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THE APPLICATION OF EARTH SCIENCE-BASED ANALYSES ON A TWIN-KURGAN IN NORTHERN HUNGARY

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Abstract: One of the biggest and archeologically still unexplored twin kurgan of Hungary was formed by the artificial piling up of a soil mass with a total volume of nearly 190 000 m^3. The source locations of the heaped material were the originally 2.5–3 meter deep, long trenches that run along the base of the mounds. Based on the sediment-geological analysis of these kurgans, four separate layers can be identified. The uppermost stratum is a "chernozem"-type (black earth) recent soil (930 and 440±50 BP), under which the hillocks' artificially accumulated loessy soil with mixed structure (5760 ± 90 BP) can be found. Below them, there is a layer of buried, fossil brown soil (4450 ± 60 BP), which can rather be considered a type of forest soil, due to its higher clay and lower organic substance contents, compared to that of the recent soil. Finally, below the buried soil, the base rock mainly consists of yellow-brown loess. By deducting the age of the natural, undisturbed soil of the boundary (located farther away from the mounds) from the age of the fossil soil (both determined by radiocarbon dating), the result gives the approximate date when the 3rd soil layer was buried, i.e. when these kurgans were being built. The corrected results of the radiocarbon dating – which was performed on both the total organic substance content and the humic acid fraction of the fossil soil – turned out to be very similar (2590±120 and 2570±110 BP, respectively). Based on this result, it can be presumed that the creation of these kurgans is closely linked to the Scythian culture which settled in the Carpathian basin in the 6th century BC. Judged by size of these hillocks, they were probably burial mounds of Scythian princes or other dignitaries. Based on the high number of rock pieces – mainly Triassic chalk-stone and Miocene rhyolite tuff – found in the surrounding plough-lands and during the excavation of the sepulchral mounds, it has been established that inside these kurgans there are tombs built of stone. Based on the lithological analysis of the rock samples, these pieces originate from the Bükk Mountains and the Szerencsi island hill (from an approximately 16–20 km distance). Our geophysical (magnetic) investigations revealed the existence of a stone crypt (about 40 m in diameter) inside these mounds. At the same time, the detected magnetic anomalies in the adjacent foreground also indicated a number of Sarmatian graves with circular ditches (3–4th century AD). Based on these findings it can be established that the area and immediate vicinity of the Zsolcai-mounds – rising on an unflooded terrace of the Sajó River – counted as an important burial place for centuries in ancient times.

Keywords: kurgans, archaeological geology, anthropogenic geomorphology, geophysical analyses, radiocarbon dating

1. INTRODUCTION

In the low-lying plains of the Carpathian Basin, especially in the Great Hungarian Plain, on flood-free river terraces, on natural levees, and more rarely on sand dunes, even today there are thousands of artificial mounds of between 3 and 12 metres in height, dating from different historical periods. These mounds of varying function were built from the Neolithic to the age of migrations, and from that period right up to the early medieval times. The majority of these potentially archaeologically significant structures are of the kurgan type, i.e. burial sites dating from the Copper Age, the age of migration and the period of the Hungarian Conquest. A small proportion of them were erected at the end of late Neolithic and the middle Bronze Age as a result of long periods of settled occupation by different cultural groups. These settlement mounds, the so-called tell structures, contain a great number of archaeological artefacts which reveal a lot about the culture and customs of those who lived there. There are also a relatively large number of mounds on the Hungarian Plain which contain no artefacts, which can be classified as sentry mounds. These were important stations for signalling information via traditional methods (light and smoke) (Virágh, 1979; Raczky, 1991; Tóth, 1999).

Initially the mounds were investigated by archaeologists exclusively as potential archaeological sites. The first mounds to be excavated by archaeologists in the Carpathian Basin were Bronze Age tell-type settlement mounds on the left bank of the River Tisza (Ásott Mound, Zsidó Mound, Lapos Mound), which featured in the VIII. International Ancient Archaeology and Anthropology Congress held in Budapest in 1876 when they were presented to the world's leading archaeological experts (Rómer, 1878). At the end of the 19^{th} and through the 20^{th} centuries approximately 70 mounds were excavated, providing us with an enormous amount of archaeological data. These excavations, however, often lasted several years, were very expensive and involved the complete opening up of the mound, thus destroying their valuable loess grassland covering and their original shape.

In addition to their archaeological value the mounds also had great value from the point of view of cultural history and the natural sciences, and so it was absolutely necessary to protect them with a national law (Act LIII. of 1996 relating to the protection of the natural environment). The preparation of a national register which was required by the law was completed in 2002, resulting in the identification and registering of 1,649 mounds on Hungarian territory (Tóth & Tóth 2004; Tóth & Tóth 2011). This large-scale programme required a series of other environmental science research activities (geomorphology, archaeological geology, soil science, island biogeography, paleoecology, etc.). This programme, for example, included the geo-archaeological and paleoecological examinations of the Bronze Age Test mound located on the edge of Szakáld in the northern Alföld (Sümegi et al., 1998). Following this, the fossil soils buried by the mound and the remaining sediments of the material produced became the focus of great attention. Analysis of the morphology and chemistry of the soil, its malacological and phytolithic structure, as well as the establishment of dates by radiocarbon methods, allowed the reconstruction of the ancient environment of three kurgans – the Csípő, Lyukas and Bán Mounds – as well as the circumstances of their construction (Barczi et al., 2003, 2006, 2009; Molnár et al., 2004; Molnár & Svingor, 2011).

The comprehensive environmental science examination of the object of our present study – the Zsolcai mound – is also part of this series of studies. The archaeologically unexcavated twin mounds, lying 30 metres apart on the flood-free terrace of the Sajó River, covering 0.8 hectares, and rising 5.8 – 6 metres above the surrounding plough land, are among Hungary's most valuable artificial mounds (Fig. 1).

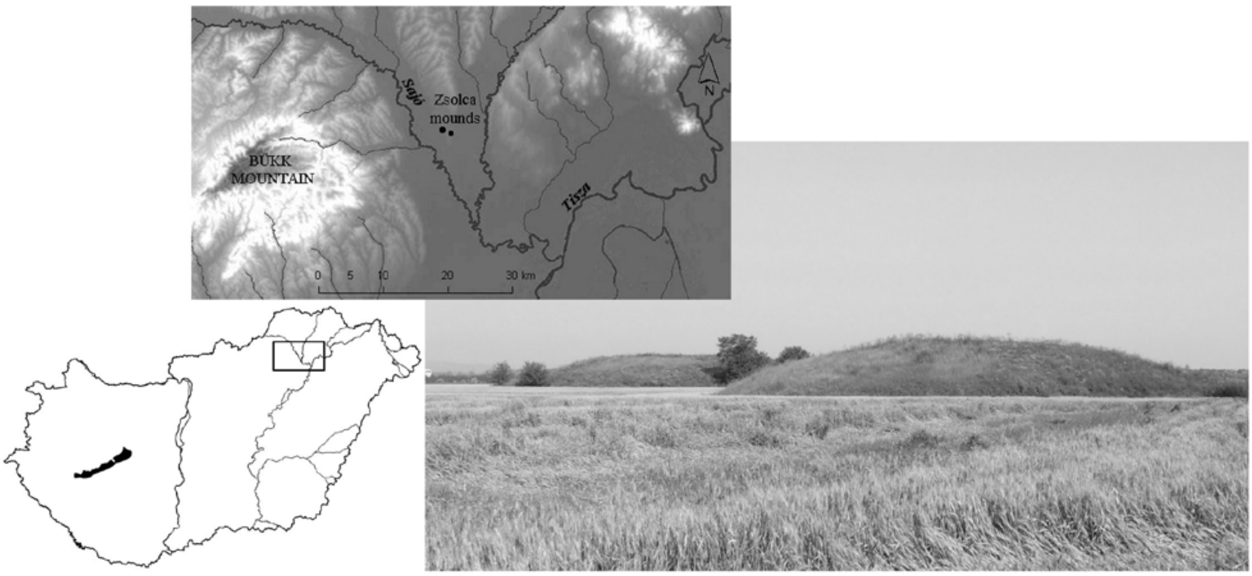

Figure 1. The Zsolcai Mounds' geographical location and the summer appearance of the mounds (Photo: Tóth, Cs.)

The surface is characterised by patches of varyingly dominant loess grassland (*Salvio-Festucetum rupicolae*). As a first step research into the surface of the mounds was begun in 2007. During the island biogeographical research more than a hundred species of plants and around three hundred animal species (mostly arthropods) were described, including many environmentally protected rarities. The ecological analysis was concentrated mainly on the base of the mounds, the belts where the loess meadow and the ploughed land met, and where the intensive spread of weeds endangered the condition of the loess meadow on the top of the mound (Tóth et al., 2008; Novák et al., 2009).

Our intention was to prepare a comprehensive evaluation of the mounds from a geographical point of view by supplementing the island biogeography research results. A part of this included the completion of geomorphological, petrographic, radiocarbon and geophysical (magnetic) analyses, as a result of which we would attempt to collect as much information as possible about the circumstances in which the mounds were constructed, their age and their function. At the same time our task could also be considered a methodological one, in which we tried to show that instead of expensive archaeological investigations which disrupt the surface layer, a quicker, cheaper earth science method, which involves minimal disruption can also bring success in studying an archaeological object.

2. MOST IMPORTANT RESEARCH METHODS

For the geomorphological analyses we mapped out the mounds and the immediate area with the help of infra-theodolite. The resulting measurements gave us the most important morphometric parameters, such as the diameter, surface area, angle of slope of the sides, relative height and volume. We used Surfer 8 software to process the results obtained into a digital surface model of the mounds.

With the layer examinations we made two shallow depth drillings, taking soil samples every 10 centimetres. We initially made two deeper drillings; the first to a depth of 400 cm on the unexcavated northern slope of the eastern mound, and then to 310 cm in the ditch extending out in front of the mound. To supplement these we made three further shallow drillings to examine the structure and age of the unexcavated soil on the mound. To establish dating we collected 10 samples from the mound, from the ditches which provide the material for its construction and from the undisturbed balk on the dirt track which leads away from the mounds. We established the granulation, and the lime and organic material content of the samples at Debrecen University's Physical Geography Laboratory.

After the autumn harvest we gathered a large amount of wattle and daub fragments, shards and stones of varying size from the area around the mound. We intended to identify the population groups which used, or lived around the mound. We were helped in the task of defining the artefacts by the archaeologists of the Déri Museum in Debrecen. To establish the origin of the rock samples we studied their external morphological characteristics and also carried out fine polishing analysis.

In the absence of archaeological excavations and surface finds it is difficult to establish the age and function of the mounds. Consequently, for radiocarbon dating we collected a total of 9 soil samples from the mound (recent soil, material from the body of the mound, buried soil) from three depth levels of the circular ditches created to provide material at the time of construction and from the less disturbed balk at the side of the dirt track near the mound. Carbon-14 dating was carried out with a MICADAS type accelerator mass spectrometer at the MTA ATOMKI AMS Laboratory (Molnár et al., 2012). Dating was carried out on the total organic matter content of the soil samples, and in parallel on the extracted humin acid fraction also.

The magnetic field of the earth can influence the processes occurring within it, and so the deposit formation as well. In the magnetic field deposits with their own magnetism are laid down according to the external direction of the magnetic field. During excavations this uniform effect disappears and being added to the surrounding space, its volume is changed. In this way we can research those objects left behind by our predecessors. To analyse the structure of the mound and its environment without excavating, we used a GSM-19 Overhauser magnetometer. The magnetometer consists of two probes and an electronic unit connected to them. The probes contain a fluid with special ingredients, surrounded by an electronic cylinder. If we connect the cylinder to alternating current this stimulates free protons in the fluid, which make precessional spinning movements around the direction created by the magnetic field, and so the whole fluid is polarised. When the stimulation is turned off the precessional movement of the protons decreases, and during this time a clearly measurable electronic signal is created in the cylinder surrounding the fluid. The electronic measuring instrument records this signal, or more precisely, its frequency. There is a linear relationship between the precessional frequency and the size of the external magnetic field, and so by measuring the frequency using the proportional factor it is easy to determine the external field.

During the magnetic analyses we can determine the size of the vertical gradient of the magnetic field on the deposited layers of the mound and the surrounding area. The measurement can be carried out quickly (0.2 seconds) and with great accuracy. The absolute accuracy of the measuring device is 0.1 nT (nanotesla), which in relation to the average measurable 47800 nT value of the magnetic field in the latitudes in which Hungary is located, makes measurements of great accuracy possible. We set up the magnetometer in the following way: we used two probes simultaneously, taking the difference between the magnetic field values measured by the probes as a base; we then divided the distance between the probes, and as a result we obtained the size of the magnetic field gradient at every point. In all cases we also used a base probe, which measured the daily magnetic field during the time the measurements were carried out. If we subtract the values measured on this probe from the results of the lower probe which was moved around during the measurement, i.e. we carried out a base correction and then we also obtain the size of the magnetic field at every point. This second data processing method is less sensitive than the first, but can act as a reference point for our measurements (Petrovszki et al., 2008). With the help of Surfer 8 software the measurement data were used to prepare a magnetic anomaly map.

3. THE RESULTS OF THE GEOMORPHOLOGICAL ANALYSES

With their excellent location and great scenic value, the imposing twin mounds, which rise out of the flood-free terrace of the Sajó River on the edge of Felsőzsolca in the northern Great Hungarian Plain, have fortunately survived the past centuries of human destruction. From air photography we can establish that there were three further similar-sized mounds in the area, but these have now disappeared, their structural material being carried away in the recent past. Unfortunately this is a tendency which can be observed all over the country. Since the nineteenth century the number of mounds has continuously decreased, mainly as a result of water regulation works, the creation of large fields for agriculture, and the spread of settlements and infrastructure. As a result the approximately 40,000 mounds which once existed in Hungary have now been reduced to fewer than 2,000.

After field examinations and geomorphological analysis of the Zsolcai Mounds we can establish that their shape resembles the Neolithic and Bronze Age tell mounds found in many sites on the northern Alföld. They are situated 30 metres apart and are 5.8 to 6 metres high with steep sides (Fig. 2). The steepness of the sides has meant that their surface has not been included in ploughed fields, and as a result they have fortunately retained a species-rich loess meadow vegetation. Another feature of interest are the encircling ditches, once 2.5 to 3 metres deep, filled with high organic matter content deposits and field soil, which were used to provide material for the mounds, and which later, filled with precipitation and ground water, could have become moat-ditches. These ditches, despite the intensive ploughed land management, can still be clearly identified today at the foot of the mounds. The construction material used for the mounds which was extracted from these ditches is an unlayered, mixed composition, yellow-brown loess deposit.

Although the mounds appear intact from a distance, from the anthropogenic geomorphological perspective they belong to the ‘opened’ mound category. The reason for this is the existence on the roof of both mounds of huge crater-like indentations. We do not know for sure who created these pits, and for what purpose. It is very likely that at some time in the preceding centuries amateur treasure hunters dug into the central part of the mounds in the hope of riches. In the pits the loess grasslands seems as intact and species rich as on the unexcavated sides of the mounds, and there are no signs of an intensive spread of weeds. This clearly suggests an ancient excavation which took place many centuries ago. The most important morphometric parameters of the two mounds are summarised in table 1.

Table 1. Morphometric parameters of the Zsolcai Mounds

	Western mound	**Eastern mound**
diameter	80 m	60 m
base circumference	251 m	188 m
area covered	5 024 m^2	2 826 m^2
relative height	6 m	5,8 m
height above sea level	132.6 m	132.4 m
angle of slope	10-17°	10-15°
volume	~133 973 m^3	~56 520 m^3

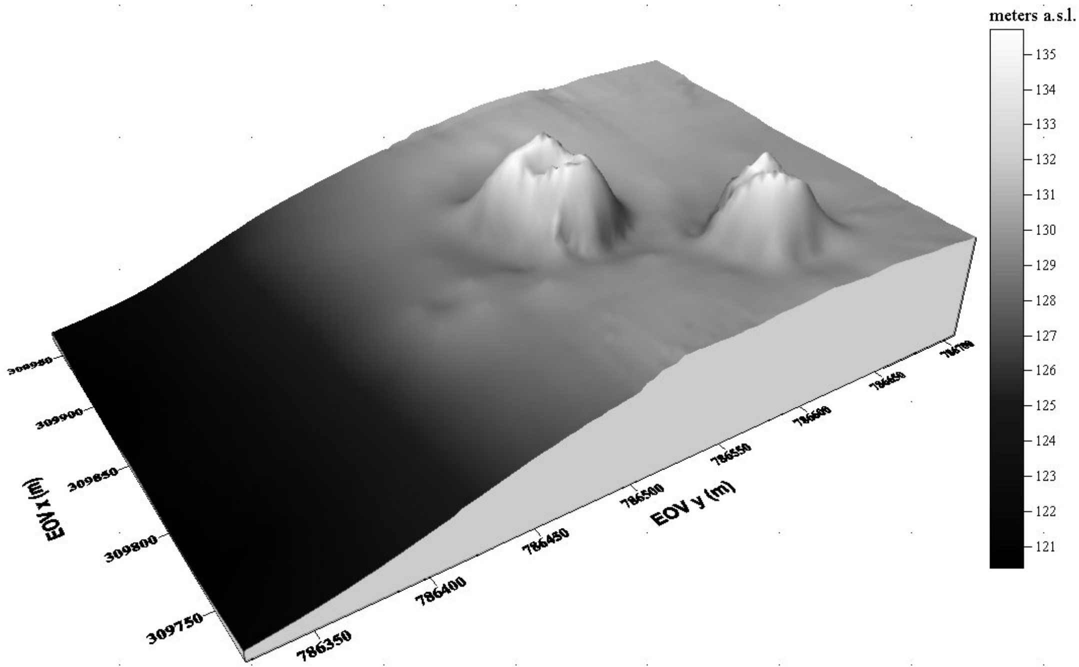

Figure 2. Digital surface model of the Zsolcai Mounds

4. THE RESULTS OF ARCHAEOLOGICAL GEOLOGICAL ANALYSES

The objective of the layer drillings and sample taking was to determine the internal structure of the mounds, their function and the date of their construction. Since there was no archaeological excavation no easily datable material (e.g. bone, charcoal) was available. For this reason we determined the absolute age of the levels from the organic matter content of the soil samples, which involved some uncertainty.

4.1. Analysis of the undisturbed balk in the area of the mound

In order to determine the age of the artificially created mounds from the organic matter- and humin acid content of the soil buried by the mounds we must establish the time of formation of the natural, undisturbed soil, in other words its absolute age. In order to establish age, we first took a sample from near the surface of the balk beside the dirt track situated some hundreds of metres from the Zsolcai Mounds. The conventional C-14 age given on the basis of the total carbon content at a depth of 20-30 cms of these recent chernozem soils are on average 1420±80 BP, while on the basis of humin acid the dates are somewhat older at 1880±90 BP (Table 2). Earlier research at the Csípő Mound in the Hortobágy area produced more or less similar results for recent soil age (Molnár et al., 2004). These figures clearly show that these soils which we consider to date from the recent, present age, are the product of long centuries and millennia.

Assuming that the buried soil found under the mound could also be of the same age when it was surface soil at the beginning of the mound construction, we should therefore use this as an ‘virtual soil age’ and use for a reservoir age correction, if we wish to determine the time it was buried. The carbon-14 date of several hundred or thousand years apparently shows the surface soil is a living ‘organism’ even today, but its lifetime can be compared to the half life of carbon-14 (5730 years), and so the carbon-14 age of the organic material long since incorporated in the construction cannot be ‘zero’.

4.2. Analysis of the mound

During the drilling of the mound we were able to identify four separate layers. The upper 50 cm layer on the top of the mound is dark brown, young recent soil, rich in organic material, in the lower zone of which the lime covering characteristic of chernozems was observable. Since in the deeper levels the drilling was obstructed by a piece of limestone, we had to repeat the drilling five metres further on in the direction of the foot of the mound. The radiocarbon dating for these two soil samples from the surface was, on the basis of the complete organic material content, 670±50 and 370±50 BP, while on the basis of humin acid it was 930±50 and 440±50 BP (Table 2). The humin acid content results gave an older age in both cases. Knowing the formation of the humin acid micro molecules this probably gives more reliable data for dating purposes than the total organic material content. The age difference between the two surface samples is probably due to the disturbance of the surface and the inside of the mound. Although the soil formed on the surface of the mound is recent, and is currently also made up of 'living' ingredients, the ages clearly show that it is the result of a long soil development during the centuries that have passed since the construction of the mound.

The underlying material used to build the mound is the yellow-brown, high lime and low organic matter content loess deposits, whose dominant particle proportion falls into the rough siltstone category. The mixed structure anthropogenic layer with its high lime secretion did not contain archaeological material (bone, wattle and daub fragments, and shards). In this accumulated loess deposit the drilling was obstructed by a limestone fragment at a depth of 250 cm, which could only have found its way into the mound material as a result of anthropogenic activity. We managed to determine the radiocarbon age of the loess building material of the mound at 5760±90 BP, which is significantly older than the recent soil above, and also than the fossil soil buried under the body of the mound. The humin acid content of the samples taken from the centre of the mound (230-240 cm) was not sufficient to obtain a humin control, and so we could only measure the age from the total organic matter content.

Underneath the built material of the mound the drill cut into the former natural soil level, which we consider to be palaeosol (Fig. 3). This dense structure, high clay content, brown fossil soil has a lower organic matter content than the recent soil formed on the top of the mound. The characteristic features tend to indicate a forest soil, which suggests the changing nature of the soil-forming environment. The total carbon of the buried soil gave an age 400 years younger (4010±70 BP), than when measured by humin acid proportion alone (4450±60 BP) (Table 2). These ages are younger than the age of the loess deposits accumulated in the construction of the main body of the mound. This is not surprising since to create the heightened shape the mound builders used not just the contemporary level of soil but mainly the older, base rock, low organic matter content yellow-brown loess deposits of the Pleistocene age.

Conventional C-14 age data for the buried soil were used to estimate the period when the mound was constructed. The buried soil data must be corrected to the apparent soil C-14 ages measured in the recent balk (buried soil age – balk soil age). We assumed that the buried soil found beneath had similar apparent C-14 age (reservoir age) at the time of the mound construction, as like our natural recent soils have. Therefore, if we wish to establish the date of the mound's construction, i.e. the point at which the soil beneath the mound was buried, we must obtain the average reservoir correction age. The reservoir corrected ages obtained from the total carbon content and the humin acid are in totally agreement (2590±120 and 2570±110 BP); in other words they give the same result for the length of time that has passed since the burial, which, calibrated, means almost certainly sometime between the 10th and the 5th centuries B.C.

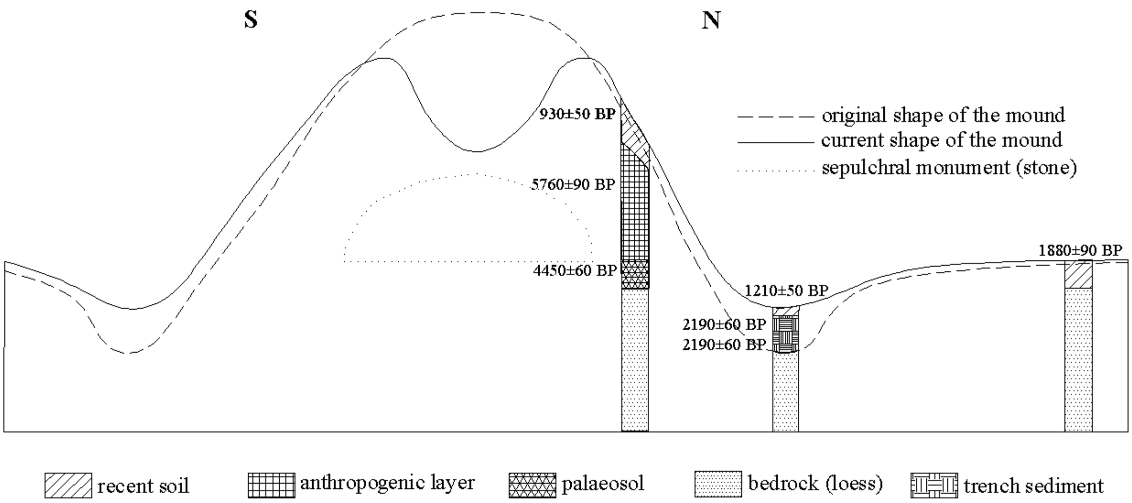

Figure 3. Schematic cross-section of the main layers of the Zsolcai Mound ditches and frontal area.

Table 2. Carbon 14 dating of the soil samples and estimated time of soil burial

Sample name (depth from surface)	**Conventional carbon-14 age of soil layer (yrs BP ± 2σ)**		**Estimated date at which the layer was buried (BP ± 2σ)**	
	total carbon	humin acid	total carbon	humin acid
balk-1 (recent soil) (20-30cm)	1490 ± 60	1780 ± 60	not buried	
balk-2 (recent soil) (20-30cm)	1350 ± 60	1980 ± 60	not buried	
Carbon-14 reservoir age of balk	***1420 ± 80***	***1880 ± 90***	***Subtraction of the carbon-14 age measured for the buried layers***	
mound recent top-1 (20-30cm)	670 ± 50	930 ± 50	not buried	
mound recent top-2 (20-30cm)	370 ± 50	440 ± 50	not buried	
middle of the body of the mound (230-240cm)	5760 ± 90	—	4340 ± 130	—
soil buried under the mound (340-350cm)	4010 ± 70	4450 ± 60	2590 ± 120	2570 ± 110
ditches, recent surface (20-30cm)	***540 ± 60***	***1210 ± 50***	***correction of the time at which ditches were filled in***	
ditches, middle (120-130cm)	1670 ± 60	2190 ± 60	1130 ± 110	980 ± 110
ditches, bottom (220-230cm)	2170 ± 60	2190 ± 60	1630 ± 110	980 ± 110

(BP: years *Before Present*, the conventional C-14 age according Libby et al. 1955 which refers to 1950 AD)

At the turn of the 6th and 5th centuries B.C. (the early Iron Age) a new, uniform, archaeological culture settled in the eastern half of the Carpathian Basin, which we now refer to as the Scythian culture. In north-eastern Hungary during the Scythian period cremation was customary and the ruling class was buried in mounds and kurgans (Selmeczi, 1993). Most of the mounds found west of the Danube belong to the Hallstatt culture of the early Iron Age. These mounds generally hold tomb structures of stone and wood or only of stone, which were often raised above the funeral pyre (Pásztor 2004). The only early Iron Age mound burial in Hungary which can be visited is in the Archaeological Park at Százhalombatta.

4.3. Petrographic analysis

The smaller fragments of limestone as well as the numerous rocks of different sizes found on the surrounding plough land allow us to conclude that in addition to the Quaternary loess deposits older hard rocks were used in building the Zsolcai Mounds. These rock samples were found in an Alföld Plain setting where they do not appear on, or close to, the surface. Their appearance together and their different original locations indicate that humans moved them from their original setting and presumably used them to build a circular cairn structure at their present location. The rock fragments found around the Zsolcai Mounds can be divided into two groups from a petrographic point of view.

The first group includes a bright pale grey coloured limestone which reveals very small crystals under the microscope with dense, porcelain structured, slivered or broken shell forms. On the surface there are light grey patches of uneven size and distribution, which could be the crystallized remains of faunal elements. In thin polishing with a rock microscope it is clearly visible that the dominant material of the stone is micritic calcite crystals, in which can be seen some fossil remains (foraminifera) with blurred outlines. This stone could belong to the Middle and Late Triassic Age Bükk Limestone Plateau formation, which can reach up to 1000 metres in thickness. This type of limestone is known from the area in the Bükk hills nearest to the Zsolcai mounds, specifically the mines in the Miskolc-Diósgyőr area. We can assume that this building material was brought from here to the location (16 km as the crow flies).

The second rock group includes the different types of Upper Miocene silicified rhyolite tuff. Various differences can be discovered in the characteristics of the rock structure, but on the basis of the mineral ingredients they can be considered as related. In the Tokaj-Eperjes hills and around the foothills in the Upper Baden level rhyolite-rhyodacite volcanism began, accompanied by hydrothermal operations (Tóth et al., 2012). These rhyolite tuffs from the Upper Miocene are of varying colours, ranging from yellow-white through pale pink, to light brown. The generally porous, rarely densely structured rock passed through thermal spring solutions, and so in places has a silicified character. Examination under the microscope reveals a few small-sized micro-crystals embedded in the base material; these mainly include acid plagioclases, sanidine and biotite. The closest location of this late Tertiary volcanic rock to the area under examination is 20 km to the northeast in the isolated formation of the Szerencs Hills. Presumably the material found in the area of the Zsolcai Mounds is the Upper Miocene holystone rhyolite tuff silicified by the spring water at the 256 metre Fuló Hill lying next to Legyesbénye in the western part of the range of hills.

Taking into consideration the dating and the rock analysis, our opinion is that the Zsolcai Mounds are early Iron Age Scythian burial mounds, which hide stone-built tombs inside. These structures, as a result of later disturbances and robbery, presumably by tomb robbers, have been partially or totally destroyed.

4.4. Analysis of the ditches created when digging for material

Throughout our drilling in the deepened ditches in the area in front of the mounds we found dark brown ditch fill with high organic matter content, which at a depth of 250cm suddenly turns into the underlying material of the ditch, the yellow-brown clayey siltstone loess base (Fig. 3). In order to establish the date when the ditch was filled in and the length of time the deposit accumulated, we determined the radiocarbon age of the lower, middle and upper level of the ditch. We also used the surface soil sample as a reservoir correction here, because these were the recent soils from the time the ditch was filled.

It is noteworthy that in the bottom level of the ditch both the dates obtained from the total organic matter and from the humin acid proportion are similar (2170 and 2190±60 BP) (Table 2). On the basis of the total organic matter the age of the lowest deposit level corrected according to the ditches' current surface age is approximately 1700 BP. This seems logical, since the infilling of the ditch was only commenced after the construction of the mound, probably during the 3rd or 4th century A.D. The ages of the middle and upper levels of the ditch fill are progressively younger, which indicates undisturbed infilling. If, however, we work on the basis of the carbon-14 dating corrected by the proportion of humin acid (980±110 BP), then we are looking at a rapid infilling, carried out in one stage. This can be imagined as a quick accumulation of material following the robbery or disturbance of the mound.

The dating of the deposits in the ditches is made more difficult by the fact that the surface water and the absorbed precipitation have greatly influenced the organic soil compounds' mobility and material processes. This cannot have occurred in the dry material of the body of the mound. To clarify the process of the infill requires further investigations. On the basis of what we have studied to date, however, we can state that during the centuries following the construction of the mound, natural erosion as well as anthropogenic effects have greatly contributed to the infilling of the ditches used to provide building material.

4.5. Results of the geophysical analysis

To complement the analysis of the internal structure of the mounds and the depth analysis of the surrounding area, during 2011 and 2012 we carried out a 1.5 ha magnetometer survey of the mounds and their immediate north-northwest surrounding area. In the internal structure of the western mound on the magnetic anomaly map there is a homogeneous accumulated soil sequence, advancing towards the centre from the edges, at the middle of which there appears a granular patch of 40 metres diameter, which could be a tomb structure made of limestone and rhyolite tuff (Fig. 4).

This reinforces the kurgan nature of the Zsolcai Mound. The smaller and larger dark patches can be explained as animal burrows and lairs (foxholes). The arch-like line visible on the side of the western mound may have developed following a washing by flowing water. Because the large strawberry trees made the area difficult to access and covered up the regular black square and rectangular patches on the edge of the mound these were not measured. The magnetic anomaly of the ditch providing building material intruding into the area in front of the mound can be clearly seen as a thick half-arch shape on the map.

What was much more surprising for us was the great number of the circles 20-50 metres from the mound. These 5-15 meter diameter single or double circles are obviously late imperial (3rd to 4th century A.D.) Sarmatian circular graves (Fig. 4). The majority of the north-south orientated graves are circular, surrounded by ditches with south-facing entrances; probably the earth removed from the ditch was used to create a small mound above the grave. These miniature mounds later became the victims of erosion, earth removal and ploughing.

From the Zsolcai Mounds in the surrounding plough land these smaller mounds are now invisible, and only the magnetic anomaly changes reveal the ditches of the graves. We know that during the Sarmatian period there was an extremely high degree of grave robbery. In order to reach the chest of the dead the descendents of the deceased entered the graves through the so-called robbers' passage, which was oval or circular and became tighter towards the base of the grave. As a result very few Sarmatian graves with intact skeletons and accessories can be found in archaeological excavations (Selmeczi, 1993). In the most recently excavated Sarmatian cemetery, on the edge of Soroksár, 70% of the graves had been robbed, which conforms to the typical statistics for the Sarmatians. On the magnetic anomaly map the central parts of the circles do not clearly show the north-south orientation of the graves, probably because of grave robbery.

Figure 4. The vertical magnetic gradient anomaly map of the area in front of the northern side of the western mound

The previously mentioned limestone and rhyolite tuff rock fragments were found during the collection of artefacts on the ploughed land, but there was no pottery found, since this area was a cemetery and not a settlement. The bone material of the graves did not come to the surface, since they are located in deeper layers not disturbed by ploughing. However, in the area of the mounds there was a relatively large quantity of late medieval and 18^{th} to 19^{th} century pottery and wattle and daub fragments, which could both have been ploughed up from the nearby farm and inn buildings.

5. CONCLUSIONS

Using earth science analysis we attempted to establish the age and structure of the mound complex which rises up on the western edge of the left bank of the flood-free terrace of the Sajó River. During the geomorphological analyses we succeeded in mapping the Zsolcai Mounds - one of the Alföld's largest twin mounds - and their immediate surroundings. The mounds, covering 0.8 hectares, and with a volume of over 190,000 m^3 have fortunately survived the past centuries of destruction. Thanks to their relatively steep sides they have not been ploughed up, and so they preserve truly valuable loess meadows on their surface. Despite the ploughing which has occurred in the area in front of the mounds the circular ditches which provided material for construction are still visible today. In terms of their shape the mounds were identified as opened Bronze Age tell-type settlement mounds. However, after the layer-, soil- and radiocarbon analyses we had to change these assumptions. It is very likely these mounds were built by Scythians during the 5^{th} or 6^{th} centuries B.C. for burial purposes. So they are probably kurgans for a prince or high ranking aristocrat. Originally there were probably stone-built tomb structures inside the Zsolcai Mounds. The limestone and rhyolite tuff used for the construction was brought from the nearby Bükk and isolated Szerencs range of hills.

Since they were burial sites, they attracted a new cemetery on their northern side, this time round cairn graves of the Sarmatian age, dating from the 3^{rd} to 4^{th} century A.D. We were able to demonstrate these with the help of a magnetic anomaly map created from magnetometer measurements. It is very probable that the huge pits on the tops of the Zsolcai Mounds, which were probably traces of grave robbing, can also be attributed to the Sarmatians. These robberies destroyed or seriously damaged the stone-built tomb structures inside the mounds, and the scattered rock material can still be found in the nearby plough land today. After the disturbance and digging up of the mounds the ditches which provided construction material were intensively infilled. The traces of grave-robbing are also visible in the Sarmatian round graves. Following this the area was unused for a long period, and only late mediaeval remains are present in the plough land next to the mounds.

With our research we tried to show that with the help of natural science analyses, which involve relatively little surface disturbance and minimal cost, we can obtain important information about archaeological objects whose origins are debated, information which can serve as valuable support for possible future excavations, and make more accurate excavations possible.

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