and the Non–Arbor Pollen (NAP) was gradually increasing at 150 cm which correlates the time of the Great Migration and the Hungarian Conquest (ca.1600–900 cal BP). These cultures put an expand pressure on the bog environment by deforestation and pasturelands (Tapody et al. 2018).

The Ca/Na ratio is usable for weathering rates (Watmough & Aherne 2008, Bailey et al. 2003, Federer et al. 1989). In these studies suggest that the disturbance of forest ecosystems, like harvesting cause depletion of available calcium (Ca) pools like lakes. Based on the Ca/Na ratios three sections of sediments were defined in the Round Lake profile. As the bedrock is volcanic and the calcium concentration correlates with arbor pollen, in contrast to the ash content, it was hypothesized that the Ca/Na ratio can indicate the changes in the surface vegetation of the bog. Therefore, the Ca/Na ratio was compared with the ash content and summarised pollen diagram. If we

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compare the Ca/Na ratio with the ash content, we can see that some sections change in the same, others in opposite directions. It is important to note that the source of calcium (Ca) can be derived from the dissolution of mineral particles and leaching from the secondary accumulation of deciduous tree leaves.

The ash yield calculated from the LOI contains both inorganic mineral matter and inorganic components of plant tissues. In this regard, the Ca/Na ratio, the ash content, the fine sand, and coarse silt content are compared. In the 560–450 cm section, there are fluctuating high Ca/Na peaks with a low ash content of 10–20%. There is a sharp peak between 510–530 cm which coincides with the first Sphagnum layer and coarse silt peak. At this stage, the AP pollen rates are between 85% and 95%, the Round Lake was surrounded by rich deciduous forest.

In the next stage (450–360 cm) the ash content rises 40–50% and the Ca/Na ratio is around 2–3%. Between 390 and 360 cm, there are 3 lithologic layers within the section the Ca/Na peak coincides with the Th3Lc1 layer and the ash peaks with the Th2Lc1As1 layers. Between 360–330 cm, a Ca/ Na peak coincides with the second Sphagnum level. Between 330 and 180 cm, the Ca/Na and ash contents move in the same direction. The Ca and Na trends are very similar because the sedge and reeds that build up the peat could fix the Na. There are no major fluctuations in the coarse silt at this stage, except for two peaks, which are at the boundary of the layers. It is assumed that a significant portion of the ash content may have been due to inorganic plant residues, which may be true for sedge and reed. The forest vegetation gradually decreased at 180 cm to ca. 60%.

Between 180 and 100 cm, the change in Ca/Na is opposite to the ash content. This phase is a transitional phase between the lake and the bog. The major part of the sediment is made up of inorganic mineral matter, but the bog vegetation is also present. At 150–140 cm, AP pollen is reduced by 10% and further 20% towards the surface. At the groundwater level the Ca/Na ratio is high, but the ash content decreases. In the upper 100 meters is the lake phase, the ash content is high and the Ca/Na ratio drops below 1%.

The Ca/Mg ratio is used to determine the peat trophic status. The trophy depends on the source of the water and the nutrient supply. Minerothropic peats receive nutrients from rainwater and incoming surface and groundwater, while ombrotrophic peat collects nutrient solely from the rainwater. Ombrothropic peat can not get in contact with ground or surface water because the peat forms a dome above the terrain level.

One procedure to determine the trophic status is to compare the Ca/Mg ratio of the peat with those of the local rainwater. If the Ca/Mg ratio of the peat exceeds the local rainwater level the peatland must have an additional source of Ca, so it is minerotrophic otherwise ombrotrophic (Weiss et al. 1997, 2002; Shotyk 1988, 1996, 2002; Muller et al. 2006; Lähteenoja et al. 2009).

The rainwater Ca/Mg ratio from the region (Giurgeu basin and Ciuc basin) is between 4–6 (Szép et al. 2018). The Round Lake Ca/Mg ratio values are under the rainwater values (**Fig. 3.**). For minerotrophic peats the ratio is usually higher than1.0. Conversely, it is less than 1.0 for ombrotrophic peats (Mattson et al. 1944; Chapman 1964, Verhoeven 1986; Shotyk 1988). Thus, sections, already defined based on the Ca/Mg ratio could be additionally described as: The lower section (560–160 cm) peat condition is a minerotrophic, between 150–100 cm is a transition phase, and the top 100 cm were ombrotrophic. It seems contradictory that the highest inorganic content lake sediment section (top 100 cm) show ombrotrophic condition. This will be a scope of our future investigation.

Conclusion

This paper describes the geochemical data analysis of the peat deposit in Round Lake to define paleoenvironmental conditions over the past 7500 years. According to the results, there are two main phase in the development history of Round Lake. The top 104 cm sediment based on lake phase and the bottom part is a manifold peat deposit.

The peat core unfolds a complex development of the bog that was influenced by climate, hydrology the vegetation and the environment. The analysed element suggests that:

(1.) The Mn and Fe concentration derived from the mineral matter of the catchment basin. The water–soluble components are only detectable above the water table because they are mobile in water.

(2.) The high Ca content unambiguously derived from the deciduous forest vegetation surround the bog. However, the vegetation has a significant effect on Ca content, the distribution is influenced by the hydrological conditions of the bog, such as the precipitation, fluctuation of groundwater level and the peat vegetation.

(3.) The Na and K are essential elements to all plants, and they could be accumulated in plant tissues. The highest concentration of the Na is on the surface below the living layer the Na and K could be leached.

(4.) The highest concentration of Mg and K are revealed in the inorganic mineral phase, besides they firmly bond the vegetation and a secondary accumulation in peat may occur. The vegetation of different peat binds calcium, magnesium differently, which can determine the minerotrophic and ombrotrophic phase.

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A DARK AGE SETTLEMENT AND ITS ENVIRONMENT AT RÁKÓCZIFALVA IN THE MIDDLE TISZA REGION, HUNGARY•

EGY NÉPVÁNDORLÁS KORI TELEPÜLÉS ÉS KÖRNYEZETE A KÖZÉPSŐ-TISZAVIDÉKRŐL, RÁKÓCZIFALVÁNÁL

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Abstract

Complex archeozoological, environmental historical and geoarchaeological results are presented from archeological sites of Rákóczifalva–Bagi-föld and Rákóczifalva–Rokkant-föld in Jász-Nagykun-Szolnok County. In this area several hectares of archeological excavations uncovered masses of Gepida settlement features around two oxbow lakes. According to geoarcheological and environmental historical analyses a model for local settling and lifestyle strategies of the Gepid communities can be reconstructed. Based on the results of the digital relief model, maps, historical maps and analysis of geoarchaeological drillings, the Bagi-földek are located on a deeper and younger alluvial surface with good water supply and are connected to the development of the Tisza River, while the Rokkant-földek are located on an older residual surface and are rising above the alluvium of the Tisza River. The Gepid communities settled on a point bar system located on the high-floodplain and low floodplain in a semi-circular, semi-peninsula-like protected area. These surfaces provided different farming possibilities for the Gepid communities of the Migration Period: the utilization of the gallery forest, gatherings in the area of the forests and floodplain, fishing and hunting, extensive animal husbandry on the higher, drier areas and plant cultivation around the settlements and houses. According to our data, the inhabitants of the excavated Gepid settlement fully utilized the Tisza valley environment for food production on an organic (non-industrial) level (Sólymos, 1995), or in the Anthropocene I. horizon (e.g. Crutzen & Stoermer 2000; Steffen et al. 2011) during the Migration Period in the 6th century. The environment occupied by the Gepid community, the floodplain islands and residual surfaces in the Tisza Valley was inhabited from the early Neolithic. The exploitation of their environment, from settlement strategy to gathering, has a similar system as in the case of the Gepid settlement we have described. Our publication is a precursor to a comprehensive work with archaeologists, so we did not aim to analyze the individual cultures in detail from the perspective of environmental history and archaeology. We plan to do that together with the archaeologists who carry out the archaeological excavations. As a result, our article deals specifically with the settlement, geoarchaeological, bioarchaeological, and above all, archaeozoological analysis of the Gepid communities.

Kivonat

Jász-Nagykun-Szolnok megyei Rákóczifalva–Bagi-földeken és Rákóczifalva–Rokkant-földeken végzett több hektárra is kiterjedő régészeti ásatások során feltárt, két holtág körül található gepida leletekhez kapcsolódó komplex archeozoológiai, régészeti geológiai és környezettörténeti vizsgálatok eredményeit mutatjuk be publikációnkban. A rákóczifalvi gepida lelőhelyek geoarcheológiai és környezettörténeti elemzése nyomán egy modellt adhatunk a gepida közösségek megtelepedési stratégiájára és életmódjára. A digitális domborzati modell, a térképek és a történelmi térképek, a földtani fúrások geoarcheológiai vizsgálati eredményei alapján a Bagi-földek egy jó vízellátású, mélyebb és fiatalabb, a Tisza folyó fejlődéséhez kapcsolódó alluviális felszínen helyezkedik el, míg a Rokkant-földek az allúvium fölé emelkedő idősebb maradványfelszínen. A vizsgált területen megtelepedő gepida közösségek így a magas ártéren és az alacsony ártéren található, félkörívben,

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félszigetszerűen árterekkel védett övzátony sorozaton telepedtek meg. Ezek a felszínek eltérő gazdálkodási lehetőséget nyújtottak a népvándorlás kori gepida közösségek számára és a galéria erdő hasznosításától, erdei és ártéri gyűjtögetéstől, halászattól – vadászattól a magasabb szárazabb térszíneken kialakított külteljes – legeltető állattartásig és a megtelepedési pontok, házak körül kialakított növénytermesztésig. Adataink alapján a feltárt gepida település lakói teljes mértékben hasznosította organikus (nem gépesített [nem indusztriális], kemikáliákat nem használó) gazdálkodás szintjén (Sólymos, 1995), más néven Anthropocén első szintjében (például Crutzen & Stoermer, 2000; *Steffen et al. 2011), Tisza- völgyi környezetüket a népvándorlás korában, a 6. századi élelmiszer termelésük során. Maga a gepida közösség által megszállt környezet, a Tisza-völgyében megtalálható ártéri szigetek, jégkori maradványfelszínek gyakorlatilag a kora-neolitikumtól kezdődően lakottak voltak és szűkebb, tágabb környezetük kihasználása, a megtelepedési stratégiától a gyűjtögetésig hasonló rendszert mutat, mint az általunk taglalt gepida település esetében, viszont az improduktív gazdálkodás (vadászat, halászat, gyűjtögetés), illetve a produktív gazdálkodás (földművelés, állattenyésztés) aránya változott az egyes közösségek esetében. Publikációnk egy átfogó, régészekkel közös munka előfutárának tekinthető, ezért nem volt célunk az egyes kultúrák részletes elemzése környezettörténeti és régészeti szempontból, mivel ezt a régészeti feltárásokat végrehajtó régészekkel közösen tervezzük megtenni. Ennek nyomán cikkünk kifejezetten a gepida közösségek megtelepedésével, geoarcheológiai, bioarcheológiai, mindenek előtt archeozoológiai elemzésével foglalkozik.*

KEYWORDS: ENVIRONMENTAL HISTORY, GEOARCHAEOLOGY, ARCHEOZOOLOGY, HUN AGE, GEPIDS

KULCSSZAVAK: KÖRNYEZETTÖRTÉNET, ARCHEOZOOLÓGIA, RÉGÉSZETI GEOLÓGIA, HUN KOR, GEPIDÁK

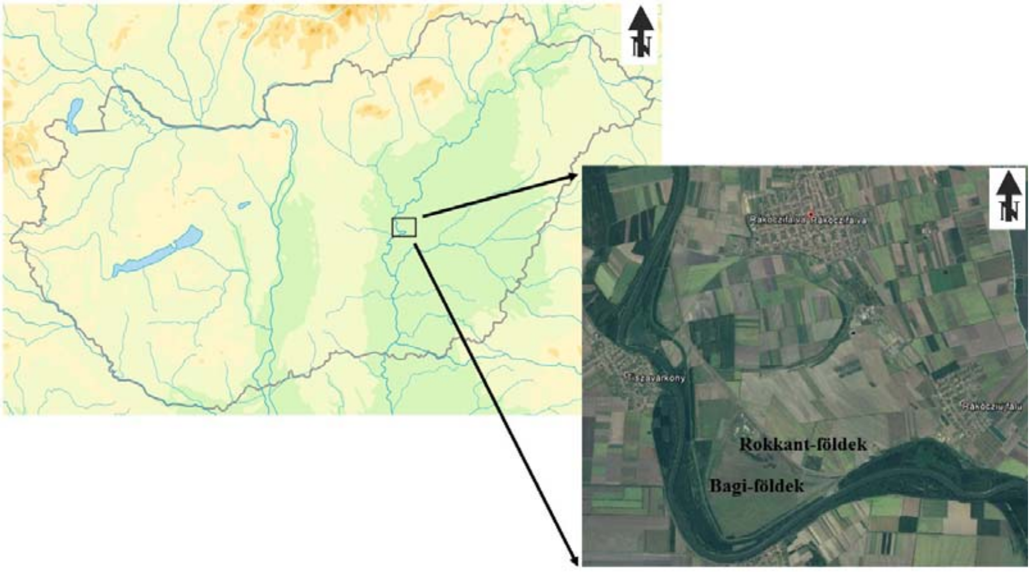

Fig. 1.: The location of the study site in Hungary and in Google Maps (scale of original maps: 1:500,000 and 1:10,000, respectively)

1. ábra: A vizsgált terület elhelyezkedése Magyarországon és a Google Maps szerint (térképek eredeti méretaránya: 1:500 000 és 1:10 000)

Introduction

We present the results of the archaeozoological, environmental historical and geoarchaeological analysis of Rákóczifalva–Bagi-föld and Rákóczifalva–Rokkant-föld (**Fig. 1.**) archeological sites in Jász-Nagykun-Szolnok County. They were discovered in the course of several hectares of archaeological excavations related to the Migration Period, especially the Hun era. A significant number of Gepid sites and finds were found in both the investigated area and the wider area of the site, in the middle reach of the Tisza valley. So the geoarchaeological and environmental historical analysis of the Gepid sites in Rákóczifalva can also provide a model for the settling strategy and lifestyle of the Gepid communities. The purpose of our work is to present how geoarchaeological and environmental historical factors impacted local settling and lifestyles in the Gepid communities (Kovács et al. 2007, 2008, Kovács and Váczi 2007, Masek 2012, 2014) during the Migration Period. In addition, to demonstrate the relationship of the Gepid communities and their environment in the Rákóczifalva site compared to other Gepid settlements in the Great Hungarian Plain (B. Tóth 1999, 2006). The composition of the domestic animal assemblage suggest the area was surrounded by extensive grazing fields, including saline pastures favorable to sheep, but the area of wet meadows and meadows was also outstanding indicated by the high ratio of cattle and horse bones in the 6th century, during the Gepid settlement. Poultry provided a significant source of meat and eggs.

The study site

Natural conditions of the area

In terms of the borders of the Rákóczifalva - Bagi-földek and Rokkant-földek sites, it can be said that it is protected from the north, south and west, as it is bordered by the Tisza River and the deeper Tisza alluvium (**Figs. 1-5.**). It is open only from the eastern direction, because the area is connected eastward to the high river bank of the Tisza River and it extends as a peninsula into the deeper Tisza floodplain. The study site belongs to the Great Hungarian Plain, including the Middle Tisza region, the Nagykunság little region group and the Szolnok-Túri alluvial plain, Szolnok-Alluvial Plain little regions. It lies in the western part of the Szolnok-Túri alluvial plain. The relative relief value of the little region is low, 2m/km^2. The slightly wavy plain in the study site and the floodplain at the edge of the Tisza River can be classified as orographic relief type (Marosi & Somogyi 1990). Examining a 1:10,000 scale map, the deepest point of the area is 79.2 m and the highest is 90 m. Despite the low relative relief value of the Szolnok-Túri alluvial plain, there is a difference of more than 10 m above sea level difference within a short distance in the study area. This value is extremely high in the Great Hungarian Plain, especially if we consider the general nature of the little region.

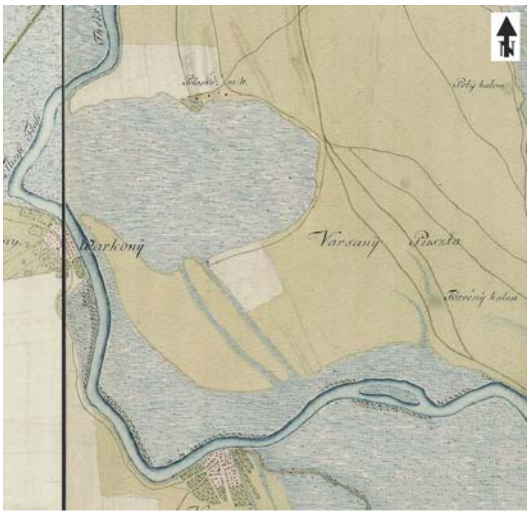

Fig. 2.: The morphological conditions and the vegetation of the study site in the First Austrian Military Survey (1782). Scale of original map: 1:28,800.

2. ábra: A vizsgált terület morfológiai viszonyai és növényzete az első osztrák katonai térképen (1782). Eredeti méretarány: 1:28 800.

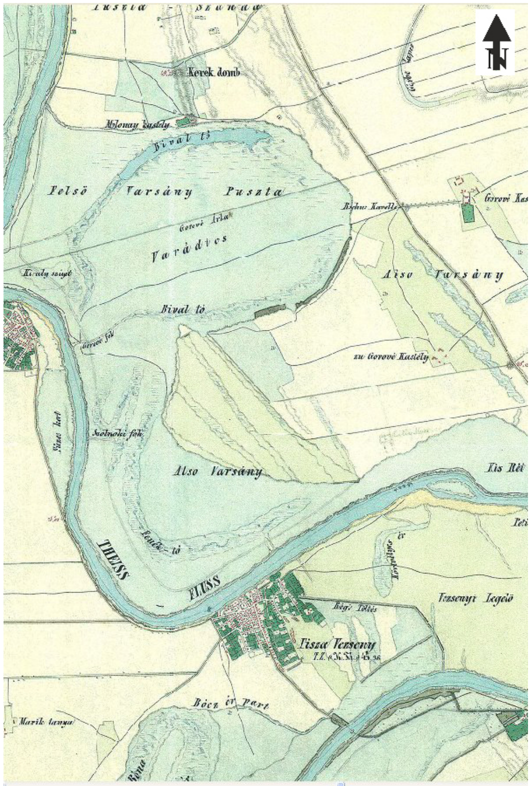

Fig. 3.: The morphological conditions and vegetation of the study site in the Second Austrian Military Survey (1869). Scale of original map: 1:28,800.

3. ábra: A vizsgált terület morfológiai viszonyai és növényzete a második osztrák katonai térképen (1869). Eredeti méretarány: 1:28 800.

Fig. 4.: The morphological conditions and the vegetation of the study site in the Third Austrian Military Survey (1875). Scale of original map: 1: 6,250.

4. ábra: A vizsgált terület morfológiai viszonyai és növényzete a harmadik osztrák katonai térképen (1875). Eredeti méretarány: 1:6250.

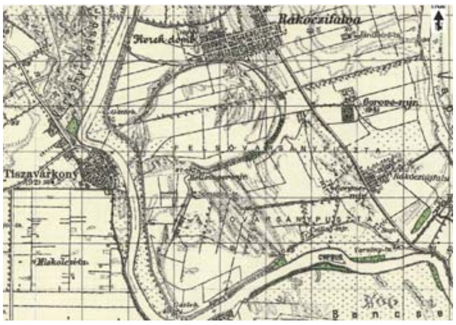

Fig. 5.: The morphological conditions and the vegetation of the study site in the Hungarian Military Survey (1943). Scale of original map: 1:5,000.

5. ábra: A vizsgált terület morfológiai viszonyai és növényzete a magyar katonai térképen (1943). Eredeti méretarány: 1:5000.

The above-mentioned little regions have a moderately warm-dry climate, close to the warm-dry climate. The annual sunshine duration is between 1970 and 2010 hours. The average annual temperature is 10.9 ºC, the mean temperature of the vegetation period is 17.3-17.4 ºC. Today the frost-free period begins on 7-8th April, the first autumn frosts are expected around 20th October. So the frost-free period is 196 days long. Annual precipitation is 510-540 mm, the growing period's precipitation is 300 mm. The aridity index is 1.3-1.38. The area is a dry, heavily anhydrous area. Precipitation is 150 mm less than the local value of the potential evaporation (Marosi & Somogyi 1990). Based on the data of the Szolnok meteorological station and the Walter-Lieth diagram (Walter & Lieth, 1960; **Fig. 5.**), the area belongs to the driest areas of the Great Hungarian Plain. On the basis of the average annual rainfall of 500 mm and the distribution of rainfall (**Fig. 6.**), there is a significant risk of drought in the second half of summer and in autumn. This occurs especially when continental and/or sub-Mediterranean climate effects develop resulting maximum monthly temperature conditions (**Fig. 6.**) in the examined area. In this case evaporation exceeds rainfall at the end of summer and early autumn and periodic steppe climatic conditions develop.

Based on the bioclimatic analysis of the Carpathian Basin (Szelepcsényi et al. 2014, 2018), the study site belongs to the central part of the Pannonian forest steppe zone (**Fig. 7.**). At the same time, the little regions belong to the Tiszántúl flora region located on the left bank of the Tisza River. Potential forest associations are willow-poplar-alder gallery forest, oak-ash-elm gallery forest, alkaline oak forest and loess-mantled terrain (*Aceri tatarico-Quercetum*) in the floodplain (Marosi & Somogyi 1990).

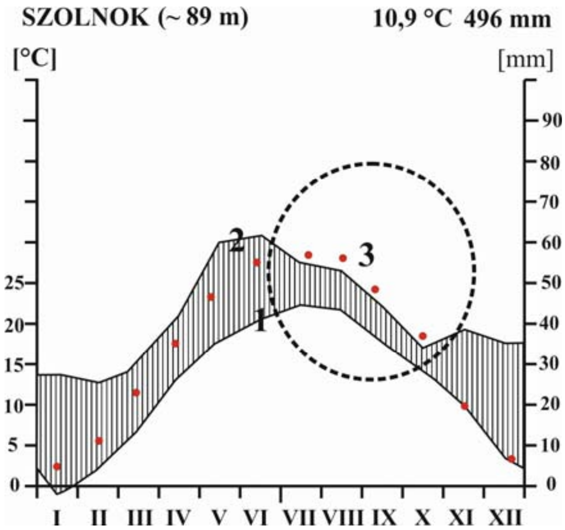

Fig. 6.: Walter-Lieth diagram based on the data from the meteorological station in Szolnok

1 = monthly average temperature values, 2 = monthly average precipitation values, 3 = dashed circle, drought period, red circle = monthly maximum temperature values

6. ábra: A vizsgált terület Walter-Lieth diagramja a szolnoki meteorológiai állomás adatai alapján

1 = havi átlagos hőmérsékleti értékek, 2 = havi átlagos csapadék bevételi értékek, 3 = szaggatott kör, aszály-veszélyes időszak, vörös körök = havi maximális hőmérsékleti értékek

Vegetation development and its change will be analyzed later, as we have a pollen core from the area that was revealed by the Department of Geology and Paleontology of the University of Szeged. Based on the recent plant associations the examined area is a cultivated steppe: pastures with weeds, poplar and black locust plantations, in deeper areas swamp vegetation mixed with weeds or with saline plants occur.

On the basis of the cores of the Department of Geology and Paleontology, University of Szeged two types of recent soils can be distinguished in the area. One of them is the chernozem (black earth) soil that can be found on natural elevations, the other is the alkaline meadow soils (**Fig. 8.**) which have a significant water effect.

The results of the Kreybig soil mapping (1933) and pedological mapping (**Fig. 8.**) were used to characterize the soils of the examined area (Kreybig 1937). In this historical map alluvial meadow, chernozem, alkaline and sandy soil types were identified in the study site, but in a different spatial extension compared to our results.

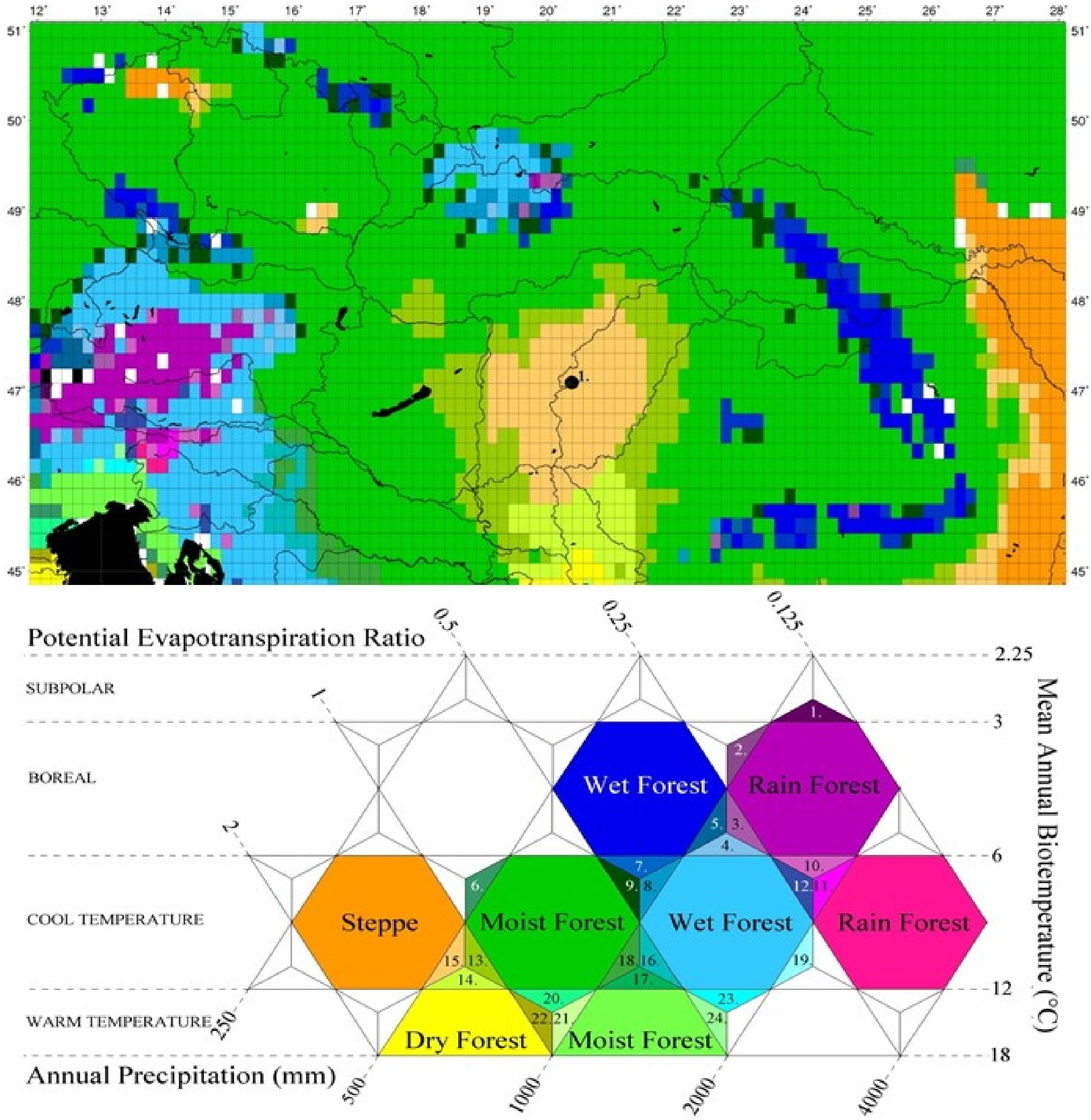

Fig. 7.: The position of the analyzed region within Holdridge's modified bioclimatic system (after Szelepcsényi et al. 2014, 2015, 2018)

7. ábra: A vizsgált terület elhelyezkedése a Holdridge féle módosított bioklimatikus rendszerű térképen (Szelepcsényi et al. 2014, 2015, 2018 nyomán)

Fig. 8.: Pedological map by Lajos Kreybig (1937) showing the study site (indicated as Felső and Alsó Varsány-puszta in the map) – brown color = chernozem soil, blue color = hydromorphic soil, purple color = alkaline soil, yellow color = sand soil. Scale of original map: 1:25,000.

8. ábra: Kreybig Lajos (1937) talajtani térképe a vizsgálati területről (a térképen Felső és Alsó Varsány - pusztaként jelölve) – barna szín = mezőségi talaj, kék szín = hidromorf talaj, lila szín = szikes talaj, sárga szín = homoktalaj. Eredeti méretarány: 1:25 000.

Geology and evolution of the area

Since only Quaternary formations could be detected on the surface of the examined area (**Figs. 9-10.**), the geological development history of the area is presented by discussing Quaternary events. The bedrock of these Quaternary formations is Tertiary sediments lying more hundred meters deep from the surface. Among these the most significant layer is the Törteli Formation (Juhász 1992) that developed at the end of the Tertiary, in the last phase of the Pannonian filling up. On the Törteli Formation the Zagyva Formation developed (Juhász & Magyar 1992; Juhász 1992). Thin-layered clay, aleurite and sandstone layers accumulated indicating a delta background, presenting marshy and floodplain environment. Its upper level evolved in an alluvial plain, in a fluviolacustrine environment. After the fluviolacustrine state the water network of the Great Hungarian Plain changed and was significantly different from the current water network: the Tisza River flowed more toward the east than nowadays. The Danube River met the Tisza at the height of Csongrád (Sümeghy 1944, 1953; Miháltz 1953; Molnár 1965). According to the latest data (Timár et al. 2005) the Tisza valley was formed about 20,000 years ago. The Tisza River, which until then followed the valley of the Körös and Berettyó Creeks, bypassed the Nyírség from the north and took its current direction (Sümeghy 1944). Thus, in the Tisza region, the Tisza River became significant regarding morphology and sedimentology from the Upper Würmian (MIS2, Sümegi et al. 2018). Due to tectonic movements sediments (of Tisza origin) of different age in different altitudes can be found in the area (Rónai 1972, 1985; Timár et al. 2005). So it is not surprising that the surface is covered by upper Pleistocene-Holocene sediments in Rákóczifalva - Bagi-földek and Rokkant-földek sites and older Pleistocene layers and the Pliocene bedrock sediments (clay, sand) are only known from drilling (Rónai 1972, 1985).

The most widespread upper Pleistocene sediment on the surface is loess; the type of loess that is connected to rivers and floodplains, i.e. a Pleistocene floodplain sediment (Sümegi 2005; Sümegi et al. 2015), formerly known as loess like Pleistocene alluvial sediment or better known infusion loess (alluvial loess). Infusion loess differs from typical loess in its porosity, carbonate and clay content and biofacies (Horusitzky 1898, 1899, 1903, 1905, 1909, 1911; Pécsi 1993; Sümegi et al. 2015).

In the Middle Tisza region there was also sand movement, which can be observed today north of the examined area in Szolnok-Szandaszőlős. The sandy area of Tiszaföldvár at the southern part of the Szolnok-Túri alluvial plain is the continuation of the sandy area of the Danube-Tisza Interfluve (Halaváts 1895; Miháltz 1953; Molnár 1965; Rónai 1972, 1985).

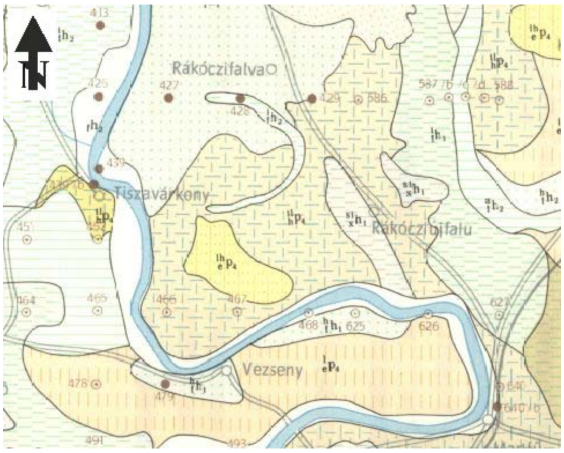

Fig. 9.: Geological structure of the study site (based on the 1:100.000 scale geological map of the Hungarian National Geological Institute, 1969)
lep4 = aeolian loess, terminal phase of Pleistocene, lhep4 = aeolian loessy sand, terminal phase of Pleistocene, ilhp4 = infusion loess, terminal phase of Pleistocene, lfh2 = fluvial fine silt from second phase of the Holocene, hfh2 = fluvial sand from second phase of the Holocene, sixh1 = alluvial silty rich sand sediment from Early Holocene, numbers = core points

9. ábra: A vizsgált terület földtani felépítése (MÁFI 100.000 földtani térképe nyomán, 1969)
lep4 = eolikus lösz, pleisztocén végi, lhep4 = eolikus löszös homok, pleisztocén végi, ilhp4 = Pleisztocén végi infúziós lösz, lfh2 = holocén második felében lerakódott fluviális finom kőzetliszt hfh2 = holocén második felében lerakódott fluviális homok, sixh1 = kora holocénben lerakódott alluviális kőzetlisztes homok, számok = fúráspontok

The results of the geological mapping were compared with the results of the geological map of József Sümeghy and András Rónai. The 1:200.000 scale geological map of the Tiszántúl (1941) by Sümeghy and the complex maps of the Great Hungarian Plain (**Fig. 9.**), the 1:100.000 scale Szolnok map sheet made by András Rónai. In the Sümeghy's map 'old-Holocene' and 'new-Holocene' alluvial soil surrounded the island-like 'upper Pleistocene lowland loess' formation. The expansion and position of the loess formation in the Great Hungarian Plain is very similar to that of the alkaline soil 'island' surrounded by alluvial soil in the map by Kreybig (1937).

The results of the mapping of the Great Hungarian Plain led by András Rónai are similar, although it showed a more inaccurate result in the examined area (Rónai 1969, 1972, 1985). Their cross-section of several drillings is slightly south of our study area (**Fig. 10.**); two drillings were conducted in the study site (**Fig. 10.**). Based on their map, an infusion loess covered (floodplain sediment) surface was explored in the area, and the residual surface was surrounded by deeper Pleistocene and Holocene channels and beds filled with fine grained sediments and still developing alluvial plains (**Figs. 9-10.**).

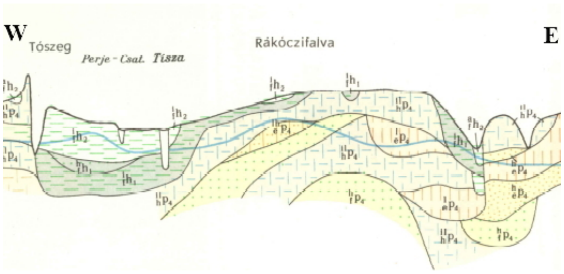

Fig. 10.: Geological cross section of the study site (based on the 1:100.000 scale geological map of the Hungarian National Geological Institute, 1969)
lfh2= fluvial sand from second phase of the Holocene, lfh1 = fluvial sand from Early Holocene, hfh1 = Early Holocene fluvial silty sand, hfp4 = fluvial sand from terminal phase of Pleistocene lep4 = aeolian loess, terminal phase of Pleistocene, lhep4 = aeolian loessy sand, terminal phase of Pleistocene, ilhp4 = infusion loess, terminal phase of Pleistocene, lfh2 = fluvial fine silt from second phase of the Holocene, hfh2 = fluvial sand from second phase of the Holocene, sixh1 = alluvial silty rich sand sediment from Early Holocene, Perje csat. = Perje canal, Tószeg, Rákóczifalva = recent settlement, Tisza = Tisza oxbow lake

10. ábra: A vizsgált terület földtani keresztszelvénye (MÁFI 100.000 földtani térképe nyomán, 1969)
lfh2 = késő-holocén fluviális homok, lfh1 = kora holocén kőzetlisztes fluviális homok, hfh1 = kora holocén fluviális homok, hfp4 = pleisztocén végi folyóvízi homok, lep4 = eolikus lösz, pleisztocén végi, lhep4 = eolikus löszös homok, pleisztocén végi, ilhp4 = Pleisztocén végi infúziós lösz, lfh2 = holocén második felében lerakódott fluviális finom kőzetliszt hfh2 = holocén második felében lerakódott fluviális homok, sixh1 = kora holocénben lerakódott alluviális kőzetlisztes homok, Perje csat. = Perje csatorna, Tószeg, Rákóczifalva = települések, Tisza = Tisza meander

The geological surveys before our study pointed to Pleistocene muddy loess and infusion loess (floodplain) sediments in the Rákóczifalva – Bagi- and Rokkant-földek sites. In the middle of this sediment Pleistocene loessy sand was found, according to these maps. In the northern part of the area semi-circular shaped Holocene aleurite appeared (**Fig. 9.**). East of this area the residual surface is covered by Pleistocene muddy loess and infusion loess. The southern area is not so uniform in a geological point of view. From east to west the map indicates loess (aleurite rich sediment), muddy loess, infusion loess (floodplain sediment), riverine sand, loessy sand and close to the Tisza River muddy, infusion loess occurs again.

Methods

Analysis of historical maps of the site

Examination of the maps before and after river regulations (1847) revealed the following. Although the study site can be recognized in the maps of Ptolemy (Fehér 2004), *Tabula Peutingeriana* from the end of Antiquity (Tóth 2004), Angelino Dulcert from the medieval period (1339; Írás 2013) and in the map of Lázár deák from 1528 (Török 1996), the first maps that can be evaluated from an environmental historical point of view are the maps from the 18th century. The first (1782), the second (1869) and the third (1875) Austrian Military Survey and the Hungarian military survey maps (Stegena 1981, Timár et al. 2006) from the Second World War were used in our study. We also used the Middle Tisza region map (Sugár 1989) of Lietzner-Sándor (1970) by János Lietzner Keresztelő, the county engineer of Heves-Külső Szolnok. By analyzing historical maps, we tried to reveal the development of the area and the effect of human impact.

Exogenous geological analysis

An EOV (Unified National Projection System: Völgyesi 1997) map with a scale of 1:10,000 is available from the area. Using this map we have calibrated the measurement points using ArcView 3.2 software. After that we created the digital relief model of the area (1:10,000 EOV map) using ArcGis software. The digital relief model was used for the geomorphological analysis of the study site. In addition, we used the aerial photographs prepared by the Archaeological Institute of the Eötvös Loránd University to map the local surface of the area. The purpose of the exogenous geological-morphological analysis was to reconstruct the environment of the site as accurately as possible.

Geoarcheological analysis

During geoarcheological analysis 300 shallow (3-5 m deep) cores were taken at 5 cm intervals by a spiral drilling machine (Sümegi 2001, 2002, 2013) in Rákóczifalva–Bivaly-tó, Bagi-földek and Rokkant-földek sites. Boreholes were created along geological sections parallel to each other in such a way that all exogenous geological-geological-pedological units were explored. We used the international nomenclature of Troels-Smith (Troels-Smith 1955) during sediment description.

Undisturbed samples were taken by a Russian corer (Belokopytov & Beresnevich 1955) by overlapping technique (Sümegi 2001, 2002, 2013) in a filled up point bar channel at the boundary of the Rokkant-földek and Bagi-földek sites. Samples were cut lengthwise and stored in the usual manner at 4˚C (Sümegi 2001, 2002, 2013). Evaluations of size distributions, organic material, carbonate content (loss on ignition, LOI) and pollen analyses were carried out. In describing the colors of the sediment the Munsell soil color charts were used (Munsell Colour Company 1954). Sedimentological analysis was carried out using an Easy Laser Particle Sizer 2.0. laser particle sizer (42 grain fractions) after proper sample preparation (Sümegi et al. 2015).

During magnetic susceptibility analysis the magnetizable element content of the sediment is measured. For this purpose air-dried and powdered samples are prepared to measure the loss of mass. Bartington MS2 Magnetic Susceptibility Meter was used at 2.7 MHz (Sümegi et al. 2015) that is suitable for laboratory and field analysis as well. Three measurements were done for each sample and values were averaged.

Dean's method (1974) was used for the determination of carbonate and organic material content. Sedimentological and LOI analyses were carried out and interpreted at 4 cm intervals. We presented the sedimentological data and succession, and the cross section of geoarcheological data using the Psimpoll software by Keith David Bennett (1992, 2005).

Pollen analyses

Pollen analytical analysis was carried out on the undisturbed samples of the core taken from the point bar channel. The retrieved cores were also subsampled at 1-2-4 cm intervals for pollen analysis. A volumetric sampler was used to obtain 2 cm^3 samples, which were then processed for pollen (Berglund & Ralska-Jasiewiczowa 1986). Lycopodium spore tablets of known volume were added to each sample to determine pollen concentrations. A known quantity of exotic pollen was added to each sample in order to determine the concentration of identified pollen grains (Stockmarr 1971). A minimum count of 500 grains per sample (excluding exotics) was made in order to ensure a statistically significant sample size (Iversen & Fægri 1964; Fægri & Iversen 1989; Punt 1976-1995; Moore et al. 1991). The pollen types were identified and modified according to Moore et al. (1991), Beug (2004) and Punt et al. (2007), Kozáková & Pokorny (2007), supplemented by examination of photographs in Reille (1992,1995, 1998) and of reference material held in the Hungarian Geological Institute, Budapest. Percentages of terrestrial pollen taxa, excluding Cyperaceae, were calculated using the sum of all those taxa. Percentages of Cyperaceae, aquatic and pteridophyte spores were calculated relative to the main sum plus the relevant sum for each taxon or taxon group. Calculations, numerical analyses and graphing of pollen diagrams were performed using the Psimpoll 4.26 software package (Bennett 2005). Local pollen assemblage zones (LPAZs) were defined using optimal splitting of the information content (Birks and Gordon, 1985), zonation being performed using the 20 terrestrial pollen taxa that reached at least 5% in at least one sample. Paleovegetation was reconstructed using the works of Sugita (1994), Soepboer et al. (2007), Jacobson & Bradshaw (1981), Prentice (1985) and Magyari et al. (2010).

Pollen extraction was carried out in the former laboratory of the Hungarian Geological Institute. We express our gratitude to the geologist Tibor Csernyi for having organized the pollen extraction.

Macrobotanical analysis

The archeobotanical material (anthracological) was obtained from the samples collected by 4 to 10 cm, flotated from uniformly 1 dm^3 (cc. 2.7 kg) of samples. The quantity of the samples is in accordance with the German standards (Jacomet & Kreuz 1992). In obtaining and processing the samples we followed the guidelines of Ferenc Gyulai (2001) regarding the sampling and flotation process. In flotating the samples the dual flotating method and 0.5 mm and 0.25 mm sieves were used (Náfrádi & Sümegi 2013).

Charcoal material was analyzed using a Zeiss Jenapol optical microscope at 10, 20, 50 and 100x magnification (Náfrádi & Sümegi 2015). Wood identification was carried using the reference book of Greguss (1945, 1972) and Schweingruber (1990) and the web based identification work of Schoch et al. (2004).

Archeozoological analysis

Over 6000 pieces of animal remains were collected from ten archeological cultures in the study sites, spanning from the middle Neolithic (Alföld LBK) to the medieval Period of the Árpád Dynasty (10th–13th century AD). So the area was often inhabited for thousands of years. In addition, there were also features from Copper Age (Tiszapolgár culture, Bodrogkeresztúr culture), Bronze Age (Tumulus culture, Gáva culture), Celtic, Sarmatian and Avar finds with varying numbers of vertebrate remains. Most of the finds are well preserved, only some of the prehistoric bones were in poor condition, often heavily laced, which made the determination difficult. Altogether 979 pieces were found in Gepid archeological features that were in excellent condition. Identification was carried out using the reference books of Sisson (2014) and Schmid (1972), and the work of von den Driesch (1976) was followed in taking bone measurements. The archeozoological compositon view was reconstructed using the works of Bartosiewicz (2006, 2017), Bartosiewicz & Choyke (2002) and Bartosiewicz & Bonsall (2004).

Results

Historical maps

The analysis of historical maps (**Figs. 2-5.**) clearly shows the transformations of landscape utilization in the study sites before and after river regulation processes (1847). Although in the first Austrian Military Survey (**Fig. 2.**) the nomenclature is still very poor and the morphological survey was not entirely accurate, in addition, the mapping of the Tisza coast was rough, it was obvious that in the coastal area of Tisza River (in the Bagi-földek site, according to the archeologists) there were only gallery forests suitable for floodplain farming and marshy, boggy areas. It was also clearly visible in the first Austrian Military Survey (1782; **Fig. 2.**) that in the Rokkant-földek (as it is called by archeologists) in the area called Varsány Puszta (in the later survey Alsó Varsány (**Fig. 3.**) and Alsó Varsány puszta - **Fig. 4.**) there are two periodic creeks between the Bivaly Lake and the Tisza Valley. The first Austrian Military Survey map does not indicate the name of the Bivaly Lake; only a temporary, swampy area is marked. An abandoned, over-developed, unregulated curve of Tisza River can be reconstructed from its drawing (**Fig. 2.**).

In other parts of the area scattered gardens, arable lands, grazing fields representing extensive animal husbandry are indicated in the first Austrian Military Survey (**Fig. 2.**). In addition, several mounds that help the identification of locations are shown in the study area (**Fig. 2.**).

The second Austrian military survey (1869) is very important in an exogenous geological and morphological point of view (**Fig. 3.**). Bivaly Lake has been shown in this map, which clearly shows that it is an earlier over-developed curve of the Tisza River, which was connected to the regulated Tisza River through water outlet (canal) only periodically, during floods (**Fig. 3.**). From this area of the Bivaly Lake (Felső (Upper) Varsány puszta), through Alsó (Lower) Varsány puszta, four deeper, canal-like formations led to the actively developing valley of the Tisza (called Bagi-földek in our work). There was a lake in the area of Bagi-földek, according to the map Lake Fenék, which was connected to the active Tisza River through the water outlet of Szolnok. Based on the map, the Bagi-földek were a suitable area for fishing, gathering, waterfront farming (gathering of gallery forest crops, sedge, reed, construction and wood utilization for energy) before river regulations. On the basis of exogenous geological characters the Bagi-földek were an point bar series of the unregulated Tisza River (**Fig. 3.**).

At the same time, in the second Austrian Military Survey map, Rokkant-földek (Alsó (Lower) Varsány) is an older (probably Pleistocene) residual surface, a point bar series rising a few meters above the alluvium of Tisza River and it did not affect the development of the Tisza alluvium at the end of the Pleistocene and during the Holocene, rather it seems to be a terrace level (**Fig. 3.**). The second Austrian Military Survey (1869) clearly showed the traces of groundwater regulation, the groundwater drainage ditches and the artificial barrier system along the active riverbed of the Tisza River (**Fig. 3.**). At the same time, settlements and the associated gardens and arable lands are extensive, while grazing fields and pasture lands can be observed in smaller regions further from the settlements and are more clearly defined than in the first Austrian Military Survey (**Fig. 3.**).

Based on the map prepared by the second Austrian Military Survey (1869), it is clear that north from the Bagi-földek, on the alluvium of the Tisza River called Varsány puszta, there is a large abandoned Tisza River channel, the Bivaly Lake, which has been transformed into an oxbow. At the same time, south from the Bagi-földek the point bar series in the riverbed of the Tisza River (that is younger than the Bivaly Lake) is called Fenék Lake (**Fig. 3.**). In the Bagi-földek (Alsó-Varsány) in the second Austrian Military Survey) that is emerging from the Tisza alluvium there are more channel like hollows (**Fig. 3.**), older point bar channels a few hundred meters apart from each other. Bagi-földek are located in a peninsula-like form in the Tisza alluvium. Its eastern part has already been utilized as a plough land, but the surface above the point bar channels has been utilized as pasture land (**Fig. 3.**).

The third Austrian military survey (1875) shows the impact of river regulation, the drainage channels, the formation of a barrier system along the Tisza River, the development of the floodplain area between the dams and the development of settlements. In addition, the geographical names and the exogenous geological units that were already noticed and described in the second Austrian Military Survey (**Fig. 4.**) can be observed.

In the Hungarian military survey (1943) a dam-system is shown that protected settlements, roads. The extension of arable land and garden cultures can be observed in the landscape transformed by the agricultural system resulting from river regulation and groundwater drainage (**Fig. 5.**). The nomenclature of the Hungarian military survey was used by geologists of the Hungarian Royal Geological Institute, later the Hungarian Geological Institute during the geological and pedological mapping of the Great Hungarian Plain (**Figs. 8-10.**).

In the Lietzner-Sándor's map of 1790 the recording of the Middle Tisza region was completed (Sugár 1989). In this map the emerged location of the point bar structure of the Rokkant-földek and the deeper location of the Bagi-földek associated with the Tisza alluvium can be clearly seen.

In addition to the analysis of historical maps, we prepared the digital elevation model (**Fig. 12.**) of the area to understand the exogenous geological situation and morphological conditions. The 1:10,000 scale digital elevation model clearly demonstrates the existence of a point bar series in a deeper position that is related to the unregulated Tisza riverbed and developed in the curve of the

Tisza River over a few centuries. To the northeastern direction in an elevated position (residual surface or terrace level) a series of an older point bar can be found (**Fig. 12.**).

Based on the digital elevation model, the Bagi-földek site is located in the deeper and younger alluvium of the Tisza River characterized by good water supply while the Rokkant-földek site in an older residual surface rising above the alluvium. In this older point bar series only periodic flood water flew through the point bar channels from the direction of the Bivaly Lake towards the Tisza alluvium (**Fig. 12.**). So Gepid communities settled in the point bar series of the high and low floodplain. These surfaces provided different farming possibilities for the Gepid communities of the Migration Period: the utilization of the gallery forest, gatherings in the area of the forests and floodplain, fishing and hunting, extensive animal husbandry on the higher, drier areas and plant cultivation around the settlements and houses.

As our goal was to reconstruct the environmental history of the Gepid settlement as complex as possible, we conducted geoarcheological drillings (**Fig. 12.**) along a double geological section that explored the deeper (Bagi-földek) and the higher (Rokkant-földek) point bar series as well (**Fig. 12.**). Based on these drillings, the geological and pedological conditions of the exogenous geological and geomorphological units could be mapped and the environmental, geological and pedological characters of the Gepid communities could be specified (**Fig. 13.**).

After the formation of the geological profile (**Fig. 13-14.**) it was confirmed that the point bar series in the Rokkant-földek developed at the end of the Pleistocene. This is proved by the loess-like sediment layers of the point bar channels excavated by drillings, the relatively high position, and the carbonate and coarse aleurite rich sedimentary environment. The deeper geological position of the Bagi-földek is of Tisza alluvium origin, its clay and organic material rich geological layers support its Holocene formation and development (**Fig. 14.**).

The Bagi-földek got continuous water supply through the water outlet system of the Tisza, until to the Tisza River regulation processes and dam building; so in the Migration Period, at the time of the settling of the Gepids, there could not be permanent settlements in this area only in higher elevations (Rokkant-földek), in the semi-peninsula-like Pleistocene point bar series (**Figs. 11-14.**). Since the Pleistocene higher, flood-free surface is semi-circular, peninsula-like (**Figs. 12.-13.**), the settling of archaeological cultures, including the Gepid houses and settlements in the Rokkant-földek, follows a camber form (**Figs. 15-16.**).

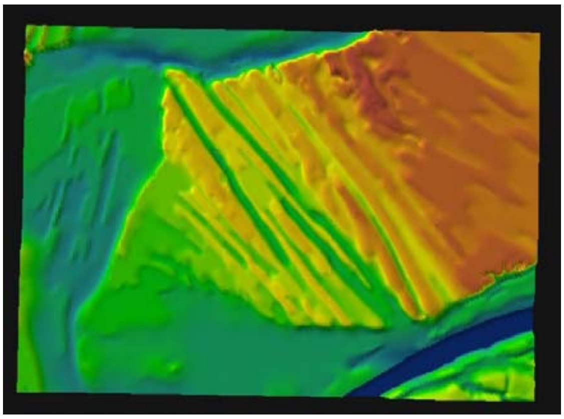

Fig. 11.: Digital elevation model of the study site

11. ábra: A vizsgált terület DDM térképe

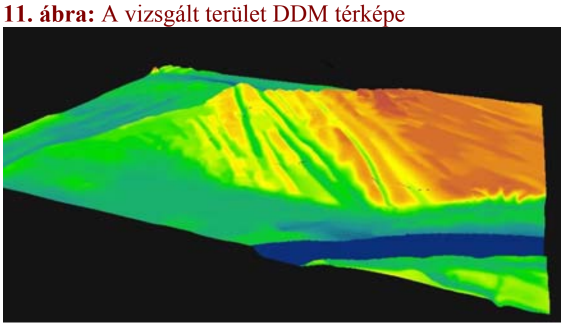

Fig. 12.: 3D drawning of the study site on the basis of the digital elevation model

12. ábra: A vizsgált terület 3D megközelítésű DDM rajza

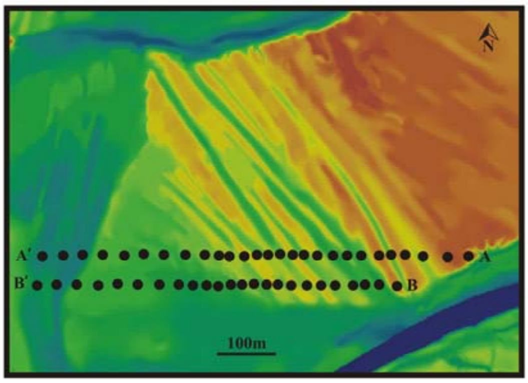

Fig. 13.: The location of parallel geological sections and geoarchaeological drilling points in the digital elevation model of the site

13. ábra: A párhuzamosan kialakított földtani szelvények és a szelvényeket alkotó geoarcheológiai fúráspontok elhelyezkedése a vizsgált területről készült DDM térképen

So, the Gepid communities lived in the boundary of two different local ecoregions, on a local ecoton spot (Sümegi, 1995, 1996, 2016; Sümegi et al. 2012) in the edge of a flood-free area that has good water supply, in a protected, elevated area surrounded by living waters (**Figs. 11-12., 14.**).

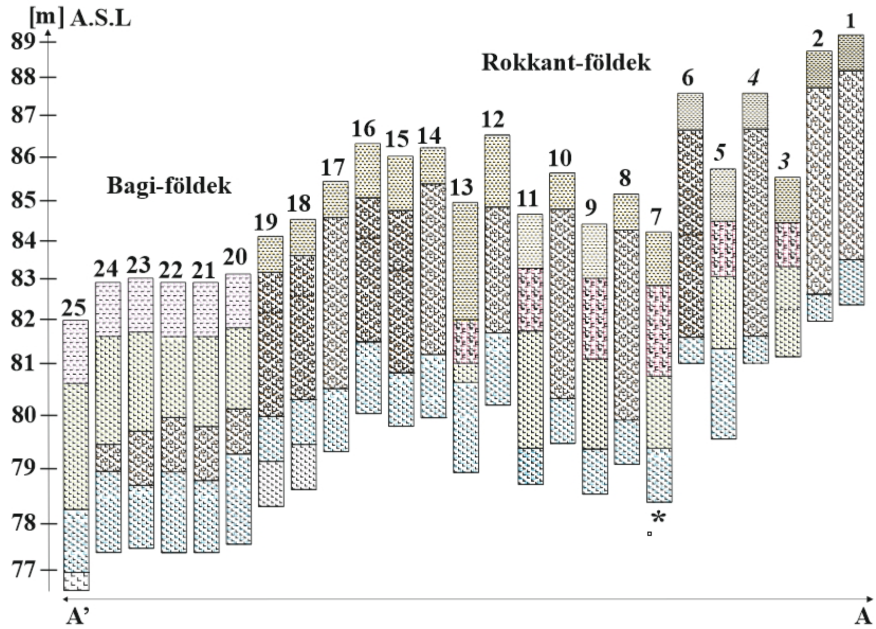

Fig. 14.:

Geological section of the Bagi-földek and Rokkant-földek in Rákóczifalva and the layers of the cores (Troels-Smith, 1955 symbols)

A.S.L. =Above Sea Level, * = undisturbed core sequence, A – A’ = geological section

14. ábra:

A rákóczifalvi Bagi-földek és Rokkant-földek területét átszelő földtani szelvény a fúrások rétegsorozataival (Troels-Smith, 1955 szimbólumokkal)

A.S.L. =tengerszint feletti magasság, * = zavartalan magfúrás, A – A’ = keresztszelvény

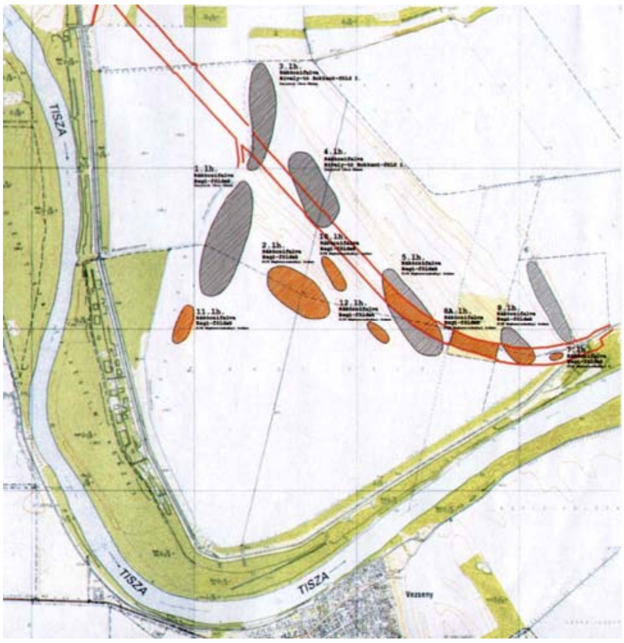

Fig. 15.:

The location of archeological sites in Rákóczifalva and the Gepidian settlement

15. ábra:

A rákóczifalvi régészeti lelőhelyek, köztük a gepida megtelepedések elhelyezkedése a vizsgált területen

This settling strategy, the closeness of living water, the high position, the flood-free island-peninsula-like Pleistocene residual surface for settling, animal husbandry and plant cultivation in the Great Hungarian Plain was established since the Early Neolithic. The first data on this type of land utilization was published by Tibor Mendöl, a Hungarian social geography researcher in 1928 and 1929, before the recognition and phasing of the Early Neolithic Körös culture (Mendöl 1928, 1929).

Mendöl made a colored contour map of Szarvas and its surroundings, including the so-called Érpart within a Neolitic settlement. He recognized that the Pleistocene loess covered higher, flood-free surfaces and ascribed them to the area of Neolithic settling, farming and livestock breeding.

He also described the periodically flooded floodplains that were covered by reed, gallery forest and tussock sedge that could be utilized for hunting and gathering. This theory has been repeatedly reinforced during environmental and geoarchaeological research along the Tisza River and its adjacent valleys (Nandris 1970, 1972, Kosse 1979, Sherratt 1982, 1983, Cremaschi 1992, Sümegi 2003, 2004, Sümegi & Molnár 2007, Sümegi, 2012, Sümegi et al. 2012). As a result, the elevated chernozem soil covered surfaces (cereal cultivation, gardens) and areas of alluvial soils (floodplain forest management, grazing, gathering, meadows fields), saline soils (sheep grazing), the canal lakes, living waters (fishing) and water outlet channels (wells) were located within 5 km, approximately one hour walk (Site – Catchment Analysis = SCA: Higgs & Vita-Finzi 1972; Vita-Finzi & Higgs 1970; Bailey & Davidson 1983) from the Gepid settlements. So, all food-producing areas were reached by the members of the Gepid community within an hour walk (within a 5 km radius). In addition, the semi-circular, peninsula-like settling in the Tisza floodplain and alluvium provided significant protection in the Great Hungarian Plain (**Fig. 15.**).

Sedimentological analysis

At the 7th drilling point of the first geological core section a 3 m deep undisturbed core was taken with overlapping technique in the Pleistocene point bar channel. During the drilling, the cores sequences layers were described by the method of Troels-Smith (1955). Magnetic susceptibility, particle size analysis, LOI and water soluble element content analysis were investigated. The Late Holocene near surface part that is significant regarding the Gepid age and Migration Period was sampled at 2 cm intervals for sedimentological and water soluble elements content, while the Pleistocene and Early Holocene bedrock level at 4 cm intervals (**Fig. 16.**).

In the bedrock between 300 and 240 cm yellowish grey (Munsell color 10 YR 7/4) slightly cross-laminated sandy silt, silty sand developed. The layer gradually transformed towards the surface, parallel laminated structure appeared, fine sandy coarse silt, coarse silt fine sand dominated sediment layer developed. In this level carbonate filled root structures appeared, called biogalleries. Grain size indicate coarse grains, although grain size distribution is variable; the organic material content is low and the carbonate content is the highest. Magnetic susceptibility (MS signal) and the sediment and LOI content indicate minimal changes in the development of the layer, but the changing values of water-soluble elements suggest significant water cover and cyclic drying periods.

The development of laminations occurred at a maximum thickness of 1 cm, and it is likely that in this interval we could have reconstructed stronger cycles of sedimentation and development due to the sedimentological changes of the sample. The development of the layer can be linked to the active evolving stage of the Pleistocene point bar and to the late phase of the channel filling up. Due to its emerged position, its high carbonate content and water-soluble Ca and Mg content, the point bar did not belong to the sedimentation area of Tisza River (Molnár 1965). Probably the development of the point bar was the result of the development of the catchment area of the Danube River.

Grain size distribution changed between 240 and 160 cm. Sand content decreased in this level of the profile and yellowish brown (10 YR 5/6) fine silty coarse silt, coarse silty fine silt dominated layer developed. In the near surface part of this level a significant sand fraction rise occurred that can be linked to an extraordinary flood period. The carbonate content increased considerably as well as organic material content, however this latter less in the color of the sediment appeared. De the slightly reddish shade was associated with the increase of water-soluble iron.

Based on the development of the sediment and sediment parameters, the point bar could gradually emerged due to the appearance and incision of the Tisza River. As a result, the active development of the point bar was completed and transformed to a drainage system at the end of the Pleistocene. In this level of the profile a flood cycle could be detected on the basis of a significant sand intercalation according to grain composition analysis. This level developed at the end of Pleistocene; however this whole layer was clearly evolved in a stagnant water environment. The development, appearance and facies of the sediment are specific to point bar loess, floodplain sediments formed at the end of the Pleistocene (Sümegi et al. 2015).

Between 160 and 70 cm (10 YR 4/2) clayey fine silt accumulated. The organic material content increased, the carbonate content was steady indicating major soil formation and weathering at the early stage of Holocene. At the same time among water soluble elements Fe content decreased. This may indicate a deeper groundwater location and post-movement of elements after water regulation processes of the 20th century, and the cyclic change of groundwater level may be indicated by the cyclic change of other water-soluble elements. The development of this sediment layer can be linked to soil formation and more favorable weather conditions at the beginning of the Holocene; in addition, to the leaching of sediments with significant clay and organic material content. However, element composition could have change as a result of groundwater level decrease associated with modern water regulation as well.

Between 70 cm and the surface a slightly polyhedron structured, blackish brown (10 YR 3/1), clay-rich fine silt with significant organic material content developed and soil formation have started. This layer may be marshy-eutrophic lake sediment originally, but its element composition has changed as a result of soil formation and modern water regulation. The latter is primarily shown by the reduction of water soluble Fe content and the less significant MS signal. Although the layer where soil formation have started represent hydromorphic soil formation characters (polyhedron structure), the significant water-soluble Na and K content indicate salinisation and an upward moving groundwater system with significant water-soluble elements in the capillary zone. As a result, besides hydromorphic soil formation, saline soil development started in the area as well. These processes were observed already in the 20th century during the geological survey and agrogeological (pedological) mapping of the area (Sümeghy 1944, 1953; Kreybig 1937).

Pollen analysis

According to the pollen analysis carried out on samples of the point bar channel, 10 pollen units (pollen horizons) were separated in the profile (**Fig. 17.**).

The first pollen horizon developed between 300 and 240 cm (from the core surface). Pollen material did not occur in statistically meaningful quantities, only a few samples contained scattered *Gramineae* and *Pinus* pollen indicating drying processes.

The second pollen horizon evolved between 240 and 210 cm. Statistically meaningful amounts of terrestrial pollen material were found that reached the recommended minimum of 500 pieces of pollen grains (Magyari et al. 2010). In this level the non-arboreal pollen (NAP) material exceeded 60% while arboreal pollen (AP) grain ratio was below 40% with *Pinus* subgenus *Pinus* taxa, which can spread to significant distances (**Fig. 17.**). On the basis of the pollen composition a Pleistocene open parkland with scattered pine trees and willow-alder trees existed. In addition, a grassy cold steppe vegetation developed in the environment of the area at this time.

The third pollen zone occurred between 210 and 170 cm. Basically, the pollen composition did not change, but the proportion of AP exceeded 50% (**Fig. 17.**). This indicates a cold forest steppe (Allen et al. 2000; Prentice et al. 1996) at the end of the Pleistocene (**Fig. 17.**). The rise of woody vegetation ratio was caused by an increase in the proportion of *Pinus* genus, which can spread to significant distances. Thermo- and mesophilous elements could not be detected among deciduous trees only narrow-leaved trees appeared such as willow and alder with higher tolerance-level. Compared to the previous zone humidity increased.

The fourth pollen horizon was identified between 170 and 130 cm. AP ratio was between 50 and 60%; although the amount of deciduous trees and shrubs, especially birch (*Betula*) and hazel (*Corylus*) is higher. Mixed forest steppe developed. Among woody vegetation coniferous trees and birch (*Betula*) dominated while herbaceous taxa indicate grasses-wormwood-pigweed dominated. Cold steppe, forest steppe existed with patches of trees.

The fifth pollen zone developed between 130 and 110 cm. The ratio of coniferous trees remained significant, while the proportion of deciduous trees and shrubs increased, especially the ratio of birch (*Betula*; **Fig. 17.**). Thermo-mesophilous (oak, ash, elm, lime) pollen appeared and AP ratio rose to 60-70%, which corresponds to the forest steppe phase (Allen et al. 2000; Prentice et al. 1996) and to the northern part of the Eurasian forest steppe zone (Magyari et al. 2010); in addition to the forest steppe zone mixed with taiga in the drier basins of the Altai region (Sümegi 1996; Sümegi et al. 1999, 2013a; Magyar et al. 2014; Törőcsik & Sümegi 2016). This pollen horizon corresponds to the transition phase of the Pleistocene and Holocene.

The sixth pollen zone developed between 110 and 80 cm (**Fig. 17.**). The ratio of coniferous elements decreased, as well as that of herbaceous taxa. AP ratio decreased to 50-60% that corresponds to a temperate forest steppe (Allen et al. 2000; Prentice et al. 1996) at the beginning of the Holocene, similarly to other residual surfaces in the Tisza valley (Sümegi et al. 2005). In other words, the climatic, pedological, relief and bedrock conditions in the area led to the development of a mild continental climate, temperate forest steppe development after the cold forest steppe phase at the end of the Pleistocene. These data clearly disprove the theories that forest steppes in the Great Hungarian Plain are the result of human transformation of a forest environment (Bernátsky 1914; Rapaics 1918; Chapman 1994, 1997, 2017; Chapman et al. 2009; Magyari et al. 2012). On the basis of these publications, human impact has been continuously increased in the Great Hungarian Plain from the emergence of Neolithic farming. This led to the creation of cut-off areas in the forest environment that had expanded due to technical development and growing population. So a mosaic-like forest steppe vegetation has stabilized in the Great Hungarian Plain probably already in prehistoric times, before the emergence of land cultivation. Our data from the Rákóczifalva sites together with our previous data (Sümegi 1989, 1995, 1996, 2005; Sümegi et al. 2012, 2013b) clearly demonstrates the natural development of the temperate forest steppe in the Great Hungarian Plain (Pannonian forest steppe biogeographic unit). This pollen horizon is the level of hardwood gallery forest (oak-ash-elm), forest steppe (oak-lime-hazel) and grassy steppe mosaics, without human impact.

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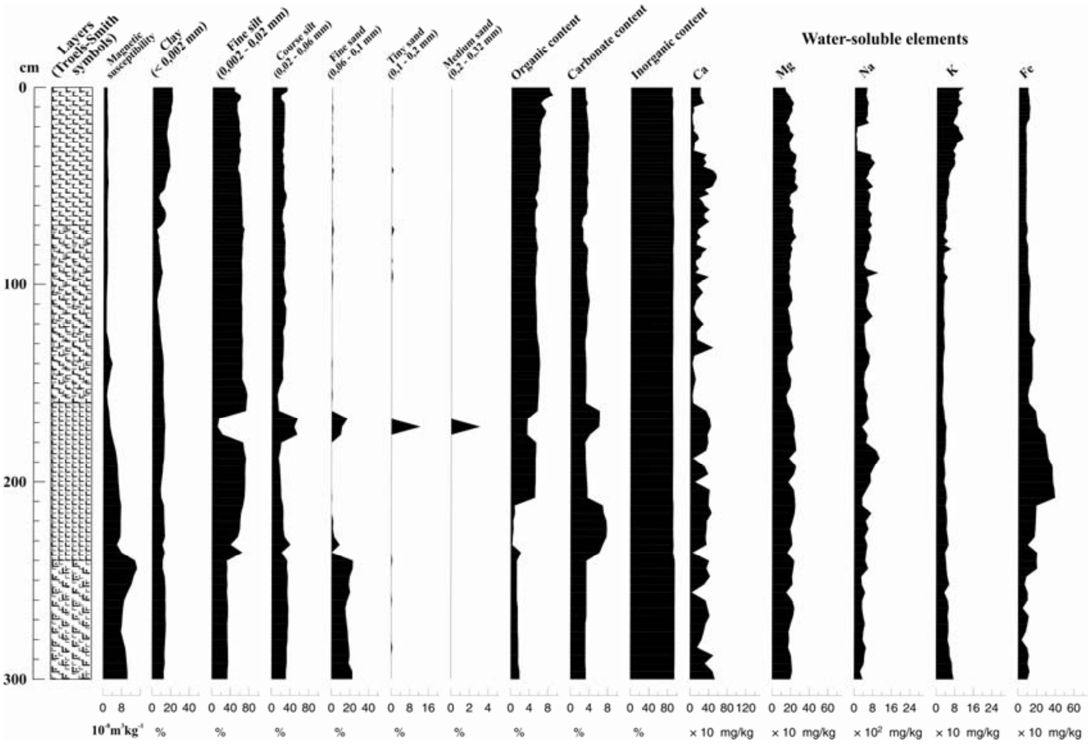

Fig. 16.: Sedimentological and geochemical results from the undisturbed core sequence of an infilled point-bar channel in Rokkant-földek at Rákóczifalva

16. ábra: A rákóczifalvi Rokkant-földek feltöltődött övzátony rendszerébe mélyített zavartalan magfúráson végzett üledékföldtani és geokémiai vizsgálat eredményei

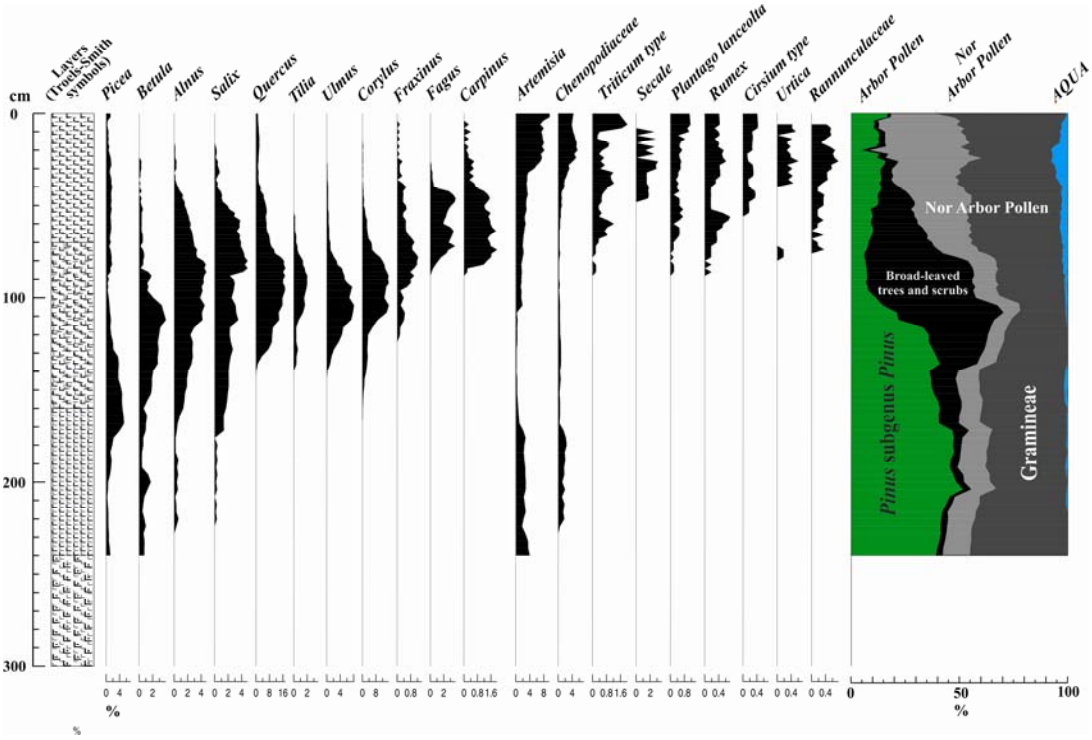

Fig. 17.: Pollen analytical results from the undisturbed core sequence of an infilled point-bar channel in Rokkant-földek at Rákóczifalva

17. ábra: A rákóczifalvi Rokkant-földek feltöltődött övzátony rendszerébe mélyített zavartalan magfúráson végzett pollenanalitikai vizsgálat eredményei

The seventh pollen zone developed between 80 and 60 cm (**Fig. 17.**) when hornbeam (*Carpinus*) and beech (*Fagus*) appeared and became dominant. Parallel to this, pollen indicating crop production and animal husbandry, cereals and pollen of weeds appeared in the section. It is likely that this pollen level is in accordance with the Neolithic and the beginning of the Copper Age, i.e. with the first plant cultivation and weed vegetation phase.

The eight pollen horizon evolved between 60 and 40 cm (**Fig. 17.**). Beech (*Fagus*) and hornbeam (*Carpinus*) pollen dominate among woody vegetation elements. At the same time, weed composition has changed dramatically and the proportion of herbaceous pollen (NAP) exceeded 60%. In this level the natural forest steppe became anthropogenic steppe vegetation, where woody vegetation (in the form of gallery forest) subsisted only in the active Tisza floodplain, in deeper locations with high groundwater level. Both crop production and animal husbandry could have been significantly increased on the basis of the pollen ratio of cultivated plants and weeds. This horizon can be identified with the end of the Copper Age and the entire Bronze Age.

The ninth pollen zone developed between 40 and 25 cm where arboreal pollen ratio decreased to below 30% (**Fig. 17.**). This significant change began in the Hungarian Great Plain at the end of the Bronze Age and the beginning of the Iron Age.

The tenth pollen horizon evolved between 25 and 15 cm that is the level of the Migration Period. The ratio of cultivated plants such as *Triticum* type, *Secale*, cereal show significant fluctuations. At the same time, the proportion of weeds (*Rumex*, *Urtica*, *Plantago lanceolata*, *Ranunculus*, etc.) spreading to trampling, chewing, grazing and the pollen of grasses, wormwood, pigweed has become dominant. AP ratio was below 20% in this level of the profile. The pollen zone of the medieval period developed from 15 cm to the surface. It is probable that post-medieval levels have dried up and destroyed during soil formation processes. During the Medieval period the impact of crop production is stronger and more stable. Weed vegetation transformed compared to the Migration Period and as a result mosaics and zones of crop production and animal husbandry could develop and stabilize in the area. It is likely that house groups or farm-like settlements with stable dirty roads evolved in the area during the medieval period.

Interpretation of pollen results

Based on the exogenous geological, geomorphological and sedimentological data, the pollen profile was formed in a Pleistocene residual surface, i.e. in a point bar channel of a point bar series rising above the Tisza alluvium. The Pleistocene point bar is probably of Danube origin and consequently its mineral composition and sedimentological development was separated from the sedimentary systems of the Tisza River. We were able to carry out a comprehensive sedimentological and geochemical study of the full development of the point bar channel. In addition, we could evaluate the development of the study area on the basis of the environment historical analysis of the profile from the end of the Pleistocene to the end of the medieval period. In spite of the outstanding geomorphological and sedimentological results regarding human settlements, the most significant environmental historical data were provided by pollen analytical results. The pollen material was moderately well and well preserved and statistically evaluable from the end of the Pleistocene to the end of the medieval period.

The most important feature of pollen material is that pollen composition indicates forest steppe vegetation (Allen et al. 2000; Prentice et al. 1996; Magyari et al. 2010; Törőcsik et al. 2018) from the end of the Pleistocene, through the late glacial/post-glacial transition period until to the early Holocene period. On the basis of our results this pollen composition corresponds to the northern part of the Late Pleistocene Eurasian forest steppe zone mixed with coniferous trees, or to the mixed-leafed taiga forest steppe in the Altai basin (Sümegi 1996, 2001, 2005; Sümegi et al. 1999, 2013a; Magyar et al. 2014, Törőcsik et al. 2015, Törőcsik & Sümegi 2016). These pollen data clearly support the models based on quartermalacological data (Sümegi 1989, 1995, 1996, 2005, 2007). According to these in some regions of the Great Hungarian Plain, in the Pannonian forest steppe zone, there was a natural shift from cold forest steppe (in the Late Pleistocene) to temperate forest steppe (in the Holocene) on a regional and local level as well.

In areas of hundreds of square kilometers at the regional level and in some square kilometers at the local level, it could be proven that a natural temperate steppe-forest steppe evolved in some parts of the Great Hungarian Plain (Sümegi 1989, 1995, 1996, 2005) at the end of the Pleistocene and at the beginning of the Holocene. Based on the previous results and analysis of different areas, due to the mosaic environmental conditions small local temperate steppe regions and patches developed in the forest steppe zone at the beginning of the Holocene; based on our previous data, mainly due to edaphic reasons (Sümegi 1989, 1996, 2011; Sümegi et al. 2005, 2012, 2013b; Törőcsik et al. 2015; Törőcsik & Sümegi 2016). In other words, parallel vegetation development evolved in the basin caused by mosaic environmental conditions. Despite increasing human effects, this parallel development has survived until to the 19th century, until to the spread of industrial civilization and water regulation. The parallel vegetation development was, of course, influenced by human effects as well; but their development and the magnitude of human effects were very different from each other and were not homogenous as it was suggested by John Chapman (Chapman et al. 2009; Chapman, 2018). There was not a general system in the development of the vegetation of the Great Hungarian Plain as a result of the different ecoregions (Sümegi 1996, 2005, 2011, 2016; Sümegi et al. 2012, 2013b).

The mosaic effect persisted in the vegetation despite the gradually increasing human impact at the beginning of and during the Neolithic. At the same time, as a result of plant cultivation, animal husbandry, human settlings and paths in the study area, a diverse composition of weed vegetation developed between the Neolithic and the medieval period. Cereals, including *Triticum* type and *Secale*, indicate a significant fluctuation in the level of the Migration Period and the level of the Hun era (c. 410-453/455 AD years) and Gepid Kingdom (453/455-567 AD years) in the Carpathian Basin. At the same time, the ratio of weeds (*Rumex*, *Urtica*, *Plantago lanceolata*, *Ranunculus*, etc.) spreading to trampling, chewing and grazing and the amount of grasses, wormwood and pigweed has become dominant. Arboreal pollen ratio was below 20% in this horizon of the profile (**Fig. 17.**).

During the Migration Period and the rule of Hun era (c. 410-453/455 AD years) and the Gepid Kingdom (453/455-567 AD years) the area was continuously inhabited and the alternating communities carried out extensive animal husbandry that was supplemented by cereal cultivation, the latter with varying intensity. Millet remains have been found among archaeobotanical finds in the Gepid settlements (Galántha 1981; Bálint 1991; B. Tóth 2003, 2004; Cseh 1999b) on the Great Hungarian Plain, but we cannot provide pollen data for this. Plant remains of millet (*Panicum miliaceum*) from the migration period found on the Great Hungarian Plain and in other parts of Eastern Europe show that the most important cereal cultivated by nomadic and semi-nomadic peoples was millet, whose cultivation requires relatively little attention. Consequently, millet meal, or porridge, must have been among the most important foods of these peoples (Wasylikowa et al. 1991). These data support the plant remains (millet, wheat, barley) of a Gepid site called Sándorfalva-Eperjes (Galántha 1981; Bálint 1991) and the local cereal cultivation (B. Tóth 2003, 2004) in Szolnok-Zagyvapart site (Cseh 1999b). It is likely that the good relief, protective features, the diverse and fertile soil conditions and the proximity of rivers and creeks have played a prominent role in the continuous use of the area. Similar settlements (Cseh 1986, 1990, 1992, 1993, 1999b) with a completely similar morphological situation can be found in several places in the Middle Tisza region (Tiszapüspöki, Kengyel, Szolnok, Törökszentmiklós). Though, these similar exogenous geological features have so far been ignored in the interpretation of the settling of Gepids.

Based on our data, Gepids settled in a completely altered Holocene vegetation environment in the peninsula-like residual surface of the Tisza valley that had a great importance with respect to protection and natural factors. We were not able to determine the vegetation environment of the Gepids more precisely, even using radiocarbon analysis, because the margin of error of these dates covers the 5th and 6th centuries, when Gepids settled in the area. This could only be refined by the archeobotanical and archeozoological analyses of samples from Gepid features, including wells. With the exception of our data, we do not have such comprehensive data regarding Gepid settlements at the moment, only archeozoological (Szabó & Vörös 1979) and sporadic archeobotanical data (Bálint 1991; B. Tóth 2003, 2004).

It is clear from the archeobotanical (anthracological) analysis of Gepid features of the Rákóczifalva site that construction wood derived from the hardwood gallery forest in the Tisza alluvium, while archeozoological finds suggest remarkable livestock in the era of the Huns (c. 410-453/455) then in the era of the Gepid Kingdom (453/455-567 AD years) (Szabó & Vörös 1979).

At the end of the Migration Period and during the Middle Ages, the stabilization and increase of land cultivation was observed. As a result, a significant, though diffuse structured settlement and permanent roads could develop in the study area (Cseh 1991) and one of the greatest of human impact evolved in the archaeological site of Rákóczifalva.

Macrobotanical analysis

Although anthracological material has been found in the archaeological sites of Rákóczifalva since the Neolithic, most of the wood residues were recovered from the features of the Migration Period, more exactly from Gepid features (Náfrádi & Sümegi 2015). Anthracological material of the Gepid features is as follows (**Table 1.**).

A total of 1069 pieces of charcoal fragments were found and identified in 13 samples from Gepid (6-7th century) features. 64.4% (688 pieces) of the charcoal fragments belong to oak (*Quercus*) genus.

Table 1.: The charcoal remains from Gepidian objects at Rákóczifalva

1. táblázat: Szenült fák maradványai a rákóczifalvi gepida objektumokból

Rokkant föld archaeological site	Gepid	
	%	i
Abies alba (fir)	1.7	18
Acer (maple)	3.6	39
Fraxinus (ash)	29.1	311
Quercus (oak)	64.4	688
Ulmus (ulm)	1.2	13
SUM (individuals = i)	100.0	1069

Ash (*Fraxinus*) is also represented in a significant proportion with a value of 29.1% (311 pieces). In addition, the ratio of maple (*Acer*) is lower which accounts for 3.6% (39 pieces) of the total material; the ratio of fir (*Abies*) is 1.7% (18 pieces), while the ratio of elm (*Ulmus*) is 1.2% (13 pieces). Charcoal fragments clearly indicate the presence of a hardwood gallery forest (oak-ash-elm) in the vicinity of the settlements. At the same time, the presence of fir (*Abies*) is a particular surprise, as it is an alien element in the Great Hungarian Plain, especially in its center of warm and dry climate (**Fig. 6.**). However, in the eastern part of the Gepid Kingdom, in the higher mountains encircling the Transylvanian Basin, including the Carpathians and Transylvanian mid-Mountains, there are larger forests of this species at a height of 1300 meters (Feurdean & Willis 2008). As a result, the presence of fir charcoal indicates exportation and it cannot be excluded that fir trees (that originate clearly from mountainous areas) have been utilized in connection with a ceremony or settlement, house warming.

Archeozoological analysis

The vertebrate fauna analysis from the Gepid features supported the combined use of the deeper Tisza alluvium that has good hydrological characters, oxbows and water outlets, and the flood-free, dry surfaces suitable for grazing fields, animal husbandry and plant cultivation. This is in concordance with the results of pollen analysis.

Most of the mid-size (979 pieces) animal bones recovered from the 11 Gepid features can be interpreted as food waste (**Tables 2-3. and Table 4.**). It was hard to find complete bones that indicates that meat and bones were cut together during cooking. In spite of this most of the bones could be identified. Only 28 bones were unidentifiable and found to be remnants of large or small mammals.

Table 2.: Excavated cultures within the Gepidian site, numbers of excavated objects and numbers of the bones at Rákóczifalva

2. táblázat: A Rákóczifalván feltárt kultúrák a gepidákkal, a feltárt objektumok számával és feltárt csontok számával

Age/Culture	Features with bones	Number of bones
Early Modern Age	2	2
Period of the Árpád Dynasty	18	533
Avar Period	66	1059
Gepids (Migration Period)	11	1012
Migration Period	1	11
Sarmatians + Gepids	1	47
Late Sarmatians	11	244
Sarmatians	88	886
Prehistoric	5	25
Celts	9	628
Scythians	1	18
Bronze Age	1	1
Gáva culture	3	31
Tumulus culture	4	79
Copper Age	2	64
Hunyadihalom group	2	31
Bodrogkeresztúr culture	13	219
Tiszapolgár culture	1	26
LBK	16	245
Non-identifiable cultures	13	592

The finds contained the remains of domestic animals, wild birds that could not be identified on a species level, fish and other aquatic animals. That suggests hunting or flowing and fishing, although antler fragments did not turn up.

This is the one and only archaeological period in the Rákóczifalva site, where the bones are not the most common; although the amount of neat bones are not much less than the number of ruminants (sheep, goat, cattle). The remains of all domestic mammals were found among the finds. Horses were rarely eaten - probably because of their high value.

Poultry remains were also found, mostly hen bones, but some goose bones were identified as well. In addition to the remains of meat-producing animals, bones of dogs and cats were also discovered.

Table 3.: Bones of animals from Gepidian features at Rákóczifalva

3. táblázat: A rákóczifalvi gepida objektumokból származó állatcsontok

Animal name	GEPID		
	NISP	%	Number of individuals Min./Max.
Cattle (*Bos taurus*)	275	28.9	8 / 22
Sheep (*Ovis aries*)	10	31.9	2 / 2
Goat (*Capra hircus*)	1		1 / 1
Sheep or goats (Caprinae)	292		9 / 19
Pig (*Sus domesticus*)	94	9.9	8 / 18
Horse (*Equus caballus*)	43	4.5	3 / 9
Hen (*Gallus domesticus*)	38	4.0	4 / 11
Dog (*Canis familiaris*)	108	11.4	5 / 5
Cat (*Felis catus*)	5	0.5	1 / 1
Domestic animals	***869***	***91.1***	***41 / 88***
Magpie (*Pica pica*)	4	0.4	1 / 1
Goose (*Anser* sp.)	4	0.4	1 / 1
Wild or pet birds	***8***	***0.8***	***2/ 2***
Pond turtle (*Emys orbicularis*)	2	0.2	1 / 2
Catfish (*Silurus glanis*)	2	0.2	1 / 2
Pike (*Esox lucius*)	2	0.2	2 / 2
Fish	40	4.2	1 / 5
Aquatic vertebrates	***46***	***4.8***	***5 / 11***
Rodents (Rodentia)	4	0.4	1 / 2
Birds (Aves)	27	2.9	3 / 6
Other species	**31**	**3.3**	**4 / 8**
Mussels (Bivalvia)	20	-	-
Snails (Gastropoda)	13	-	-
Small and large ungulate	28	-	-
Sum	**1012**	**100.0**	**52 / 109**

Table 4.: Meat regions of animals from Gepidian features at Rákóczifalva

4. táblázat: A rákóczifalvi gepida objektumokban feltárt állati húsrégiók

Bones/Animal	Cattle	Sheep	Goat	Sheep/goat	Horse	Pig	Hen	Dog	Anser	Bird
Cornus	4	-	1	-	-	-	-	-	-	-
Skull	22	1	-	10	2	9	2	3	-	-
Nasale	3	-	-	-	-	-	-	-	-	-
Hyoid	4	-	-	-	-	-	-	-	-	-
Maxilla	12	-	-	10	-	14	-	2	-	-
Premaxilla	2	-	-	1	-	-	-	-	-	-
Mandibula	12	-	-	22	4	18	-	3	-	-
Dentes	22	-	-	25	4	17	-	5	-	-
Atlas	4	-	-	1	-	1	-	1	-	-
HEAD REGION	**85**	**1**	**1**	**69**	**10**	**59**	**2**	**14**	**-**	**-**
Axis	-	-	-	-	-	-	-	-	-	-
Cervical vertebra	1	-	-	4	9	-	-	-	-	-
Thoracic vertebra	8	-	-	5	-	1	-	5	-	-
Lumbar vertebra	6	-	-	2	1	-	-	10	-	-
Sacrum	1	-	-	1	1	-	1	1	-	1
Caudal vertebra	-	-	-	-	-	-	-	-	-	-
Vertebra	-	-	-	-	-	2	-	-	-	1
Rib	41	-	-	27	3	6	-	38	-	-
Sternum	-	-	-	-	-	-	1	-	-	1
Coracoid	-	-	-	-	-	-	2	-	2	-
Clavicle	-	-	-	-	-	-	-	-	-	5
Pelvis	20	-	-	5	-	3	1	4	-	-
TRUNK	**77**	**-**	**-**	**44**	**14**	**12**	**5**	**58**	**2**	**8**
Scapula	7	2	-	7	1	4	-	-	-	2
Humerus	8	4	-	7	1	6	2	5	2	3
Radius	4	-	-	16	1	3	3	6	1	2
Radius+ulna	-	-	-	-	-	-	-	-	-	-
Ulna	3	-	-	3	1	1	1	5	1	2
Femur	12	-	-	16	4	3	5	4	1	1
Patella	-	-	-	-	-	-	-	-	-	-
Tibia	13	-	-	39	4	3	8	3	1	2
Tibia+fibula	-	-	-	-	-	-	-	-	-	-
Fibula	-	-	-	-	-	1	-	1	-	-

Table 4.: Meat regions of animals from Gepidian features at Rákóczifalva, cont.

4. táblázat: A rákóczifalvi gepida objektumokban feltárt állati húsrégiók, folyt.

Bones/Animal	**Cattle**	**Sheep**	**Goat**	**Sheep/goat**	**Horse**	**Pig**	**Hen**	**Dog**	**Anser**	**Bird**
MEATY LIMB REGION	**47**	**6**	**-**	**88**	**12**	**21**	**19**	**24**	**6**	**12**
Carpale	4	-	-	1	-	-	2	-	-	-
Metacarpus	8	1	-	13	-	-	-	-	-	4
Malleolare	-	-	-	-	-	-	-	-	-	-
Astragalus	6	-	-	3	-	1	-	-	-	-
Calcaneus	4	-	-	-	-	1	-	1	-	-
Tarsale	5	-	-	-	-	-	-	-	-	-
Metatarsus	2	2	-	18	1	-	10	-	-	3
Metacarpus/metatarsus	2	-	-	1	-	-	-	11	-	-
DRY LIMB REGION	**31**	**3**	**-**	**36**	**1**	**2**	**12**	**12**		**7**
Phalanx proximalis	3	-	-	5	1	-	-	-	-	-
Phalanx media	3	-	-	3	2	-	-	-	-	-
Phalanx distalis	3	-	-	2	-	-	-	-	-	-
Sesamoideum	3	-	-	-	1	-	-	-	-	-
TERMINAL BONES	**12**	**-**	**-**	**10**	**4**	**-**	**-**	**-**	**-**	**-**
Long bone fragment	22	-	-	45	2	-	-	-	-	-
Flat bone fragment	1	-	-	-	-	-	-	-	-	-
Total NISP	**275**	**10**	**1**	**292**	**43**	**94**	**38**	**108**	**8**	**27**

Probably dogs gnawed several bones; there are tooth marks on 16 finds including bones of cattle, small ruminants, pigs and even hens. It is not possible to estimate the number of bones that have been fully eaten. The cartilagenous epiphyses of young poultry bone, especially hens, could be easily consumed by cats or even by humans resulting in taphonomic loss. Significant numbers of fish bones indicate fishing and the extensive use of the alluvium. Fishing covered several species, the larger catfish, pike and smaller fishes.

We calculated the minimal and maximal number of individuals for each species. In the first case we calculated the number of bones for all of the same species of the site, and in case of the maximum number of individuals we took the features into one-one unit, calculated separately for each feature and then summed up the results. The actual number of individuals of each species can be between the two values; the minimum number of individuals is certainly under- and the maximum is overestimated due to the possibility of aggregation effects.

In the vicinity of the settlement, a grazing livestock of 23-53 individuals (sheep, goats, cattle, horses) was required. These numbers do not seem to be significant, especially since we do not have information about how many years the Gepid settlement was inhabited. But still the continuous catering, grazing and winter feeding of a few dozen animals could be challenging. It should also be taken into account that not the entire Gepid settlement was excavated so the number of individuals was definitely higher.

The difference between the numbers of cattle and small ruminant remains (sheep and goats) is only 28 bones (the number of small ruminants is higher), so their proportions can be considered as equal. There is little or no difference between the minimum and maximum number of individuals either. Small ruminants include sheep and goats. Because of the high degree of similarity between the bones of the two species, it is difficult to distinguish them. 10 bones of the 303 small ruminant bones were identified as sheep, one from a goat, and 292 from either of these species. In general, sheep are more common in every period of time and goats are less frequent. Among the sheep/goat findings there are several bones that were chewed by dogs, most of them come from meat-rich regions of the body. The age distribution of individuals was diverse. Two sheep and one goat were adults; the age distribution of the only sheep/goat individuals was mixed.

Based on the minimum number of individuals, one of them was 1-2 years old, one 1-1.5 years old. Three animals were young (less than 2.5 years old), one nearly adult (2.5-3.5 years) and three adults. On the basis of the other individual count, the number of the two sheep and one goat did not change. In case of the 19 sheep/goats, young and adult animals were found in nearly half-half ratio: 9 specimens were juvenile (young), one of them was between 1 and 2 years old, one of them less than 1.5 years old and one between 2 and 3 years old. The age of the other 6 young animals could not be identified more precisely, but they are certainly less than 2.5 years old. Three animals were of subadult age, i.e. nearly mature and 6 were adult specimens. The age of one animal could not be identified. Interestingly, the bones of very young animals, younger than 1 year, were not found. The slaughter of young animals indicates meat production as milk and wool use is only possible in the case of adult domesticates. The majority of animals were slaughtered in the excavated area of the settlement that is indicated by the anatomical distribution.

The 275 neat bones of cattle represent 28.9% of the identifiable finds. The bones come from at least 8 up to 22 animals, their age distribution is mixed. Out of the 8 individuals one was juvenile, which is 1-3 years old in case of neat. One was subadult, that is, 3-4 years old, 3 individuals were adults, so over 4 years old. One individual was 6-7 and one was 6-8 years old, already mature. One specimen died or was slaughtered as an old animal. The number of gnawed bones was small in the Gepid material. Of the seven finds there were 4 phalanges, 1 astragalus, 1 calcaneus and 1 tibia. The number of cut cattle bones was two, one is a tibia and the other is a 5 cm long horn-core attached to a skull fragment with parallel trimming and pole-axe traces.

The age distribution was slightly different in the case of the 22 individuals, more heterogeneous. The number of young animals was 7, 3 were nearly adults, 7 were adult, 2 matured, 2 were old, and 2 were undetermined. A metatarsus bone of a neat could be used to calculate the withers and to determine the sex of the animal. The 236 mm long bone derived from an approximately 126 cm tall cow (Nobis 1954; Calkin 1960). This cow is considered to be large compared to other samples from different periods. Bones suitable for withers calculation from Celtic, Sarmatian, Late Sarmatian, bones from the 4^{th}-5^{th} century, late Migration Period and Period of the Árpád Dynasty occurred and were used for calculation; each animal was a cow. The height of the Celtic individual was small, around 107 cm. The Sarmatian cows were 111 and 117 cm tall, the AD 4^{th}-5^{th} century animals were 114-115 cm, from the late Migration Period they were 106, 114, 116 and 122 cm tall. The cow from the Period of the Árpád Dynasty was small, only 108 cm at the withers. The skull fragment with the horn-core also originated from a cow.

Among the meat-producing animals, ruminants are followed by domestic pigs: 94 of their bones account for 9.9% of the finds. Regarding the number of individuals, the lowest number is 8, the highest is 18. Compared to the amount of bones, this number is very significant, as it approximates those of small ruminants and cattle. The age distribution of individuals is mixed. In the case of pigs, it is common that very young animal remains appear among the finds, as they are short-lived, fast-growing animals that have more piglets at the same time, making it easy to replace slaughtered animals. Compared to other domestic species pigs are meat producing animals, they have no other forms of utilization.

Based on the minimum number of individuals, one pig was only ½ years old and one was ¾ years old when it was slaughtered. A 1 year old animal can be considered as young as well. There were a few specimens that could not be precisely defined: one 2-3 years old, a younger than 2.5 years old, one 2.5-3.5 years old and 2 adult pig, including a male animal.

The number of individuals per feature (the maximum number of individuals) was as follows. It added 10 animals to the above mentioned: the number of juvenile pigs (less than 2.5 years old) was not one, but 4, there were 2 individuals that were 2.5-3.5 years old and 3 individuals (instead of 2) were adult. The age of 5 animals could not be defined.

On the basis of charcoal analysis, hardwood gallery forest existed in the vicinity of the settlement, mostly with oak trees. Oak acorn served as the basis for pig feeding. In October and November pigs ate fallen acorns in the forest, while in the case of early heavy snowfall they ate the rest of the acorns during the spring.

The number of horse bones is 43 that represents 4.5% of the identifiable bones. The number of individuals is at least 3 (one juvenile, one subadult and one adult), maximum 9. The age distribution of the 9 individuals indicates 6 adult individuals, 2 young (1-3 years), and one subadult, i.e. nearly mature. Complete long bones for withers height calculation could not be found in the bone assemblage. The minimum number of individuals was at least 4, maximum 11. Based on the minimum number of individuals, 2 specimens were not yet mature and there were 2 adults, including one male and one female. Based on the number of individuals per feature (maximum number), 11 specimens could be identified, of which 4 were non-mature, 7 were adults including 3 female and one male.

From one feature (No. 194, a building) 8 bones of an adult goose-like bird were found. In addition, the number of dogs and cats were the same for both calculations.

Five dog bones were identified. One of them was newborn, one was a young puppy, one subadult and 2 were adults. Withers height calculation could be done on the basis of a complete thigh bone (Koudelka 1885). A short, 24-29 cm tall dog with slightly curved legs could be identified. Such small dogs are very rare during this period and can only be observed during the Roman Period in Pannonia. This animal can be categorized as a small-sized dog (Bökönyi 1974, 323). The five bones of one cat originated from the same feature, a pit, and were identified as adult animals. Their role could be to keep rodents away in the vicinity of houses and crop storage pits. Based on the composition of domestic animals the Gepid settlements were surrounded by extensive pastures, including saline pastures that are more favorable for sheep. Furthermore, the ratio of wet meadows and meadows was also outstanding due to the high number of cattle and horse remains.

The number of fish bones was 44 in the manually collected samples. It would have been possible to multiply this quantity by the sieving of the fill from features. The remains included 2 catfish and 2 pike bones (Figs. 19, 20). The catfish is common in slow-flowing rivers and lakes while the pike favor lakes and oxbows with fresh water income and rich vegetation. The catfish is a large fish; its meat is delicious, fat-rich, and bone free. The advantage of the pike is that it does not pit in winter, so it can be fished from below the ice. Its meat is white, clean, tasty, but rich in bones. The quality of the meat is influenced by the purity of the water and the taste of small fishes eaten by the pike. The minimum number of fish individuals was 4, of which 1 catfish, 2 pikes and a non-identifiable species could be identified. According to the maximum calculation 2 catfishes, 2 pikes and 5 unidentified fishes were found in the Gepid features.

The shell remains of the European pond turtle were also discovered. This turtle is the only native turtle species in the Carpathian Basin. It favors shallow, muddy stagnant water that could be found in the vicinity of Rákóczifalva as well. As a reptile, it favors sunny places, dense forest lakes and oxbows surrounded by gallery forest. Only turtle shell fragments occurred among the finds, which may indicate the consumption of turtle meat.

Bone artefacts did not turn up, although a cattle cervix (15.2 cm) with signs of diaphysis was found, with rubbing-like abrasion signs on its back side, its distal end was gnawed (**Tables 2-3.** and **Table 4.**).

Fig. 18.: Gepidian horse jaw used as a bone anvil

18. ábra: Gepida csontüllő ló állkapocsból

Fig. 19.: Catfish vertebra from Gepidian object

19. ábra: Egy gepida objektumból származó harcsa csigolya

Fig. 20.: Pike dentale from a Gepidian feature

20. ábra: Egy gepida objektumból származó csuka dentale

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An interesting find, a bone anvil was found made from a horse's jawbone (**Fig. 18.**). On the flat surface of the jawbone, the mold of sickle teeth blade appears in rows. The bone anvil was used when the sickle teeth was repaired or recovered, or when the broken teeth of a metal anvil was replaced by a bone anvil.

This feature has already been known in the Mediterranean region from the Greek-Roman period, and Medieval age (Idoia 2012; Gál & Bartosiewicz 2012; Anderson et al. 2014; Crassi 2016; Vuković-Bogdanović & Bogdanović 2016; Valenzuela et al. 2017) but in Hungary the earliest bone anvil appeared from the Period of the Árpád Dynasty (Bartosiewicz 2010; Gál 2010; Gál et al. 2010; Kvassay & Vörös 2010; Tugya 2014). In Rákóczifalva, besides the Gepid anvil, Late Sarmatian anvils occurred as well. The significance of bone anvils is that they carry information about both animal husbandry and bone processing, offer evidence that blacksmith operated in the settlement, where metal tools were maintained and they indicate cereal production as well (Lichtenstein et al. 2006; Lichtenstein & Tugya 2009; Tugya & Lichtenstein 2014; Tugya, 2014, 2015).

We know very little about Gepid animal husbandry and hunting so the archaezoological research of as many archeological excavations as possible and their publication of results is very important. At the site of Battonya in Southeast Hungary, farm-like Gepid settlements were excavated (Szabó & Vörös 1979). The archeozoological material of some houses and pits were revealed and the same environmental historical finds were discovered as in the case of Rákóczifalva. The most important livestock were cattle, sheep and goats. Pig was not important in Battonya, but in Rákóczifalva the number of pig bones was significant. Dog, cat and chicken remains occurred in Battonya as well. There is no proof of hunting in Rákóczifalva while in Battonya red deer hunting was observed. Fishing, which could supplement the amount of meat obtained from the slaughter of domestic animals, can be observed in both sites of the Great Hungarian Plain.

Summary

Geoarcheological, archeobotanical and archeozoological analysis have been carried out in the central Tisza valley, one of the hottest parts in the Great Hungarian Plain. A Gepid settlement and its surroundings were excavated. Based on the results of the digital relief model, maps, historical maps and geoarchaeological analysis of geological drillings, Bagi-földek are located on a deeper and younger alluvial surface with good water supply and are connected to the development of the Tisza River, while Rokkant-földek are located on an older residual surface and rising above the alluvium.

The Gepid communities settled on a point bar series located on the high-floodplain and low floodplain in a semi-circular, semi-peninsular area. These surfaces provided different farming possibilities for the Gepid communities of the Migration Period: the utilization of the gallery forest, gatherings in the area of the forests and floodplain, fishing and hunting, extensive animal husbandry on the higher, drier areas and plant cultivation around the settlements and houses. The area was continuously inhabited during the Migration Period and the communities continued to carry out extensive livestock farming and cereal production in varying intensity (Willis et al. 1995, 1998; Bartosiewicz 2001, 2003, 2004, 2006, 2017; Bartosiewicz & Choyke 2002; Tugya & Lichtenstein 2014).

Pollen data from point bar canal core sequence in the analyzed region suggest there was a natural shift from cold forest steppe (in the Late Pleistocene) to temperate forest steppe (in the Holocene) on a regional and local level as well. Similar pollen composition and vegetation changes formed in some regions of the Great Hungarian Plain, in the Pannonian forest steppe ecoregion (Sümegi et al. 1999, 2006, 2012, 2013a,b; Magyari et al. 2010; Törőcsik et al. 2018). Thus, the concept that explains the development of the entire forest steppe zone with human effects (Bernátsky 2014; Rapaics 2018; Chapman 2017; Chapman et al. 2009) in the Great Hungarian Plain, although this theory has survived to the present day, cannot be sustained anymore. Therefore the Gepid communities utilized one of the most important features of the Great Hungarian Plain, i.e. its local (few hundred m^2 to a few km^2), mosaic-like nature. Thus, the settlements were in a transition zone regarding geomorphological situation (**Fig. 15.**).

According to our data, the inhabitants of the excavated Gepid settlement fully utilized the Tisza valley environment for food production on an organic level during the Migration Period, in the 6th century. The environment occupied by the Gepid community, the floodplain islands and residual surfaces in the Tisza Valley was inhabited from the early Neolithic. The exploitation of their environment, from settlement strategy to gathering, has a similar system as in the case of the Gepid settlement we have described. However, the ratio of exploiting natural resources (hunting, fishing, gathering), and productive farming (land cultivation, animal husbandry) was different in the life of these communities.

According to our data, during the Migration Period, during the existence of the Gepid Kingdom (453/455-567 AD years: Nagy 1999; B. Tóth 1999), an organic material rich lake-swamp system appeared in the examined area. This layer has transformed due to soil formation that was the result of recent river and groundwater regulation.

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POLLEN-BASED RECONSTRUCTION OF THE PLANT CULTIVATION IN THE CARPATHIAN BASIN FROM THE MIGRATION AGE TO THE END OF THE MEDIEVAL AGE•

POLLEN ALAPÚ NÖVÉNYTERMESZTÉSI REKONSTRUKCIÓ A KÁRPÁT-MEDENCÉBEN A NÉPVÁNDORLÁS KORÁTÓL A KÖZÉPKOR VÉGÉIG

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Abstract

From the beginning of the Migration period to the end of the Ottoman period, from the turn of the IV-Vth century until to the XVI-XVIIth century, we examined the changes of 1300 years of grain production throughout the Carpathian Basin in a centennial resolution, through 13 centuries, and 137 pollen sites. Based on the spatial distribution of the total cereal pollen ratio, which is related to cultivation, agriculture, population density, and headcount, the following statements were made regarding the age of the Migration period, the Hungarian conquest, the Middle Ages and the Ottoman period. Our analysis is only the beginning of a comprehensive environmental history analysis, which, together with significant material and time investment, archaeological data, historical analyses, pollen data, and other archaeobotanical, archaeozoological data, allows us to conduct an almost complete economic history analysis of the Carpathian Basin.

Kivonat

A népvándorláskor kezdetétől az oszmán kor végéig, a Krisztus előtti IV/V. század fordulójától a Krisztus utáni XVI/XVII. század fordulójáig 1300 év gabonatermesztési változásait vizsgáltuk meg az egész Kárpát-medencében 100 éves felbontásban, 13 évszázados szintben és 137 üledékgyűjtő lelőhely adatai alapján. A gabonatermesztéssel, ezzel együtt a földműveléssel és a népsűrűséggel, lélekszámmal összefüggést mutató gabona összpollen arány térbeli eloszlása alapján megállapításokat tehettük a népvándorlás, magyar honfoglalás korára, a középkorra és az oszmán hódítás korára vonatkozóan. Elemzésünk egy átfogó környezettörténeti elemzés kezdete, amelynek alapján jelentősebb anyagi forrásokkal és időbeli befektetésekkel, régészeti adatokkal, történelmi elemzésekkel, pollen adatokkal, valamint más archeobotanikai, archeozoológiai adatokkal kiegészítve szinte teljes gazdaságtörténeti elemzést végezhetünk a Kárpát-medencére vonatkozóan.

KEYWORDS: POLLEN ANALYSES, CEREALS RATIO, DATABASE, MIGRATION AGE, MEDIEVAL AGE

KULCSSZAVAK: POLLENELEMZÉS, GABONÁK ARÁNYA, ADATBÁZIS, NÉPVÁNDORLÁSKOR, KÖZÉPKOR

Introduction

We wanted to reconstruct the climate and flora in catchment basins based on 1500-1600 years of pollen data. Most importantly, we wanted to know which communities were involved in crop production and to what extent. Of course, this seemingly minor issue is related to almost all issues of the Migration Age, the Hungarian conquest of the Carpathian Basin, and the Medieval Age, as the existence, lack, or advancement of crop production points to significant social issues.

Thus, we must take into consideration the questions mentioned above and the total judgment of the last 1500-1600 years on this question. That is why we chose a factor independent of written sources, namely the analysis of pollen residues in the catchment basins, deposited in layers of that age.

This factor, pollen analysis, has been used several times in the discussion of historical botanical issues (Győrffy & Zólyomi 1994; Járainé-Komlódi in Tardy, 1982).

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At the same time, the question that pollen analysis does not solve the chronological classification even locally over centuries has been obscured in these summary pollen analyses (Cushing 1967; Stieber, 1967). This is remarkable because pollen analysis of centennial resolution requires independent chronological studies, above all radiocarbon analyses. However, there were no such chronological tests until 1995, when the first radiocarbon and AMS analyses were made in a series of Hungarian-British collaborations (Willis et al. 1995, 1997, 1998; Sümegi 1995, 1998, 2000, 2001, 2002, 2003, 2005). Without these data, pollen data could not be placed chronologically accurately. This problem was also avoided in pollen analyses (Zólyomi 1987; Járainé-Komlódi 1987), in which the vegetation development of the basin, the Holocene climatic conditions and human effects were attempted to be presented. Independent chronological analysis was not used at all for these analyses, although a fully functional radiocarbon laboratory was already available in Hungary and several researchers used the results of radiocarbon analysis, including for pollen analysis (Csongor & Hertelendi 1986; Hertelendi et al. 1989, 1992). Officially accepted pollen analysts in Hungary tried to solve the chronological problem by taking the pollen phases initially described in the area of southern Scandinavia following the work of Firbas (1947) and applying them to determine the stratigraphy. Thus, in many cases, they provided their data without an independent chronological scale with chronological data from the Atlantic area and fitted their chronological scale to a different ecoregion scale (Sümegi 2016). They might even have believed that this was an existing and scientifically acceptable approach.

However, these originally southern Scandinavian pollen phases were already reported in the 1960s to be unsuitable for the stratigraphic analysis of larger regions because they can only be used locally and spatially for determining stratigraphy (Cushing 1967; Stieber 1967). This problem became apparent at the beginning of the Hungarian pollen analyses on the Kis-Mohos and Nagy-Mohos mires in Kelemér (Zólyomi 1931, 1936, 1952) and the new comparing analyses on the same mires (Willis et al. 1997, 1998; Sümegi 2001, 2004, 2005, 2007, 2008, 2011, Sümegi et al. 2008), where several thousand years of chronological slippages could be detected compared to the original idea. It is no coincidence that correct pollen data could not be obtained until 1993 for the age of the Migration Period, the age of the Hungarian conquest of the Carpathian Basin, and for the age of the Middle Ages. It is no coincidence as well that the presence of significant corn pollen was first pointed out in the Hungarian-British pollen survey, as well as a fish pond, which was formed during the Hungarian conquest, X. century (Willis et al. 1995, 1998; Sümegi 2004).

At the same time, we must accept the fact that even the most advanced sampling and radiocarbon technology cannot achieve a more accurate approach to calibrated radiocarbon chronological data than a few decades. For example, we will still have some chronological uncertainty about the age of the Hungarian conquest and the age of the Hungarian invasions of Europe (860-970). However, the uncertainty of the resolution will be around a few decades off and not centurial or millennial, as in previous pollen analyses without radiocarbon or palaeoclimatological analysis (Rácz 1993; Győrffy & Zólyomi 1994; Járainé-Komlódi 1982).

Methods

For the last 1500-1600 years, we have set up a pollen database, which was achieved by extending a pollen database from the Middle Ages (Sümegi et al. 2009a, b, 2012, 2013, 2016a). Pollen data does not come from archaeological sites, but from the nearby catchment basins, marshes, and ponds where, over the last 2000 years, a thicker layer of sediment has accumulated than in areas outside the basin. Finer-scale sampling from thick sediment layers allows for decades-long reconstructions. Detailed analysis of catchment basins and the relationship between them and pollen accumulation has been extensively studied in the Anglo-Saxon literature, and these results have been utilized in new approaches in Hungary (Bell & Walker 1992; Jacobson & Bradshaw 1981; Willis et al. 1995, 1997, 1998).

There are now thousands of pollen profiles created at the European level with undisturbed coring, but only about 1032 of these form the European Pollen Database (EPD) program (2009 status: Fyfe et al. 2009). Out of the 1032 EPA pollen sections, 668 sections have been established using a radiocarbon-based sedimentation rate and chronological reconstruction (Fyfe et al. 2009; Ralska-Jasiewiczowa 2004), making these sections suitable for former human-environmental reconstruction - on a continental scale. Of these, less than 500 pollen profiles have so far been analysed by comparative analysis in monographical form, resulting in very large-scale pollen analyses of European vegetation at the level of each culture (Huntley & Birks 1983).

In our work, we selected pollen analyses from 137, predominantly new catchment basins in the Carpathian Basin for our medieval, Hungarian conquest and Migration Period pollen database (**Fig. 1.**). Thus, we have suitable data sets that can be used for the EPD database, but only 13 of these can be found in the European Pollen Database (Bodor et al. 2000; Juhász 2002).

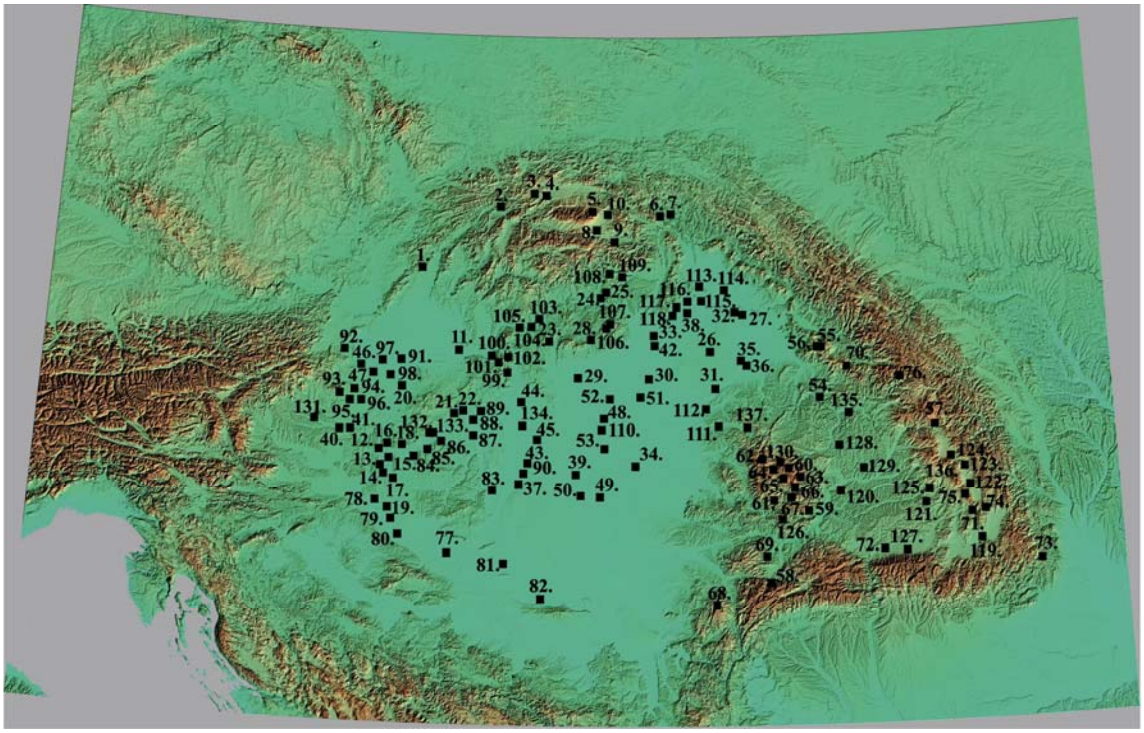

Fig.1.: The pollen sites that constitute the presented database (scale of original map: 1:1,000,000)

1. ábra: A bemutatott adatbázist alkotó pollen lelőhelyek (eredeti térkép léptéke: 1:1 000 000)

Key / Jelkulcs: 1 = Tlstá Hora, Biele Karpaty, Slovakia, 2 = Kubríková, Západné Beskydy, Slovakia, 3 = Dolina Zlatného potoka, Podbeskydská brázda, Slovakia, 4 = Bobrov, Oravská kotlina, Slovakia, 138 = Trojrohé pleso, Tatra Mts, Slovakia, 5 = Regetovka, Busov, Slovakia, 6 = Kružlová, Ondavská vrchovina, Slovakia, 7 = Hozelec, Popradská kotlina, Slovakia, 8 = Šafárka, Volovské vrchy, Slovakia, 9 = Sivárňa Spišká Magura, Slovakia, 10 = Popradcké pleso, Štrebké pleso, Mts, Slovakia, 11 = Parížske, Slovakia, 12 = Kis-Balaton peatland, Alsópáhok, Hungary, 13 = Kis-Balaton peatland, Zalavár 1, Hungary, 14 = Kis-Balaton peatland, Fenékpuszta, Hungary, 15 = Úsztatómajor peatland, Keszthely, Hungary, 16 = Kis-Balaton peatland, Főnyed, Hungary, 17 = Kis-Balaton peatland, Vörs, Hungary, 18 = peatland, Balatonederics, Hungary, 19 = Baláta lake, Kaszó, Hungary, 20 = Szélmező peatland, Mezőlak, Hungary, 21 = Sárrét peatland, Nádasdladány, Hungary, 22 = Sárrét peatland, Sárkeszi, Hungary, 23 = Nádas lake, Nagybárkány, Hungary, 24 = Kis-Mohos peat-bog, Kelemér, Hungary, 25 = Nagy-Mohos peat-bog, Kelemér, Hungary, 26 = Nagy-Mohos floting mat, Kállósemjén, Hungary, 27 = Nyíres peat-bog, Csaroda, Hungary, 28 = Nyírjes peat-bog, Sirok, Hungary, 29 = Meggyes paleochannel, Jászberény, Hungary, 30 = Halasfenék paleochannel, Zám, Hungary, 31 = Töviskes paleochaennel, Pocsaj, Hungary, 32 = Báb lake, Csaroda, Hungary, 33 = Sarló-hát paleochannel, Tiszagyulaháza, Hungary, 34 = Fehér lake, Kardoskút, Hungary, 35 = marshland core, Bátorliget, Hungary, 36 = marshside profile, Bátorliget, Hungary, 37 = Vörös marshland 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 = Vörös-mocsár II. core-profile, Császártöltés, Hungary, 44 = Selyemrét peatland, Ócsa, Hungary, 45 = Kaszálók peatland, Hajós, Hungary, 46 = Fertő lake, Hidegség, Hungary, 47 = peat-mine, Osli, Hungary, 48 = Rokkantföldek paleochannel, Rákóczifalva, Hungary, 49 = Pana paleochannel, Maroslele, Hungary, 50 = Maty paleochannel, Szeged, Hungary, 51 = Kunkápolnás, Nagyiván, Hungary, 52 = Tisza paleochannel, Tiszapüspöki, Hungary, 53 = Tisza paleochannel, Tiszaalpár, Hungary, 54 = Turbuta peatland, Transylvanian Basin, Romania, 55 = Preluca Tiganului peat-bog, Gutaiului Mts, Romania, 56 = Steregoiu peat-bog, Gutaiului Mts, Romania, 57 = lezerul Caliman, Caliman Mts, Romania, 58 = Taul dintre Brazi, Retezat Mts, Romania, 59 = Ic Ponor, Apuseni Mts, Romania, 60 = Padis Ponor I, Apuseni Mts, Romania, 61 = Padis Ponor II, Apuseni Mts, Romania, 62 = Padis Plateau, Apuseni Mts, Romania, 63 = Bergerie, Apuseni Mts, Romania, 64 = Capatana, Apuseni Mts, Romania, 65 = Molhasul Mare, Apuseni Mts, Romania, 66 = Calineasa, Apuseni Mts, Romania, 67 = Pietrele Onachii, Apuseni Mts, Romania, 68 = Taul Zanogutii, Apuseni Mts, Romania, 69 = Semenic, Banat Mts, Romania, 70 = Pesteana, Poiana Rusca Mts, Romania, 71 = St Anna lake, Harghita Mts, Romania, 72 = Avrig-1, Fagaras basin, Romania, 73 = Bisoca, Curbura, Romania, 74 = Mohos peatland, Harghita Mts, Romania, 75 = Luci peatland, Harghita Mts, Romania, 76 = Poiana Stiol 3, Rodnei Mts, Romania, 77 = Drava paleochannel, Drávaszabolcs, Hungary, 78 = Lankóczi paleochannel, Berzence, 79 = Drava paleochannel, Barcs, 80 = Drava paleohannel, Drávatamás, 81 = Danube paleochannel, Draž, Croatia, 82 = Danube paleochannel, Novi Sad, Serbia, 83 = Batta paleochannel, Decs - Ete, Hungary, 84 = Balaton lake, Balatonkeresztúr, Hungary, 85 = Balaton lake, Balatonboglár, Hungary, 86 = Balaton lake, Zamárdi, Hungary, 87. Sárvíz peatland, Soponya, Hungary, 88 = Sárvíz peatland, Sárszentmihály, Hungary, 89 = Nádas lake, Gárdony, Hungary, 90 = Kaszálók peatland, Hajós, Hungary, 91= Országút felőli dűlő, Rábapatona, Hungary, 92 = Kismalom lake, Sopron, Hungary, 93 = Égeres peatland, Velem, Hungary, 94 = Borzó creek, Zanat, Hungary, 95 = Surány creek, Nemesbőd, Hungary 96 = Hosszú creek, Vát, Hungary, 97 = Marcal creek, Kemenespálfa, Hungary, 98 = Barbacsi lake, Barbacs, Hungary, 99 = peat-bog, Csikóvár, Hungary, 100 = Búbánat creek, Esztergom, Hungary, 101 = Dera creek, Pilisszentkereszt, Hungary, 102 = Sirbik domb, Visegrád, Hungary, 103 = Ménes creek, Karancsság, Hungary, 104 = Fort garden, Szécsény, Hungary, 105 = Nagy lake, Ipolyszög, Hungary, 106 = Petény cave, Peskő, Hungary, 107 = Rejtek cave, Répáshuta, Hungary, 108 = Aggtelek lake, Aggtelek, Hungary, 109 = Martonyi creek, Martonyi, Hungary, 110 = Bivaly lake, Rákóczifalva, Hungary, 111 = Bai 1 Mai, Haiu, Romania, 112 = Daru marshland, Bagamér, Hungary, 113 = paleochannel, Karos, Hungary, 114 = Latorca paleochannel, Szirénfalva, Ukraina, 115 = paleochannel, Pallagcsa, Hungary, 116 = paleochannel, Karcsa, Hungary, 117 = paleochannel, Viss, Hungary, 118 = paleochannel, Zalkod, Hungary, 119 = Nyír peatland, Reci, Romania, 120 = Tăul fără fund peatland, Băgău, Romania, 121 = Kerek lake, Sânpau, Hungary, 122 = Mlastina Csemő, Vrabia, Romania, 123 = Mănăstirea franciscanilor, Şumuleu Ciuc, Romania, 124 = Mlaştină, Delniţa, Romania, 125 =

marshland, Comăneşti, Romania, 126 = Turbaria Calul de Piatra, Bistra, Romania, 127 = Mlaştina eutrofă de la Hărman, Hărman, Romania, 128 = Mureş, paleochannel, Sâncraiu de Mureş, Romania, 129 = Lacul Racului/Rat, Sec, Romania, 130 = Padiş Ponor II, Apuseni Mt, Romania, 131 = Rohr – Heugraben, Austria, 132 = Külső lake I, Tihany,Hungary, 133 = Külső lake II., Tihany, Hungary, 134 = Danube paleochannel, Tököl, Hungary, 135 = Măguruci cave, Răstoci, Romania, 136 = Uver mlaştină, Racu, Romania, 137 = Mlaştina de la Iaz, Plopiş, Romania

Also, many of the Hungarian sections were incorrectly recorded because the first reports (e.g. Jakab et al. 2005) reported incorrect coordinates and altitudes. The latter mistakes were made because the first publications, in several cases, reported the materials without participating in the drilling and the extraction of the samples (Sümegi et al. 2008).

The pollen analysis works of the Carpathian Basin, including Hungary, were selected in the following steps:

1.) The stratigraphy of the catchment basin was explored with a drilling rig providing undisturbed core samples. If the type of drill was not reported, the test results were not considered. As we pointed out earlier in the pollen drilling in Hungary, we had to omit all pollen analysis work until the end of the 1980s due to inadequate sampling both in Nyírség, Bodrogköz or in different parts of the country (Braun et al. 1993; Sümegi 2001). We took only into consideration the works of the Geoarchaeological and Environmental History Team, which is a joint research team of the Institute of Archaeology of the Hungarian Academy of Sciences and the Department of Geology and Palaeontology of the University of Szeged, and its predecessor the Debrecen Palaeoecological Group (Sümegi 2001). Apart from the work of the researchers trained in these groups (Mihály Braun, Enikő Magyari), we could only consider the works of Tibor Cserny and Elvira Bodor in Hungary. This is mainly because Tibor Cserny utilized the drilling equipment we have developed (Sümegi 2001), among other things during his drilling, and was able to provide undisturbed cores for the pollen research work of Zsófia Medzihradszky & Járainé-Komlódi (1996).

2.) For undisturbed core sampling, it was essential that Lycopodium tablet digestion was performed during pollen processing and that a minimum of 300/500 terrestrial plant pollen was counted from a sample. Only pollen analytical work where the pollen concentration was determined using the Lycopodium spore tablet method (Stockmarr 1971) was considered. It has been used extensively in pollen analytics in Europe and globally since the 1970s, except in Hungary, several areas of Yugoslavia, Romania, and Bulgaria. As a result, the results of the Hungarian pollen analyses were not considered reliable and acceptable, even internationally in the 1990s (Berglund et al. 1996).

3.) Only the sections where correct bulk or AMS radiocarbon analyses were performed in first-class laboratories were reported and reported with primary physical measurement data, measurement depth, and measurement code number.

4.) Only the pollen data where the position of the catchment basin and the undisturbed core drilling were given in coordinates in the publications were considered. It is impossible to reconstruct the locations of the drillings in the absence of the coordinates. This was the case with the Hungarian pollen drilling data until the end of the 1980s. No one in Hungary fulfilled this fundamental condition except the Debrecen Palaeoecological Group, the Geoarchaeological and Environmental History Group in Budapest and Szeged, and their students and Tibor Cserny and Elvira Bodor (Hungarian Geological Institute). It is no coincidence that pollen data from Hungary were not considered reliable in international research (Berglund et al. 1996).

5.) The size of the catchment basin was also considered, so the boreholes drilled into the Balaton riverbed could not be considered as the size of the lake is too large. In the case of internationally used catchment basin selection, river basins should have been excluded from our analysis due to pollen banding uncertainties. Without these, however, pollen data from significant areas of the Great Hungarian Plain and the Little Hungarian Plain would not have been available. Although pollen data can be used primarily to reconstruct regional crop production, these data can be used to demarcate and localize crop production within a maximum range of 10-100 km^2. The otherwise perfectly correct boreholes and excellent pollen results in the 600 km^2 main basin of the Balaton (Cserny & Bodor 2000) were not used in our work because we would have gotten data from the whole basin, about 300,000 km^2.

The setting up of the database, therefore, required comparisons of samples from different parts of the Carpathian Basin, extracted with the same methods and extracted by drilling to ensure mix-free sampling and dated by independent chronological methods. As a result, analyses that did not reach this standard were excluded. This was the only way for us to achieve correct and comparable results. Of course, this is a painful process that has highlighted that most Hungarian pollen analyses conducted in the second half of the 20th century were unsuitable for international comparison (Berglund et al. 1996) and could not solve even a fundamental issue. The erroneous results and fallbacks of a generation have been eliminated through the work of the new generation between 1986 and 2006 (Törőcsik & Sümegi 2016).

6.) 137 radiocarbon-dated pollen sites and sequences, which have been published and created so far during the processing of our research group, have been extracted to the database. The development of the database was not problem-free, and, based on the experience so far, there were problems with more pollen sections in Hungary. Particularly the borehole at the border of Tiszagyula, considered essential for the development of the entire Hungarian Great Hungarian Plain vegetation, caused the most significant problem. Our first and severe problem is that the drilling profile was projected to different places and areas by the authors of very different composition. Sometimes the pollen data changes were projected to the Tisza valley (Magyari et al. 2010, 2012; Gábris et al. 2001; Gábris & Nagy 2005), sometimes to the Polgár alluvial island about 20 km from the site, and to the Hortobágy region, which is at a distance of at least 60 km from the drilling site and is genetically utterly different from the Tisza Valley (Magyari 2010, 2011; Fekete et al. 2011, 2014). We do not know of any such profile in the Hungarian Great Hungarian Plain, which could represent the development of vegetation in so many diverse regions characterized by different environments, including saline areas, steppes, forest steppes, forests, all with a good water supply, hydromorphic soil-covered neotectonical depression, an oxbow lake surrounded by a grove forest, and the studied sections come from several kilometres from the places where pollen results were projected.

This problem is increased by the fact that in different articles the location with the same coordinates on the maps shown is once at the mouth of the Sajó, once at 20 km from Polgár, once at a height of Tiszafüred about 50 km to the south (Magyari 2011), other times on the right bank of the Tisza (Magyari 2010) or the left bank (Magyari et al. 2012), always as if the sites were closer to saline or steppe areas or the Polgár archaeological sites (Magyari et al. 2010).

Also, it should be noted that no pollen analysis work focused on the last 2000 years, including the age of the Hungarian conquest, except the Transylvanian project (2014-2018) led by the archaeologist *Elek Benkő*, the Transdanubian project (2012-2016) led by the archaeologist *Gyöngyi Kovács*, and the projects led by *Professor Pál Sümegi*: the Hungarian Environmental History project (2002-2006), the Tóköz project (2004-2008) and the Bodrogköz project (2006-2009). This is tremendously true for the peripheral states of the Carpathian Basin and for the successor states that broke away from the Kingdom of Hungary, where after Trianon due to the inordinate education of history and the scientifical mindset, this whole historical issue has been and is treated as a political issue. It is no coincidence that the first correct pollen data for the age of the Hungarian conquest comes from the work of a Hungarian-British project (1993-1996) (Willis et al. 1998, Sümegi 1998, 2000). With this work, we wish to continue the journey begun in 1993 with the support of the British Council - OMFB, including the pioneering work of Professor Katherine Jane Willis from Oxford, honouring her achievements, which set the new ground for pollen research in Hungary and produced internationally valuable results since the mid-1990s.

Results

For the last 1500-1600 years of the 137 pollen sites, the following findings regarding the distribution of Cerealia pollen were made. We chose to present the spatial and temporal distribution of the dominance (proportion) of pollen in cereals because it is one of the best indicators of human activity, the existence of a farming community, and the number of farming communities in the area. The temporal resolution has reached a decade resolution in about 50 sections, but for most sections, sampling and processing have resulted in calibrated timelines, with a margin of error of 60-100 years. Thus, we only discussed pollen data for the entire basin for the last 1500-1600 years in a centennial resolution (Sümegi et al. 2016). Before our National Science Fund application launched in 2002, we did not produce a map series based on the change in pollen ratio based on such a database, as we did not have any adequate sections with radiocarbon data. Thus, there was no dated pollen database available which we could compare to in Hungary or abroad in 2002. However, we have already developed a considerable number of first comparative databases on the Mesolithic and Neolithic for the beginning of the Holocene (Sümegi 1996, 1998, 1999, 2004, 2005, 2007, 2011).

IV-Vth century (350–450 cal AD) (Fig. 2.)

The proportion of cereal pollen in Transdanubia, on the Danube Great Hungarian Plain, above all in the Danube Valley, is more than 2%. In the Tisza Valley, the foreground of the Northern Carpathians, the dominance of cereals decreased sharply towards the Subcarpathian region, although in the Tisza Valley and in the Southern Great Hungarian Plain there was still a relatively large proportion of cereals, but in the North-eastern Great Hungarian Plain, in the high and middle mountains, there was a minimum cereal dominance of less than 0.5% (**Fig. 2.**).

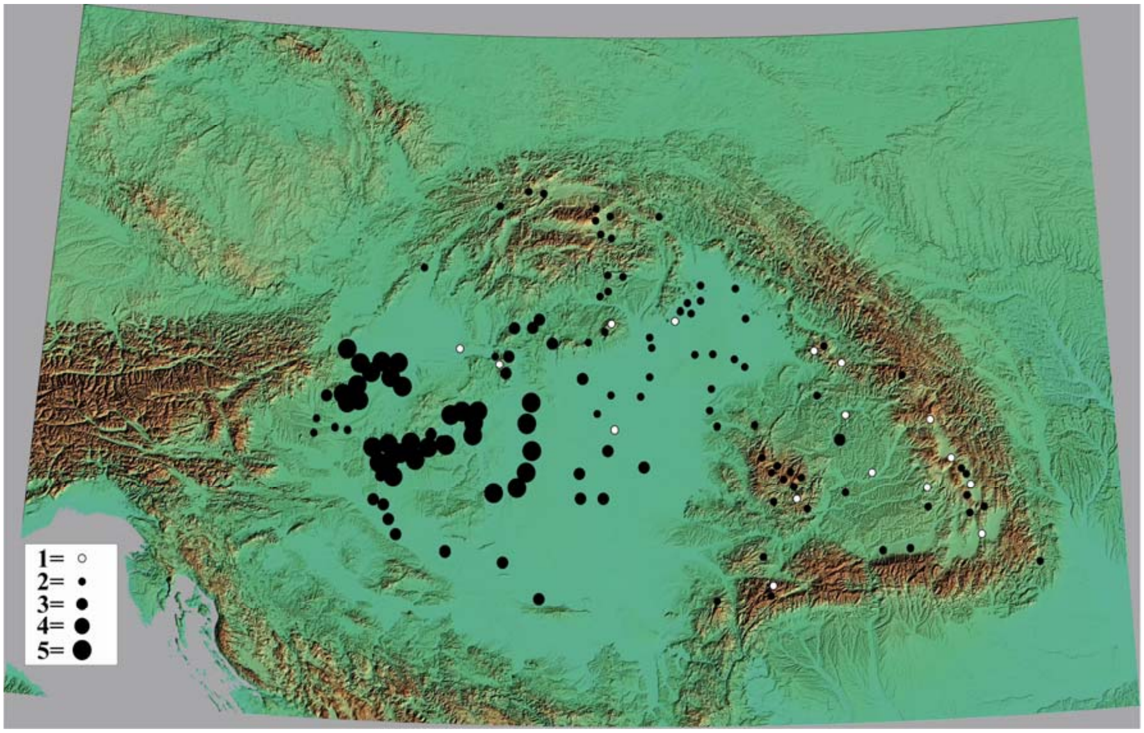

Fig. 2.: Cerealia's summa pollen dominance from different pollen sites in the Carpathian Basin during the transition time of IV/V centuries AD (350 – 450 AD years)

1 = there is no data or dominance of Cerelia = 0 %, 2 = dominance of Cerealia between 0.0 and 0.5 %, 3 = dominance of Cerealia between 0.5 and 1.0 %, 4 = dominance of Cerealia between 1.0 and 2.0 %, 5 = dominance of Cerealia between 2.0 and 4.0 %

2. ábra: A gabona (cerealia) pollenek összdominanciájának változása a pollenszelvényekben a Kárpát-medencében a Krisztus utáni IV/V. század fordulóján

1 = nincs az adott korra vonatkozó adat, vagy a *Cerealia* dominancia = 0 %, 2 = A *Cerealia* dominancia 0,0 és 0,5 % közötti, 3 = A *Cerealia* dominancia 0,5 és 1,0 % közötti, 4 = A *Cerealia* dominancia 1,0 és 2,0 % közötti, 5 = A *Cerealia* dominancia 2,0 és 4,0 % közötti,

The same value was observed in the Drava valley and throughout Transylvania, except in the Mezőség, where a greater cereal pollen dominance was observed. As a result, we can count on a more settled human community and farming in Transdanubia, in the Great Hungarian Plain region of the Danube Valley and in the Mezőség region during this period. As a result, the proportion of crop production communities was minimal in the eastern half of the Carpathian Basin, in the vast majority of the Great Hungarian Plain and Transylvania. In these areas, livestock grazing may have dominated during this period and/or have a low population density during the first century of the Migration period.

V-VIth century (450–550 cal AD) (Fig. 3.)

The proportion of cereal pollens decreased in the whole basin, but in Transdanubia, above all, in the Keszthely culture (Sümegi et al. 2009a, 2011), the proportion of cereal pollens remained significant, and in the Prealpine region it remained relatively significant (**Fig. 3.**). In the North Hungarian Mountains, in the Great Hungarian Plain and the Tisza Valley, relatively steady low levels of cereal pollen dominance occurred. However, in Transylvania, in the Northern Carpathians, in the North-eastern Great Hungarian Plain, wholly subordinate cereal pollen dominance occurred during this period. In the wake of pollen dominance, we have to reckon with the remains of the ancient imperial cultures, the communities with antique cultivation experience and the ability to pass it on, and the scattering of them in the western part of Transdanubia (Sümegi et al. 2009a, 2011). In the western part of the North Hungarian Mountains, in isolation in the Subcarpathian region, the percentage of cereal pollen increased minimally. In this area, marked by Quadi and Marcomanni settlements in earlier Roman sources, a local population increase can be reconstructed in the V-VIth century. Of course, based on these scientific data, it is impossible to tell who lived in this Subcarpathian region during this century.

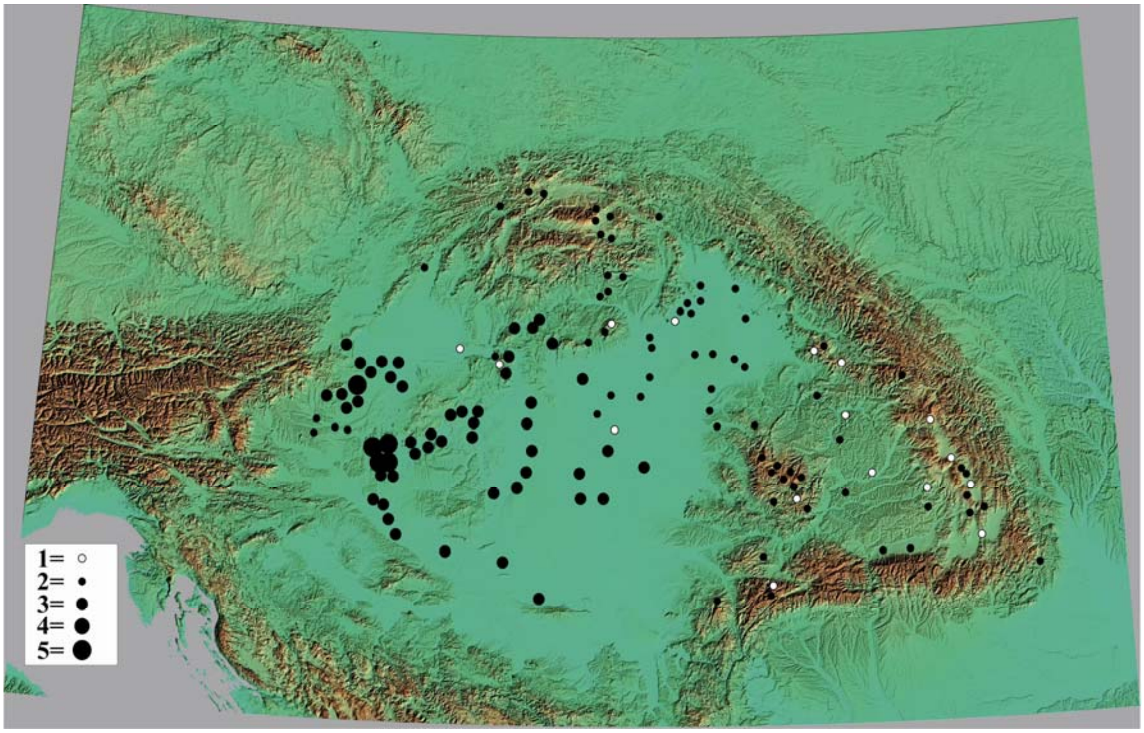

Fig. 3.: Cerealia's summa pollen dominance from different pollen sites in the Carpathian Basin during the transition time of V/VIth centuries AD (450 – 550 AD years)

(For distribution vakues, see Fig. 2 – also for Figs. 4-14)

3. ábra: A gabona (cerealia) pollenek összdominanciájának változása a pollenszelvényekben a Kárpát-medencében a Krisztus utáni V/VI. század fordulóján

(A mennyiségi adatok jelkulcsának feloldásához ld. a 2 ábrát, amelyet a továbbialban (4-14 ábra) következetesern használunk

However, archaeological and possibly historical sources reveal, or at least make probable, which community's activity resulted in this increase in relative cereal pollen ratio due to more intensive farming (**Fig. 3.**).

VI-VIIth century (550–650 cal AD) (Fig. 4.)

The proportion of cereal pollen in pollen deposits continued to decline throughout the basin, with relatively balanced low-level cereal production. At the same time, lower pollen dominance can be observed in the Balaton region, in the Prealpine region and the southern Great Hungarian Plain, both in the Tisza and the Danube valleys (**Fig. 4.**). As a result, it appeared as if there was no longer a centre, but more independent territorial development at the end of the VIth century in the Carpathian Basin, which was fully occupied by the Avars at the beginning of the VIIth century. Based on the distribution of cereal pollen, a cultivation centre was established in the Danube-Tisza region, near Lake Balaton and in the Little Hungarian Plain – Prealpine region (**Fig. 4.**). It cannot be ruled out that these pollen cultivation centres were already developed in the Avar Empire and were linked to the process of decentralization, culminating in the middle of the VIIIth century. (Curta 2006; Preiser-Kapler 2018).

VII-VIIIth century (650–750 cal AD) (Fig. 5.)

Based on the distribution of cereal pollen, a cultivation centre was established in the southern part of the Danube-Tisza region, in the southern part of the Lake Balaton and in the region of the Little Hungarian Plain (**Fig. 5.**). Compared to the previous century, cultivation centres based on pollen proportions have continued to evolve based on the proportion of cereal pollen, and these processes were already clearly linked to the process of decentralization in the Avar Empire culminating in the mid-VIIIth century (Pohl 1988; Curta 2006; Preiser-Kapler 2018). The increase in the proportion of cereal pollen in eastern Transylvania is particularly noticeable (**Fig. 5.**).

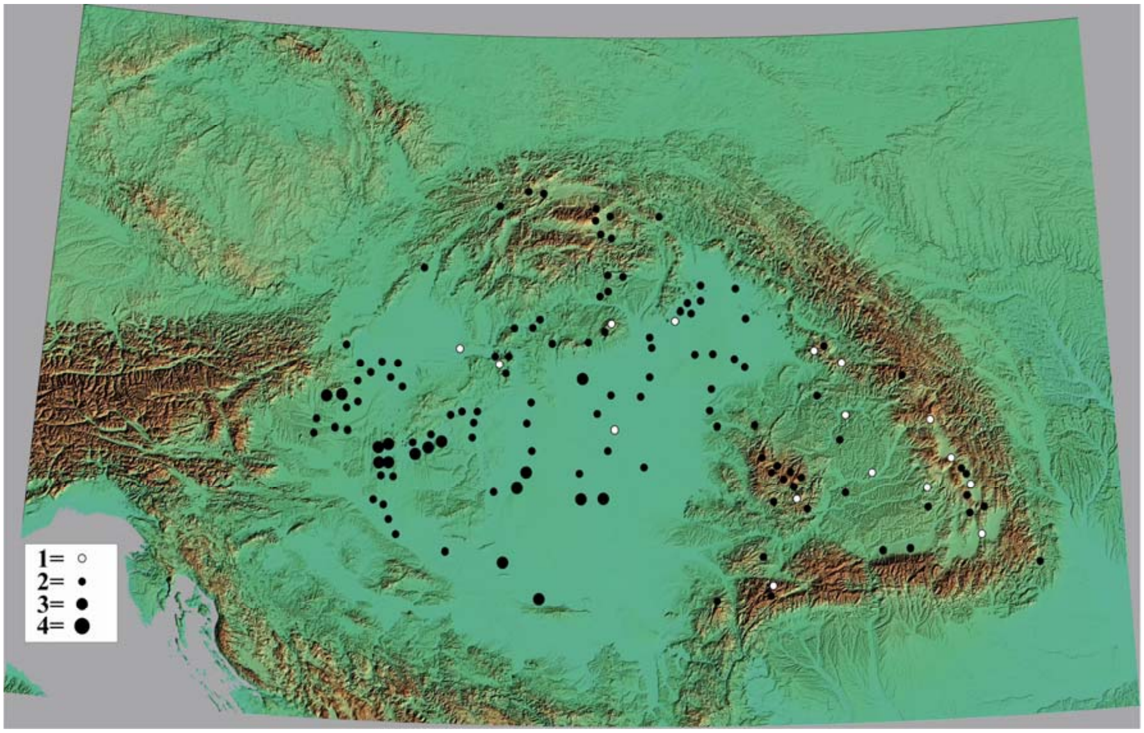

Fig. 4.: Cerealia's summa pollen dominance from different pollen sites in the Carpathian Basin during the transition time of VI/VIIth centuries AD (550 – 650 AD years)

4. ábra: A gabona (cerealia) pollenek összdominanciájának változása a pollenszelvényekben a Kárpát-medencében a Krisztus utáni VI/VII. század fordulóján

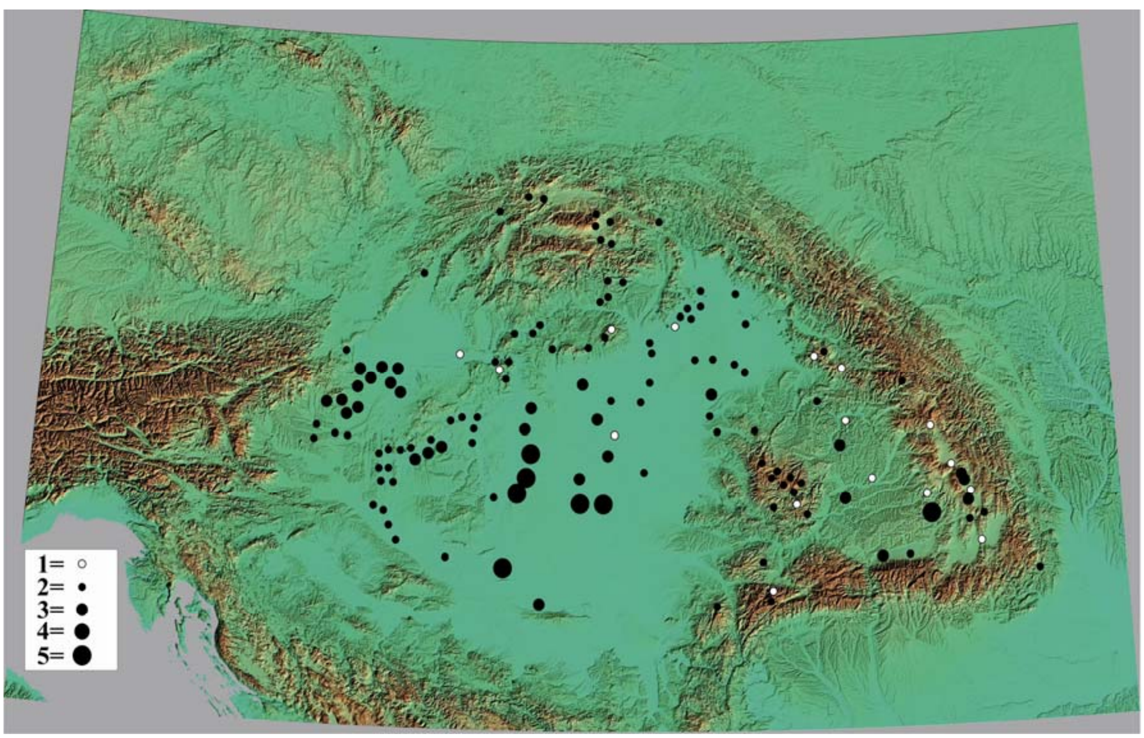

Fig. 5.: Cerealia's summa pollen dominance from different pollen sites in the Carpathian Basin during the transition time of VII/VIIIth centuries AD (650 – 750 AD years)

5. ábra: A gabona (cerealia) pollenek összdominanciájának változása a pollenszelvényekben a Kárpát-medencében a Krisztus utáni VII/VIII. század fordulóján

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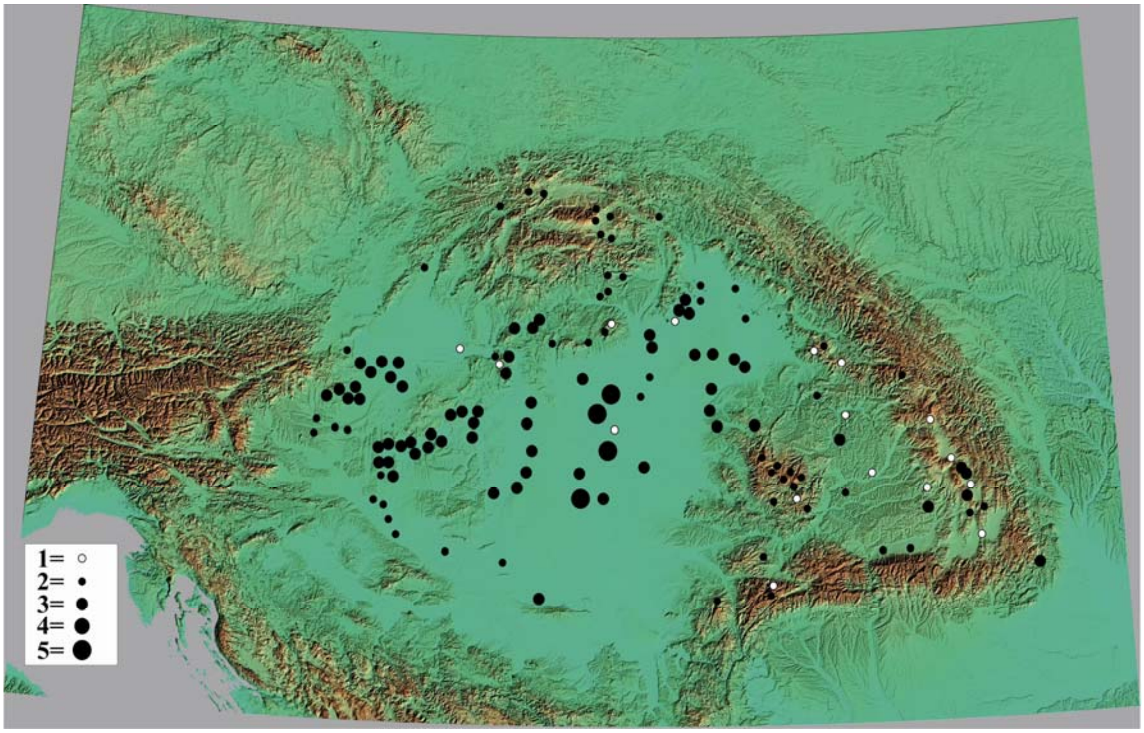

Fig. 6.: Cerealia's summa pollen dominance from different pollen sites in the Carpathian Basin during the transition time of VIII/IXth centuries AD (750 – 850 AD years)

6. ábra: A gabona (cerealia) pollenek összdominanciájának változása a pollenszelvényekben a Kárpát-medencében a Krisztus utáni VIII/IX. század fordulóján

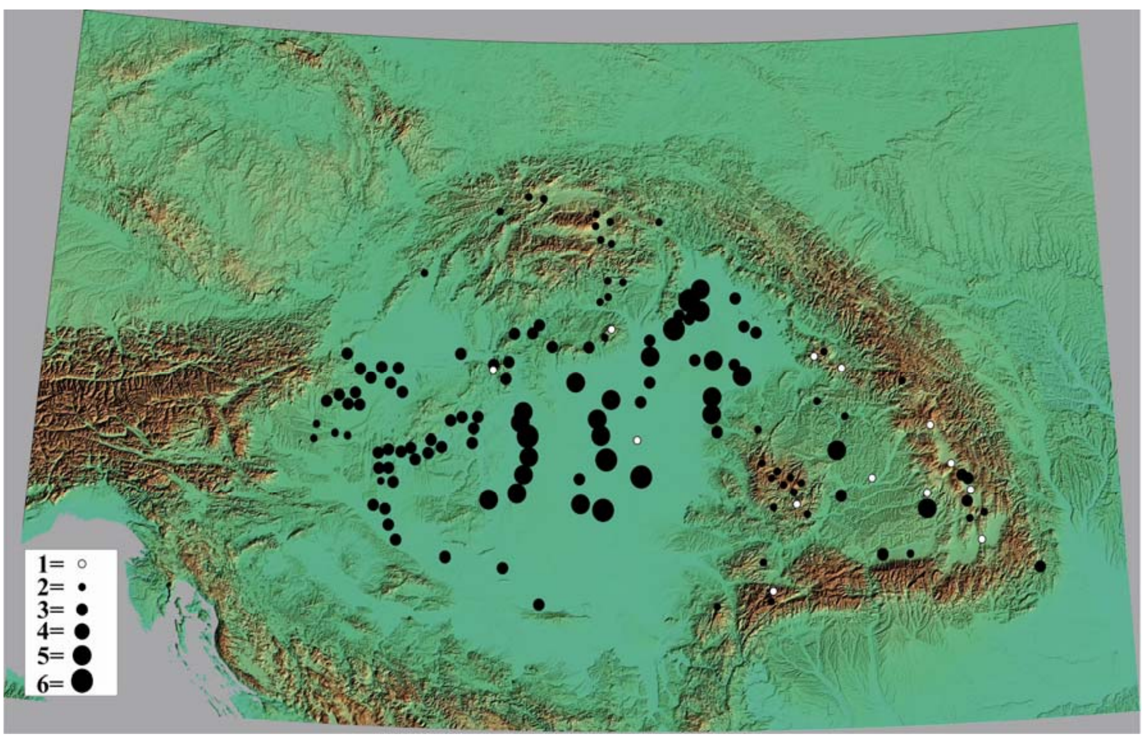

Fig. 7.: Cerealia's summa pollen dominance from different pollen sites in the Carpathian Basin during the transition time of IX/Xth centuries AD (850 – 950 AD years)

7. ábra: A gabona (cerealia) pollenek összdominanciájának változása a pollenszelvényekben a Kárpát-medencében a Krisztus utáni IX/X. század fordulóján

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As a result, we have been able to reconstruct the existence of a major community of farmers in this area. It seems that agriculture has come to the forefront in diffuse centres and around them during the driest period (or perhaps just after the dry period) of the VIIth and VIIIth centuries (Preiser-Kapler 2017, 2018). In our opinion, the multi-centre distribution of cereal pollens within the Avar Empire, which dominated the entire Carpathian Basin, is like the development of polycentric metallurgy (Diam 2000, 2003) and could have been linked to the process of social decentralization. (Pohl 1988; Curta 2006; Preiser-Kapler 2018). At the same time, it is also clear that the most significant pollen ratios were found in the central part of the Great Hungarian Plain, in the Danube-Tisza Interfluve, in the southern part of the Great Hungarian Plain and in the eastern part of Transylvania. As a result, a larger farming community and a larger population are expected in these areas during the Late Avar period.

VIII-IXth century (750–850 cal AD) (Fig. 6.)

The percentage of cereals in the sites and their dominance at the turn of the VIII-IXth century showed minimal grain production in the high mountains, in the higher Carpathian regions, in the Upper Tisza Region, in Hortobágy, in the southern part of the Transylvanian Basin, in the Drava Valley, in the Upper Tisza region (**Fig. 6.**). It is likely that there was no actual cereal production in these areas during this period, but that a minimum cereal dominance of less than 0.5% may have resulted from sediment supply from remote areas. The same low dominance of remote supply occurs in most of the middle mountain zone, even in regions considered by many historians as a settlement zone for Slavic farming (Bartha 1984; Fridvalszky 2014). In contrast to these areas characterized by a minimum amount of cereal pollen, the most significant cereal pollen ratio (above 2%) was formed in the Tisza Valley in its central and southern parts (**Fig. 6.**). Also, in the Danube Valley, in the Little Hungarian Plain, in the southern shore of Lake Balaton, in Nyírség and in the Csík Basin, a relatively significant 1-2% of cereal pollen was formed. We can infer the presence of a significant farming population at the turn of the VIII-IXth century in the Tisza valley, generally in the Great Hungarian Plain, in the southern shore of Lake Balaton, in the Little Hungarian Plain, the gravel cover of Western Hungary and the Csík Basin. As a result, in these areas, we can count on a significant population of cultivated farmers in the VIIIth century, at the end of the IXth century, at the time of the collapse of the Avar Empire.

It is striking that the highest proportion of cereal pollen was found in one of the driest parts of the Great Hungarian Plain in the eco-region developed in the central and southern part of the Tisza Valley. Even these data are in complete contradiction with the uncontrolled dehydration hypothesis (Rácz 1993, 2008; Győrffy and Zólyomi, 1994), which they sought to substantiate with no specific chronological data (Jakab et al. 2009, 2010) and clearly demonstrate that the collapse of the Avar Empire requires the study of complex socio-economic processes (Diam 2000, 2003; Curta 2006; Pohl 2015; Preiser-Kapler 2016, 2018), rather than the one-sided and one-factor disaster theory focusing on dehydration (Sümegi et al. 2009b, 2016b; Sümegi 2011).

IX-Xth century (850–950 cal AD) (Fig. 7.)

At the turn of the IX-Xth century, precisely in the second half of the IXth century and in the first half of the Xth century, this cereal pollen aspect ratio changed significantly (**Fig. 7.**). In the Upper Tisza Region, in the Nyírség, in the Tisza and Danube valleys, in several parts of the Transylvanian Basin, the proportion of cereal pollen developed between 2 and 3%. In Transdanubia, the proportion of cereal pollen was lower than that of the former, relatively significant area, but lower than the Great Hungarian Plain, but it was even to the Drava Valley, to the north and west peripheries.

This clearly shows that at the turn of the IX-Xth century, pollen data showed a significant increase in an east-west direction in agriculture and grain production, especially in the Upper Tisza region. Based on a factor independent of these historical sources, at the turn of the IX-Xth century, significant arable farming and grain cultivating community settled in the Great Hungarian Plain, primarily in the Upper Tisza region, in the Tisza Valley, in the Danube Valley, and in Transylvania (**Fig. 7.**).

Of course, these data do not allow us to infer the origin of the settled farmer and grain cultivating communities. However, it is true that in the age of the Hungarian conquest and at the turn of the IX-Xth century, the proportion of cereal pollen, which refers to cultivation and grain cultivating, has increased significantly in the Great Plain, especially in its north-eastern region and in several places in Transylvania. As a result, significant agricultural populations may have arrived in the basin during the Hungarian conquest, and the Hungarian leaders could have reorganized the activities of the peoples living there, and based on the location of pollen data sections, most of the basin was occupied and cultivated at least up to 600 meters above sea level by them.

Our pollen data confirm the archaeobotanical and pollen data of Gyulai (1994), Willis et al. (1998), and Sümegi (1998, 2000) on crop production during the Hungarian conquest. It also confirms the archaeological and ethnographic data of Balassa

(1973, 1994) and Müller (1992, 2000) on agriculture during the Hungarian conquest. Especially the findings of crop production, first of all, cereal production from archaeological sites of the Hungarian conquest period (Sági & Füzes 1967; Hartyányi et al. 1968, 1974; Hartyányi 1983; Gyulai 1994, 2001, 2010) are of great importance because they provide decisive evidence for crop production during the Hungarian conquest.

According to pollen data, rye (*Secale*), wheat (*Triticum* type), barley (*Hordeum* type) were present among the cultivated cereals of Hungarians during the Hungarian conquest. This is also supported by plant remains from archaeological sites dating back to the Hungarian conquest (Gyulai 1994, 2001, 2010). Millet remains have been found among archaeobotanical finds, but we cannot provide pollen data for this. Our pollen results indicate the presence of a significant cereal grower and farmer population during the Hungarian conquest period and, also, a significant population increase over the last century in the Carpathian Basin, but above all in the Great Hungarian Plain and the Transylvanian Basin (**Fig. 7.**). Pollen data clearly support the ideas of Bálint (1989) on the establishment of farmer and agricultural communities during the Hungarian conquest and the inclusion of areas suitable for agricultural production and soil types.

X-XIth century (950 – 1050 cal AD) (Fig. 8.)

At the turn of the X-XIth century (**Fig. 8.**) the proportion of cereal pollen changed in Transdanubia, and the same proportion of cereal pollen was found in the Little Hungarian Plain, in the .Prealpine region, in the Balaton region, in the Mezőföld and the Drava valley like in the Great Hungarian Plain and Transylvania. The higher proportion of cereal pollen that was present in the eastern half of the Carpathian Basin, in the Great Plain and the Transylvanian Basin at the turn of the IX-Xth centuries now extended to the western half of the basin, and consequently the farming communities and their way of life were evenly distributed throughout the basin. Due to the uniformly significant proportion of cereal pollen covering the whole Carpathian Basin, we can expect a uniformly high population density throughout the basin (**Fig. 8.**).

The processes revealed during the Hungarian conquest extended to the entire basin during this century. It is of great importance for our environmental history studies that due to the significant share of cereal pollen in Transylvania and Székely Land, we can expect a significant population and significant cultivation during the formation of the medieval Hungarian Kingdom (**Fig. 8.**). The proportion of cereal pollen also increased significantly in the middle mountain region, which resulted in the further development of the middle mountain farming system established during the Hungarian conquest, and the development of agricultural activities in the upper middle mountain region. The extremely subordinate background cereal pollen supply rate remained only in the high-altitude region.

XI-XIIth century (1050–1150 cal AD) (Fig. 9.)

At the turn of the XI-XIIth century (**Fig. 9.**), the proportion of cereal pollen increased uniformly throughout the basin. Even in the valleys of the high mountains, in the higher zones of the middle mountains, the proportion of cereal pollens increased significantly (**Fig. 9.**). Throughout the Carpathian Basin, this pollen composition and spatial pattern of cereal pollen may have resulted in a significant population increase and the emergence of agriculture. Except for areas and regions with the least suitable and fertile soil (pebble or acidic peat covered) for cultivation, there was a significant increase in the percentage of cereal pollen.

By the turn of the XI-XIIth century, the entire agricultural and settlement system had developed in the Kingdom of Hungary, extending to the edge of the high mountains (**Fig. 9.**). Based on these data, a consistent and significant population has been formed throughout the Carpathian Basin, and these data may indicate the functioning of a central leadership with proper governance mechanisms.

XII-XIIIth century (1150–1250 cal AD) (Fig. 10.)

At the turn of the XII-XIIIth century, the proportion of cereal pollens changed dramatically (**Fig. 10.**). In Transtisza, in the Upper Tisza Region and the Tisza Valley, the proportion of cereal pollen decreased significantly despite the excellent and appropriate soil conditions. In the rest of the Carpathian Basin, the proportion of cereal pollen did not change significantly compared to the previous century, moreover in the middle mountain region, in protected areas like Transylvanian Basin, Székely Land, Lake Balaton, Sárrét region, the amount of cereal pollen dominance even increased (**Fig. 10.**). Due to the centennial resolution, it is not possible to decide whether the change of the system of estates or as a result of the Mongol invasion of Europe, the dominance of cereal pollen has changed compared to the previous century. Whatever change caused the transformation, agriculture and grain production in the Tisza region changed the most, and in the Tisza Valley, neither the population density nor the cultivation focused on grain production fall back in the rest of the basin. If the Mongol invasion of Europe altered the spatial distribution of the pollen dominance of the grain, the most significant losses occurred in the Transtisza and the Tisza valley.

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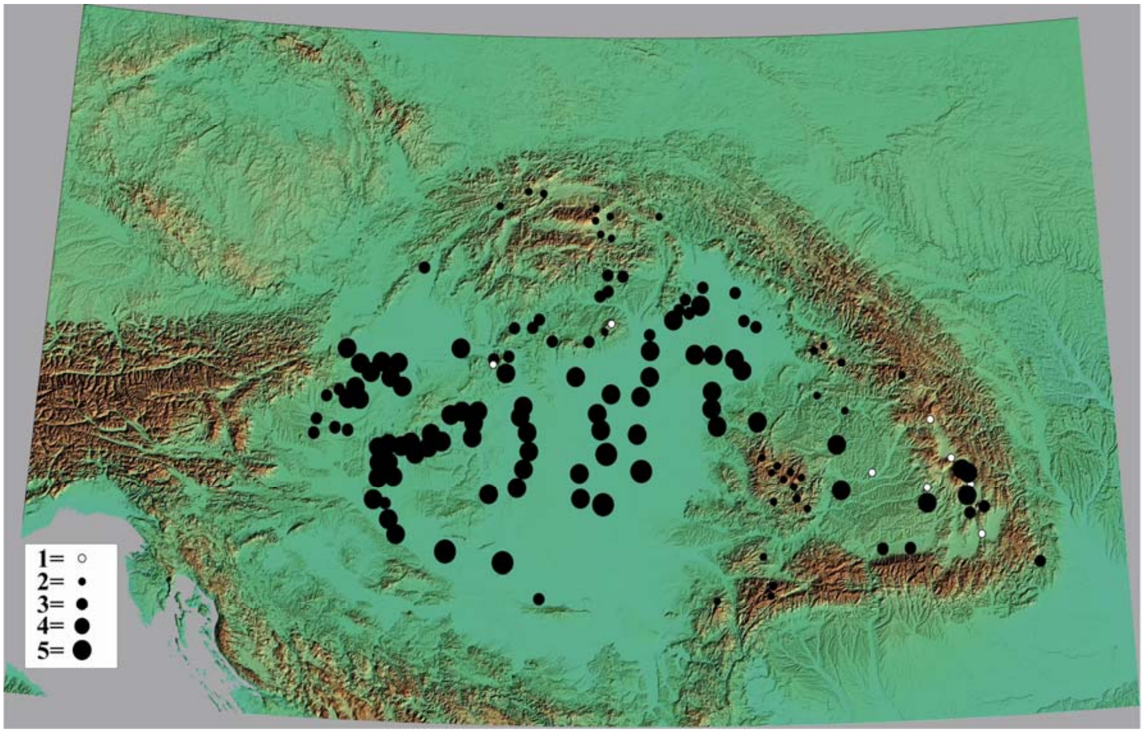

Fig. 8.: Cerealia's summa pollen dominance from different pollen sites in the Carpathian Basin during the transition time of X/XIth centuries AD (950 – 1050 AD years)

8. ábra: A gabona (cerealia) pollenek összdominanciájának változása a pollenszelvényekben a Kárpát-medencében a Krisztus utáni X/XI. század fordulóján

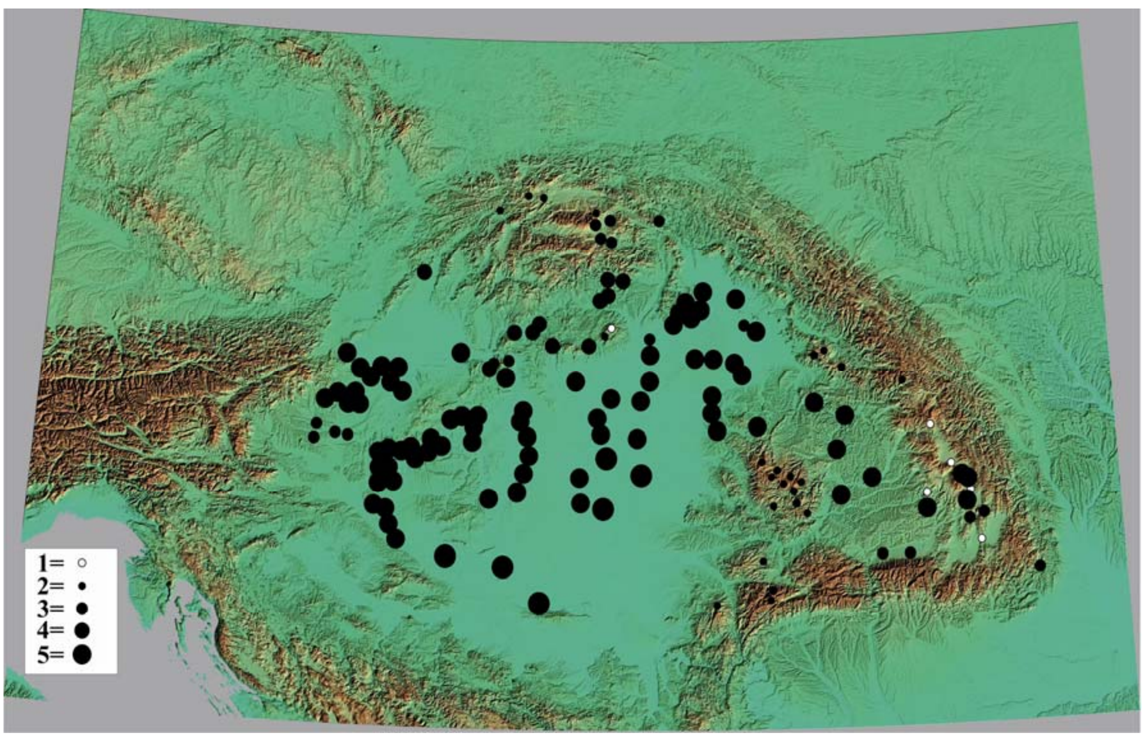

Fig. 9.: Cerealia's summa pollen dominance from different pollen sites in the Carpathian Basin during the transition time of XI/XIIth centuries AD (1050 – 1150 AD years)

9. ábra: A gabona (cerealia) pollenek összdominanciájának változása a pollenszelvényekben a Kárpát-medencében a Krisztus utáni XI/XII. század fordulóján

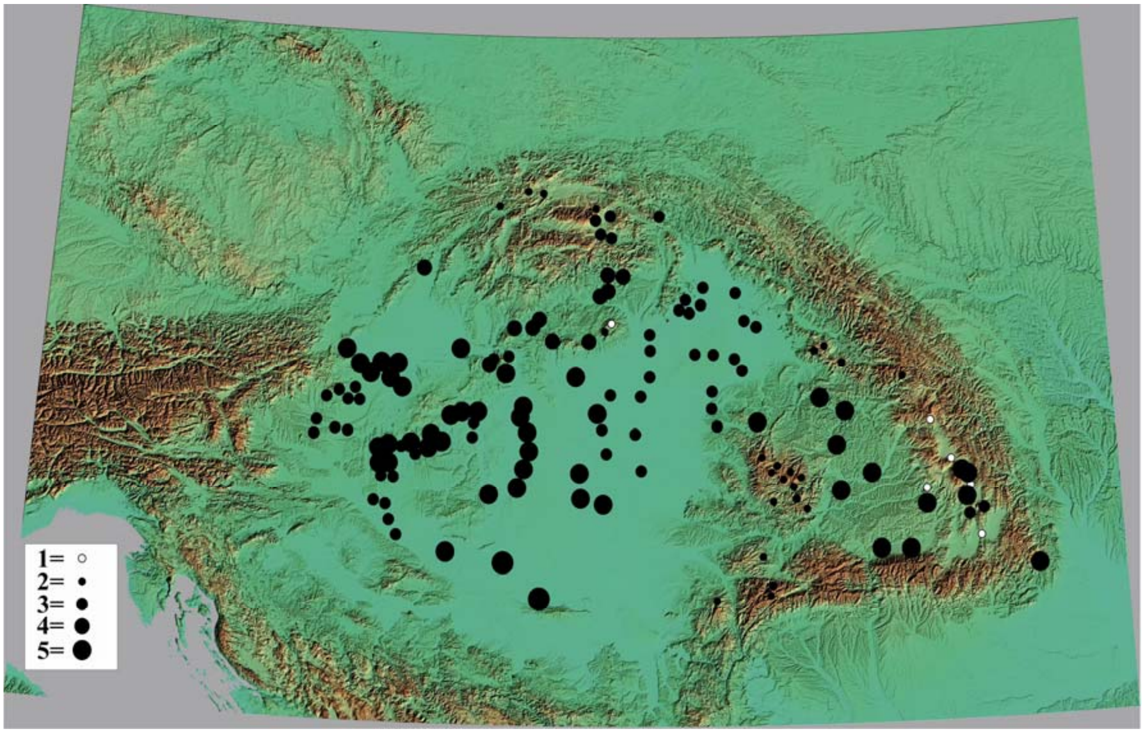

Fig. 10.: Cerealia's summa pollen dominance from different pollen sites in the Carpathian Basin during the transition time of XII/XIIIth centuries AD (1150 – 1250 AD years)

10. ábra: A gabona (cerealia) pollenek összdominanciájának változása a pollenszelvényekben a Kárpát-medencében a Krisztus utáni XII/XIII. század fordulóján

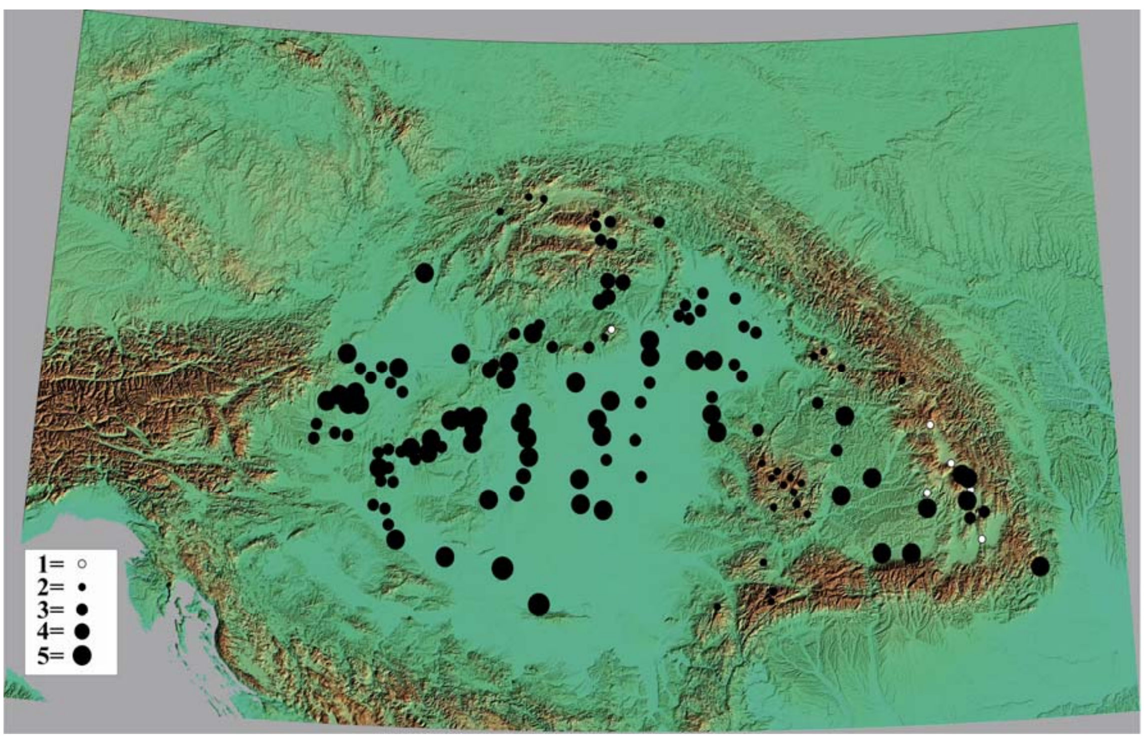

Fig. 11.: Cerealia's summa pollen dominance from different pollen sites in the Carpathian Basin during the transition time of XIII/XIVth centuries AD (1250 – 1350 AD years)

11. ábra: A gabona (cerealia) pollenek összdominanciájának változása a pollenszelvényekben a Kárpát-medencében a Krisztus utáni XIII/XIV. század fordulóján

In other areas, either the decline in population or the replacement of the population was not as forceful, and the immigration of the population took place much faster after the Mongol invasion of Europe than in the centre and eastern part of the Great Hungarian Plain.

XIII-XIVth century (1250–1350 cal AD) (Fig. 11.)

At the turn of the XIII-XIVth century, the proportion of cereal pollens again changed dramatically (**Fig. 11.**). In the middle section of the Tisza valley, the pollen ratio increased sharply, but in the Transtisza region, above all in the Upper Tisza region, it did not return to the typical dominant cereal pollen values of the XI-XIIth century. There is also a substantial decline in the river valleys, the Drava valley, the upper and lower part of the Rába, along the Körös rivers, in the Upper Tisza Region, and on the Danube part of the Great Hungarian Plain. Several more hypotheses can be assumed based on these cereal pollen changes, but each requires further investigation or analysis of historical sources. At the same time, based on earlier assumptions and recent surface morphological analyses modelling, though not tested, water history and climate history data (Réthly 1963, 1970, 1998-1999; Bodor et al. 2008; Rácz 2009, 2011; Pinke et al. 2016, 2017) in the Tisza river, in the Körös valley, and possibly in other river valleys, such as the valleys of the Rába, Danube and Drava rivers, arable land was flooded due to the significant rainfall during this period. As a result of these climate changes, environmental changes have led to a shift from arable farming and grain cultivating to meadow and pasture farming in several areas, leading to a reduction in cereal pollen rates in this region, particularly in river valleys. This seems to be supported by the stronger dominance of cereal pollen at the pollen sites in higher altitudes during this period (**Fig. 11.**). However, given the problem of single-factor environmental history approaches (Popper 1962, 1972, 2005; Birks & Birks, 1980), there are several factors that need to be considered in the context of these changes. Thus, it is also necessary to include the social processes according to which early town and market town development may have started during this period (Major 1966; Kubinyi, 1971, 1996, 2000; Benkő, 1997). It cannot be ruled out that the two processes evolved in parallel and caused the transformation of agriculture in the indicated areas and pushed the cereal production into the background, but these data must be evaluated together with the archaeozoological data for each region (Matolcsi 1973, 1982; Bökönyi 1974, 1978, 1994; Red 1983; Bartosiewicz 2006). It is only through these science-based multiproxy data and studies, as well as historical and medieval archaeological analyses of the individual areas that we can determine what role these processes, or a combination of these, or other social, natural processes, may have been played in these spatial changes in the cereal pollen ratio at the turn of the XIII-XIVth century.

XIV-XVth century (1350–1450 cal AD) (Fig. 12.)

The trends from the turn of the XIII-XIVth century continued with minor changes at the turn of the XVI-XVth century. However, it should be borne in mind that between the XIV-XVth century, the overlap is quite significant based on radiocarbon studies, even with the most advanced special AMS (TAM) analyses (Molnár et al. 2013), which has only a minimal physical measurement margin of error. This chronological overlap was mainly found in the places where the devastation associated with the Ottoman occupation in the XVIth century has left visible traces (for example, the sediment section of the oxbow lake located near the ruined medieval market town of Decs-Ete: Sümegi et al. 2016). As a result, the XVth century horizon before the level of destruction could be separated by a combination of stratification and chronological methods.

Even with this distinction, we must be aware that during the XIV-XVth century, the typical settlement of historical Hungary, including the town and market town development, was the most critical social trend which controlled the economy, agriculture, and farming (Major 1966; Kubinyi 1971, 1996, 2000; Benkő 1997). It would be essential to analyse this time horizon since, from this end of the Middle Ages, there is already considerable written material available (Szabó 1969). Thus, comparative analysis of environmental history and written materials would represent a significant step forward in modelling the development of economic space. Namely, based on pollen analyses at the borders of market towns and larger marketplaces (centres), the Thünen economic circle structure (Thünen 1826) typical of medieval towns, has already been established in the Kingdom of Hungary (Sümegi et al. 2016). However, as a result of the mosaic environment and the development of the marketplace associated with river valleys and crossings, the economic space around the central location is made up of mosaics known from fractal geometry instead of mosaics known as elongated and non-homogeneous bands (Sümegi 1996; Sümegi in Raczky et al. 2010; Sümegi et al. 2012, 2013). As a result, many elements of the natural environment have likely survived in the economic space around towns and market towns, meaning that the economic space was not homogeneous. All these processes are probably reflected in the spatial distribution of the pollen ratio of the cereals plotted on the pollen database (**Fig. 12.**).

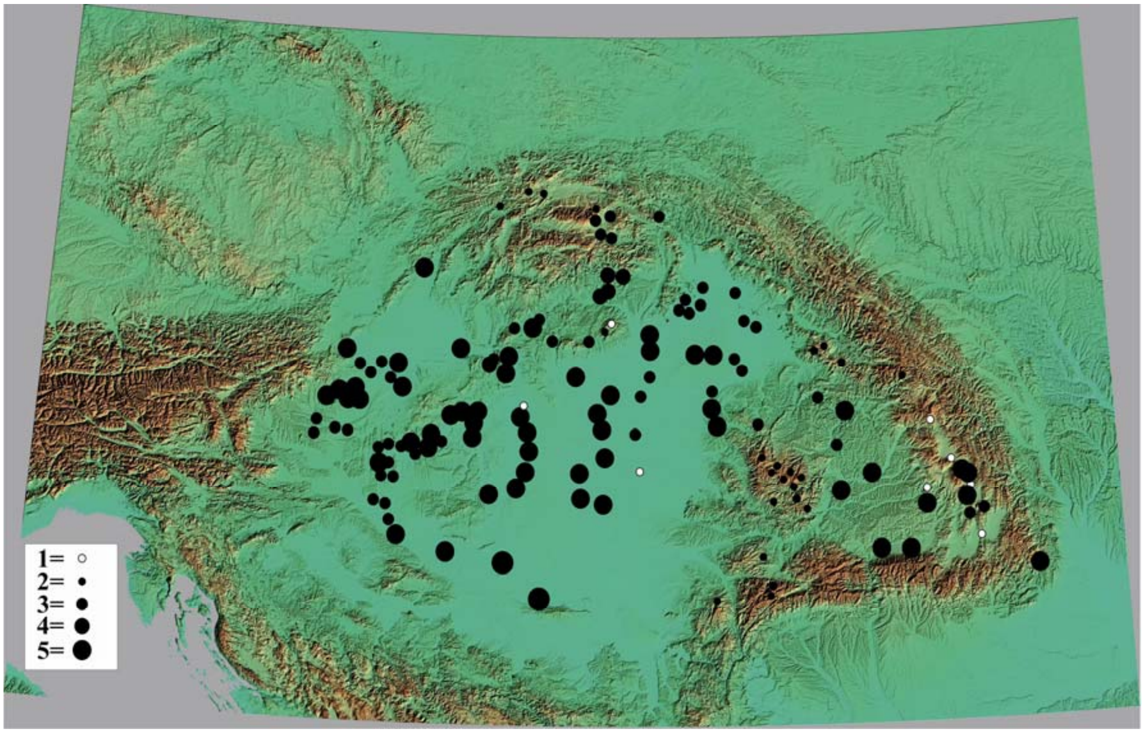

Fig. 12.: Cerealia's summa pollen dominance from different pollen sites in the Carpathian Basin during the transition time of XIV/XVth centuries AD (1350 – 1450 AD years)

12. ábra: A gabona (cerealia) pollenek összdominanciájának változása a pollenszelvényekben a Kárpát-medencében a Krisztus utáni XIV/XV. század fordulóján

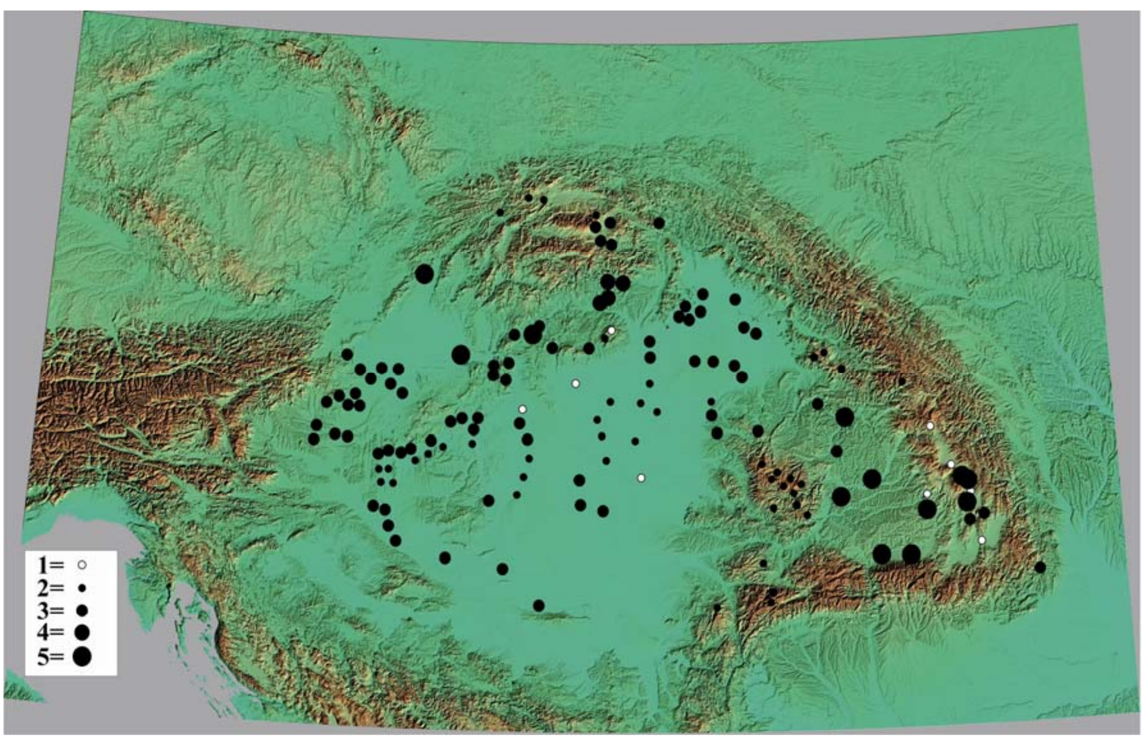

Fig.13.: Cerealia's summa pollen dominance from different pollen sites in the Carpathian Basin during the transition time of XV/XVIth centuries AD (1450 – 1550 AD years)

13. ábra: A gabona (cerealia) pollenek összdominanciájának változása a pollenszelvényekben a Kárpát-medencében a Krisztus utáni XV/XVI. század fordulóján

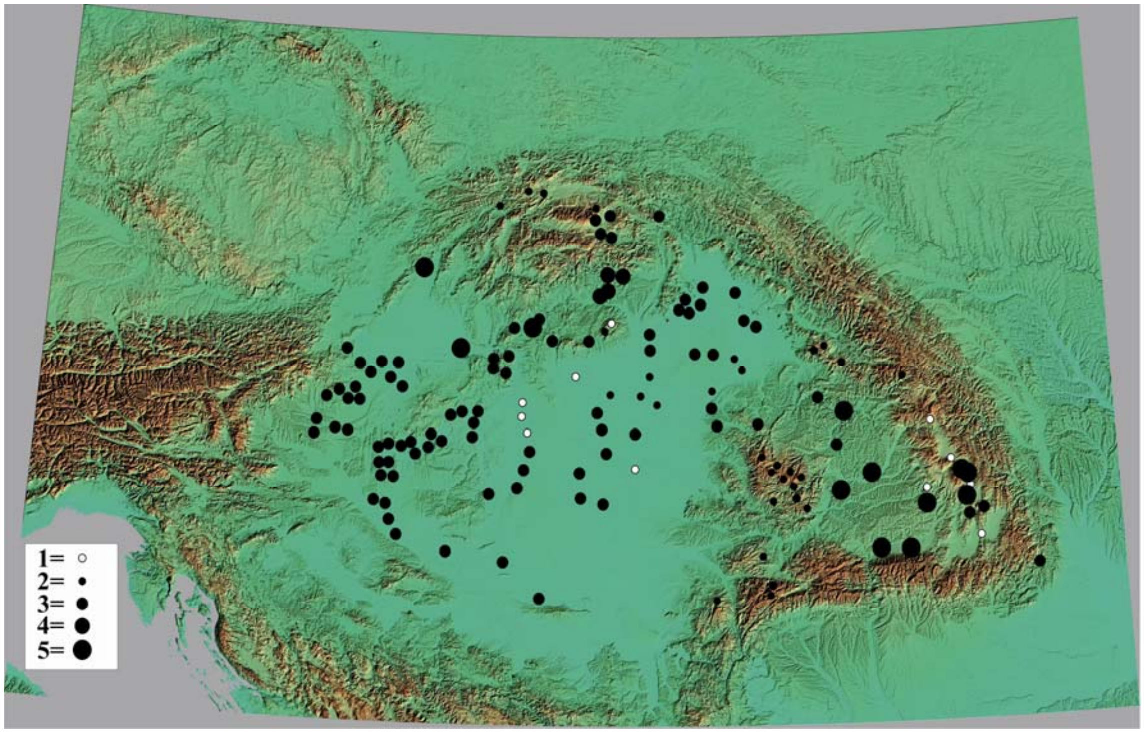

Fig. 14.: Cerealia's summa pollen dominance from different pollen sites in the Carpathian Basin during the transition time of XVI/XVIIth centuries AD (1550 – 1650 AD years)

14. ábra: A gabona (cerealia) pollenek összdominanciájának változása a pollenszelvényekben a Kárpát-medencében a Krisztus utáni XVI/XVII. század fordulóján

Still, for these, more in-depth analyses of the relationship between settlements and pollen sites need to be explored and discussed in detail.

XV-XVIth century (1450–1550 cal AD) (Fig. 13.)

The proportion of cereal pollen in the southern and central basin, but even in the Little Hungarian Plain and the .Prealpine region decreased drastically during this period from 1450 to 1550 (**Fig. 13.**). It only endured to a significant extent in the Transylvanian parts and the middle mountains. At the same time, it should be pointed out that due to the margin of error of radiocarbon measurements, it is extremely difficult to make a centennial distinction at the end of the Middle Ages. We have to take into account that between the XVth and XVIth centuries, as between the XIVth and XVth centuries, the overlap is quite significant based on radiocarbon studies, even with the most modern AMS (TAM) analyzes with minimal physical measurement margin (Molnár et al. 2013). This chronological overlap was found mainly in places where the destruction associated with the XVIth century Ottoman occupation left visible traces (Sümegi et al. 2019). Based on the level of destruction and historical sources, we were able to separate this horizon with a combination of stratigraphical and chronological methods. The other places were the lakes and bogs with significant biogenic and/or abiogenic accumulation, which allowed centennial or even decadal resolution (like the section in the castle lake of Pápa, Sümegi et al. 2019).

Most of the sections could not achieve such precise resolution, but pollen material can be evaluated on a centennial scale. Spatially differentiated grain pollen ratio decline is clear based on pollen material and is parallel with Polish pollen analysis and spatial evaluation, where in the XVth century similar spatial differences were found in grain pollen ratios and, consequently, in medieval grain production (Ralska-Jasiewiczowa 2004; Wacznik et al. 2016). There were several reasons for spatial differentiation and a decline in certain areas. It is presumed that the Ice Age (Rácz 1993, 2008; Grabnet et al. 2008; Wacznik et al. 2016), which has already evolved during this period, also affected the Carpathian Basin. The effect of the Ice Age may likely have varied spatially. For example, the average temperature in late summer decreased, and rainfall increased during the growing season. Their effect on crop production may have been particularly favourable in the southern part of the Carpathian Basin, on the loess plateaus with a total area of several thousand km^2 (Törőcsik & Sümegi 2018; Rácz 2019). However, the increased intensity and duration of floods during this period may have covered broader areas of deeper basins and lasted longer (Kiss 2011, 2012; Kiss & Laszlovszky 2013; Pinke et al. 2016, 2017). The effect of floods, which increased at the beginning of the Ice Age and increased in time and space, could thus occur in an area of 40-50,000 km^2 (Kiss 2011, 2012; Kiss & Laszlovszky 2013; Pinke et al. 2016, 2017). This is already a significant factor influencing grain production, and it is no coincidence that the decline mainly occurred in the basin-like areas, river valleys, except the flood plain islands, which have island-like features and have fertile soil features (Sümegi et al. 2005). At the same time, the decline in grain pollen ratios and the consequent decline in grain production do not allow us to infer the agricultural crisis in the Carpathian Basin at the end of the Middle Ages. These environmental conditions generated by the Ice Age may have been particularly favourable for the meadow, pasture and hay management that was already present at that time (Rácz 2019). Besides the natural factors, like the effect of the Little Ice Age, humans also had effects on grain production. For example, between 1450-1550, the Ottoman Empire annexed the Balkan-region and the Byzantine Empire and extended the wars, campaigns and robberies to the Carpathian Basin, which already had internal conflicts (Dózsa rebellion). Thus, the restructuring of production due to war uncertainties, the decline of farming, the spread of grazing, decreasing population density and declining numbers in headcount could all have contributed to the decline in grain pollen ratios. However, these factors do not explain, for example, the decline in grain production in the Little Hungarian Plain. As a result, the reduction in grain pollen ratio between 1450 and 1550, which is spatially differentiated but can be detected in basin areas, is mainly due to changes in natural factors, mostly the increase in flood intensity and duration (Kiss 2011, 2012; Kiss & Laszlovszky 2013; Pinke et al. 2016, 2017).

XVI-XVIIth century (1550–1650 cal AD) (Fig. 14.)

The trends from the turn of the XV-XVIth century continued with minor changes at the turn of the XVI-XVIIth century. However, it should be borne in mind that between the XVI-XVIIth century, the overlap is quite significant based on radiocarbon studies, even with the most advanced special AMS (TAM) analyses (Molnár et al. 2013), which has only a minimal physical measurement margin of error.

Thus, XVI. and XVII. centuries are difficult to distinguish from each other with radiocarbon studies, primarily since climate trends of the XVIth century and the consequent changes in agriculture were accomplished during the XVIIth century. In the XVIIth century, the annual average temperature decreased, with significant precipitation in almost all parts of the basin (Sümegi et al. 2009, 2014), but especially in the middle mountains and hills. Due to an increase in precipitation of about 50-100 mm/year and a decrease in the average temperature of 0.5-0.6 °C, several areas, especially lakes and marshlands, became wet and marshy and unsuitable for grain production (Sümegi et al. 2009a, 2009b, 2014).

At the same time, it is striking that during the Ottoman age and the coldest part of the Little Ice Age, it reached a golden age of viticulture, which is extremely sensitive to temperature factors, sunshine and length of the growing season in the Carpathian Basin (Gyulai 2010). Even though in the XVIIth century fruit production, and especially viticulture, fell significantly in the XVIIth century due to climate change, wars, and continuous frontier struggles and campaigns, especially in Upper Hungary and in the Little Hungarian Plain belonging to the Kingdom of Hungary (Gecsényi 1988; Kalesny, 1993). It may seem strange to talk about the development of vine culture during the Ottoman rule, although it was at this time that the cultivation of table grapes also gained momentum since raisins made from it were a popular delicacy at that time (Árendás 1982). The written data on the cultivation of grapes, grape, wine, pomace pálinka and their tax, and the findings of the grapevines found in Ottoman objects, grape cultivation and processing of the grapevine (Fodor 1998; Csoma 1995; Égető 1993; Hegyi 1976; Káldi-Nagy 1985; Andrásfalvi, 1961; Székely 1981; Feyér 1981; Fekete 1981; Pákay 1984; Müller 1982, 2000), the Little Ice Age had a differentiated climatic effect between 1550 and 1650. Likely, the environmental mosaic described in the Carpathian Basin (Sümegi 2016) has led to a deterioration of production conditions in certain areas for grain cultivation and (vine) production during the Ice Age, while in other areas relatively favourable production conditions may have remained mosaic-like. In addition to this, the extent of grain production was influenced by the spread of animal husbandry and rigid grazing at this time (Bartosiewicz & Gál 1997).

The wars extending across the entire Carpathian Basin, the structural change in agriculture, the spread of grazing, the development of the Little Ice Age (Vadas 2011, 2019; Dobrovolný et al. 2010) and the increased intensity and duration of the floods all played a role in the decline in grain production between 1550-1650.

Summary

From the beginning of the Migration period to the end of the Ottoman period, from the turn of the IV-Vth century until to the XVI-XVIIth century, we examined the changes of 1300 years of grain production throughout the Carpathian Basin in a centennial resolution, through 13 centuries, and 137 pollen sites (catchment basins). Based on the spatial

distribution of the total cereal pollen ratio, which is related to cultivation, agriculture, population density, and headcount, the following statements were made regarding the age of the Migration period, the Hungarian conquest, the Middle Ages and the Ottoman period.

At the outset of the Migration period, the experience of antique farming, including grain cultivation, probably preserved antique farming communities in western Transdanubia, around Lake Balaton, in the .Prealpine region, and perhaps in the southern part of the Hungarian Little Plain. These communities were probably dissolved during the VIIth century. Grain cultivation did not decline even in the late Avar Empire, moreover, according to dendrochronological, dripstone analysis and catchment basin data, during the driest period, at the turn of the VII-VIIIth century, due to the increase in the proportion of cereal pollen, cultivation expanded to several parts of the basin. The decentralization of the Avar Empire began in the VIIIth century based on several centres of the dominance of the cereal pollen. However, based on the proportional distribution of the cereal pollen ratio, the ecological crisis of dehydration and the ensuing collapse of the Avar Empire was untenable. The reason for this, on the one hand, is that there was no severe drought in the VIIIth century, and the early medieval agriculture and settlements led by the Carolingians were built without problems in Transdanubia from the end of the VIIIth century until the beginning of the IXth century, where the Avars were said to have been pushed back by the drought at the same time. On the other hand, in the central and southern parts of the Great Hungarian Plain, where drought was expected to have the strongest impact – a cereal pollen ratio maximum dominated, indicating the most significant and extensive cultivation and population number in the VIII-IXth century (**Fig. 6.**).

In connection with the age of the Hungarian conquest, according to the proportion of cereal pollens, at the turn of the IX-Xth century, pollen data showed a significant increase in an east-west direction in agriculture and grain production. Based on a factor independent of these historical sources, at the turn of the IX-Xth century, significant arable farming and grain cultivating community settled in the Great Hungarian Plain, primarily in the Upper Tisza region, in the Tisza Valley, in the Danube Valley, and in Transylvania (**Fig. 7.**). Of course, these data do not allow us to infer the origin of the settled farmer and grain cultivating communities. However, it is true that in the age of the Hungarian conquest and at the turn of the IX-Xth century, the proportion of cereal pollen, which refers to cultivation and grain cultivating, has increased significantly in the Great Plain, especially in its north-eastern region and in several places in Transylvania. As a result, significant agricultural populations may have arrived in the basin during the Hungarian conquest, and the Hungarian leaders could have reorganized the activities of the peoples living there.

The remarkable increase in the pollen ratio of cereals suggests a significant increase in population compared to the previous century at the turn of the IX-Xth century, and these data are correlating with previous pollen analyses (Willis et al. 1998). In the following centuries, due to the evenly significant proportion of cereal pollen covering the entire basin area between the X-XIIIth centuries, we can expect an uniformly high population density throughout the basin (**Fig. 8.**). The processes revealed from the time of the Hungarian conquest extended to the whole basin during these centuries, and the medieval agriculture of the Kingdom of Hungary developed.

From the XIIIth century onwards, trends emerged, which peaked in the XVth century in the Carpathian Basin. The uniform proportion of cereal pollens has changed throughout the basin, and several dominance centres have developed. Likely, the emergence of market towns, major marketplaces (centres) took place during these 250-3000 years, and pollen analyses at the boundaries of the centre cities had already shown the Thünen economic structure of the medieval towns. However, as a result of the mosaic environment and the development of the marketplace associated with river valleys and crossings, the economic space around the central location is made up of mosaics known from fractal geometry, in which natural factors are retained to a greater extent, instead of mosaics known as elongated and non-homogeneous bands. Thus, the medieval economic space could not be homogeneous - natural factors also influenced it.

Related to a cooling, a rainy climate trend, a little ice age which formed at the XVIth century and peaked at the XVIIth century, the precipitation increased by about 50-100 mm/year and the average temperature decreased by 0.5-1.0 °C, and several areas, especially lakes and marshlands, became wet and marshy and unsuitable for grain production.

Despite all the climatic changes, the wars extending across the entire Carpathian Basin, the Ottoman Empire, the Kingdom of Hungary, and the Principality of Transylvania, decreased the dominance and ratio of the cereal pollen in the whole basin. The decline in cereal production, mainly due to worsening climatic conditions, was caused primarily by war uncertainties, a declining population, and a drastic reduction in the number of grain cultivating communities. Significant agriculture and grain cultivation survived only where natural and social factors protected human communities, like in the upper region of the Kingdom of Hungary and the territory of the Principality of Transylvania.

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THEORETICAL POSSIBILITY OF THE ASTRONOMICAL USE OF HAT ROCK IN BOZSOK DURING THE LATE BRONZE AGE PERIOD•

A BOZSOKI KALAPOS-KŐ CSILLAGÁSZATI HASZNÁLATÁNAK ELMÉLETI LEHETŐSÉGE A KÉSŐ BRONZKORBAN

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In memoriam István Tóth (1944 – 2006)

Abstract

During the Late Bronze (14th-8th century BC) and Iron Age period (7th-1st century BC) on the top of the Szent Vid hill in the in the Kőszeg Mountains, close to the Amber Road along the valley of Gyöngyös river, there was a significant settlement, also a power, industrial and trade center. The Hat Rock is a cliff group of natural origin with a distinctive morphology situated approximately two and a half kilometers from this place, above Bozsok village. Presently Szent Vid hill is still clearly visible from this place. Archaeological research in both places during the last decades presumed the possible astronomical-related use of the Hat Rock, primarily related to the Sun. At the south part of the cliff group, in a leeward place suitable for shelter too, an archaeological excavation found a fire place and potsherds, a clay spoon and a grinding stone from the Late Bronze - Early Iron Ages. In this research we try to reveal such easily available astronomical related functions of the Hat Rock, which are linked to the time, agricultural activities, maybe the productiveness as well. Based on the geodesy data of the territory of Hat Rock, we found its southeast-northwest direction, which coincides with the direction of the sunrise of the winter solstice and the sunset of summer solstice. We found that the times of equinoxes of vernal and autumn can be determined by the position of the Sun correlate with given parts of the Hat Rock, observed from the twin rocks, the possible entrance of the procession route. From this observation point, the apparent positions of Pleiades open cluster also the Orion and Taurus constellations close to the horizon can help to determine the time of vernal equinox. This point is also suitable to forecast the time of winter solstice by the position of Altair star. In the inner place of the area, among the items of cliffs at the highest position, we can mark out an observation point, where the approximate time of the event of summer solstice by the observation of the Sun can be determined. The rising and setting Sun shines into the northern hollow part of the cliff of presumed observatory point during the significant agricultural time period, which is determined by this. The platform shaped cliff item in the highest position from the units of Hat Rock is approachable on a stairway-like path. Its direction coincides with the sunset of the summer solstice also the sunrise of the winter solstice, its feature suitable for ritual purposes. The observers were able to determine the times of annual significant astronomical events of Sun also with the use of skyline and the starry sky from the middle of the area. The significant and other noticeable positions/places we found during our research at the Hat Rock need further archaeological excavations, metal detection works. The complex archaeometrical analysis (like dating, pollen analysis) of possible finds, phenomena cannot be ignored.

Kivonat

A késő bronzkor (Kr.e. 14–8. század) és a vaskor (Kr.e. 7–1. század) idején a Kőszegi-hegységben, a Gyöngyös-völgyében haladó ún. Borostyánkő út közelében, a velemi Szent Vid hegyen jelentős település, hatalmi, ipari- és kereskedelmi központ helyezkedett el. Ettől légvonalban mintegy két és fél kilométerre a mai Bozsok község felett található a Kalapos-kő nevű, sajátos morfológiájú, természetes eredetű sziklatömeg. Innen ma is jól látható a Szent Vid-hegy. A két helyszínen az elmúlt évtizedekben végzett régészeti kutatások felvetették a Kalapos-kő csillagászati vonatkozású használatának lehetőségét, elsősorban a Nappal kapcsolatban. A sziklatömeg déli, szélárnyékos, „menedék” céljára is alkalmas részén végzett régészeti szondázás tűzhely maradványait, a késő bronzkor végére – a kora vaskor elejére datálható edénytöredékeket, agyagkanál darabját és őrlőkő töredéket tárt fel. Jelen kutatásunkban a Kalapos-köveknek olyan könnyen elérhető asztronómiai jellegű funkcióit próbáltuk feltárni, amely az időhöz, a mezőgazdasági tevékenységhez, netán a termékenységhez köthető. A terület geodéziai adatai alapján megállapítottuk annak dél-keleti, észak-nyugati irányultságát, amely egybeesik a

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téli napforduló napkeltéje és a nyári napforduló napnyugtája irányával. A feltételezett processziós út bejárati kapujának vélt sziklapárostól a sziklatömeg adott tagjaihoz viszonyítva a napnyugta helyzete alapján megállapítható a tavaszi/őszi napéjegyenlőség ideje. A Fiastyúk (Plejádok) nyílthalmaz, valamint az Orion és Bika csillagképek látszó horizonthoz közeli helyzete a tavaszi napéjegyenlőség időszakára ad információt. Ugyanebből a pontból nézve az Altair csillag a téli napforduló előrejelzésére alkalmas. A terület belső részén, a legmagasabb pozíciójú sziklatömegek egységei között kijelölhető egy megfigyelőhely, ahonnan a Nap megfigyelésével a nyári napforduló időpontja viszonylag jól meghatározható. Az obszervatórium pontjának gondolt homorú sziklatömeg északi oldalára a mezőgazdaságilag jelentősebb időszakban süt be a kelő és nyugvó Nap, amely ezáltal így behatárolható. A Kalapos-kövek sziklatömegei közül a legmagasabb helyzetű sziklaegység egy lépcsőzetes úton megközelíthető teraszos formát alkot, amelynek iránya a nyári napforduló napnyugtája és a téli napforduló napkeltéje irányával is egybeesik, jellege alkalmas lehetett szertartási célokra is. A terület középpontjáról a látható horizontprofil segítségével a Nap nevezetes pozícióinak időpontjai az év során a csillagos égbolt segítségével is hozzávetőlegesen meghatározhatók lehettek. A Kalapos-kő ezen vizsgálata során megállapított fontosabb, valamint más jellegzetes pozíciókban/helyszíneken további régészeti szondázás és fémkereső tevékenység indokolt. A majdani új jelenségek, leletek komplex archeometriai feldolgozása (pl. kormeghatározás, pollen-analízis) nem mellőzhető.

KEYWORDS: ARCHEOASTRONOMY, HAT ROCK, SUMMER SOLSTICE, WINTER SOLSTICE, EQUINOX, SUN, CONSTELLATIONS, BRONZE AGE, IRON AGE, PLEIADES

KULCSSZAVAK: ARCHEOASZTRONÓMIA, KALAPOS-KŐ, NYÁRI NAPFORDULÓ, TÉLI NAPFORDULÓ, NAPÉJEGYENLŐSÉG, NAP, CSILLAGKÉPEK, BRONZKOR, VASKOR, FIASTYÚK (PLEJÁDOK)

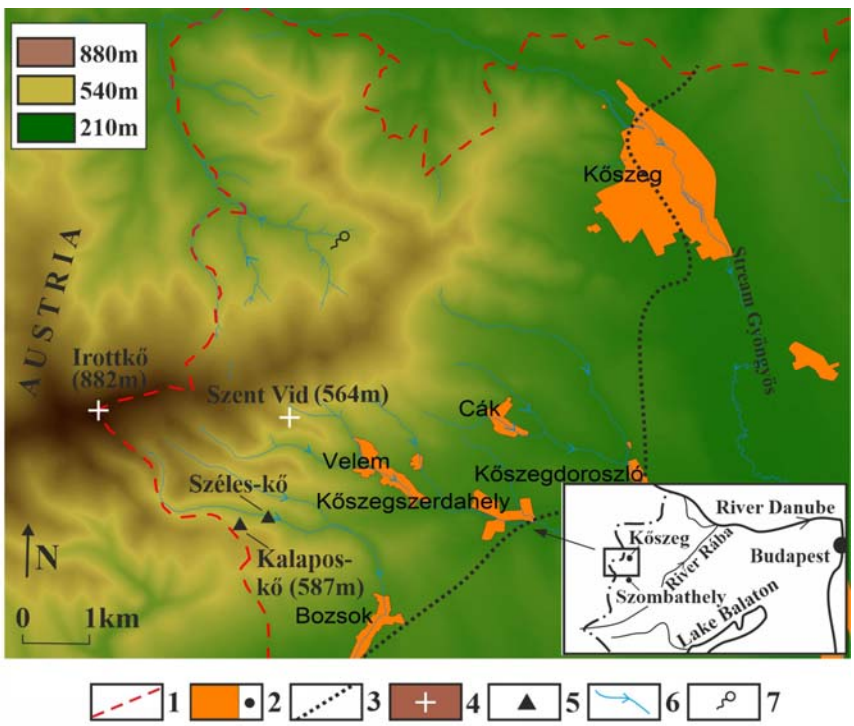

Fig. 1.: Location of examination. Legend: 1. national border; 2. settlement; 3. boundary of the Kőszeg Mountains; 4. peak; 5. rock formation; 6. stream; 7. spring (Veress et al. 2015)

1. ábra: Vizsgált helyszín elhelyezkedése. Jelmagyarázat: 1. országhatár; 2. település; 3. Kőszegi-hegység széle; 4. hegycsúcs; 5. kő formáció; 6. patak; 7. forrás (Veress et al. 2015)

Introduction

In the paper we present a study to reveal the theoretical possibility and resources of the astronomical use of the Hat Rock in Bozsok for a given time period of the late Bronze Age (1200-1000 BC). We were motivated for the examination due to the typical east-west orientation of the site recognized by former examinations, because this is logically linked to the direction of the apparent daily movement of the Sun and sky. Moreover, the artifacts from the area and the excavations in Szent Vid, close to the site, with clear symbolisms are also linked to archaeoastronomy (Ilon 2002, 2012, 2015; Vértes 2002). Research is also reasonable because, in case of favorable environmental conditions (suitable landscape, vegetation), many cultures used natural formations and/or purposely built artificial landmarks to appoint and observe the rising and setting positions of the Sun, Moon, planets, brighter stars, constellations. In case of the Sun, according to the assumptions, observation of solstices and equinoxes had an especially important role (Bartha 2014; Kelley & Milone 2005; Magli 2016; Pásztor & Barna 2015; Ruggles 2015).

Geological and morphological review

Hat Rock is a greenschist cliff group with unusual morphology stretches 100x30 meters, and rises 5-10 meters above its environment. It is located in the western Hungarian outskirts, Pre-Alps middle land, Kőszeg Mountains minor land, on the periphery of Bozsok village in Vas county, northwest from this settlement, approximately 600 meters above the sea level. This cliff group is one of the heights of the greenschist ridge along the direction of east-west, which ends with a steep forehead close to the village Velem (Dövényi 2010; Veress & Szabó 1996) (**Fig. 1.**). In the present the Szent Vid hill is still clearly observable from the site of Hat Rock.

Two processes formed the present appearance of Hat Rock: rise of the mountain, during this process it tipped and rose compared to its surroundings, and a destruction process, which resulted in the morphology we see today. The tilt of the surface in the direction of south-west verifies the tip process, at the same time its surface continuation in the west direction tilts in the east direction. Both north and the south sides of site of Hat Rock are surrounded by plain surfaces with tilt, situated 5-6 meters lower. The tilt of plain surface is larger in the south direction but there are fewer craggy cliff walls with remarkable relief than in the north direction. In the latter direction a long, complex, uniform cliff wall separates the examined cliff group from the surface of the plain in lower position. The line of strike of cliff walls bordered the place is such like that they follow almost exactly one of the well measurable tectonic direction in northwest- southeast. In the place both of tectonic directions in north-east south-west and probably an east-west one is also recognizable. The appearance of chasms is also characterizing the tectonic directions (Veress & Szabó 1996; Veress et al. 1998).

The present form treasure of Hat Rock is a remnant form, the formation of terraces, platforms and typical hat form due to solution processes among other ones (**Fig. 2a**). Although the material of cliff group is basically greenschist, but it also has lime content in various scales as contamination.

Fig. 2a: The highest position cliff item (No. III) of the Hat Rock (Photo by Mitre, Z.)

2a ábra: A Kalapos-kő legmagasabb helyzetű (III-as) sziklatömege (Fotó: Mitre Z.)

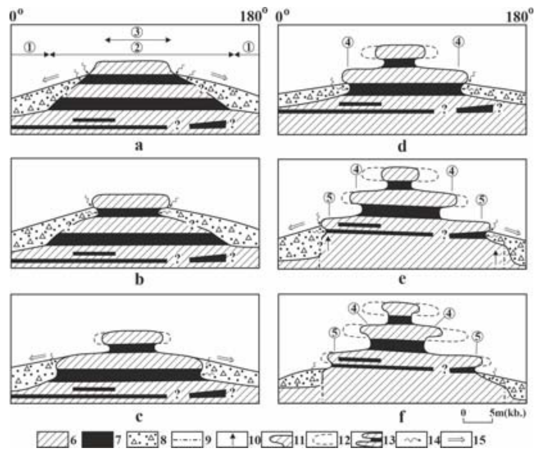

Fig. 2b: Theory of origin of grand features of Hat Rock by Veress & Szabó (1996). Legend: 1. younger surface; 2. remains of younger surface; 3. apical level of Hat Rock, remains of older surface; 4. upper denudation level of Hat Rock; 5. lower denudation level of Hat Rock; 6. greenschist without lime; 7. lime bed and limestone; 8. soil and loose ground; 9. possible fault; 10. uplift; 11. hat; 12. ruined part of hat; 13. platform; 14. percolation of water in detritus in the direction of solution places; 15. denudation of detritus

2b ábra: A Kalapos-kő nagyformáinak kialakulási elmélete Veress-Szabó (1996) alapján. Jelmagyarázat: 1. fiatalabb felszín; 2. fiatalabb felszín maradványa; 3. Kalapos-kő tetőszintje, idősebb felszín maradványa; 4. Kalapos-kő felső lepusztulási szintje; 5. Kalapos-kő alsó lepusztulási szintje; 6. mészmentes zöldpala; 7. meszes összlet és mészkő; 8. talaj és kőzettörmelék; 9. valószínűsíthető vető; 10. emelkedés; 11. kalap; 12. kalap elpusztult része; 13. szinlő; 14. vízszivárgás a törmelékben, oldódási helyek irányába; 15. törmelék lepusztulása

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When debris with soil cover is situated up to the height of lime beds in greenschist material, then a solution-type destruction begins which results large platform formations while the debris cover is exist and the ratio of supply and dispatch are equals. When the uncovering process of this layer becomes more intense and dispatch also increases the development process stops or rather begins in a lower location, creating a new level. Frost effect may also play a role in the development of platforms (**Fig. 2b**) (Veress & Szabó 1996; Veress et al. 2015).

Both the morphological analysis and the character of the cliff group preclude that they were put in this site artificially or their forms were manually constructed.

There were not any noticeable changes in the form treasure of Hat Rock between the examined time period and the present state. According to our lights regarding the dissolution of rocks with lime content we suppose the dissolution negligible considering the elapsed time and environment of the site (Dreybrodt 1988).

Archaeological research of the area

The presume of Hat Rock as a sacral place originate from Mária Fekete archaeologist and her husband István Tóth ancient historian. Not incidental moment of the birth of this hypothesis is a bronze statuette, perhaps a votive early Iron Age object which was published by Kálmán Miske (1908). The 66 mm tall statuette represents a bare woman, which originally had a vessel in her hand (**Fig. 3.**). In the "B" inventory book of the Museum of the Cultural Association of Vasvár County, on the page of 93 under the number of 2988 can be read the following: "Bronze woman statuette. Outskirts of Velem Szt. Vid."

Furthermore, in the Prehistoric inventory book of the Antiquity Storage of Museum of Vasvár County (1925-1937) under the number of 480. on the page 123, the following is written: "Velem, Hat Rock – Woman with vessel in its hand." Unfortunately, the vessel already broke down and disappeared but in addition to the descriptions above in the photo pictures of Miske's publication it is still visible in three points of views (Miske 1908). This statuette may be referring to a public ritual that the community collectively performed in this place (Kalla et al. 2013).

The first step in verifying this hypothesis was an archaeological probe. We executed it in 1997 as a part of the archaeologist technician training of History Department of Berzsenyi Daniel College.

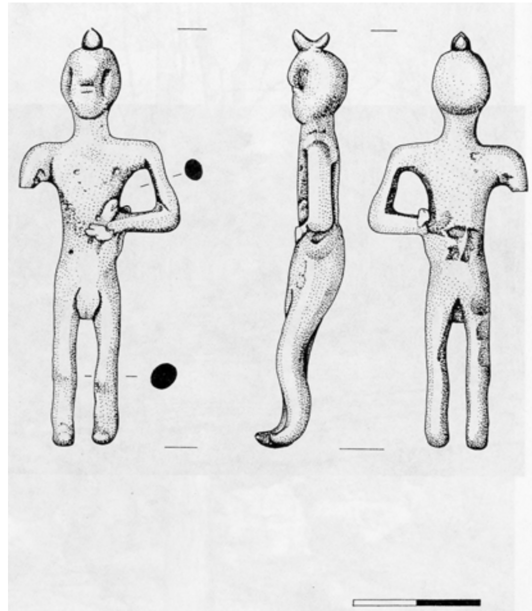

Fig. 3.: Bronze sculpture from the Hat Rock in Bozsok (after Ilon 2002)

3. ábra: Bronz szobrocska a bozsoki Kalapos-kőről (Ilon 2002 nyomán)

We worked one weekend at three selected locations of the Hat Rock (**Fig. 4.**). In the thin humus layer above the bedrock at the workplace *1*. (cliff *item I*), we found only tangible findings from the modern history. We worked at the workplace *3*, which is a small sized rock cavity (Holler-cave) at the west side of the Hat Rock, in a research pit to the level of greenschist bedrock. In the fill we found only a small number of ceramics from the medieval and modern ages. The research probe *2*. (cliff *item IV*) was the interesting place regarding the subject of our examination. At the leg of the south-east side, in wind shade we found the remains of a fire place with a pounder stone and fragments of pots, clay spoon, dated to the transition of late Bronze Age and Iron Age (?) (**Fig. 5a-b**; Ilon 2002a, b). Maybe we entitled to think that, it is remains of a ritual ceremony attached to repast and also presumable, that we maybe consider the above-mentioned bronze statuette at an early Iron Age occasion as a votive present linked to one individual from the community.

In the second step, years later, in the re-publication of gold treasure from Velem we touched also the archaeoastronomy-related adaptation of diadem and spherical slices (Ilon 2015). In Velem, on the top of the Szent Vid hill in the Hungarian Kőszeg-mountain, next to the Amber Road edge along the valley of Gyöngyös river, during the Late Bronze

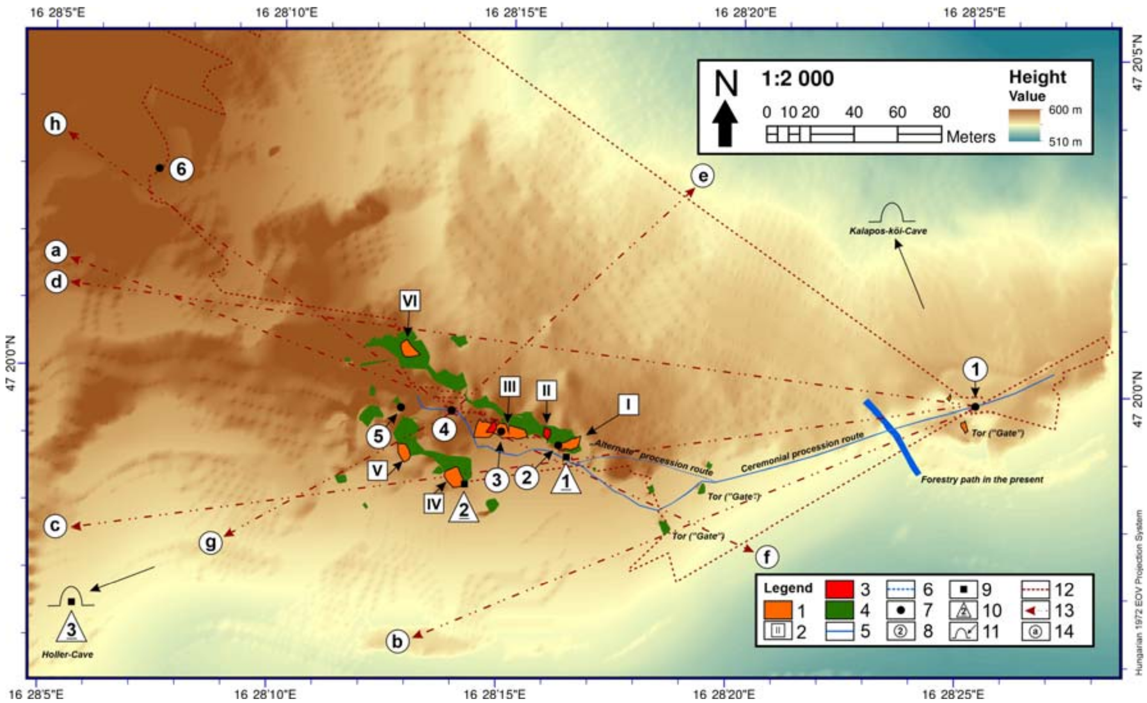

Fig. 4.: Review map of the area and examination. Legend: 1. significant cliffs regarding the examination; 2. numbering of significant cliffs regarding the examination (I-VI); 3. important hat form; 4. other cliffs; 5. present paths (possible procession route separately signed); 6. possible alternate procession route; 7. astronomical examination places (also panorama shooting places); 8. numbering of astronomical examination places (1-6); 9. sites of archaeological examinations; 10. numbering of sites of archaeological examinations (1-3); 11. important caves outside the represented area of map, and their directions; 12. horizon skyline influenced by the landmarks from the site 1.; 13. examined directions of given astronomical objects; 14. data of specific directions of given astronomical objects, for detailed data of the signs of (a-h) see **Table 1.** (Edited by Mitre, Z., based on data of Veress – Szabó 1996; Ilon 2002 and geodesy survey of Isztin, Gy.)

4. ábra: A terület és a vizsgálat áttekintő térképe. Jelmagyarázat: 1. vizsgálat szempontjából jelentős sziklák; 2. vizsgálat szempontjából jelentős sziklák számozása (I-VI); 3. fontosabb kalapforma; 4. egyéb sziklák; 5. mai ösvények (feltételezett felvonulási útvonal külön jelölve); 6. lehetséges alternatív felvonulásiútvonal; 7. asztronómiai vizsgálati helyszínek (egyben panorámafelvételezés helyei); 8. asztronómiai vizsgálati helyszínek számozása (1-6); 9. régészeti vizsgálatok helyszínei; 10. régészeti vizsgálatok helyszíneinek számozása (1-3); 11. térkép ábrázolt területén kívülre eső fontosabb barlang és iránya; 12. tereptárgyak által befolyásolt horizont profil az 1-es helyszínről; 13. adott égitestek vizsgált irányai; 14. adott égitestek jellegzetes irányainak adatai, az (a-h) jelölésekhez tartozó részletes adatokért lásd az **1. táblázatot** (Veress – Szabó 1996; Ilon 2002 adatai és Isztin Gy. geodéziai felmérése alapján szerkesztette Mitre Z.)

(14th-8th century BC) and Iron Age periods (7th-1st century BC) there was a significant settlement, also a power, industrial and trade center. The site of Hat Rock is situated approximately two and a half kilometers from this place.

Archaeoastronomical background

It is presumed that the observation and representation of the Sun and the starry sky already appeared in the culture of the people living in the Pleistocene. In France, several caves were examined and found that several cave drawings were made such places where the sunlight appeared around solstices. In the cave drawings of Lascaux Cave researchers feel as if they identify constellations or the Pleiades open cluster (Messier 45, M45), but many others cautiously and doubtfully accept this theory (Jégues-Wolkiewiez 2011; Pásztor & Priskin 2010; Rappenglück 2004).

In Eurasian and American cultures, the east-west orientation of late Stone Age tombs appears independently of each other. The east-west symbols related to the Sun in Egyptian culture were a symbol of rebirth and death. The orientation not only followed the daily movement, but also tried to appoint the places of highlighted solstices and equinoxes (Bartha 2014).

Fig. 5a: The archaeological probe No. 2., 1997. (Photo by Ilon, G.)

5a ábra: A 2. számú régészeti szonda, 1997. (Fotó: Ilon G.)

The correlation with Sun also recognizable in orientation of late Neolithic round ditches in the Carpathian Basin at the Transdanubia region. Many examinations refer to that the eastern gates of round ditches were orientated to the current sunrise of the time of their position measurement. The relationship with the Sun can also be linked to the death culture and burial (Pásztor & P. Barna 2009; P. Barna et al. 2015).

The Sun veneration appears from Egypt through Central Europe to Scandinavia till the Bronze Age (Ilon 2015). By this time, the idea of the annual decline and renewal of the Sun could have evolved, which was dominant mainly in cultures far from the equator. The difference between winter short daylight and long nights, as well as summer long daylight and short nights is more decisive at higher latitudes (Bartha 2014).

It is perceptible in many cultures, that their artificial build-ups were configured, oriented in such a way that the Sun illuminates a certain point of the structure on special occasions (such as solstice or equinox) or its rise or set position considered from a certain part of the structure coincident with the direction of a given part of building or landmark of natural origin. A part of researchers assume an astronomical orientation associated with the Sun in the case of the well-known Stonehenge as well, but many other artificial and natural observation sites are also proper examples. Orientations and observation points associated with the Moon and brighter stars in the starry sky are also recognizable in case of installations that have astronomical purposes as well (Bartha 2014; Kelley & Milone 2005; Magli 2016; Ruggles 2015). For example, in Siberia there are some locations from the late Bronze Age where Larichev et al. (2015) assumed that important positions of the Sun or Arcturus star could be observed and used often natural landmarks as point of reference, but they also assumed observation point for the position of the Betelgeuse star (in constellation Orion).

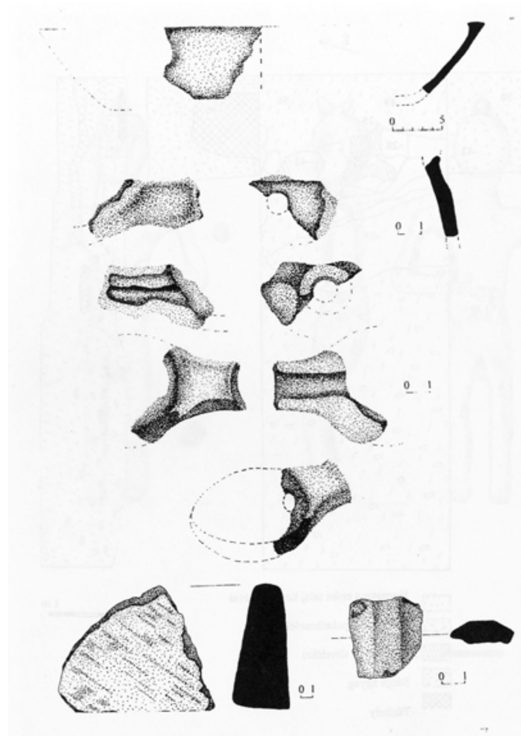

Fig. 5b: Drawings about finds from the archaeological excavation in 1997 (after Ilon 2002)

5b ábra: Az 1997. évi régészeti szondázás során előkerült leletek rajza (Ilon 2002 nyomán)

Observation of stars also helped to predict the times of significant positions of the Sun (for example winter solstice) (Larichev et al. 2015).

Direction of the east-west orientation is also typical in later eras and cultures, for example it is recognizable in the orientation of a part of medieval Hungarian churches (Guzsik 2002; Keszthelyi 2012) and the effect were built on the movement of sunlight within the space (Pásztor – P. Barna 2017). In addition to orientation in the direction of the Sun, Moon, stars, other astronomical related solutions may occur. Near Magdalenenberg in Germany, for example, Mees (2007) assumed that the Hallstatt-age tombs were placed in the vast heap grave in such a way that they represented an exact replica of the observable constellations in the night sky during the summer solstice of the 7th century BC. At the same place, the extreme positions of the rise and set of the Moon (due to the lunar standstill phenomena) were also employed for orientation (Mees 2007).

In addition to precisely oriented burials and buildings, symbols depicting the sky, Sun, Moon, stars appear in many cultures on articles of personal use and symbols of power. Astronomical symbols can also be assumed in the objects of the golden treasure turned up in Szent Vid (**Fig. 6a-c**).

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Fig. 6a: Gold treasure from the Szent Vid hill at Velem, with presumed astronomical symbol decorations: sphere slices and diadem (after Ilon 2015)

6a ábra: A velemi Szent Vid feltételezhetően asztronómiai szimbólumokkal díszített aranykincsének tárgyai: gömbszeletek és diadém (Ilon 2015 nyomán)

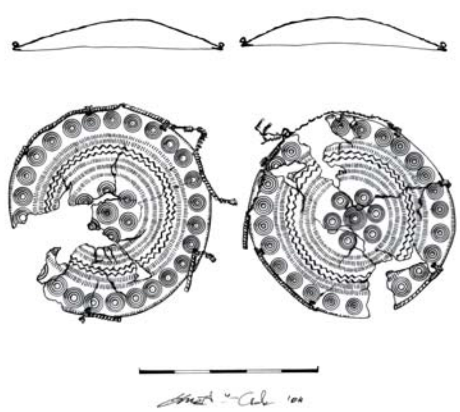

Fig. 6b: Drawings of the pair of sphere slices no. II. (after Ilon 2015)

6b ábra: A II. gömbszeletpár rajza (Ilon 2015 nyomán)

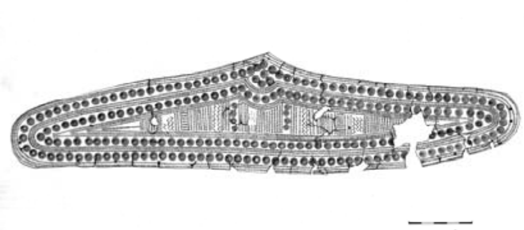

Fig. 6c: Drawing about the diadem before conservation (after Ilon 2015).

6c ábra: A diadém restaurálás előtt készített rajza (Ilon 2015 nyomán)

The number of the concentric circle symbols on the edge of the diadem is 221, which may indicate the length of the Pleiadic year in days. The Pleiadic year consist of 7 synodic (an average of 29.53 days) of lunar months and 14.3 days. The record of length of this time can be recognized in other cultures as well (Ilon 2015; Schlosser 2010). The recognized 27-28 symbolic numbers attached to the Moon may indicate the Moon's sidereal (27.3 days) orbital period. The number 7 also can be recognized which refer to the phases of the Moon (Ilon 2015). But this number can represent the stars of the Pleiades too (Ilon 2015; Schlosser 2010), or the seven bright stars of the Orion constellation, perhaps the stars of the Big Dipper, but also may symbolize the 7 astronomical objects of the solar system visible with naked eye.

The symbolism of the golden treasure is also concordant with the symbolism system of other European finds of the Late Bronze Age, which is linked to the passage of time, fertility, the cycle of nature (Ilon 2015). The solar symbols found in the diadem and other artifacts from the examined period not definitely refer to the solar culture, it may be just decorative elements referring to the Sun (Pásztor 2009, 2015). The representation (hence its observation) of stars in the Bronze Age got an important role in societies. The observation of characteristic stars can be related to time, over and above ritual significance can also be attributed to this fact (Bartha 2014; Pásztor 2010).

Former surveys of the Hat Rock used for research

Over the last two decades geomorphological and archaeological researches were also made in the area of Hat Rock. In case of both of these occasions accurate maps were made, suitable for orientation with right directions. In the mid-1990s, to recognize the accurate geomorphology of the place a very detailed, large-scale geomorphological map was created for research purposes, using a traditional method (Veress & Szabó 1996). In 2005-2006 at the request of Gábor Ilon for archaeoastronomy purposes the surveyor Gyula Isztrin in collaboration with college students of archaeology technician made an accurate digital survey.

The first sketchy astronomical survey of Hat Rock in relation to the position of main astronomical directions was carried out for the researches of G. Ilon (2002). Based on the position measurements of Ernő Vértes (2002) a sketch map was made from the field with right scales and directions about important major cliff items. Position measurements showed that the location of some rock units of the Hat Rock coincides with the main (astronomical) points of the compass. Furthermore, the path through the ceremonial procession gates supposed by István Tóth historian of antiquity (**Fig. 4.** and

10.) is in the direction of east-west has only a few degrees in bias, at the end point of it there is a large cliff item (*no. III*), a part of it may be a venue of some kind of ceremony (Ilon 2002; Vértes 2002). This assumption, so the use of the Hat Rock as a ceremonial place, the Early Iron Age bronze figurine in the **Fig. 3.** also may confirm.

Data about the climate of Bronze- and Iron Age, also status of landscape and vegetation – condition of the sky observation

The examined archaeological period is situated in the Sub-boreal section of the Holocene epoch of Quaternary period. In general, the climate of the Late Bronze- and Early Iron Age are characterized by one of the wet temperature minimums in the Hallstatt-cycle. The system approached research of the approximately 2300-year-old Hallstatt-cycle presumes an astronomical background to the engine of the cycle, the last minimum of the cycle coincided with the medieval Little Ice Age (Scafetta et al. 2016).

Evidence could be found at several places to the cool climate of the examined time period. Due to the drop in temperature, Greek settlements in Bronze Age have depopulated (some data refer to low solar activity as well), in Turkey, Lebanon, the Arabian-peninsula and the Middle East pollen data and the change in Dead Sea water level refers to a drier and cooler climate (Drake 2012; Falkenstein 2013; Finné et al. 2011).

In the Carpathian Basin, the climate was also cooler, but wetter. The general reconstruction with high resolution of climate and humidity was made by László Kordos (1977) with the use of the spread of sensitive vole species to these. With the help of further data retrieved from environmental archaeological research, small changes in the climate become recognizable. The time of Hungarian Late Bronze Age is characterized by a continental climate section with somewhat more moderate humidity which rises again in the Iron Age (Horváth 2002; Sümegi 1998; Sümegi et al. 2003, 2011). The wet cool climate favorable for richer vegetation, but the considerable anthropogenic effect can influence this. Landscape formation by anthropogenic origin also causes a significant change in the nature and morphology of vegetation and landscapes (Pécsi 1991). Hungarian stratigraphic examinations indicate significant logging which led to the spread of species prefer open space, it may result sparse, highly visible areas (**Fig. 7.**) (Sümegi et al. 2003; Willis et al. 1997).

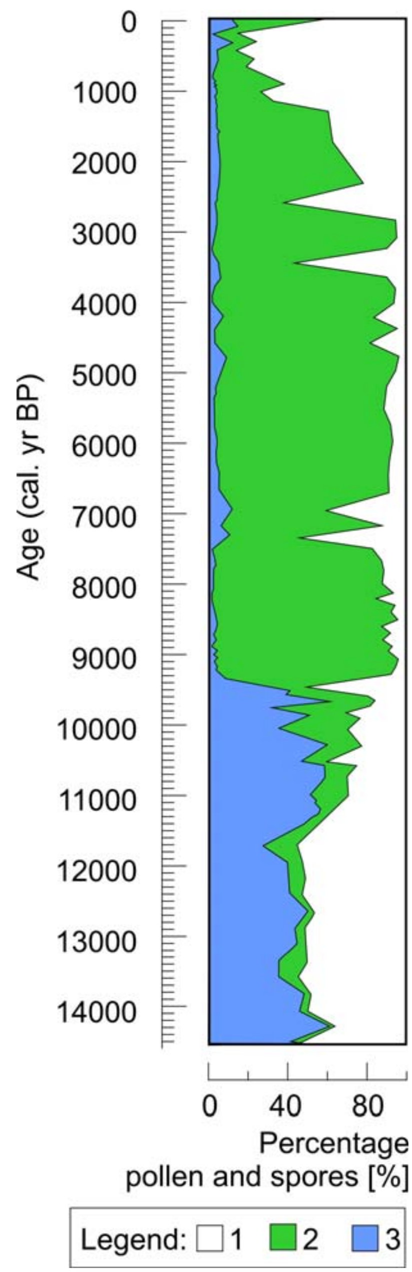

Fig. 7.: Change of nature of vegetation in the last 14 thousand years based on pollen and spore data (Kelemér, Kis-Mohos). During the Late Bronze period the ratio of herbs preferring open space significantly rose. Legend: 1. sum herbs; 2. sum broad-leaved; 3. sum needle-leaved (Sümegi et al. 2003; Willis et al. 1997)

7. ábra: A növényzet jellegének alakulása pollen és spóra adatok alapján az elmúlt 14 ezer évben (Kelemér, Kis-Mohos). A késő bronzkorban jelentősen megnövekedett a nyílt területeket kedvelő fajok aránya. Jelmagyarázat: 1. nyílt területet kedvelő fajok; 2. lombos fák; 3. tűlevelűek (Sümegi et al. 2003; Willis et al. 1997 nyomán)

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In connection with archaeological research, detailed geological, pollen and macro-plant particle examinations were made close to the place of the Hat Rock in and around the Cemetery of Szombathely-Zanat dated to the younger phase of Urnfield culture in Late Bronze Age (about 20 km) and much closer, at the turf bog at the foot of Szent Vid (about 5 km). Thus, we have a lot of information about the condition of vegetation in the close area. Data of pollen, macrobotanic and scale refer to in the examined area forest extraction and very active agriculture, grazing livestock, i.e. significant anthropogenic activity and landscape-transforming work. At the border of the Bronze and Iron Ages, the transformation of vegetation decreased and then became significant again during the Iron Age, maybe due to the increase in population (Juhász 2007; Jakab & Sümegi 2007; Sümegi 2007; Sümegi & Törőcsik 2011).

The change in the nature of the vegetation at the place of examination was typical of recent past as well, since there are references to extensive mountain pastures and meadows. Surroundings of villages Velem and Bozsok are mainly characterized by offset forests (Dövényi 2010). Multiple changes in vegetation may also lead to changes in the degree of transport of soil and material from greenschist cliff masses. We estimate that soil thickness in the area was maybe 10-20 cm above than the present status, but cycles of short-term soil accumulation and transfer periods are assumed by changes in vegetation and climate, result soil thickness is not changed significantly compared to present status. Sparse vegetation and open areas are significantly preferable for archaeoastronomy use.

Examination methods

Before the astronomical examination, we analyzed the astronomical capabilities of the site based on map information. We processed the Isztrin's geodesic survey using geoinformatics solution, developed the 3D model of the area and compared, refined this digital survey with the map of Veress & Szabó (1996), which helped accurately identify given landmarks. Archaeological excavations and significant sites were localized by the sketch map of Ilon (2002) oriented to the points of compass.

Astronomical survey is limited from some selected points for examination by the present vegetation of the site. We were able to capture accurate field panorama shoot about nearby landmarks during winter minimal vegetation, but already had to digitally produce the horizon profile from the geodesic survey data in case of landmarks in medium distance. We examined the horizon profile composed by far relief landmarks with the help of geoinformatics data about the wider area (e.g. SRTM). The production of horizon models helped to determine from the examination points in the Hat Rock the visible position in which the covering of Sun, Moon, planets, stars are start by a given topography element, landmark and rock. We made further examination of panorama shoots and horizon profiles in digital planetarium software after computer procession.

To determine the visible position of the astronomical objects, we use classic spherical astronomy calculations in topocentric horizontal coordinate system. In case both of celestial bodies and visible landmarks we worked with the angles of altitude (*h*) and azimuth (*Az*) – due to the work with geodesy data – the latter we measured from the beginning north point to the direction of east.

To the calculation of these essential visible positions, the

$$\begin{aligned}\cos h \sin Az &= \cos D \sin t \\ \sin h &= \sin D \sin\varphi + \cos D \cos\varphi \cos t \\ \cos h \cos Az &= -\sin D \cos\varphi + \cos D \sin\varphi \cos t\end{aligned} \quad (1)$$

equations can be used, where *h* altitude above horizon, *Az* is azimuth (take into consideration, that in astronomy calculations its starting direction is south), *D* is declination, *t* is hour angle, *φ* is geographical latitude of observer (Kelley & Milone 2005; Marik 1989). To value *t*, we need to know the *RA* right ascension of the astronomical object and the hour angle of the point of vernal equinox at the observation place. The required values *Az* and *h* for the examination could be determined by the combination of equations (1). The value of *h* must be corrected by the refraction of the atmosphere (Marik 1989).

Many solutions and perturbation calculations could be used to determine the ephemerides *RA* and *D* of planets, the Sun and the Moon to a given time (Érdi 2001; Marik 1989). These calculations are not required in case of examining stars; only their coordinates need to be corrected. We took into consideration stars brighter than 2 magnitudes visible in the sky of 11-13th centuries BC during our work. Regarding the corrections for the practical part of the examination of astronomical objects we mention two important long-term movements of the Earth. The *ε* obliquity of the Earth's axis is change as the function of time; we applied the sufficiently precise solution of Laskar (1986) covering 20 000 years to calculate the change (**Fig. 8.**). In addition, lunisolar precession has to also take into consideration; its effect causes significant change in the coordinates of astronomical objects over thousands of years. We do not detail the theories and methods of each mentioned individual calculations (Érdi 2001; Gábris 1998; Kelley & Milone 2005; Marik 1989; Meeus 1991).

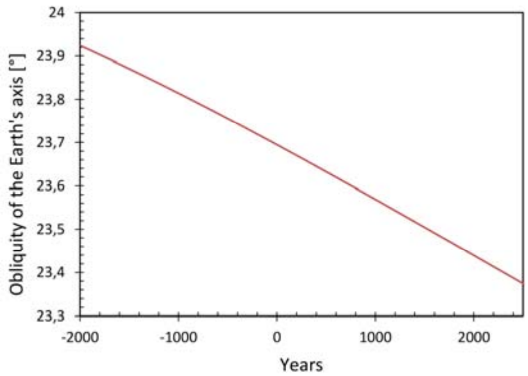

Fig. 8.: Graph of change of obliquity of Earth's axis between 2000 BC and 2500 AD based on the calculations of Laskar (1986)

8. ábra: Laskar (1986) számításai alapján készült grafikon a Föld dőlésszögének változásáról Kr.e. 2000 és Kr.u. 2500 között

However, more – also free, like Stellarium – planetarium software and online calculators give quick and adequately accurate outcome from archaeoastronomy point of view. Digital planetarium software is widely used in archaeoastronomy research (Conolly 2016; Zotti 2016).

Despite of the difficult celestial mechanics background, many positions of the Moon and the planets – such as transits, conjunctions – are repeated with more or less accuracy, so we summarized them from the examined period. For example, in case of planets, the planet Venus returns to almost the same position in every 8 years (we dispense with small angular deviations). In the case of the Moon, the lunar phases – with a relatively larger error – are repeated in every 8 years (octaeteris). Lunar phases occur in every 19 years on the same day of the year, the latter is the Metonic cycle. Eclipses are repeat in an 18 years 11 days cycle – so-called Saros cycle (Meeus 1991; Marik 1989). Archaeoastronomy also highly examine the extreme positions of Moon, the lunar – minor or major – standstills, that are the result of the rotation of its orbit plane with an 18.6-year-old cycle due to perturbation. As a result of this phenomenon, the *Az* values of rising and setting positions of the Moon get into extreme positions, these are recognizable e.g. in case of Iron Age artifacts as well (Mees 2007).

Even the subject of archaeoastronomy examinations is searching for signs of periodic phenomena. Episodic phenomena can be comets, meteor showers, solar and lunar eclipses, Moon covers stars or planets, supernova explosions, interesting conjunctions. Due to the small amount of the artifacts, we did not pan out about examination of them, but only even checked the positions of zodiac light.

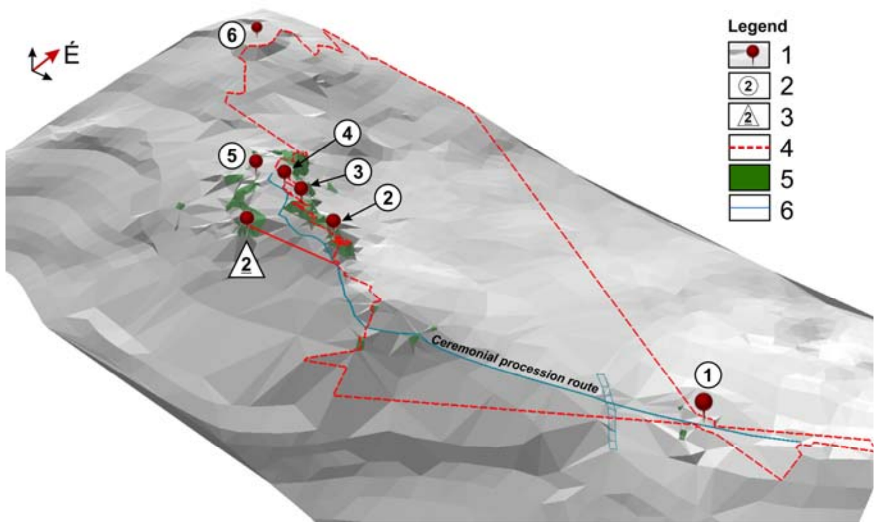

Fig. 9.: Digital model of terrain surface based on the geodesy survey with signs of some important examination sites and the skyline from the site 1. Legend: 1. astronomical examination places (also panorama shooting places); 2. numbering of astronomical examination places (1-6); 3. numbering of sites of archaeological examinations (2); 4. horizon skyline influenced by the landmarks from the site 1.; 5. other cliffs; 6. present paths (possible procession route separately signed) (Edited by Mitre, Z. based on the geodesy survey of Isztin, Gy.)

9. ábra: Geodéziai felmérés alapján készült digitális domborzatmodell a fontosabb vizsgálati helyszínek jelölésével és az 1-es helyszínről látott horizontprofillal. Jelmagyarázat: 1. asztronómiai vizsgálati helyszínek (egyben panorámafelvételezés helye); 2. asztronómiai vizsgálati helyszínek számozása (1-6); 3. régészeti vizsgálatok helyszíneinek számozása (2); 4. tereptárgyak által befolyásolt látott horizont profil az 1-es helyszínről; 5. egyéb sziklák; 6. mai ösvények (feltételezett felvonulási útvonal külön jelölve) (Isztin Gy. geodéziai felmérése alapján szerkesztette Mitre Z.)

Results

The stated approximate east-west orientation carried out by Vértes (2002) was confirmed by high-precision data from the geodetic and mapping survey, but this orientation is not accurately east-west rather southeast-northwest, which also coincides with one of the tectonic directions founded by Veress & Szabó (1996). This direction - within acceptable margin of error - is the same as the horizontal direction of the setting Sun during the period around the summer solstice and also the rising around the winter solstice.

During the executed fieldwork we identified four places that, or rather combinations of these could be interesting in archaeoastronomy point of view. One place from these allows approximately accurate astronomical observation too. We do not consider the astronomical use feasible of the further two examined places. In **Fig. 4.,** the data of former examinations and also the geodetic and astronomic surveys are summarized. **Fig. 9.** gives a spatial review from the area. The locations of interest for examinations are numbered in these latter figures, which we refer in the later parts of the paper.

According to the executed astronomical calculations for the examination, during the BC 1200-1000 period due to the precession movement of the Earth, the notable astronomical events during a year are occurred in the following constellations: vernal equinox in Aries, summer solstice in Cancer, autumn equinox in Libra, and winter solstice in Capricornus. That is why – based on the present time – on average, in the examined time period the vernal equinox occurred on 31 March, the summer solstice on 3 July, the autumn equinox on 3 October and the winter solstice on 31 December. The direction of the Earth's rotational axis did not point to any bright star at that time. In the examined period obliquity of this axes was greater than the presently known value of 23° 26’, approximately 23° 50’ (**Fig. 8.**), it has to take into account in case of rising and setting astronomical objects. This amount in obliquity difference results in excess of 30% plus in the *Az* value near the horizon than the angular appear diameter of the Sun.

Using of east gate to determine the equinoxes

For the observation of the spring and autumn equinoxes, we regard principally *site 1* and, under certain conditions, *site 2* suitable. *Site 1* lies on the path edge along the greenschist back from the direction of the Wide Rocks (Széles-kövek), its place appointed by two cliff formations apiece of them containing more platforms, diameter between 2-3 meters with a height of 1.5 meters (**Fig. 4.** and **10.**).

Fig. 10.: Two greenschist rocks, which mark the entrance of procession route (present path) (Photo by Mitre, Z.)

10. ábra: A felvonulási út (mai ösvény) bejáratát jelző két zöldpala szikla (Fotó: Mitre Z.)

As we have described before, these two cliff items are could be interpreted as a kind of gate by their type, the track is connected as a procession path to them. The cliff mass of the Hat Rock is located west from here at a distance of 200 meters, its highest visible altitude point reaches *h≈8°* altitude. Looking west from observation *site 1* during the vernal and autumn equinoxes, when the Sun reached h≈7° altitude, it appeared in the direction of the leg of cliff *item I* of the Hat Rock, lowering till its coverage. We also mention, that the direction of cliff height (cliff *item IV*) above the archaeological probing place *number* 2 falls exactly the same direction, but it is covered by the relief.

Looking in the west direction the observer could see the Hat Rocks in the highest position as a group at a relief section in a range of about *Az≈248°-277°*. The south part of this range is bounded by the rise of large south cliff item of the assumed third “*tor*” gate and at the north the edge of the steep rock wall, which separates the examined rock mass from the flat surface in the lower position. Within this interval, the Sun appeared about 1-1 months before and after the vernal equinox, so the time of the equinox could therefore be approximately determined. Regarding of forecast, it is obvious that, approaching to the autumn equinox the north part of the interval, in case of the vernal one the south part of the interval was first touched by the Sun (**Fig. 11.**). To control the time, use of the full moon could also be used, as in the period around the equinoxes, just before sunrise, it set with slightly deflection behind the Hat Rocks in the same direction of sunset.

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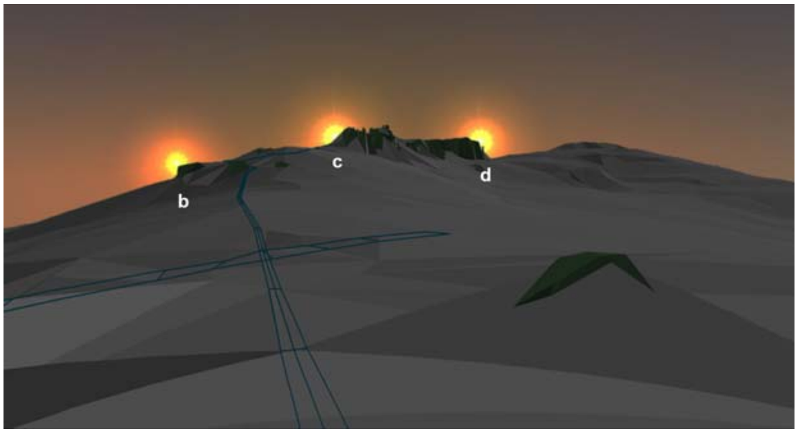

Fig. 11.: Simulation of b, c, d, Sun-positions as seen without vegetation in the direction of western horizon from the examinationsite 1. in 1100 BC. See **Table 1.** for more details in this figure.

11. ábra.: A b, c, d Nap-pozíciók szimulációja az 1. vizsgálati pontból növényzet nélkül látható nyugati horizont irányában Kr.e. 1100-ban. A jelölésekhez tartozó részletes adatok a **1. táblázatban** láthatók.

Looking east from *site 1*, there is no significant landmark for our examination, the altitude of area rises about 3 meters, which covers the background topography. It is seen in **Fig. 10.**, which is a photo taken in the direction of east. During the summer solstice, in the morning, when the Sun reached an altitude *h*≈*10°* above the horizon, it was seen in the direction of *site 1* in case of receding in the direction of east from the Hat Rock cliff mass, leaving the second gate on the ceremonial procession path.

Table 1.: Data for the astronomical positions represented in **Fig. 4.**

1. táblázat: A 4. ábrán szereplő csillagászati pozíciókhoz tartozó adatok

Mark	Observation site	Date, time period of observation	Astronomical object	Azimuth (*Az*)	Altitude (*h*)	Fig. of reference	Remark
a	2	07.03.1100. BC summer solstice	Sun	291.1°	13.1°	-	-
-	2	06.22. 2018. BC summer solstice	Sun	290.5°	13.1°	**Fig 16b**	Control observation
b	1	03.01.1100. BC	Sun	247.9°	4.4°	**Fig. 11.**	Approxiamtely at 11.01.1100. BC Sun was in the same position
c	1	03.31.1100. BC spring equinox	Sun	262.4°	7.3°	**Fig. 11.**	Approximately at 10.03.1100. BC during the autumn equinox Sun was in the same position
d	1	04.27.1100. BC.	Sun	277.9°	6.9°	**Fig. 11.**	Approxiamtely at 09.06.1100. BC Sun was in the same position
e	4	03.31.1100. BC spring equinox	Vega	43.2°	12.2°	**Fig. 18.**	-
f	4	03.31.1100. BC spring equinox	Antares	114.8°	3.1°	**Fig. 18.**	-
g	4	03.31.1100. BC spring equinox	Sirius	241.3°	2.5°	**Fig. 18.**	-
h	4	03.31.1100. BC spring equinox	Capella	306.2°	16.1°	**Fig. 18.**	-

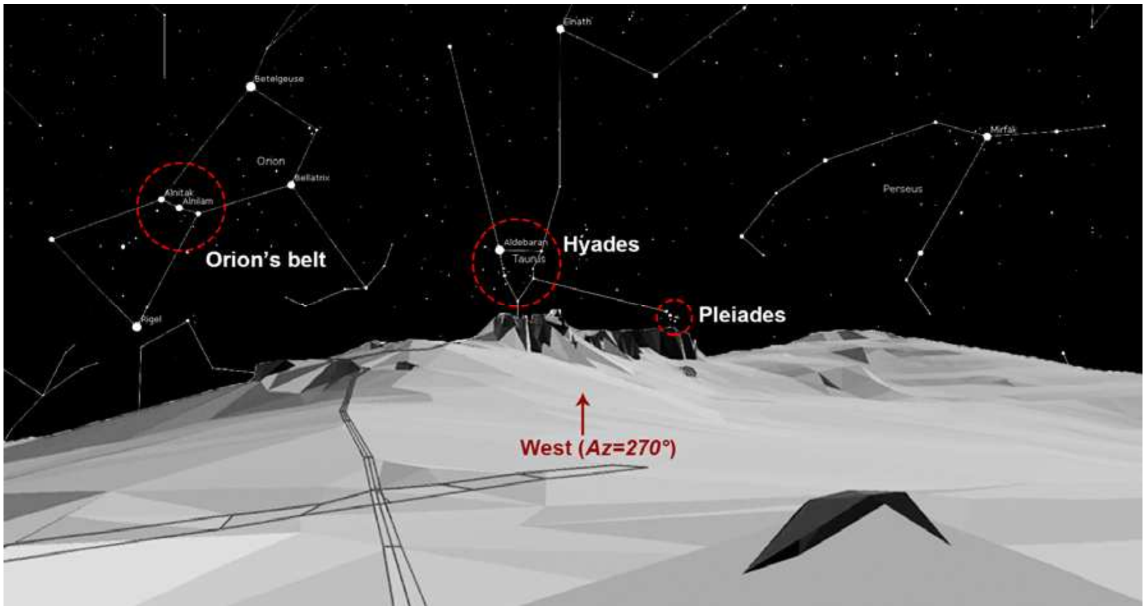

Fig. 12.: The visible starry sky from the examination site 1. in 1100 BC, one week before the spring equinox, at the time of the Sun's height h=-12° (start of astronomical twilight)

12. ábra: A csillagos égbolt látványa az 1. pontból a Kr.e. 1100. évi tavaszi napéjegyenlőség előtti héten, a Nap h=-12°-os magasságának időpontjában (csillagászati szürkület kezdete)

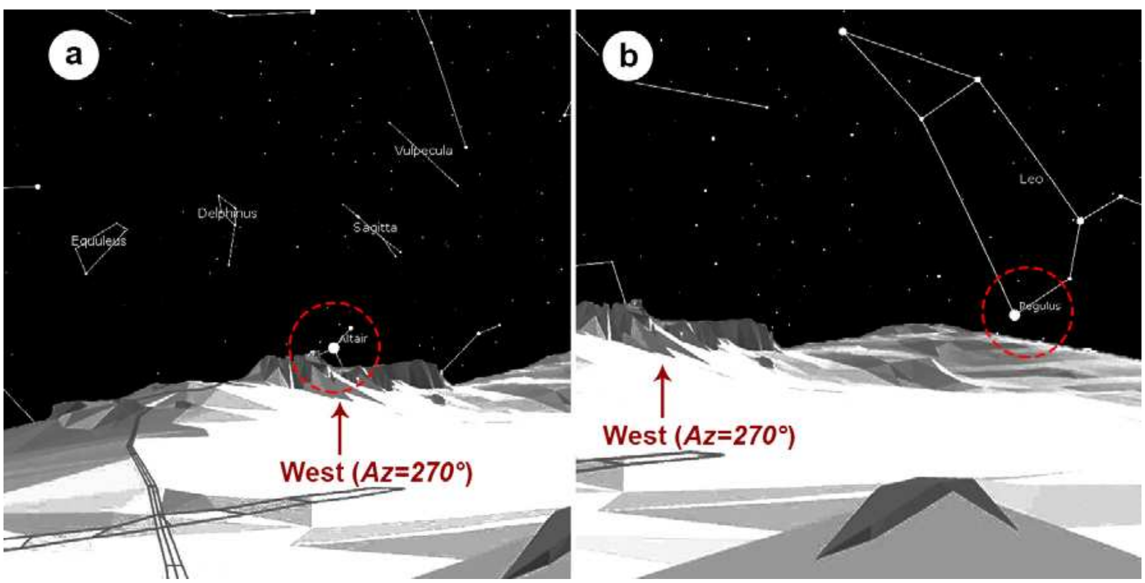

Fig. 13.: a) The heliacal setting of Altair star at the winter solstice on the 12.31.1100 BC. b) The heliacal setting of Regulus before the summer solstice on the 06.20.1100 BC. Both of the simulations were made from the examination site 1.

13. ábra: a) A téli napforduló idején az Altair nevű csillag heliákus nyugvása Kr.e. 1100.12.31-én. b) A Regulus heliákus nyugvása a nyári napforduló előtt Kr.e. 1100.06.20-án. Mindkét égboltkép szimuláció az 1. vizsgálati pontból készült.

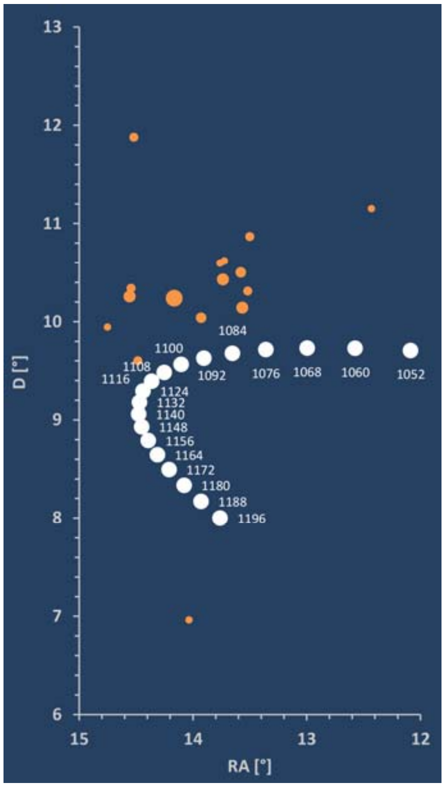

Fig. 14.: Spring conjunctions of Venus and Pleiades on every 1st of March in the highlighted years BC at 18.5 hours UT, in the western sky. We use the epoch of equinox point in 1100 BC to represent the positions.

14. ábra: A Vénusz és a Plejádok tavaszi együttállásai a jelölt Kr.e. években március 1-én 18,5 óra UT-kor a nyugati égbolton. Az ábrázolt pozíciók a tavaszpont Kr.e. 1100. évi epochára vonatkoznak.

The time of the vernal equinox could also be estimated by examining the visible starry sky close to the horizon in the direction of the Hat Rock. During this notable time, after sunset, the direction of setting constellation Orion (and the three stars that form its belt) coincided with the direction of the greater part of the supposed procession route goes from *site 1* (observer on the path essentially moves in the direction of the constellation). Before the equinox, the Pleiades open cluster approached the visible horizon in the northern part (*Az≈277°*) of the relief containing the cliff items of Hat Rock and did a heliacal setting. The cosmical setting of the cluster before sunrise was possible to observed in the middle of October, and possible to linked to the autumn equinox. Interesting phenomenon that clusters of Hyades and Pleiades observed from the examination point almost clasped the Hat Rock in *Az≈263°–277°* section *(***Fig. 12.***)*. The Big Dipper, compiled from 7 spectacular stars, had a characteristic position without any comparison with landmarks during the vernal equinox, when it reached its highest position in altitude in the sky and was in the same position in dawn during the autumn equinox.

In addition, with the help of positions of brighter stars close to the horizon and their heliacal settings, prediction of the winter and summer solstice was also possible. In the former case from the examination point in the middle of December, the Altair star of the constellation Aquila in the direction of *Az≈270°* was seen close to the horizon profile of the Hat Rock. In the latter case, the Regulus star approached the visible distant horizon in the weeks before the summer solstice in the direction of *Az≈298°* after sunset (**Fig. 13.**). The Spica star of the constellation Virgo in the direction of *Az≈270°* was seen after sunset in mid-end of July close to the horizon of Hat Rock, the same place where the Altair star was seen in winter.

We highlight the bright planet Venus as an example in our examination, because this astronomical object did a repeating conjunction in every 8 years with the Pleiades cluster close to the vernal equinox. There were such years, when observer saw this astronomical object situated inside the open cluster. Venus's recurring positions, however, shift over time due to various celestial mechanical effects, although recurrence was relatively regular at a longer examination time period, there is a good example for this in **Fig. 14.**

In relation with the setting extreme positions of Moon regarding the lunar standstill phenomenon such position cannot be assigned where these extreme positions would have associated with an outstanding landmark or topography element.

The possibility of the use of “observatory site”

The place of *site 2* can essentially be attributed to an "observatory" function. In this location the observer had to stand on the north side of the cliff block *item I* (**Fig. 4.**), where the shape of this cliff is concave (**Fig. 15.**). The wall of the cliff item has a line of strike in the east-west direction with a slight difference (in the direction of linked *Az≈75°* and *255°* positions).

When the observer standing on the mentioned side of the cliff item, at the western end of that, looking at the direction of *item II* and *item III* cliff blocks, between them in the direction of *Az≈290° (± 2°)* can see a gap (**Fig. 16.**). The area is rising in this direction, it follows that the surface is seen at an altitude of *h≈10°*, the visible highest point of the two cliff items are approximately *h≈20–25°*, the bottom of the gap between the two cliff items ends at an altitude of *h≈12°*. Around the position of the summer solstice, in the late afternoon, the Sun becomes visible through the gap, partly lowering along its tilt in the direction of the horizon.

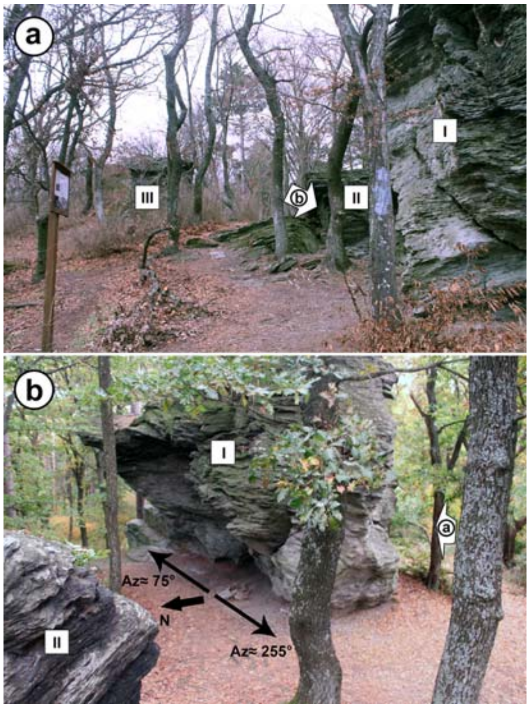

Fig. 15.: Important cliffs and the observatory point. In the pictures we marked the numbers of cliffs according to the **Fig. 4.**, place and direction of photoshoots by arrows, in these with a) and b) the appropriate picture.

15. ábra: Lényeges sziklatömegek és az obszervatórium pontja. A képen jelöltük a **4. ábra** szerint a sziklák számozását, nyíllal a fényképezés helyét és irányát, a nyílban szereplő a) és b) betűvel a megfelelő fényképet.

This assumption was confirmed by the field examination on the 22 June 2018 (**Fig. 16.**). We remark, that the time of summer solstice was on the 10 hours 07 minutes UT on 21 June 2018. Our field work delayed due to weather circumstances, but this time difference meant negligible shift in the Sun's position (Nautical Almanac of The Stars 2018). We also found that based on the change in the angle of obliquity of the ecliptic the position of the Sun was slightly more favorable for its observation through the gap during the 1200-1000 BC time period.

During the solstice the Sun reaches the most favorable extreme position for observation through the gap between cliffs for the observer, and in the days before/after the solstice, the observation possibility is becoming less and less favorable. Despite of the large parallactic displacement of the close cliff items, the ideal observation point can be clearly marked standing at the wall of cliff *item I*. The Regulus star described earlier could be suitable for forecasting the summer solstice, which position during the examined time period permitted its observation before heliacal setting too through the observation gap.

From this point, assignment of positions of vernal and autumn equinoxes is heavier. In case of sparse vegetation, it was possible to observe, that the Sun set behind the visible horizon in approximately halfway between the cliff *item IV* with lowered position and the cliff *item III*, but this point is not adequately suitable for accurate observations.

Also, in case of the Moon we cannot sign out notable points. When its digression in the northern sky is positive from the ecliptic as plain of reference, then during its stay in constellation Cancer it could be observable in the observation gap while moved towards the horizon. In case of negative digression, it was covered by the cliff *item III*. In winter, the light of full moon close to its rising and setting position could have reached the north concave part of cliff *item I*, in case of major standstill its duration could have been slightly longer.

Worthy of note, that after the sunset during vernal equinox the zodiac light may visible from the observatory point in the direction of cliff *item III*. Ideally, during the ages of examination, the top of the zodiac light may approach the Regulus star, which appeared in high altitude this time. Through the gap of examination assigned by cliff *items II and III* from the *site 2*, moving both of the – naked eye visible as misty spot – M44 Beehive cluster and the M31 Andromeda galaxy to the direction of the horizon could be observable. However, the observation possibility of these latter objects cannot be linked to a notable time of astronomical event.

The heliacal setting of Antares star in Scorpion constellation could be observed above the cliff *item IV* in the direction of *Az≈245°* in the middle of September, which could prognose the autumn equinox a few weeks before. The cosmical setting of Antares in the same position occurred after the vernal equinox. It is obvious, based on the data shown in **Table 1.,** that the "b" Sun position in the **Fig. 11.** coincident with the above-mentioned position of the Antares close to the horizon.

Therefore, the star could be used as a control star from observation *site 1* to detect the time period of these notable astronomical dates, because before its set it was visible very close to the south point of the relief.

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Fig. 16.: a) From the examination site 2. in the direction of Az≈290° we can see a gap between the cliffs of II. and III. b) position of the Sun close to the summer solstice on the 22nd June 2018, at 17:26 UT from the same point (Photo by Mitre, Z.)

16. ábra: a) A 2-es jelzésű vizsgálati helyszínről Az≈290° irányban tekintve látható a II-es és III-as sziklatömb által közrefogott rés. b) A Nap pozíciója ugyanebből a pozícióból a nyári napforduló környékén, 2018. június 22-én 17:26 perc UT időpontban (Fotó: Mitre Z.)

Orientation of the highest point

Connected to the summer solstice, cliff *item III* (**Fig. 4.**) can be attributed to an additional role. We appointed the *site 3* next to the highest point of the cliff item. The highest point (587 m) of it (and simultaneously the area) is a "hat cliff" about an elliptical shape with approximately a semi-major axis 3 meters and a semi-minor axis 2 meters, separated by a remarkable platform from the level below it (**Fig. 2a** and **17.**).

This cliff item can be approached via a small terrace, both of orientations the longitudinal direction of terrace and semi-minor axes of the cliff item are approximately *Az≈300°*. Next to the hat cliff item, when the observer stands on this small terrace faces opposite the Sun approach its sunset during the time of the summer solstice, sees its setting in the direction of the examination *site 6*. The examination *site 6* is currently not visible due to trees, but it is well detected in the simulation based on geodesy survey data. The observation *site 3* is well accessible, essentially without much effort, used by the stair-like positions of platforms of the cliff mass. The natural shape and approach of the cliff mass has an individual aspect, it may seem ideal for a sacral site associated with the Sun (**Fig. 17.**).

The orientation of southern side of the cliff *item III* is east-west, between spring and autumn the light of the Sun was limited or could not be reached it in the morning or late afternoon when this was in low altitude. In all cases, the light of the Sun between its position *Az=90°-270°* illuminates the southern wall. During the equinoxes sunrises and sunsets can be assigned along the southern wall of the cliff item. In the east direction, the cliff *item I* also coincides with the direction of this assignment, which is essentially surrounded by the light of the Sun when rising.

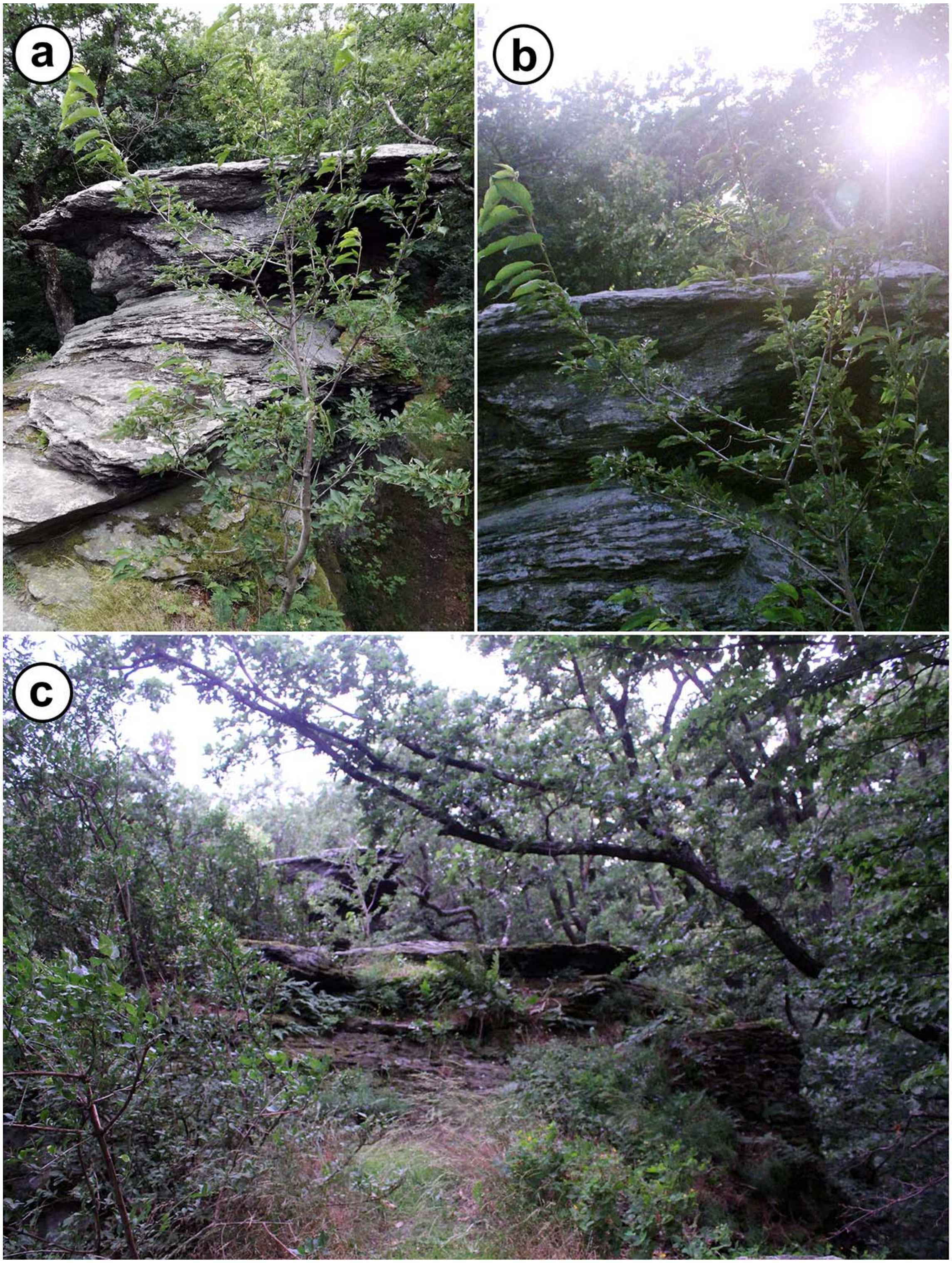

Fig. 17.: a) Specific hat-formed peak of the examination site 3. (also the highest point of the area); b) position of the Sun during the afternoon of summer solstice; c) this place is approachable on a stairway-like path (Photo by Mitre, Z.)

17. ábra: a) 3-as helyszín különleges kalapos sziklacsúcsa (egyben a helyszín legmagasabb pontja); b) Nap helyzete a nyári napforduló délutánján; c) a helyszín lépcsőzetes teraszokon keresztül közelíthető meg (Fotó: Mitre Z.)

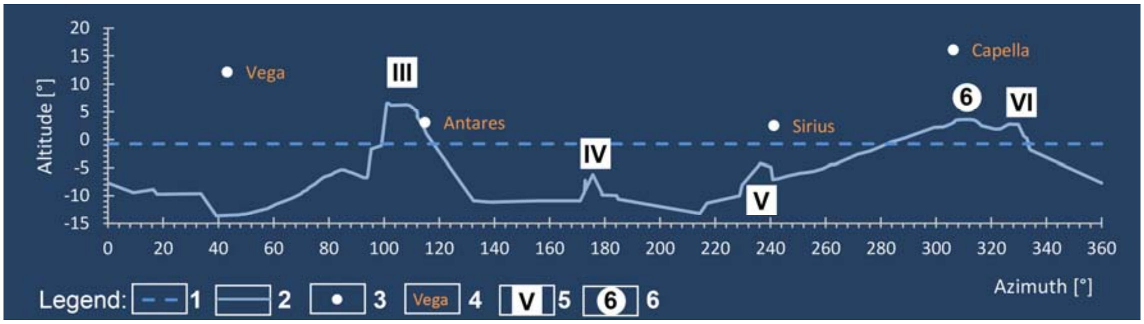

Fig. 18.: Simplified horizon skyline and some important stars from the examination site 4. at 03.31.1100 BC, in the night of vernal equinox at 20h UT based on the data of geodesy survey. We use the epoch of equinox point in 1100 BC to represent the positions. Legend: 1. position of calculated sea level horizon; 2. profile of relief based on the data of geodesy survey; 3. important stars; 4. name of important stars; 5. numbering of significant cliffs regarding the examination (see **Fig. 4.**); 6. astronomical examination places (also panorama shooting places, see **Fig. 4.**)

18. ábra: A horizont egyszerűsített profilja és néhány fontosabb csillag Kr.e. 1100.03.31.-én, a tavaszi napéjegyenlőség estéjén, 20 óra UT-kor, a geodéziai felmérés alapján a 4. vizsgálati pontból, a tavaszpont Kr.e. 1100 szerinti epocha szerint. Jelmagyarázat: 1. tengerszintre számított horizont helyzete; 2. domborzat profil a geodéziai felmérés adatai alapján; 3. fontosabb csillagok; 4. fontosabb csillagok neve; 5. vizsgálat szempontjából jelentősebb sziklák számozása (ld. **4. ábra**); 6. asztronómiai vizsgálati helyszínek (egyben panorámafelvételezés helye, ld.. **4. ábra**).

Centre of the area

The examination *site 4* essentially the center of the area, which is a remnant of a lower terrace on the greenschist rock. We examined it because we assumed that it could be used primarily to observe the sunrise of the vernal and autumn equinoxes, but we did not find clear possibility to it. It is obvious, that viewed from this examination site only a few close cliff items rise above the horizon, only the *item III* is the one, that raised more significantly in the direction of *Az≈110°* reach up to the altitude of *h=6–7°* (see the photo of the cliff block from the examination site in the **Fig. 2a**). The cliff *item IV* essentially visible in the direction of south (*Az≈180°*) and the *item V* in the direction of *Az≈235°*, but height of these are below the position of horizon, otherwise these might be suitable for mark out directions. Two bulges are visible as low-rise height on the one hand the distant one in the position of *Az≈310°* and *h≈3,5°* where we mark out the examination *site 6* and on the other hand the cliff *item VI* in the position of *Az≈330°* and *h≈3°*.

Several bright stars were possible to observe from this location used the landmarks mentioned above as points of references. As it is seen in **Fig. 18.**, in the turn of the centuries $12^{th}/11^{th}$ BC, the set of Sirius star during the evening of vernal equinox was visible in the direction of hat cliff *item V* at the same time, when the rise of the Antares star was observable in the direction of cliff *item III*. The Capella star was situated with relatively higher altitude in the direction of examination site 6 (also the direction of sunset of the summer solstice). The Vega star appeared in the direction of north-east in similar altitude like Capella (approximately opposite the Sirius) (**Fig. 18.**). In the dawns right after this equinox the observer could observe the Antares star in the direction of hat cliff *item V*.

The observer could also observe during the dawns around of the summer solstice the cosmical setting of Arcturus star in the direction of northwest (*Az≈325°*) which approximately coincides with the direction of cliff *item VI*. To the east, in the direction of cliff *item III* the Pleiades cluster and Taurus constellation located in high altitude and both of them disappeared in the light of the rising Sun. Regarding the Regulus star, we already described about its heliacal setting during the evening of summer solstice.

At the dawn, during the autumn equinox we cannot appoint distinctive positions, only Sirius could be seen close to its culmination and the zodiac light could be observed in the direction of east, however its direction did not coincide with the cliff *item III*. In the evening sky it was not possible to appoint distinctive positions, a few hours after the sunset the appropriate positions of former mentioned summer solstice dawn sky appeared.

We already described the heliacal setting of Altair star during the winter solstice, but at the same time in dawn it was possible to observe its heliacal rising as well. During its dawn position it was visible in the direction of cliff *item III* relatively high before disappeared in the light of the rising Sun, at the same time the Antares star reached its culmination, high in the direction of cliff *item IV*.

Fig. 19.: The sunlight shines into the northern hollow part of the cliff item I. during the late afternoon of summer solstice in 2018. The edge at western part of the cliff partly covers the sunlight (Photo by Mitre, Z.)

19. ábra: A I-es számú szikla északi, homorú oldalára bejutó napfény a 2018-as nyári napforduló késő délutánján. A sziklatömeg nyugati pereme a napfény egy részét kitakarja (Fotó: Mitre Z.)

In the evening of the winter solstice the sunset happened in the direction of cliff *item V*. After sunset, the constellation Orion was seen in the direction of cliff *item III*, and after the darkness arrived the Sirius star appeared next to the same cliff item. While the Regulus star rose in the direction of north-east, at the same time the Vega star lowered close to the horizon in the direction of cliff *item VI*.

Possible agriculturally active period indicator cliff item

The Sun shone during the examined period into the northern concave side of the cliff *item I*, when it was north from $Az \approx 75°$ during its rise or $Az \approx 255°$ during its set (**Fig. 15.**). The topography conditions are somewhat reducing the length of this time period.

During the time period of 13-11. century BC the Sun's light touched the examined part of the cliff item approximately between the first part of April and October (approximately the time between the vernal and autumn equinoxes), which could be indicative taking into also account agricultural and production aspects. Within this, between early May and September are the time section when rising Sun close to the horizon from east may illuminated the north side of the cliff item, not just only the setting one. We should add that there are edges on both of the eastern and western parts of the concave side of the cliff *item I*. These reduce the amount of the sunlight reach both of the area and the concave side behind them (**Fig. 19.**).

We already wrote before about the cosmical setting of Antares star, which is also observable from this point. We add that at the beginning part of September, when the Sun touched the northern part of the relief section visible from the *site 1* (marked "d" in the **Fig. 11.**), the Sun touched the visible horizon at $h \approx 11°$ altitude from the observation *site 2* at the left root side of the cliff *item III*.

It is interesting that the direction of the center of the Milky Way (where it is the densest, most spectacular) from *site 2* was seen during the autumn equinox at the end of the astronomical dusk in the direction of cliff *item IV*.

We notice, that the formerly described south wall of the cliff *item III* may also be suitable for assign the boundary of the active-passive period separated by the equinoxes.

The "shelter" and fireplace

The *site 2* was appointed by the former archaeological probe in 1997, where artifacts and trace of a fireplace were successfully excavated from Late Bronze-Early Iron Age. The place is located at the leg of the hat rock *item IV*, in the root under a cliff platform in the direction of south and south-east (**Fig. 4.** and **5a**). Its altitude is 574 meters above the sea level, which is 10-15 meters lower than the height of the cliff items of Hat Rocks in the highest position. This point provided relatively tolerable protection against the northern down-wind and precipitation due to its concave shape (a larger platform covers it) at the leg of the cliff form.

The Sun by moving along in low altitude could light well the examined archaeological *site 2* between the autumn and vernal equinoxes until the early afternoon. Between the vernal and autumn equinoxes, however, the light of the Sun close to the horizon was covered on the one hand in the direction of east by the relief of the area on the other hand in the direction of south-west by the wall of cliff *item IV*. The line of strike of the cliff wall, which gives place to this *site 2* has a coincident direction with the sunset of winter solstice, so the light of the setting Sun can only reach this place only during winter solstice. This hypothesis was checked on field during the winter solstice.

A few meters from the above-mentioned site, at the south-west part of the cliff *item IV*, the cliff wall leading towards the Limax Cave roughly coincident with the direction of the sunrise during the winter solstice, so the light of the rising Sun that time could graze it. However, the light of the rising Sun is covered outside this solstice, it can only reach the place later from a higher altitude, so the Sun between the positions of $Az \approx 125°$ and $Az \approx 270°$ could surely shine on it. The light of the setting Sun could reach the cliff wall and the surroundings of the cave between the autumn and vernal equinoxes.

The shelter-like use of the Holler Cave close to the examined area, southwest from it, would seem logical, but the archaeological probing (*site 3*) in 1997 – regarding the now examined time period – was unprofitable. We do not know whether the artifacts of the examined period were "cleaned" from there or whether the cave was not used at all.

Regarding the whole area it is a priori problem that the small amount soil on the greenschist rock affects rather unfavorably the possibility of successful archaeological probing. We add that the Hat Rock Cave and its environment may also be interesting for archaeological examinations, its total length is approximately 30 meters, situated north from the examined area (**Fig. 4.**).

Uncertain sites

In the previous sections we examined such locations, which astronomical resources are easily recognizable. However, we cannot exclude that there were other sites that may suitable for observation, so our examination is far from complete. There were also sites that astronomical use we considered possible, but during our examination we did not find easily accessible astronomical resources for them.

The *site 5* is located on the slope of the greenschist cliff mass oriented to south, at the center of a semi-circular evolved edge, on a cliff item whence several cliff masses with hats can be seen in the directions of east, south, west including also a possibility to assign appropriate positions. However, in the simulation tests following the panorama survey we did not find convincing points to assign directions.

At the same time, *site 6* may be interesting for further examinations. From here as well, due to the vegetation currently not possible to see the location of the Hat Rock cliff group (the same as from the *site 1*), but the examination of the geodesy survey data showed that the winter solstice is able to observe from the site. In case of sparse vegetation due to its high position the observer could have a full view to the highest cliff items of the Hat Rock, so at the previous mentioned time the Sun could be visible to rise in exactly that direction.

During the examinations the question also arose whether the supposed procession path followed another track and missed the third "*tor*" gate, because edge along on the uplift seems the most ideal trail. Based on the geodesy examinations the site is easier accessible on a path along on the back of the cliffs than on the less favorable trail path currently used (**Fig. 4.**).

Conclusions

The location of the Hat Rock which is coincident with the direction of the movement of the Sun and the sky in correlation with both of the archaeological finds of Szent Vid and the examination place, propose the possibility of the astronomical related sacral use linked to productivity, agricultural, perhaps mountain culture. The people of the cultures living here "found" this formation with distinctive morphology "ready to use" which could strengthen its sacral character.

Astronomical use – i.e. observing the rising and setting of the Sun and other astronomical objects close to the horizon – is the most efficient in case of an environment with sparse vegetation, rich in open spaces, with good view to landmarks. According to the climate model created, based on the previous researches of this time period, there was a cooler, wet climate, which was favorable to the rich vegetation. However, environment history data confirming mosaicity refer to significant forest extraction in the Carpathian Basin and the examination site as well. This and the increase in the number of species that prefer open spaces refer to favorable observational conditions.

The astronomical resources and capabilities of the area could use as an indicator of a kind of agricultural activity. The observation made from the *site 1*, which is able to determine and predict the vernal and autumn equinoxes, may have already set out the beginning and the end of the productivity-active period. For example, the observation *site 4* in the middle of the area is suitable to check the time of vernal equinox where this time after sunset, in the early evening in the direction of cliff *items III-V-VI* a brighter star could be seen. We notice, that equinoxes could not compose a subject of typically accurate observations due to their brief nature and difficult detection of these moments. We consider the nature of illumination rather as a time marker in case both of cliff *items I and III*. The south wall with its east-west orientation of cliff *item III* and its inclusive nature regarding vernal and autumn equinoxes could clearly help to separate the spring-summer (productivity) and autumn-winter (decline, rejuvenation) time periods.

Within the area, cliff *item I* and examination *site 2* may also was suitable for observation of active agricultural time period. On the one hand, the section between the vernal and autumn equinoxes as the late afternoon Sun close to the horizon lit the northern side of this cliff block during this period, on the other hand the section between early May and early September, when the light both of the rising and the setting Sun close to the horizon may touched that. The time of the summer solstice could be clearly determined by observing the lowering Sun in the direction of western horizon through the cliff gap from observatory *site 2*. The heliacal setting of Regulus star was also suitable to prognose the time. The time of the autumn equinox can be estimated from *sites 1 and 2* as well. The time of the winter solstice can be well determined from the *sites 1 and 4* by the position of the Altair star both of its heliacal setting and at the same time rising at dawn.

The small number of archaeological finds in the Hat Rock complicates the reality of the theoretical results of our examination. The decorations of the artifacts found on Szent Vid Hill may refer to mainly to solar symbols as well as to the Moon month and the Pleiades cluster. However, it is difficult to find a vestige regarding how much the Hat Rock were used for astronomical observation in relation to these symbols. Presumably it could have also a limited observatory role in respect of observations regarding it is not an artificial creation. The further possible functions of the cliff items regarding the shadow effect will have to be a subject of a separate examination.

The raised astronomical thinking and resource exploration in this paper was intended to denote a theoretical possibility of use. New targeted archaeological excavations and comparative researches would be essential for further examinations in the practice and confirmation of archaeological theory. In the area the very thin soil layer on the greenschist rock makes the research with archaeological probe difficult, so only small number of finds of artifacts can be expected. As a result of climatic and vegetation effects, the thickness of the soil layer may have changed, but in general we assume transport from the area. Based on field examinations we find that further archaeological research everyhow must be carried out in places where artifacts fell down or transported with soil by rainwater and these can gather due to pluvial processes in area with lower altitude due to the relief circumstances around the environment of Hat Rock. Metal search activity is an urgent task too. Complex archaeometry processing (e.g. dating, pollen analysis) of subsequent new archaeological phenomena cannot be ignored. The results of the new archaeological researches would greatly contribute to the clarification of the theoretical approach in this paper and the planning of further steps of archaeoastronomy research.

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KÖZLEMÉNYEK

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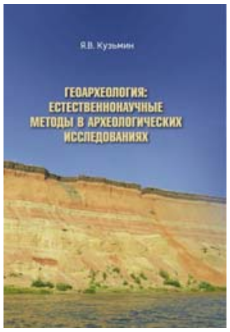
Könyvismertetés

Кузьмин, Ярослав Всеволодович: Геоархеология: естественнонаучные методы в археологических исследованиях. Томск: Издательский Дом Томского государственного университета, 2017. – 396 с.



(Kuzmin, Jaroszlav Vszevolodovics: Geoarcheológia: természettudományos módszerek a régészeti kutatásokban. Tomszk: A Tomszki Állami Egyetem Kiadóháza, 2017. – 396 p.)

A szerző a földrajztudományok doktora, az Orosz Tudományos Akadémia Novoszibirszki Földtani és Ásványtani Intézetének vezető kutatója, a Földrajzi Információs Technológiák és Távérzékelés Kutatólaboratórium munkatársa. A Szerző kapcsolata a geoarcheológiával 1979-ben kezdődött, amikor megismerkedett Valerij Petrovics Sztyepanov régésszel, s a most bemutatott könyv iránti igény is először a régészet oldaláról merült fel. Az egyik altaji expedíció során Gennagyij Fedorovics Barsüsnikov régész 1998-ban arra hívta fel a Szerző figyelmét, hogy egy évtizeden belül szükséges lesz egy geoarcheológiai könyv megjelentetése. Ebben aztán nagy segítséget nyújtottak az 1990-es – 2000-es években az Egyesült Államokban az Arizonai Egyetemen tett látogatásai, az ottani gazdag könyvtár használatának lehetősége.

Az orosz geoarcheológiai kutatások úttörője Andrej Alekszejevics Velicskov volt az 1950-es évek elején. A Szerző ahhoz a fiatalabb, már külföldi tanulmányokra is lehetőséget kapott generációhoz tartozik, amely jelenleg meghatározó az orosz kutatásban. Így nemzetközi kutatástörténeti szempontból is különösen érdekes a két, egymástól távol eső világ közötti összekötőszálat és egyfajta szintézist jelentő kutató szemlélete. A nyugati oldalon – talán a személyes ismeretség miatt is - leginkább mintának tartott Colin Renfrew és Paul Bahn hetedik kiadáson is túljutott könyve (Archaeology: Theories, Methods and Practice) mellé sajnos hasonló orosz munkát nem lehetett odatenni. Ezt az űrt Jaroszlav Vszevolodovics Kuzmin éppen a megjelent művével, a geoarcheológia alapjainak első orosz nyelven megjelent, szisztematikus bemutatásával szeretné legalább részben kipótolni. Célul tűzte a régészeti ismeretek bemutatását, azon geoarcheológiai kutatások módszereinek és eszközeinek a megismertetését, amelyek lehetővé teszik az interdiszciplináris szakmai kérdések helyes megvilágítását és megválaszolását a természettudományos módszerek alkalmazásával a régészet területén. Meghatározása szerint a geoarcheológia olyan interdiszciplináris tudományág a természettudományok és a régészet metszéspontjában, amelynek célja az őskori ember természeti-klimatikus viszonyainak rekonstruálása, annak geológiai korának, gazdaságának (élelmiszereinek és nyersanyagainak), a természeti környezettel való kölcsönhatásai, a tájra gyakorolt befolyásának és az egykori emberek életének egyéb aspektusainak kutatása, amelyek tisztán régészeti módszerekkel nem vizsgálhatók.

Meghatározásának megfelelően az öt fő témacsoport köré szerkesztett művének tartalmi része jóval szűkebb határok között mozog, mint Colin Renfrew és Paul Bahn mintának tekintett, a régészetet általános megközelítésben és teljes szélességében tárgyaló könyve. A Szerző a földtudományok felől közelítve, s végig azon a területen maradva tárgyalja a régészeti vonatkozású szálakat. Mindezt olyan formában és nyelvezettel, hogy az a régészettel, geológiával behatóbban foglalkozó szakemberek mellett a széles olvasóközönség, egyetemisták számára is érthető és élvezhető legyen. Ezt segítik a szövegben a lényeget jelző, vastagon szedett kiemelések, a minden esetben jól összeválogatott konkrét esettanulmányok, valamint a kötet végén lévő kombinált fogalom, tárgy, hely- és személynév mutató is. Továbbá a munka szerkezete is logikusan felépített, az első, a mű célját, a geoarcheológia fogalmát, forrásait, kutatástörténetét áttekintő rövid fejezet után a legbőségesebb, a földtani és geomorfológiai rész alapozza meg az olvasó ismereteit. Az erős inspirációt adó angol művel szélesebb átfedés azonban csak a mindkét kötetben bemutatott, az orosz szerzőnél a 3. fejezetben ismertetett különböző datálási technikák (^{14}C, egyéb radioaktív izotópok, dendrokronológia, stb.) között van. Azonban a mostani munka javára kell írni, hogy ha nem is olyan színes formában, mint a korábbi mű, de jóval részletesebben és mélyebb összefüggéseiben, a teljességre törekedve tárja elénk a ma elérhető, változatos kormeghatározási módszereket.

A negyedik részben tárgyalt, a kutatásban viszonylag új, az 1970-es években induló, de széles körben csak az ezredforduló után elterjedő stabilizotópos vizsgálatok a geoarcheológia egyik legdinamikusabban fejlődő területe, ahol a szén, nitrogén és kén stabil izotópjainak elemzésével vizsgálják a pleisztocén környezet változásait és a régészeti korszakok embereinek táplálkozási szokásait. A fejezetekhez tartozó esettanulmányok sorában itt bemutatott, késői példa a kutatóknak is remek lehetőséget nyújtott a természettudományos eredmények kontrollálására. Egy áruházi parkoló alatt 2012-ben megtalálták a Shakespeare drámájából is ismert III. Richárd földi maradványait. A stabilizotópos vizsgálatok során az azonosításhoz szükséges adatokon túl többek között arra is keresték a választ, hogy mi volt a királyi étrend, mit ivott és evett a király? A történeti forrásokból ismert, hogy a későbbi uralkodó Közép-Angliában, 1452-ben Fotheringhay kastélyában született, majd hétéves korától a Wales határán lévő Ludlowban, később pedig Anglia északi részén, Middlehamban nevelkedett. Felnőtt korában is - rövid idejű emigrációjától eltekintve - Angliában élt. A jól megtervezett és gondosan előkészített vizsgálat során a C, N, O, Sr stabilizotópokat vizsgálták a különböző csontokban és fogakban az életkori szakaszok figyelembe vételével, a kapott eredmények pedig összevetették a történeti adatokból ismert helyszínek földmintáival. A sípcsont vizsgálati eredményei azt mutatták, hogy a fiatal herceg főleg növényi ételeket fogyasztott, míg a borda adatai egyértelműen azt jelezték, hogy az uralkodó étrendje az utolsó években drasztikusan megváltozott, főleg halakat és vízimadarakat fogyasztott, ami egyezett a történeti adatokból és a kontrollmintákból kirajzolódó képpel. Azonban egészen különös volt és a történeti adatoknak ellentmondónak tűnt a vízből származó oxigén stabilizotópjának $\delta^{18}O$=–5,2 ‰ aránya. A kutatók végül abban találták meg a helyzet megoldását, hogy a király nagy mennyiségben hozatott be bort Franciaországból ($\delta^{18}O$ = +2,7‰), a Rajna-vidékről és a Földközi-tenger medencéjéből is, amit a helyi vízzel ($\delta^{18}O$ = –8‰) keverve jelentős mennyiségben ivott, s szervezetében ez okozhatta az Angliában egyébként szokatlan arányú oxigén stabilizotóp felhalmozódását.

A magyar olvasó számára különösen jóleső érzés lehet, hogy legalább az utolsó, ötödik témakörnek, a tárgyak és anyagok petrográfiai valamint kémiai elemzési lehetőségeinek bemutatása kapcsán, ha csak egyetlen hivatkozás erejéig is, de közvetlen Kárpát-medencei vonatkozása van. A nemzetközi kutatásban a régészeti obszidián források tanulmányozásának kezdetét J. Cann és C. Renfrew 1964-ben megjelent munkájához kötik (Cann J.R., Renfrew C., The characterization of obsidian and its application to the Mediterranean region. Proceedings of the Prehistoric Society. 1964. V. 30. 111–133). A kutatási lehetőségeiben, eszközeiben és módszertanában is gyorsan fejlődő területen különös módon az orosz régészet kevésbé jelent meg. Ebből a szempontból is érdekes, hogy a magyar kutatás viszont korán elég erőteljesen és eredményesen bekapcsolódott a témakör vizsgálatába, s ennek az elismerése is T. Biró Katalin munkájának (Carpathian obsidians: myth and reality. Proceedings of the 34th International Symposium on Archaeometry. Zaragoza: Institución "Fernando el Católico", 2006, 267–277) megemlítése. A Szerző a szívéhez is láthatóan közel álló kérdéskör leírása során részletesen tárgyalja a vulkanikus obszidián keletkezésének körülményeit, a lelőhelyek geológiai és földrajzi elhelyezkedését, az egyes típusok elkülönítésére használt vizsgálati módszereket, e fontos őskori alapanyag kereskedelmét. A hazai őskori régészeti lelőhelyeinken legtöbbször található fekete vulkáni üvegből készült eszközök mellett olvashatunk a színtelen, teljesen átlátszó, sötétkék, zöld, vörösesbarna változatokról is. A kőzet részletes elemzése során elsősorban analitikai módszerekkel a minden lelőhelyre jellemző geokémiai ujjlenyomatát határozzák meg az alapösszetevők és a nyomelemek alapján. A vizsgálatokhoz napjainkban használt neutronaktivációs (NAA), röntgen-fluoreszcens (XRF), induktív tömegspektrometriai eszközök és vizsgálati módszerek ismertetése mellett megemlíti azok előnyeit és hátrányait is – ami a modern nagyműszerek használhatóságával kapcsolatban más kutatási területeken, például az archeometallurgiai elemzések esetében is számos tanulsággal szolgál. Különösen elgondolkodtató az a megállapítása, hogy a kézi XRF berendezésekkel mért eredmény nagymértékben függ a minta formájától (vastagsága, alakja), a felületi egyenetlenségektől, így a megfigyelt elemek és azok mennyisége is akár jelentősen eltérhet a NAA módszerekkel mért adatoktól.

Jaroszlav Vszevolodovics Kuzmin könyve szép példája annak, miként lehet az évtizedeken át külön utakon járó két tudományos világ közötti szinkront, a nemzetközi kutatás egységét helyreállítani. Az egyre gyorsuló technológiai váltás miatt könyvének további nagy jelentősége, hogy az olvasó a nálunk jobban ismert angol nyelvű szerzők (K. W. Butzer, M. J. Aitken, M. Pollard, R. Taylor, M. Waters stb.) részben magyarul is megjelent hasonló témájú műveinek információit a legújabb, naprakész ismeretekkel egészítheti ki.

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Az Archeometriai Műhely 2019 XVI. évfolyam 1-3 számainak lektorai voltak:

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