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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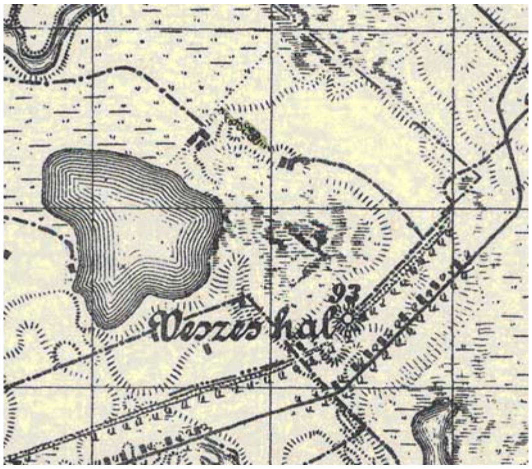

Fig. 1.: Vesszős-halom (mound) can be found on theboundary zone between Pusztaszer and Ópusztaszer villages'areas on the topographic map of Hungary in the period of the IInd World War

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).

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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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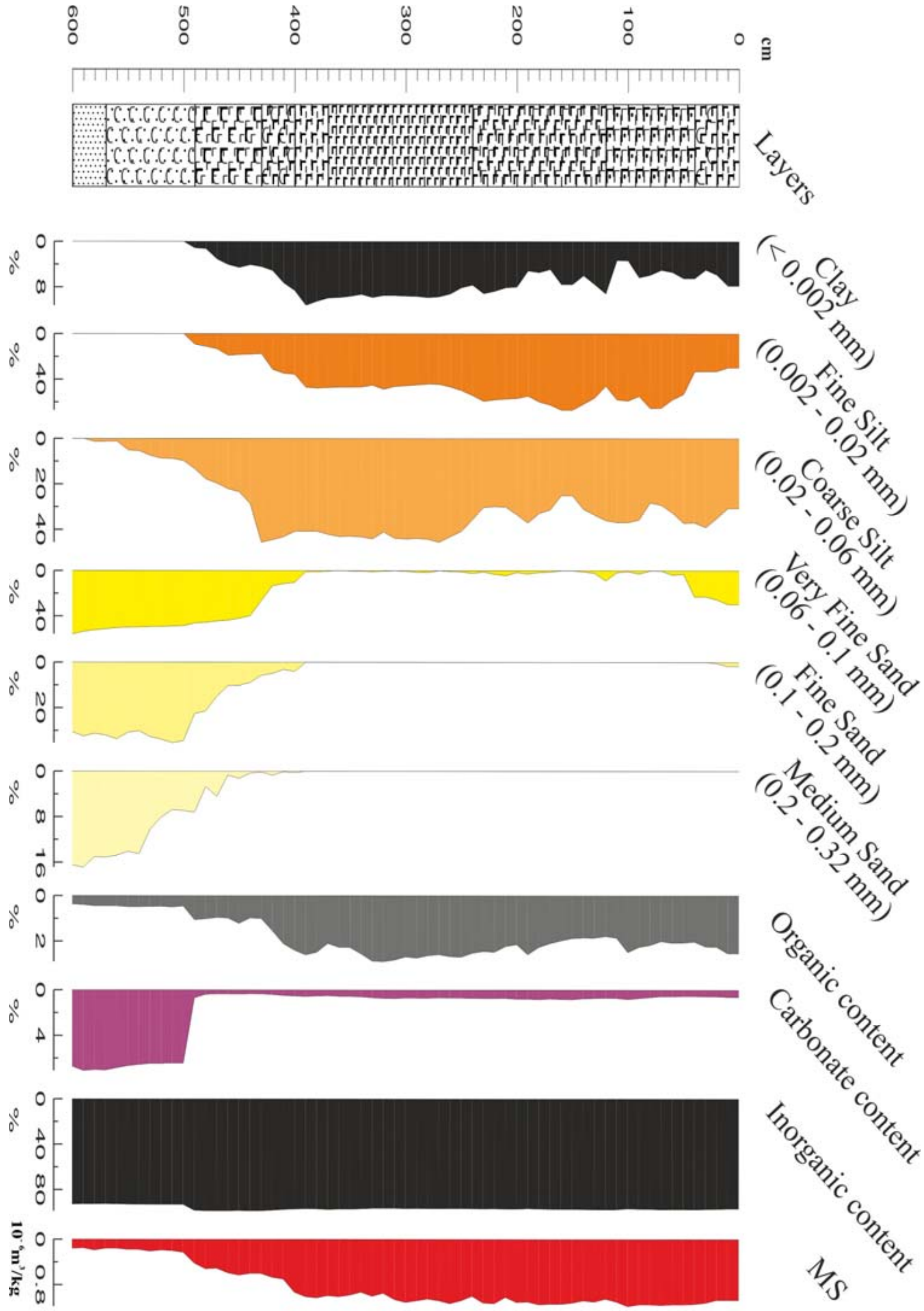

Fig. 3.: The results of the georchaeological analyses of the core sediment sequence of the Vesszős-halom (mound). The core sequence was drawn using Psimpoll programme (Bennett, 1992, 2005) within Troels-Smith's soft sediment categories (Troels-Smith, 1955) and granulometical, loss on ignitation (LOI)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

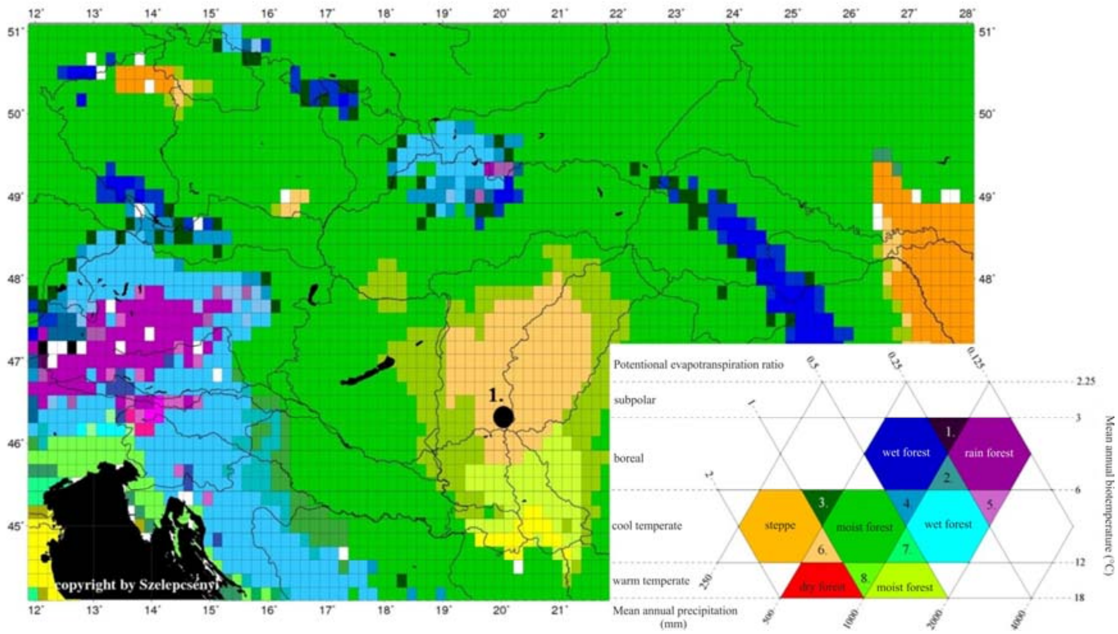

Fig. 4.: Spatial distribution of the modified Holdridge life zones on the map and the figure caption of the map

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.

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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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References

ALLEN, J. R. M., WATTS, W. A., HUNTLEY, B. (2000): Weichselian palynostratigraphy, palaeovegetation and palaeoenvironment: the record from Lago Grande di Monticchio, southern Italy. *Quaternary International* **73-74** 91–110.

BARCZI, A., HORVÁTH, T., PETŐ, Á., DANI, J. (2012): Hajdúnánás - Tedej – Lyukas-halom: egy alföldi kurgán régészeti értékelése és természet-tudományos vizsgálata. In: KREITER, A., PETŐ, Á., TUGYA, B. (szerk.), *Környezet – Ember – Kultúra: Az alkalmazott természettudományok és a régészet párbeszéde.* Magyar Nemzeti Múzeum Nemzeti Örökségvédelmi Központ 2010. október 6–8-án megrendezett konferen-ciájának tanulmánykötete, Budapest, 25–46.

BEHRE, K. E. (1981): The interpretation of anthropogenic indicators in pollen diagrams. *Pollen et spores* **23** 225–245.

BENNETT, K. D. (1992): PSIMPOLL: a quick BASIC program that generates PostScript page description files of pollen diagrams. *INQUA Commission for the study of the Holocene: working group on data handling methods newsletter* **8** 11–12.

BENNETT, K. D. (2005): Documentation for psimpoll 4.25 and pscomb 1.03: C programs for plotting pollen diagrams and analysing pollen data. Department of Earth Sciences, University of Uppsala. http://www.chrono.qub.ac.uk/psimpoll/psimpoll_manual/4.26/psman3.htm

BIRKS, H. H. & BIRKS, H. J. B. (1980): *Quaternary Palaeoecology.* E. Arnold Press, London, 1–289.

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

CHU, J., STABNIKOV, V., IVANOV, V. (2012): Microbially induced calcium-carbonate precipitation on surface or in the bulk of soil. *Geomicrobiology Journal* **29** 544–549.

DEAN JR, W. E. (1974): Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss on ignition: comparison with other methods. *Journal of Sedimentary Research* **44** 242–248.

DEARING, J. (1994): *Environmental magnetic susceptibility. Using the Bartington MS2 system.* Chi Publishing, Kenilworth, 1–104.

ECSEDY, I. (1973): Újabb adatok a tiszántúli rézkor történetéhez. *A Békés Megyei Múzeumok Közleményei* **2** 3–40.

ECSEDY, I. (1979):The People of the Pit-Grave Kurgans in Eastern Hungary. *Fontes Archaeologici Hungaricae.* Akadémiai Kiadó, Budapest. 1–85.

ELENGA, H., PEYRON, O., BONNEFILLE, R., JOLLY, D., CHEDDADI, R., GUIOT, J., HAMILTON, A. C. (2000): Pollen ‐ based biome reconstruction for southern Europe and Africa 18,000 yr bp. *Journal of Biogeography* **27** 621–634.

KERESZTÚRI, A., GYOLLAI, I., SZABÓ, M. (2015): Case study of chondrule alteration with IR spectroscopy in NWA 2086 CV3 meteorite. *Planetary and Space Science* **106** 122–131.

KROLOPP, E. (1961):A Buda környéki alsó-pleisztocén mésziszapok csiga-faunájának állatföldrajzi és ökológiai vizsgálata. *Egyetemi doktori értekezés*, Budapest, 1–141.

MAHER, L. J. (1972): Nomograms for computing 0.95 confidence limits of pollen data. *Review of Palaeobotany and Palynology* **13** 85–93.

MAGYARI, E., SÜMEGI, P., BRAUN, M., JAKAB, G. (2001): Retarded hydrosere: anthropogenic and climatic signals in a Holocene raised bog profile from the NE Carpathian Basin. *Journal of Ecology* **89** 1019–1032.

MAGYARI, E. K., CHAPMAN, J. C., PASSMORE D. G., ALLEN J. R. M., HUNTLEY J. P., HUNTLEY, B. (2010): Holocene persistence of wooded steppe in the Great Hungarian Plain. *Journal of Biogeography* **37** 915–935.

MOLNÁR B. (2015): A Kiskunsági Nemzeti Park földtana és vízföldtana. JATE Press, Szeged, 1–524.

MUNSELL COLOR COMPANY, (1994): Munsell Soil Color Charts, Revised Edition. Macbeth Division of Kollmorgen, New Windsor, NY. 1–28.

PRENTICE, I. C., WEBB T., (1998): BIOME 6000: reconstructing global mid-Holocene vegetation patterns from palaeoecological records. *Journal of Biogeography* **25** 997–1005.

PRENTICE, I. C., GUIOT, J., HUNTLEY, B., JOLLY, D., CHEDDADI, D. (1996): Reconstructing biomes from palaeo-ecological data: a general method and its application to European pollen data at 0 and 6 ka. *Climate Dynamics* **12** 185–194.

STEFANOVITS, P. (1963): *Magyarország talajai*. 2. kiadás, Akadémiai Kiadó, Budapest. 1–442.

STEFANOVITS, P. (1972):Talajtan. Mezőgazda Kiadó, Budapest.

SÜMEGI P. (1988): Jelentés a Hortobágy - Szálkahalmon végzett geomorfológiai, üledékföldtani és quartermalakológiai vizsgálatokról. Ásvány- és Földtani Tanszék, Debrecen, *kézirat* 1–37.

SÜMEGI P. (1992): Jelentés a sárrétudvari Őr-halmon végzett geomorfológiai, üledékföldtani vizsgálatokról. Déri János Múzeum, valamint Ásvány- és Földtani Tanszék, Debrecen, *kézirat* 1–32.

SÜMEGI, P. (1993): Sedimentary geological and stratigraphical analysis made on the material of the Upper Paleolithic Settlement at Jászfelsőszent-györgy-Szúnyogos. *Tisicum* **8** 63–70.

SÜMEGI, P. (1994 – 1999): Régészeti geológia hivatalos speciális kollégium előadás és gyakorlat jegyzet- és ábraanyaga. Kossuth Lajos Tudomány-egyetem Földtani és Őslénytani Tanszék, Debrecen, kézirat, 211 pp.

SÜMEGI, P. (1998.): Az utolsó 15000 év környezeti változásai és hatásuk az emberi kultúrákra Magyarországon. In: Ilon, G. szerk., *A régésztechnikus kézikönyve I.* Szombathely, Panniculus Régiségtani Egylet és Savaria Múzeum Kiadványa, 367–397.

SÜMEGI P. (2001): *A negyedidőszak földtanának és őskörnyezettanának alapjai.* JATE Press, Szeged. 1–262.

SÜMEGI P. (2002): *Régészeti geológia és történeti ökológia alapjai.* JATE Press, Szeged. 1–224.

SÜMEGI P. (2003a): Régészeti geológia - tudományos interdiszciplinák találkozása. *Habilitációs dolgozat*. Szegedi Tudomány-egyetem, Szeged. *kézirat* 1–150.

SÜMEGI, P. (2003b): Quarter-malacological examinations. In: BOGNÁR, A.; SCHWEITZER, F.; SZÖŐR, Gy. eds., Susak. Environmental reconstruction of a loess island in the Adriatic. MTA Földrajzkutató Kiadványa, Budapest, 110–117.

SÜMEGI P. (2004a): Jelentés a sárrétudvari Őr-halmon végzett környezet-történeti vizsgálatok eredményéről. NKFP részjelentés, Földtani és Őslénytani Tanszék, Szeged. *kézirat,* 1–34.

SÜMEGI P. (2004b): The results of paleo-environmental reconstruction and comparative geoarcheological analysis for the examined area. In: SÜMEGI, P. & GULYÁS, S. eds., *The geohistory of Bátorliget Marshland*. Archaeolingua Press, Budapest, 301–348.

SÜMEGI P. (2005): *Loess and Upper Paleolithic environment in Hungary.* AureaKiadó, Nagykovácsi. 1–268.

SÜMEGI, P. & SZILÁGYI, G. (2011): A quarter-malacological inventory of Hungarian kurgans. In: PETŐ, Á. & BARCZI, A. eds., Kurgan Studies: An environmental and archaeological multi-proxy study of burial mounds in the Eurasian steppe zone. *British Archaeological Reports* **2238** Oxford. 279–291.

SÜMEGI, P., BEDE, Á., SZILÁGYI, G. (2015a): Régészeti geológiai, geoarcheológiai és környezettörténeti elemzések régészeti lelőhelyeken – a földtudományok és a régészet kapcsolata. *Archeometriai Műhely* **XII/4** 135–150.

SÜMEGI, P., NÁFRÁDI, K., MOLNÁR, D., SÁVIA, Sz. (2015b): Results of paleo-ecological studies in the loess region of Szeged-Öthalom (SE Hungary). *Quaternary International* **372** 66–78.

SÜMEGI, P. GULYÁS, S., MOLNÁR, D., NÁFRÁDI, K., TÖRŐCSIK, T., SÜMEGI, B. P., MÜLLER, T., SZILÁGYI, G., VARGA, Z. (2018): Ice Age Terrestrial and Freshwater Gastropod Refugia in the Carpathian Basin, Central Europe. In: SAJAL, Ray ed., *Biological Resources of Water*. IntechOpen Access Publisher, Rijeka, 93–117.

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

SZELEPCSÉNYI, Z., BREUER, H., KIS, A., PONGRÁCZ, R., SÜMEGI, P. (2018): Assessment of projected climate change in the Carpathian Region using the Holdridge life zone system. *Theoretical and Applied Climatology* **31** 1–18.

SZILÁGYI, G., SÜMEGI, P., MOLNÁR, D., SÁVAI, Sz. (2013): Mollusc-based paleo-ecological investigations of the Late Copper - Early Bronze Age earthmounds (kurgans) on the Great Hungarian Plain. *Central European Journal of Geosciences* **5** 465–479.

SZILÁGYI, G., SÜMEGI, P., GULYÁS, S., MOLNÁR, D. (2018): Revision of the age of construction phases of a mound dated to the Late Copper–Early Bronze Age in Eastern Hungary Relying on 14-C Based Chronologies. *Radiocarbon* **60** 1403–1412.

TARASOV, P. E., WEBB, T. III., ANDREEV, A. A., AFANAS, E. N. B., BELEZINA, N. A., BEZUSKO, L. G., BLYAKHARCHU, T. A., BOLIKHOV-SKAYA, N. S., CHEDDADI, R., CHERNAVSKAYA M. M., CHERNOVA, G. M., DOROFEYUK, N. I., DIRKSEN, V. G., ELINA, G. A., FILIMONOVA, L. V., GLEBOV, F. Z., GUIOT, J., GUNOVA, V. S., HARRISON, S. P., JOLLY, D., KHOMUTOVA, V. I., KAVAKAZE, E. V., OSIPOVA, I. M., PANOVA, N. K., PRENTICE, I. C., SAARSE, L., SEVASTYANOV, D. V., VOLKOVA, V. S., ZERNITSKAYA, V. P. (1998): Present-day and mid-Holocene biomes reconstructed from pollen and plant macrofossil data from the former Soviet Union and Mongolia. *Journal of Biogeography* **25** 1029–1053.

TARASOV, P. E., VOLKOVA, V. S., WEBB, T. III., GUIOT, J., ANDREEV, A. A., BEZUSKO, T. G., BEZUSKO, L. G., BYKOVA, G. V., DOROFEYUK, N. I., KAVAKAZE, E. V., OSIPOVA, I. M., PANOVA, N. K., SEVASTYANOV, D. V. (2000): Last glacial maximum biomes reconstructed from pollen and plant macrofossil data from northern Eurasia. *Journal of Biogeography* **27** 609–620.

TROELS-SMITH, J. (1955): Karakterisering af lose jordater (Characterisation of Unconsolidated Sediments). *Danmarks Geologiske Under-sogelse* **ser. IV/10** 39–73.

ZHU, R., LIU, Q., JACKSON, M. J. (2004): Paleo-environmental significance of the magnetic fabrics in Chinese loess-paleosols since the last interglacial (<130 ka). *Earth and Planetary Science Letters,* **221** 55–69.

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