The Kakucs-Turján archaeological site was investigated by a Polish-Hungarian-German research team of archaeologists and various specialists. This volume contains the first, preliminary results of their work, giving the reader an insight into the complex history of the Bronze Age settlement and its economic activities as reflected in the multi-layered stratigraphy of the site.
The currently analysed materials from Kakucs-Turján may help to indicate the basic parameters of the development and functioning of the Middle Bronze Age Vatya culture; on the one hand strongly based on local tradition, on the other contextualized within a wider network covering the Carpathian Basin.

In Kommission bei Dr. Rudolf Habelt GmbH

Kakucs-Turján

Mateusz Jaeger, Gabriella Kulcsár, Nicole Taylor, Robert Staniuk (eds.)

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a Middle Bronze Age multi-layered fortified settlement in Central Hungary

Studien zur Archäologie in Ostmitteleuropa
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Preface from series' editors

The following volume addresses the topic which is intensively covered in the 'Studien zur Archäologie in Ostmitteleuropa/Studia nad Pradziejami Europy Środkowej' series – Bronze Age settlement archaeology, especially the subject of fortified settlements.

The subject of fortified settlements and the various aspects related to their formation and functioning during European Bronze Age was covered in conference proceedings (volumes 5 and 9), a monograph (volume 17), as well as extensive reports on specific sites (the Únětice settlement in Bruszczewo; volumes 2, 6 (1 and 2), 13 and 14).

The following volume summarizes the first stage of Polish-Hungarian-German interdisciplinary research of the Kakucs-Turján settlement located in Central Hungary. Although the settlement was mostly related to Middle Bronze Age Vatya culture, it provided evidence of older, i.e. Early Bronze Age habitation. Excavations provided evidence of a complex stratigraphy related to centuries of habitation. Apart from stratigraphic information the site provided rich amount of archaeological material representing different types of material culture.

The presented volume summarizes the preliminary results of the archaeological and specialist analyses of the excavated archaeological material. It is the opinion of series' editors that it provides valuable input in studies of the dynamics of the communities inhabiting one of the key regions of the European Bronze Age – the middle Danube basin.

Janusz Czebreszuk • Johannes Müller • Sławomir Kadrow

Preface

Multi-layered and fortified settlements are one of the most characteristic features of the Middle Bronze Age in the Carpathian Basin, especially the area of present-day Hungary. The extensive size of such settlements is often a logistical and financial challenges for modern archaeology. Despite the organizational challenges, studying such settlements provides invaluable information regarding the development of local Bronze Age communities.

One way of overcoming challenges related to studying multi-layered fortified settlements is by forming extensive scientific co-operations. The presented volume results from the collaboration of many people. The Polish-Hungarian-Germany scientific project aiming at studying the settlement in Kakucs-Turján was a collaboration of researchers from the Adam Mickiewicz University in Poznań, the Hungarian Academy of Sciences in Budapest and the University of Kiel. The research undertaken between 2013 and 2017 involved both field work and data-processing, which extended beyond the work of archaeologists and included specialists from other fields, students, sometimes simply friends from various institutions in Poland, Hungary and Germany.

Participation of such a large group of people coming from different personal backgrounds and representing different scientific practices and the exchange of experiences and knowledge is one of the main successes of the project. We would like to express our gratitude for all the work and help we received from everyone involved personally or simply supporting us throughout this journey. Special thanks go to the official representatives of the region – István Szalay – the mayor of Kakucs between 2013 and 2014; and Mária Toma Kendéné – the mayor of Kakucs since 2014. It is impossible not to mention the relentless organizational and technical support from István Greman and Pál Kulcsár, whom we would like to say thank you.

The scientific potential of the Kakucs-Turján settlement exceeds our current state of knowledge. We hope to continue our scientific project and work on other documented finds. The results of such works will be published in the upcoming volumes of Studien zur Archäologie in Ostmitteleuropa/Studia nad Pradziejami Europy Środkowej series.

Mateusz Jaeger • Gabriella Kulcsár • Nicole Taylor • Robert Staniuk

ARCHAEOLOGICAL RESEARCH-PRELIMINARY RESULTS

CHAPTER 3

Geoarchaeological and non-invasive investigations of the site and its surroundings

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1. Geoarchaeological investigations in Kakucs-Turján

Both prior to excavations, during those as well as following their completions, surveys were conducted in order to explore the site in terms of geoarchaeological features, targeting the fortified settlement and its surroundings alike. These procedures relied on a range of methods developed in various scientific fields, including conventional soil and shallow geological drillings and corings, non-invasive prospection methods such as magnetometry, electrical resistivity tomography and ground-penetrating radar survey, sedimentological studies, geochemical analyses, and interpretation of satellite imagery.

The main aim of the geoarchaeological research was to examine spatial distribution of different anthropogenic activities performed at the settlement during its habitation, to assess the degree of anthropogenization and explore its stratigraphy using non-invasive or minimally invasive methods. Also, natural aspects related to the immediate context of the settlement were taken into consideration, as they may have had an impact or might have conditioned its functioning.

Desk work and laboratory procedures were conducted at research institutions in Hungary and Poland, involving experts from numerous fields, to whom we would like to express our immense gratitude.

1.2. Satellite imagery

The first step in non-invasive and geoarchaeological research consisted in a review of satellite imagery, in order to estimate the size of the site through reference to observable vegetation landmarks. Based on multiple-source satellite images, the dimensions of the fortified settlement were preliminarily determined, and the first observations on the site's internal structure were made. Among the many sources of satellite imagery, data obtained via the ESRI ArcGIS – World Imagery proved the most reliable and offered the highest resolution for that particular area.

The defensive settlement of Kakucs-Turján was relatively easily discernible in said images thanks to the aforementioned vegetation indicators. The oval, belt-like structures show up as dark-green areas suggesting different soil substrate, which is reflected in the quality of agricultural plant species (Fig. 1). The belt-like shape and the more vivid colour of vegetation captured in the images indicates a more fertile substrate underneath, which may be interpreted as secondary infill, rich in organic compounds. Hence, tentative interpretations already indicated the presence of ditches surrounding the settlement and dividing it internally (Fig. 2).

It followed from satellite imagery that the settlement was divided into the western and the eastern part, which together formed an enclosed structure with a distinctly elongated westward section. According to imagery-based size estimations, the settlement measured 230 m along the E-W axis and between 170 to 185 m along the N-S axis, with an overall surface of ca 3.2 ha. The circular western part is slightly larger than the eastern section. The surface, measured along the inner circumference of the ditches does not exceed 0.8 ha for the western part. The eastern part is oval in shape, elongated along the N-S axis, with a surface of 0.6 ha.

As can be seen, interpretation of satellite imagery yielded a provisional assessment of the site's potential structure, which in its turn served as basis for detailed geoarchaeological and non-invasive surveys by means of which a more precise picture would be obtained.

Fig. 1. Satellite imagery of the Kakucs-Turján archaeological site.

Fig. 2. Satellite imagery of Kakucs-Turján archaeological site with outlined vegetation indicators.

1.3. Magnetometric prospection

The aim of the survey was to examine previously identified site on the basis of aerial and satellite imagery. First of all, a detailed picture of the site's inner structure had to be obtained. Considering the objective, a geophysical survey appeared to be the most appropriate method. The Magneto MX® system developed by SENSYS GmbH (Berlin, Germany) was employed for that purpose; this is a complex multi-sensor magnetometer system consisting of several components, the chief of which are as follows:

- Vehicle-towed carrier system made by GRP and other non-magnetized materials. The traction in the field was performed by a measurement optimized four-wheel drive Mitsubishi L200 type vehicle;
- Eight vertical fluxgate gradiometer sensors (type FGM650B). Each sensor contains two probes. The vertical base distance between probes is 650 mm. The measurement range ± 10.000 nT and sensitivity 0.1 nT. The spacing of the sensors was 250 mm. Consequently, the interpolated point distance is 125 mm;
- RTK-capable GPS receiver pairs. The exact coordinates of the base station are very important for an accurate survey. The latter were defined using official real-time network RTK correction services supplied by KGO FÖMI GNSS Service Centre (Hungary, Penc). The rover unit was equipped with Trimble R5 GPS and Trimble Sephyr antenna. The base station correction signal was recorded at 1 pps, while using local coordinate system HDS 1972 (Egységes Országos Vetületi Rendszer – EOV);
- Magneto MX® data acquisition unit. The recording occurred with 20 Hz frequency, meaning that the spacing of the measurement points – as a function of the traction axial velocity – occurred between 80 to 100 mm. The navigation and sensor data capture control was performed through MonMx software on an Xplore iX104C5 tablet.

The sensor and GPS data combination as well as primary track-compensation was carried out with DLMGPS software. The generated 3-dimensional array of data was then subjected to further processing. Magneto® ARCH 1.00-03, TerraSurveyor 3.0.22.1, Golden Surfer 11.6.1159 and EHT2 software for data cleaning and filtering procedure.

Subsequently, GIS analysis of the output picture was conducted in ESRI ArcGIS 10.1. Magnetometric view was also converted to a pyramid-based raster in order to perform different representation procedures. Various ranges of color representation made it possible to digitize magnetic anomalies into the shapefiles, facilitating spatial analyzes and better understanding of the distribution of anthropogenic objects and structures in the magnetometric view.

The total area investigated was ca 11 ha, divided into the western and eastern part separated by a dirt road. The western part of the area comprised ca 5 ha, while the eastern one embraced a total surface of 6 ha.

1.4. Magnetometric view of the site

The results of magnetometric survey show the defensive settlement of Kakucs-Turján to be composed of three parts, divided by strips of land where higher magnetic susceptibility is observed (Fig. 3). Just as in satellite imagery (see section 1.2) the western and the eastern zones could be discerned. However, use of geophysical methods made it possible to distinguish yet another, northern part.

The overall output image demonstrates a distribution of magnetic anomalies ranging from -15 nT to 136 nT, excluding extreme values corresponding to contemporary metal waste. Mean value of the magnetization gradient for the studied area was 0.08 nT, with standard deviation at 1.31. Consequently, value distribution in this case approached normal.

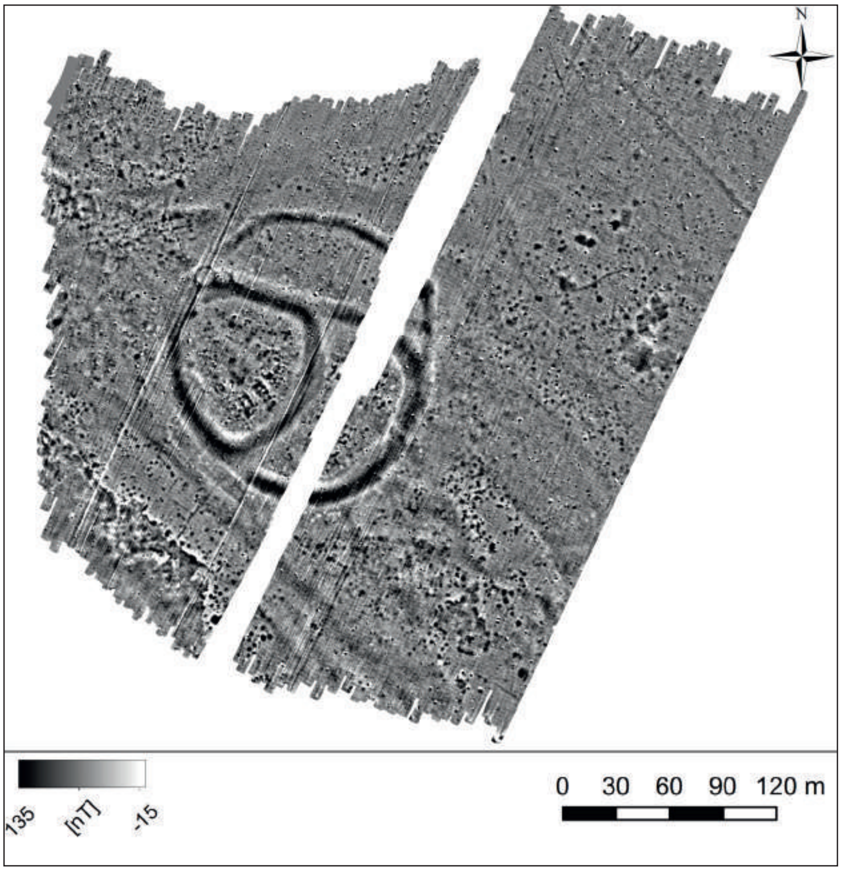


Fig. 3. Magnetometric view of the Kakucs-Turján archaeological site. Initial maximum-minimum value representation.

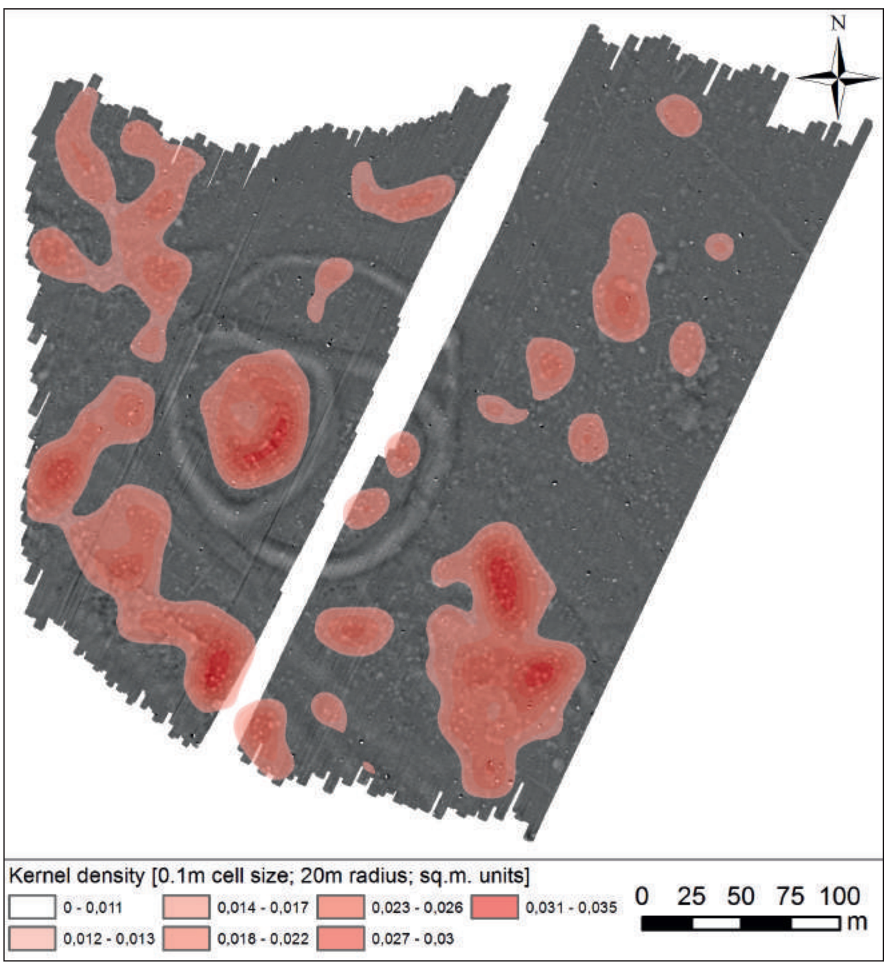


Fig. 4. Density of anomalies with gradient intensity of 2 nT and surface exceeding 0.4 m^2 at the Kakucs-Turján site. Analysis based on kernel density estimation.

Considering spatial distribution of anomalies whose magnetization values set them apart from the background (ca 0 nT), it may be concluded that they were evidently concentrated where the settlement was expected to be found. Kernel density analysis of the raster image, with 0.1 m cell size and 20 m sampling radius as input parameters and results expressed in square meters indicated locations where the concentration of magnetic anomalies was highest (Fig. 4). Analysis of the spatial density of anomalies focused on those whose magnetization gradient reached ca 2 nT and whose surface exceeded 0.4 m^2. The largest cluster was detected in the western part, whereas the fewest number of anomalies was observed in the northern section. In the light of the analysis, the eastern part constituted an intermediate area, with a moderate density of anomalies. In addition, a range of such anomalies and their clusters were found beyond the perimeter of the settlement. Given the current state of research, it remains unclear whether the structures represent traces of human activity or resulted from natural processes, e.g. drainless hollows being filled with biogenic material.

The analysis of the magnetometric image focused primarily on the interpretation and spatial examination of single-pole anomalies, while all dipole complexes were dismissed as they were presumed to indicate modern metal waste. The majority of anomalies which are interpreted as anthropogenic are characterized by an elevated magnetization gradient, ranging from 1 to 10 nT. Not infrequently, they are accompanied by heterogeneous negative clusters, which nevertheless do not exceed -2 nT.

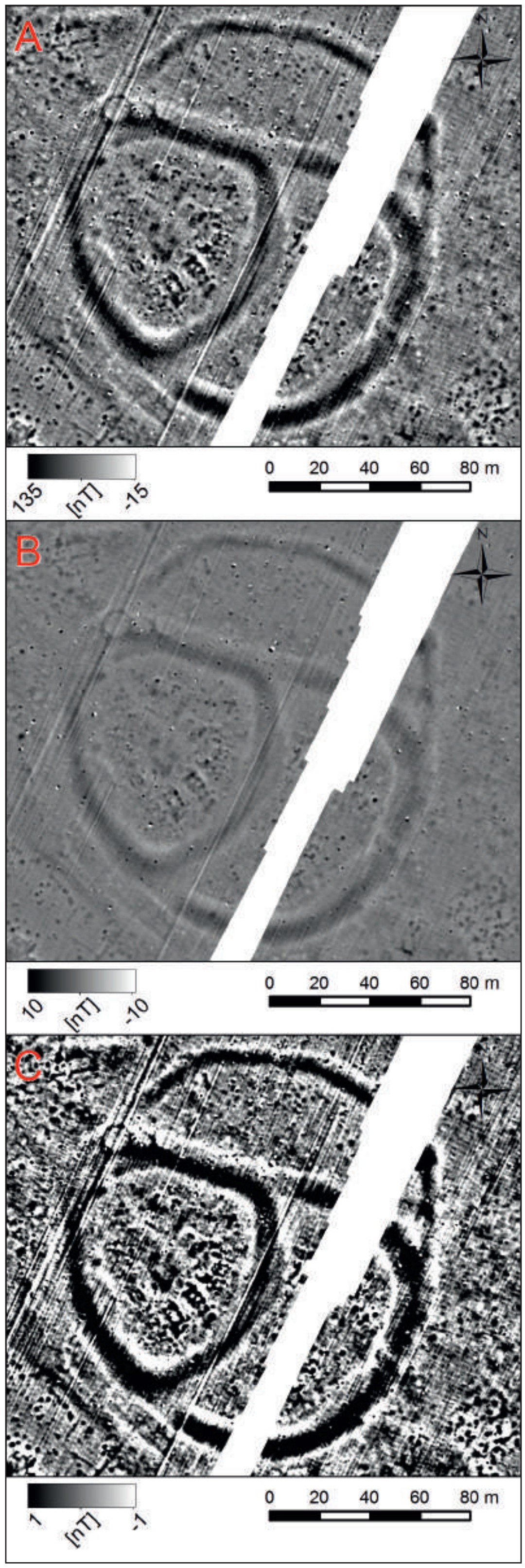


Fig. 5. Three levels of resulting raster representation.

It should be noted that the spatial elements were distinguished in the course of interpretation of the magnetometric image based on three levels of raster representation (Fig. 5). The first showed the general range with minimum and maximum values of the magnetic gradient (-15 nT to 136 nT). At that stage, all types of anomalies with extreme magnetization values were identified, and locations of larger clusters of less prominent features were established (Fig. 5:a). In the second level the value bracket was narrowed down to -10 nT – 10 nT (Fig. 5:b). Within this range, it was possible to distinguish all anomalies which may have corresponded to anthropogenic infills, secondarily burnt clay or wooden artefacts, as well as concentrations of ceramic items. The last value range to be examined was

-1 nT – 1 nT, enabling detection of subtle differences in the magnetic field gradient in the area (Fig. 5:c). At this stage, attempts were made to identify the remnants of earlier elements of the natural environment, such as palaeohydrographic features.

The analysis of output rasters showing distinct representations revealed varied magnetic anomalies with respect to which anthropogenic origin was conjectured. These anomalies were then divided into the following types (Fig. 6):

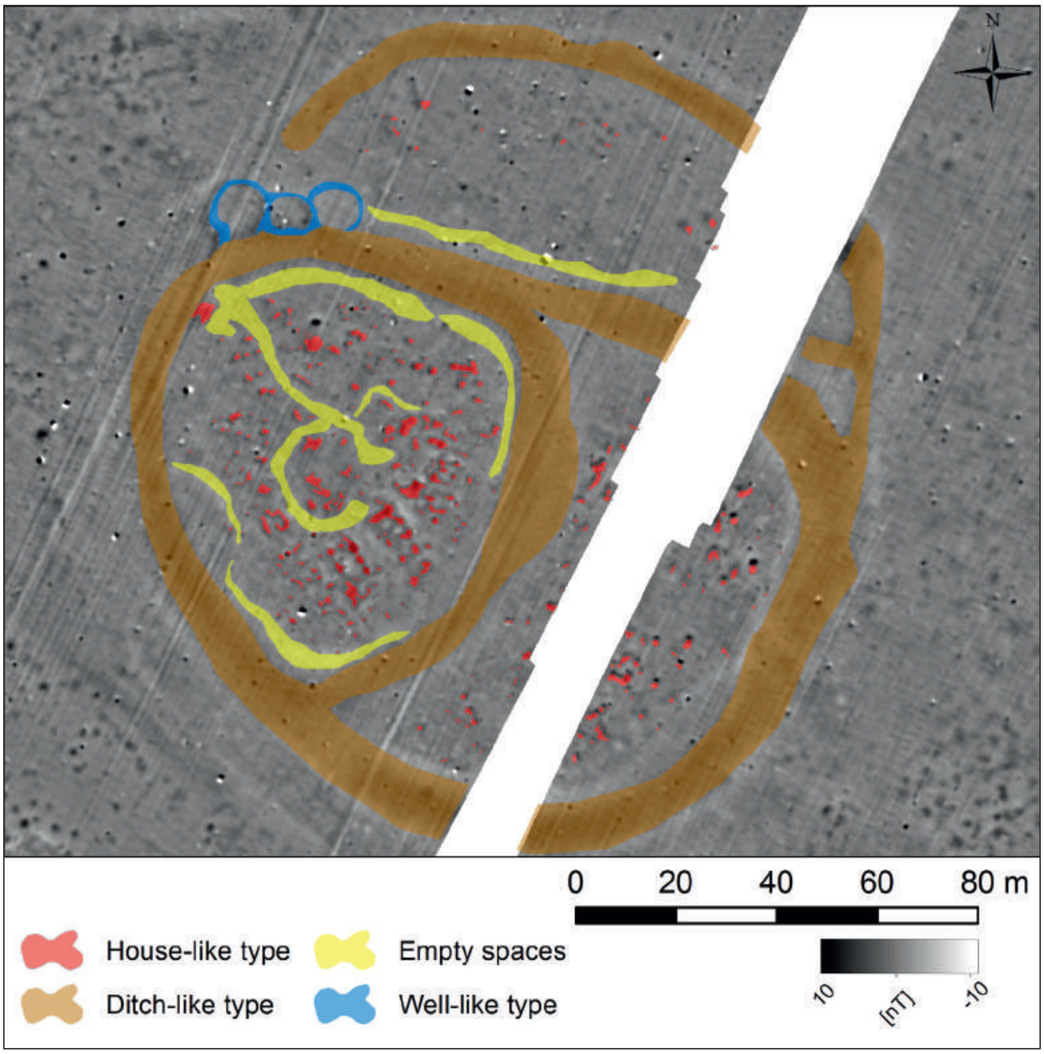


Fig. 6. Interpretation of magnetic anomalies at the Kakucs-Turján archaeological site.

- ***house-like type of anomalies*** – groups of objects with increased magnetism whose layout suggested remnants of rectangular dwellings. In total, 370 such features were identified, with magnetization values ranging from 1 to 4 nT. They were characterized by irregular outlines and highly variable dimensions, from several centimetres to over 3 metres. Their main concentration is found in the western part of the site, containing 251 structures of that type. In the eastern section, as established in kernel density analysis, their number is smaller (104 features), though it has to be noted that some of them may lie under the present-day embankment of a dirt road, where survey was not performed. Only 18 such features, the lowest quantity of all, were detected in the northern part;

The anomalies encountered in the western part proved to be the most interesting due to their arrangement, in most cases demonstrating rectangular outlines of housing structures. Symmetrical lines traced along those features suggested that at least 9 variedly sized huts could have existed in that part of the site, constructed largely on a rectangular plan. Apart from that a number (10) of other groups of anomalies were detected, but their arrangement does not resemble the shape of dwellings, or follows a house-like outline only to a minor extent. Features located in the southern section of the westward part of the settlement are the most representative and bear the highest resemblance to building-type structures:

- ***ditch-like structures*** – as already observed in the beginning of this section and in section 1.2, the settlement is both surrounded and internally divided by a system of belt-like structures whose conjectured provenance is that of an infill. Following interpretation of the geophysical image, it turned out that magnetic properties of these "belts" were higher compared with the geological background. This suggested the presence of an infill which differed considerably from the remaining sediments of which the research area was composed. It was therefore presumed that a system of trenches or a ditch had existed there – the traces of which were being investigated at that point – enclosing the entire settlement and separating its individual sections. The width of these higher magnetization belts is not consistent, ranging from 5 up to 13 m. Nor is it clear whether they represent a chronologically homogenous anomaly, since in certain locations, e.g. in the central part which divides the northern section and the other two, the ditch network is interrupted, at least on the horizontal plane. Magnetization values fluctuate across the network, from 1 to 3nT, which may be indicative of the presence of organic matter.
- ***well-like structures*** – investigations in the north-western part of the site revealed three minor anomalies whose arrangement suggested circular structures. In their case, the value of the magnetization gradient did not exceed 1.5 nT. Tangent to one another, they are situated within the ditch system, indicating potential cavities in the ground and sedimentary fills which may be interpreted as wells or unidentified hydrotechnical arrangement devised to collect underground and surface waters from the surrounding area (hydrogeological depression?).
- ***open spaces*** – although a definite majority of anomalies in the settlement display higher levels of magnetism, a negative gradient was encountered as well (from -0.01 to -15 nT). The main concentrations of such structures, which may attest to human activity, are located in the western and northern part. They are found along the inner edge of the ditches, adjoining the latter and, in a sense dividing the elevated magnetization belts from house-like features. Furthermore, a number of those were detected in the central section of the western part, where they are likewise situated strip-like between clusters of dwellings. It should be observed that the structure of those strips is relatively homogenous and no other anomalies could be detected in the space that they cover (with the exception of dipole ones, most likely corresponding to contemporary waste). Consequently, it was concluded that the structure in question may be associated with places whose utilization in the past had a distinct nature, i.e. was not related to construction activities. The decreased value of the magnetic gradient may also be indicative of lithological differences, while homogeneity and clear-cut boundaries would suggest anthropogenic provenance. This led to the assumption that these particular strips may represent erstwhile infrastructural component, such as paths, or areas outside economic use (a buffer zone in front of a line of fortifications in the form of ditches?). Taking into account the lay of those structures on the inner side of the ditches, it may equally well be supposed that they are remnants of embankments which, due to pressure, changed the structure and texture of the soil, but the absence of any morphological landmarks, i.e. a rise of the terrain, speaks against it.

1.5. Verification of magnetic features

Based on the output images from magnetometric surveys, a selection of anomalies were chosen to undergo verification procedures. The composite methodology which was used for that purpose may be generally defined as geoarchaeological. Field investigations and laboratory analyses encompassed excavation and probing, coring and conventional drillings, non-invasive prospection using GPR and electrical resistivity tomography, sedimentological analyses of samples from drillings and probings, including analyses of grain size distribution parameters, tests for organic matter, calcium carbonate, heavy metals or ancient phosphorus.

The first to be chosen for verification was an anomalous structure interpreted as remnants of a hut in the western part of the site (see section 1.5.1). The verification procedure consisted of conventional excavation and a range of laboratory analyses of sedimentological samples obtained during earthwork.

The belt-like structures interpreted as a system of trenches or ditches (see section 1.5.2) were the next type of features to undergo verification. In this case, assessments were made based on corings and lithological analysis of infill sediments (see Pető et al. *Report on the geoarchaeological survey of Kakucs-Turján site*, in this volume).

Drillings and laboratory analyses were also employed to verify the features interpreted as wells or hydrogeological systems in the north-western part of the site (see section 1.5.3).

The structures interpreted as empty spaces or communication facilities were verified by means of drillings in the western part of the settlement and partially in the archaeological trench excavated to explore a structure conjectured to have been a hut (see section 1.5.4). Naturally, samples from drillings were then subjected to detailed laboratory analyses (see Pető et al. *Report on the geoarchaeological survey of Kakucs-Turján site*, in this volume).

1.5.1. House-like type of anomalies

The highest quantity of features interpreted as remnants of buildings was determined in the western part of the site. It was in that area that the course of the walls or outlines of huts could be reconstructed based on the arrangement of anomalies or groups of anomalies (Fig. 7). For that purpose, lines were traced symmetrically to anomalies with elevated magnetization gradient. Consequently, potential number of buildings could be assessed as well. It should be noted that the resulting picture does not have to reflect one time point of settlement but rather a cumulative outcome of numerous settlement phases. However, assuming that the magnetometric image can, to an extent, delineate the organization of the inhabited space, spatial reconstruction was performed, thanks to which the most representative and the best rendered feature could be chosen for verification procedures.

The pattern of anomalies suggests a concentric arrangement of dwellings in the eastward section of the settlement's western part. The longer axes of the features are oriented towards the central part, where an outline of a larger building was identified; significantly enough, the latter appears to have a square outline unlike the remaining, rectangular structures.

In most cases, the anomalies displayed higher magnetization gradient than their surroundings, which would indicate presence of walls made of daub which was secondarily exposed to fire (or underwent primary firing at the moment of construction).

The feature which was most distinctly manifested in the magnetometric image was the conjectured remnant of a dwelling structure in the south-eastern section of the western part. (Fig. 8). The recorded layout of anomalies denoted the presence of remains of a hut, built on a rectangular plan and aligned with its longer side to the NW-SE axis. Based on the distribution of

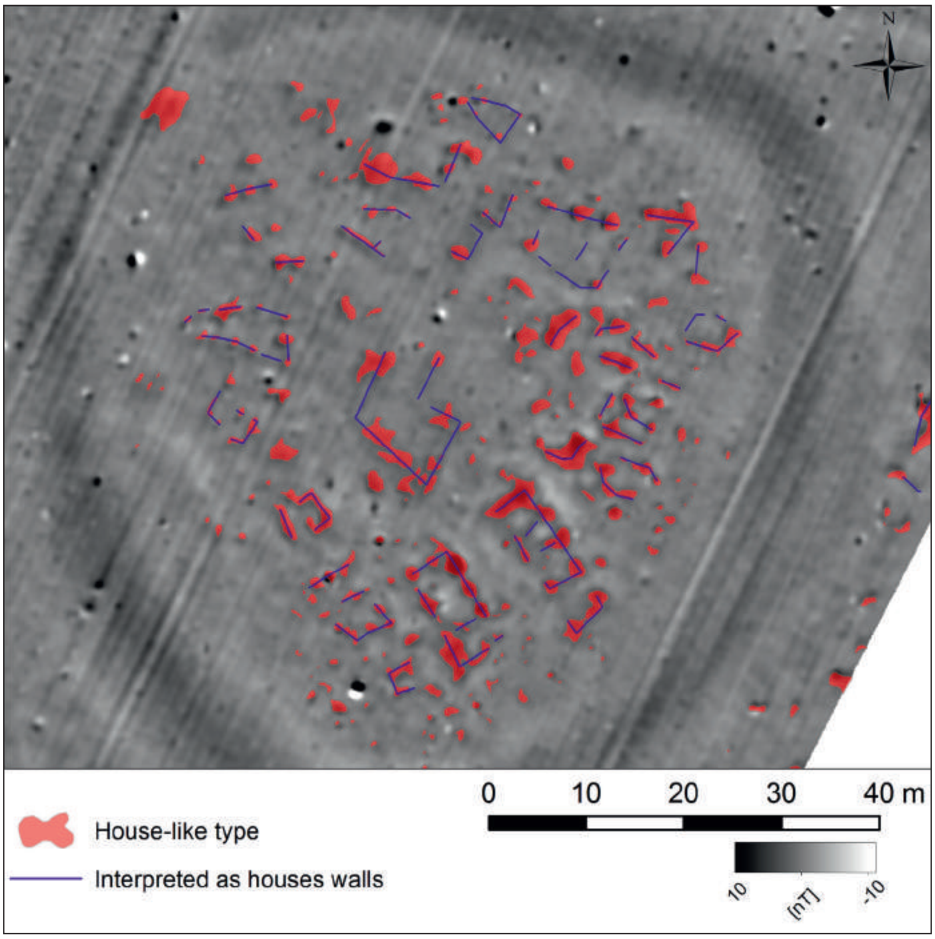


Fig. 7. Distribution of the house-like type of anomalies and the inferred course of the walls.

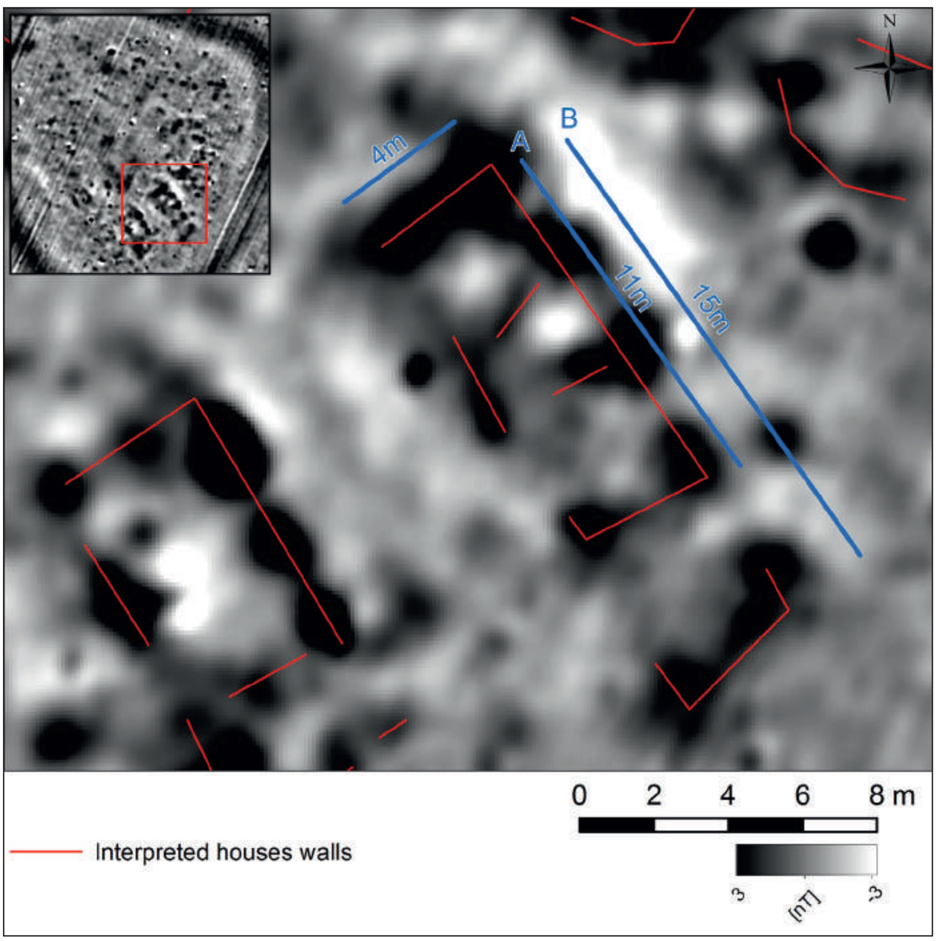


Fig. 8. Location of the house-like type of anomaly selected for verification.

anomalies interpreted as walls, the width of the hut was assessed at ca 4.5 m, whereas the lengthwise dimension could not be definitely determined. For the core pattern of anomalies (Fig. 8: line A) the length was 11.5 m, but if the two anomalies to the south-east were adopted as continuation of the hut, the length would reach almost 15 m (Fig. 8: line B).

The image of distribution of magnetic anomalies showed that the best preserved element was the north-eastern wall, as the structures with heigher magnetization were relatively uninterrupted there. The highest values of the gradient were recorded in the conjectured north-eastern wall, reaching approximately +10 nT.

The hypothesis that the remnants served a domestic function was verified in the course of excavations. In the two trenches executed for that purpose, researchers found numerous remains of wall and floor covering which had been made of clay, i.e. daub, which was then secondarily burned. Still, it has to be considered that the analysed image may be a result of accumulation of structures from different periods and does not necessarily correspond to a specific settlement phase (see Jaeger et al. *History of Bronze Age Habitation*, in this volume).

The north-eastern wall was one of the elements where the geophysical image and the actual archaeological feature overlapped. The results of non-invasive prospection suggested that the structure is continuous, unlike the parallel south-western wall, which proved less discernible in the course of excavations. A pottery kiln was explored during these investigations as well; it was located in the northward part of the hut and most likely constituted the source of the aforesaid high magnetic signal.

Planigraphy of excavations confirmed the hypothesis that the structure rendered in magnetometric image was a residential one. In the course of the work, 248 samples were taken from trench 1, which subsequently underwent sedimentological (Folk, Ward 1957) and geochemical analyses. All samples (ca 0.5 l each) were obtained at a depth of around 50 cm below ground level, from locations marked by a regular grid plotting (Fig. 9 and 10). This layer falls within the K1 cultural layer identified during the pre-excavation geoarchaeological mapping of the site (see Pető et al. *Report on the geoarchaeological survey of Kakucs-Turján site*: Fig. 5; in this volume).

As regards representativeness of the level from which material was sampled for sediment studies, one has to bear in mind that two zones were being investigated. The first of those, i.e. the western section of trench 1, contained negligible amounts of archaeological relics or traces of architecture, whereas the second, encompassing the remaining area, yielded traces of several huts (see Harris Matrix; Jaeger et al. *History of Bronze Age Habitation*, in this volume). Therefore, when examining grain size of the sampled soil (anthropogenic sediment), it was assumed that they represent two zones of settlement intensity – an open part with a minor number of archaeological remains and a residential part, where settlement processes – in this case habitation – were significantly more intense. It should therefore be remembered that the results for the residential part given below illustrate the cumulative effect of sedentary processes rather than depict a selected stratigraphic level, which in this case would mean one building stage of the hut.

Mean grain size (Fig. 9) in the trench ranges from 5.15 to 6.16 on the phi scale (0.031 to 0.016 mm), which corresponds to fine silts (Racinowski et al. 2001: 54). Spatial distribution of that parameter shows three main areas where particular mean grain sizes occur. The smallest diameters were observed in the central-northern and the south-western sections of the trench. Between them, one sees evident concentration of lower grain size parameters, suggesting higher mean diameter (Fig. 9). Presence of the finer fractions in the northern-central section is most likely due to considerable accumulation of elements of residential architecture, such as the walls and the kiln which, having been made of fired clay, may have affected the results of the analysis.

The sorting of sediments in trench 1 may be defined as poor, as evidenced by

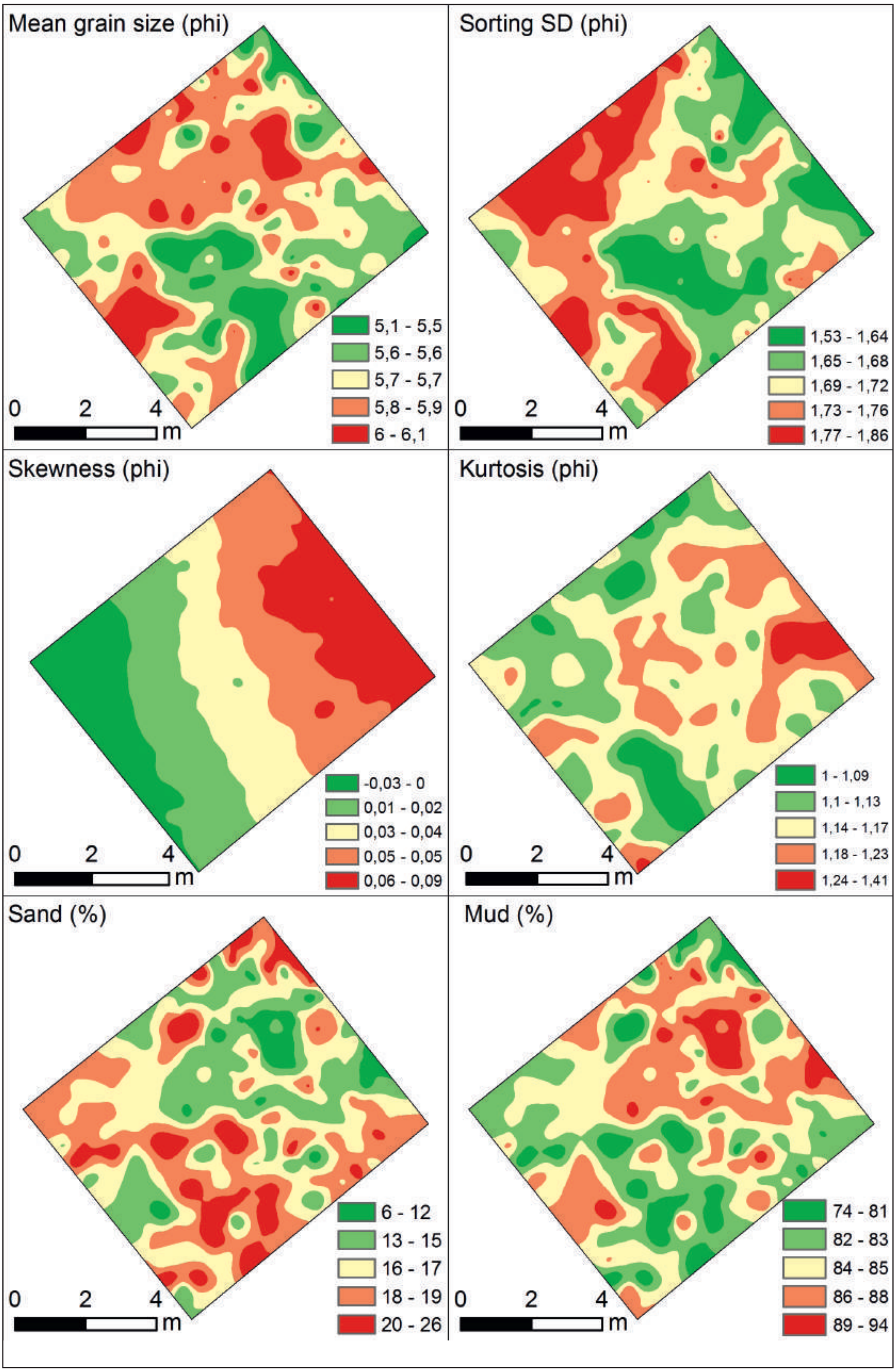


Fig. 9. Basic parameters of grain size curve following sieve analysis and laser diffraction spectrometry.

the standard deviation (Fig. 9) of grain size distribution (with SD range of 1.48 – 1.92). It is within this range that one observes spatial differentiation across the area. Also, it may readily be noticed that to a degree, it duplicates the horizontal distribution of values in excavation planigraphy. Poorer sorting is seen in the zone beyond the residential one, while better sorted sediments are found within the area of the huts. It needs to be noted that given the lithology of sediments (silt fraction) which are naturally deposited owing to aeolian processes, the extra-residential zone is characterized by poor sorting, which may attest to anthropogenic nature of deposition.

Skewness of grain size distribution appears to reflect the differences between zones most lucidly (Fig. 9). The curve for the area associated with the hut layers is symmetrical or positively skewed, which indicates that sediments are rich in minor fractions or that they are stable. This may be correlated with the presence of weathered pieces of daub or other fragments of clay-based structural components. In the western and northern segments Sk drops to slightly negative (0 to -0.2) which suggests minor addition of physically larger fractions.

Kurtosis for the entire trench 1 is within the range of 0.9 to 2 (Fig. 9), in other words it its lepto- or very leptokurtic. Parameters in such value range denote highly pulsed sedimentation environment. Considering the kurtosis for the aforesaid silty sediments, one should presume anthropogenic deposition in unstable conditions (discrete deposition). Just as with skewness, the distribution of values for that parameter is reflected in the planigraphy of the trench. The north-western and the south-western parts are characterized by a less pulsative sedimentation environment compared with the area where numerous remains of buildings are found.

Another lithological parameter taken into consideration is mean grain size of sediments in the stratum from which samples were taken in trench 1. The results demonstrate presence of the two main fractions observed, i.e. silt and sand fractions. Gravels and clays were found in marginal amounts (Fig. 9).

The percentage share of the sand fraction in trench 1 ranges from 5 to 27 %. Spatial differentiation for that component shows disparities between the northern-central section and the remaining area under investigation (Fig. 9). There, the share of sand is the lowest, which is probably due to the largest concentration of daub elements, with finer fractions predominating. In the remainder of the trench, the percentage of sands is relatively even, from 18 to 27 %.

The silt fraction was dominant in all samples (from 75 to 98 %). Spatial distribution of the fraction is almost inversely proportional to sands. In the northern-central section, where remains of daub were identified, silt prevails content-wise in the entire sediment sample (Fig. 9).

Sediment samples were also tested for basic soil components, such as calcium carbonate ($CaCO_3$; Dean 1974; Heiri et al. 2001) and organic matter (OM). The organic matter share was calculated basing on the difference in weight between the dried sample and after the calcination for 6 hours in 550 ° C. The same method concerns the carbonates except the temperature and time, which in this example was respectively 950 °C and 2 hours (Heiri et al. 2001).

Here, differences in spatial distribution are most easily perceptible with respect to $CaCO_3$ content (Galas, Jaeger 2016: 67, Fig. 10). Its presence is negligible in samples from outside the residential part (1 – 2 %), but in the area where remnants of buildings were inferred, the share of the compound increased several-fold, up to 12 %. Organic matter content in the samples ranged from 5 to 13 %, with no palpable horizontal variability. This might be due to the shallow sampling and the impact of current soil-forming processes, or due to situation which developed in the course of prehistoric settlement processes.

Determination of ancient phosphorus content is an important element in the assessment of sediment anthropogenization. The samples from the archaeological trench were analysed in this matter using the colometric method with the ammonium molybdate (Murphy, Riley 1962; Spychalski et al. 2016). The amounts of the element fluctuated in the analysed samples from 1,200 to over 4,400 ppm (Fig. 10), but the spatial layout of its concentrations may be deemed surprising. In the section interpreted as non-inhabited, phosphorus values soar to 4,400 mg/kg, whereas in the dwelling zone it displays lower values in comparison. It may be noted that content exceeding 1,200 ppm already qualifies as high and suggests substantial degree of anthropogenization of the area.

Apart from phosphorus, sediments were evaluated for contamination with zinc, copper, iron, and manganese (Fig. 10). In most cases, the varied distribution of particular elements in the trench appears to coincide with grain size analysis which demonstrated distinct lithological profiles of sediments in the residential section and the remaining area.

Zinc content was estimated between 31 and 48 ppm, with higher values being observed in the south-western section, beyond the buildings (Fig. 10). Also, higher copper concentrations were detected in that location as well; the overall range for the latter element was 11 – 24 ppm. Among the dwellings, the values for both copper and zinc dropped to the lowest recorded limit. Such differences may be due to more intensive occupational/economic processes, such as use of bronze tools or casting of those outside one's household or in its immediate vicinity.

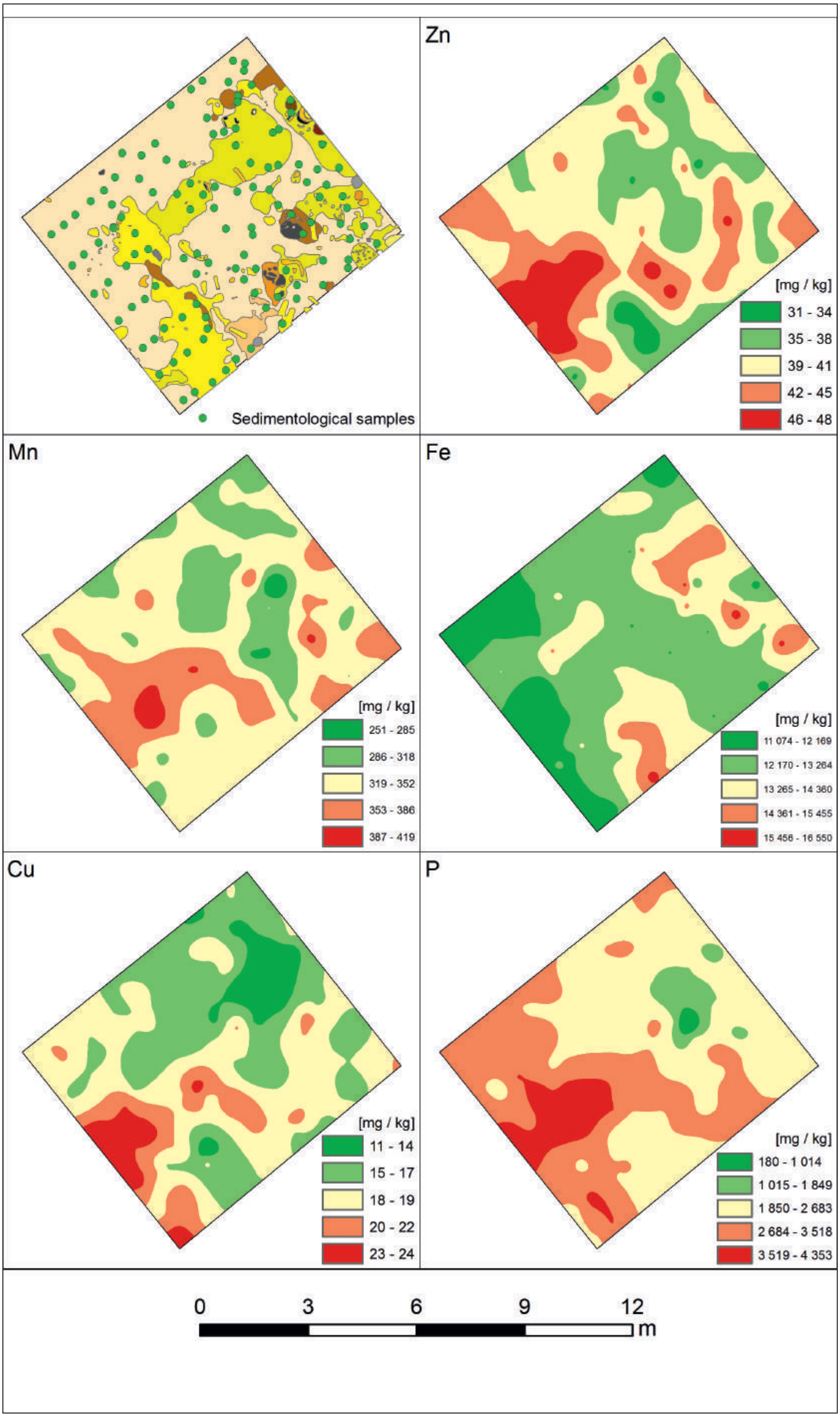
The distribution of manganese in the trench resembles the dispersion pattern observed in the case zinc and copper (Fig. 10). The lowest detected values reached 219 ppm, being concentrated mostly in the residential section, whereas extremely high content (419 ppm) was again observed in the south-eastern section. The accumulation of the element outside dwellings could be attributed to more extensive effect of erosion processes than it was in the case of inside the dwellings.

In contrast, spatial distribution of iron proved to be altogether different. Its content within the trench ranged from 11,000 to 16,500 ppm (Fig. 10). The highest concentrations were detected where remnants interpreted as erstwhile daub walls were to be found. It should therefore be expected that the high iron levels in those locations reflect its original high content in the clay deposits from which material for the walls was extracted.

To sum up the above sedimentological analyses, it has to be observed that all parameters of grain size distribution offer evidence of anthropogenic sedimentation environment. In this respect, kurtosis and sorting are perhaps the most evident, Given that the dominant fraction in the entire studied section of the settlement is silt, grain size parameters speak against its deposition via aeolian processes. Poor sorting of sediments and leptokurtic distribution of grain sizes must therefore be accounted for by human intervention. High content of compounds and elements such as calcium carbonate, phosphorus, copper and zinc are additional markers of anthropogenic nature of deposition. In particular, ancient phosphorus in quantities exceeding 1,200 ppm (up to as much as 4,400 ppm) suggests the existence settlement processes in the past.

Sedimentological analysis also made it possible to verify the spatial limits of a feature which was interpreted as a house based on the magnetometric image. The disparity in grain size parameters and geochemical composition of sediments between the anomaly in its contexts to the south west and north-west confirms lithological difference. The area of the anomaly is characterized by similarly anthropogenic markers, whose values differ from what is observed outside the residential zone. It seems that a proportion of those indicators, such as the share of particular fractions or mean grain diameter might be due to the presence of numerous remains of residential architecture (daub, eroded vessel sherds or clay kiln and floors). In the area beyond the conjectured hut, the circumstances of sediment deposition appear to have been dissimilar, although they occurred as part of settlement processes. Lack of distinctive archaeological remains in the south-western and north-western section, low magnetization gradient detected during geophysical prospection, and simultaneously evident presence of markers of anthropogenic deposition, warrant the interpretation that it had been a path or area surrounding and belonging to a household. This concept will be eluci-

Fig. 10. Spatial variation in distribution of chemical elements in sediment samples.



dated in detail in the following sections of the chapter (see section 1.5.4).

One should also draw attention to the varying spatial distribution of ancient phosphorus. Its low content in the inhabited zone and high concentration beyond it are nothing short of striking. Perhaps this is a result of disposal of household waste outside its bounds or economic activity having taken place there? This is a likely alternative in view of higher values for zinc and copper in that very spot. However, the interpretation requires further studies into the functional aspects of the Kakucs-Turján settlement.

Summing up, both archaeological investigations in the two trenches as well sedimentological and geochemical analyses of obtained samples bear out the interpretations based on the magnetometric images as far as occurrence of dwelling remnants is concerned. By analogy, similar findings should be expected when verifying other anomalies in that part of the settlement which display clearly rectangular outlines. Nevertheless caution is advised if these particular findings were to be extrapolated to other sites surveyed using the magnetometric method, as in each case verification methodology should be adjusted for existing geological, geomorphological and archaeological conditions.

1.5.2. Ditch-like type of anomalies

Magnetometric prospection demonstrated the presence of elongated, oval structures which surrounded the settlement and divided it into three main parts: the northern, the western and the eastern (Fig. 5, Fig. 6). The structures in question were preliminarily interpreted as a system of ditches. The total length of those belts, which can be distinguished thanks to higher magnetization gradient, is 750 m. The structures were divided in view of their possible function. Thus, the line of anomalies encircling the settlement would be referred to as the outer ditch system, while the inner system would consist of those stretches which separated individual parts of the settlement.

Average magnetization value for the anomalies was 2.5 nT, ranging from 1 nT and 3.5 nT. The width of the anomaly belt was between 6 and 15 m, with an average breadth of ca 10 m. The outer ditch system varied considerably in terms of width: the anomalies to the north were much less broader than those to the south, west and east. In contrast, the inner ditches maintained a fairly consistent width which did not exceed 11 m.

It should be noted that not all structures are connected in an uninterrupted fashion. For instance, the anomalies are discontinued in the north-western part, where there is a gap between the northward belt and the outermost belt to the west. A likewise situation is observed in the eastern part of the site where on the outer belt to the east the structures combine into a more complex arrangement in which chronological and stratigraphic variation and overlap may be expected. The issue of co-occurrence of all elevated magnetization belts calls for further studies, in order to disentangle the mutual stratigraphic relations. At this point however, the specific stages in which those structures developed cannot be reconstructed.

The interpretation according to which the anomalies in question were infills in the form of elongated ditches was verified through geoarchaeological corings performed in two test areas (Fig. 11) (Pető et al. 2016; see also Pető et al. *Report on the geoarchaeological survey of Kakucs-Turján site,* in this volume). The first, located in the eastern part, was intended as a means of lithological and stratigraphic exploration of the outer ring surrounding the settlement. The second targeted the inner system of ditches in the central part of the settlement. In both cases, a U-shaped form of the infill was determined, whose bottom reached the maximum depth of over 3 m below ground level, though not exceeding 3.5 m. (Fig. 12; for detailed stratigraphy see also Pető et al. *Report on the geoarchaeological survey of Kakucs-Turján*

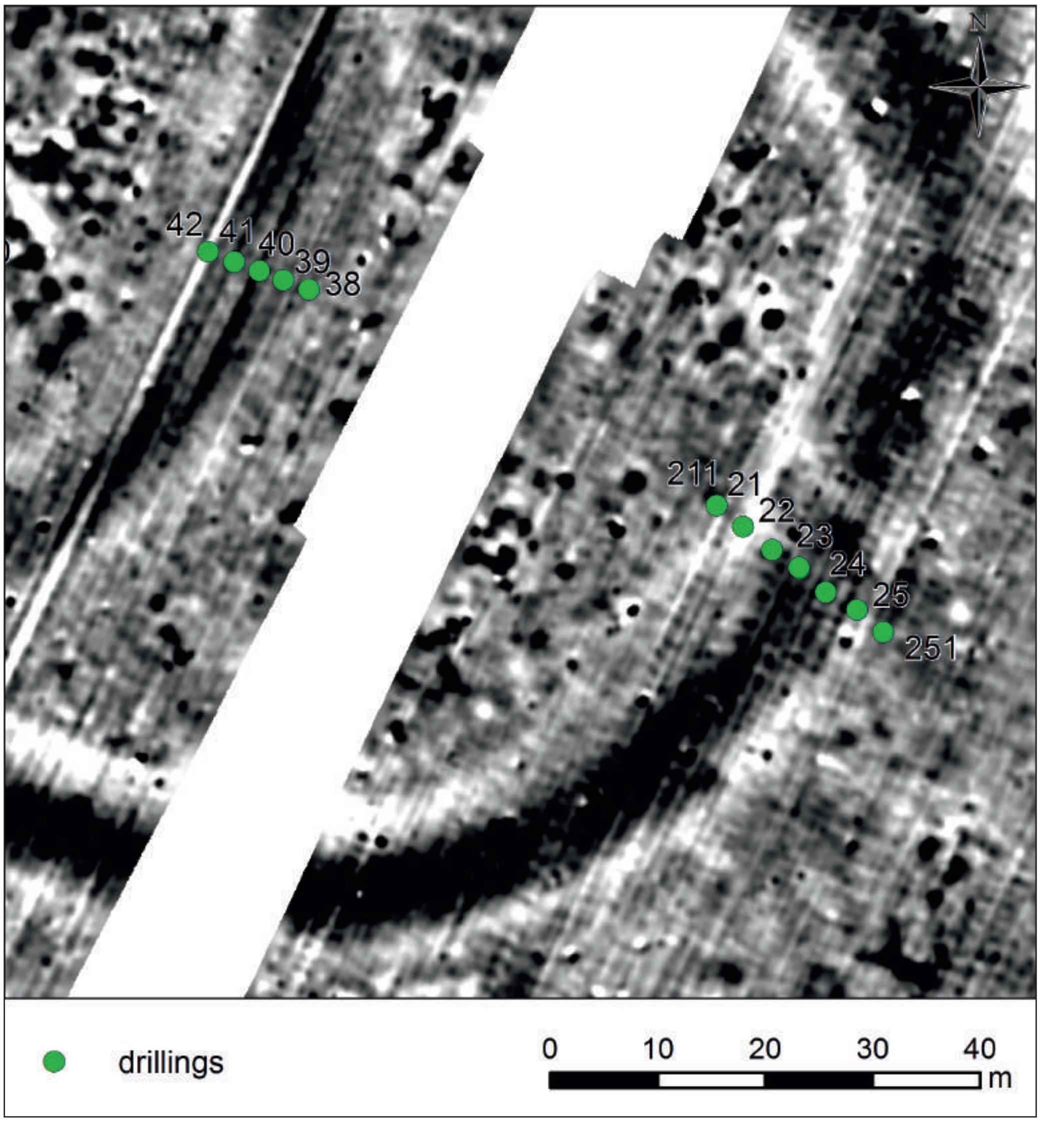


Fig. 11. Location of profile drillings in the outer and inner ditch systems.

site: Fig. 6 – 9; in this volume). Here, predominant types of sedimentation were associated with aquatic (lacustrine) environment and biogenic accumulation. Pottery and other artefacts were detected as well. Taking into account the stable sedimentation environment in the ditch area, it should be expected that the relics originated from the phase where the ditches were being used, as opposed to finding their way there post-depositionally in the course of backfilling episodes (Pető et al. 2015: 8; Pető et al. 2016: 234-235; for detailed description of the geoarchaeological observations see also Pető et al. *Report on the geoarchaeological survey of Kakucs-Turján site*, in this volume).

Stratigraphic data indicates that at least in a proportion of sediments, their lithology, structure and texture attests to stable sedimentation in stagnating water (Pető et al. 2015: 8; Pető et al. 2016: 234-235). Moreover, the corings acquired in the inner ditch system managed to capture a backfilling incident over which another cultural layer was found, which may signify that the conjectured ditch ceased to be used (Pető et al. 2015: 8-9). As for the synthetic profile of the inner ditch, the incline of that concave form could not be determined. This may be due to the fact that it may have been constructed with angular edges, which would be revealed if drilling resolution were higher or if a probe trench were executed.

Thus, thanks to methods of field geology used for verification, it was possible to confirm the predictions regarding the belt-like anomalies, which turned out to be concave structures filled with biogenic material that contributed to elevated magnetic signal.

Also, the stratigraphy in the profiles also showed that the ditch became fairly stably

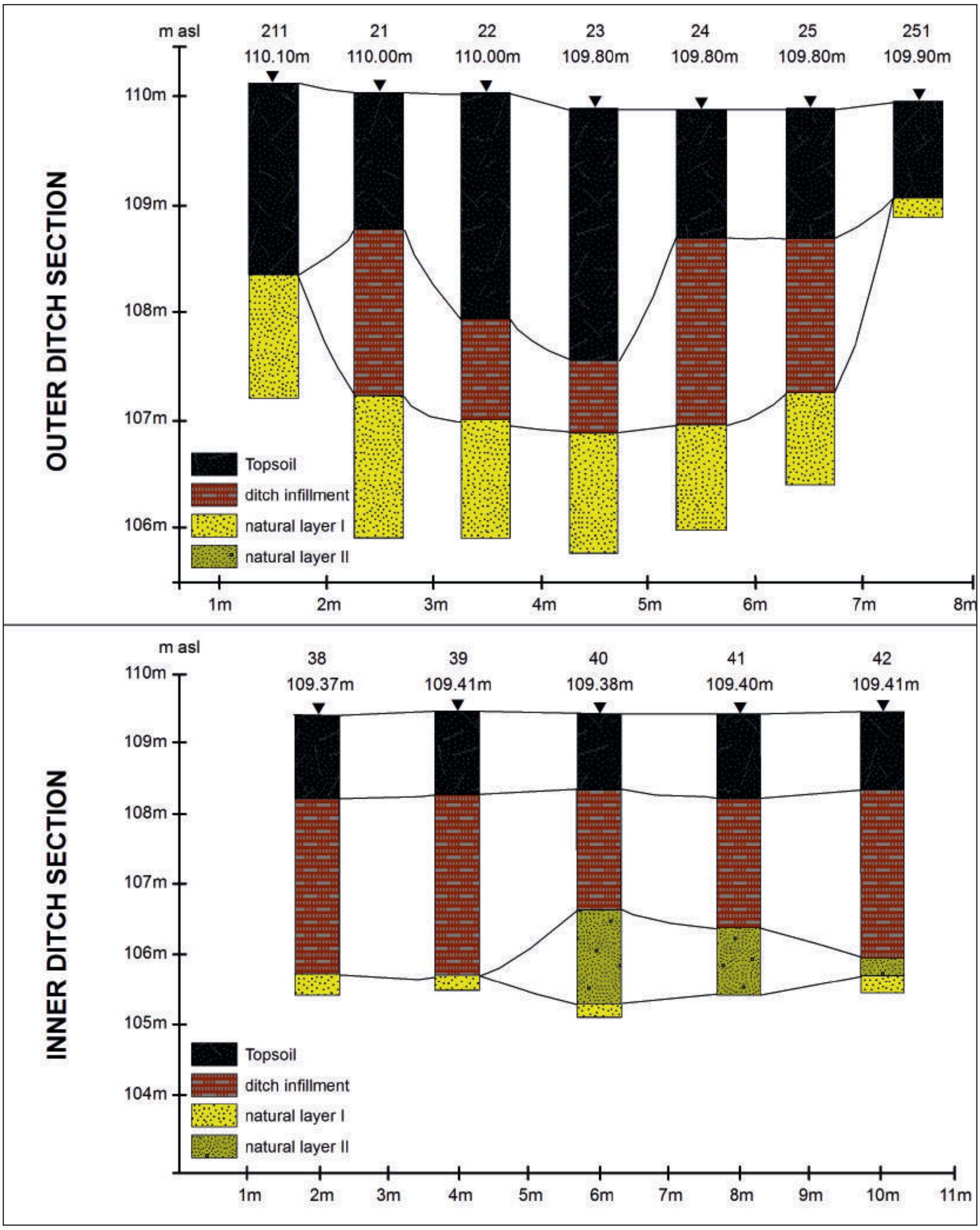


Fig. 12. Simplified cross-sections of the outer and inner ditch structure. Drilling numbers refer to Fig. 11 (after Pető et al. 2015: Fig 7 and Pető et al. 2016; see also Pető et al. *Report on the geoarchaeological survey of Kakucs-Turján site*, in this volume).

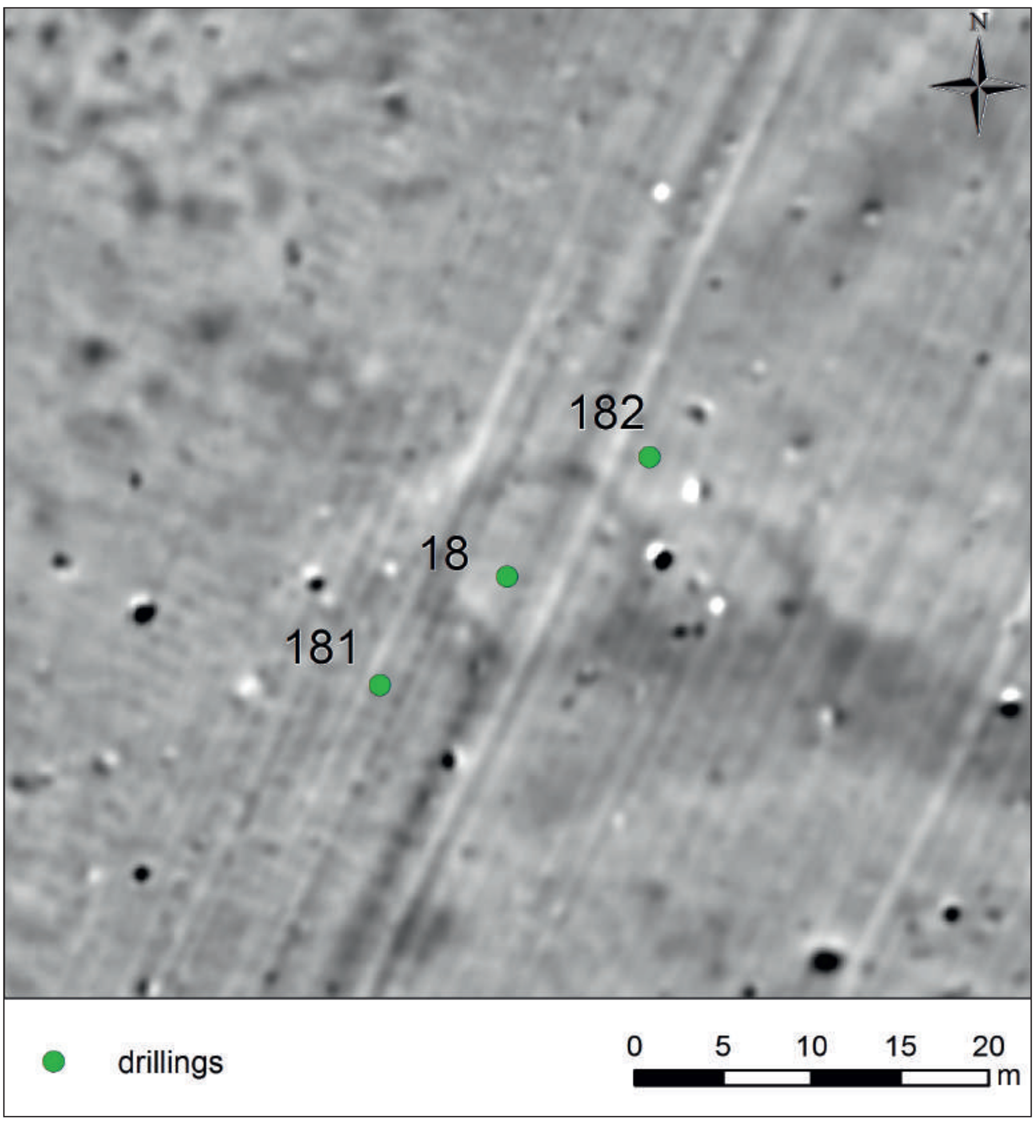
filled up in the environment of stagnant water. Meanwhile, presence of artefacts in the obtained material was an indication that the structures were contemporary to habitation in the settlement. Nonetheless, it needs to be noted that the probings reflect only topical stratigraphy and may not actually offer a reliable overall picture of sediment configuration. However, similar parameters of the magnetization gradient and the relatively well-outlined structures in the horizontal renderings from non-invasive surveys suggest that other sections of the ditches would yield like results. However, chrono-stratigraphic continuity in particular ditches remains an open issue. As observed at the outset, horizontal view of the anomalies shows gaps, therefore at this stage of research it cannot be stated whether all structures seen in the magnetometric image were utilized in the same time periods.

1.5.3. Well-like type of anomalies

In the western part of the site where the ditch structures skirting the northern and the western zone connect, magnetometric survey demonstrated 3 oval anomalies which displayed increased magnetization gradient (Fig. 5, Fig. 6). The perimeter of these features partially lies within the ditch system, while the features themselves are latitudinally adjacent. All have a similar radius from 4.5 to 5.5 m. The structures were preliminarily interpreted as hollows filled with biogenic content which may have been remnants of wells or cistern-like features.

Again, shallow geoarchaeological corings were performed as a verification measure (Pető et al. 2016; see also Pető et al. *Report on the geoarchaeological survey of Kakucs-Turján site*, in this volume), whereby the procedures were planned in such a way as to obtain a synthetic profile of the westernmost structures, as the latter was the most distinctly outlined of all three in the magnetometric image (Fig. 13). Three drillings were executed in total; the central one (Fig. 13: drilling 18) was situated within the structure, and the subsequent was made at a spot located to the east, where low anthropogenization of sediments was expected (Fig. 13: drilling 182). The final drilling (Fig. 13: drilling 181) was within the zone of the westward ditch; its aim was to document the relationship of the conjectured well structure with the system of the extended depressions encircling the settlement (for detailed description of the geoarchaeological observations see Pető et al. *Report on the geoarchaeological survey of Kakucs-Turján site*, in this volume).

Fig. 13. Locations of profile drillings in the area of features interpreted as wells.



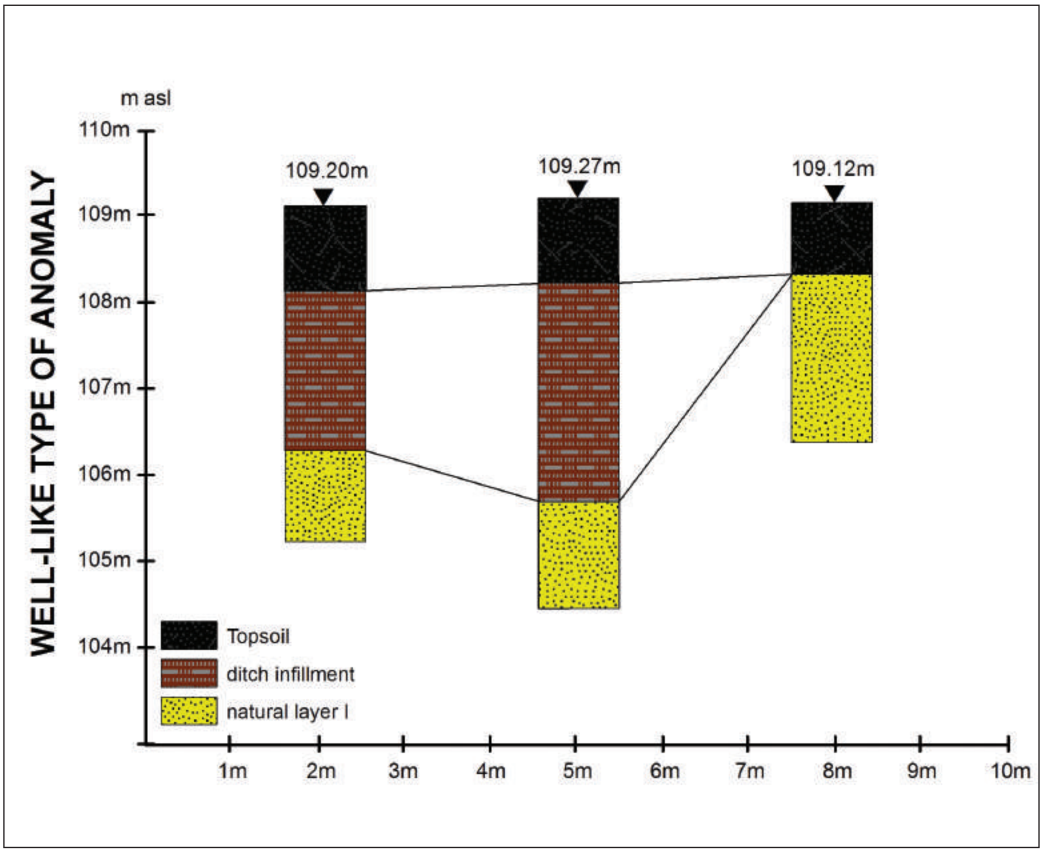


Fig. 14. Simplified cross-section of the well-like type of anomaly (after Pető et al. 2015: Fig. 6 and Pető et al. 2016; see also Pető et al. *Report on the geoarchaeological survey of Kakucs-Turján site*, in this volume). Drilling numbers refer to Fig. 13.

The corings provided an insight into the subsurface structure in the central part of the anomaly (Fig. 13; see also Pető et al. *Report on the geoarchaeological survey of Kakucs-Turján site*: Fig. 7; in this volume), which consisted of biogenic sediments with a substantial content of archaeological relics. Sedimentation in that cavity reached over 300 cm, while the stratigraphic texture assumed the form of microlamination at places (see Pető et al. *Report on the geoarchaeological survey of Kakucs-Turján site*: Fig. 8; in this volume), which is indicative of aquatic deposition environment. The coring to the east showed a natural record of the site's stratigraphy, with the natural background immediately underneath the ploughed soil horizon. As for the last coring, the sequence of successive layers was similar as in the well, though the biogenic infill stratum was thicker (Fig. 14). This could be attributed to direct connection between the presumed well in drilling 18 with the ditch infill in drilling 181 (Fig. 13: 18 and 181). Given that chrono-stratigraphic data is lacking, the incline of the cavity's slope and mutual relations of sediments in the well and the ditch have not been captured in sufficiently high resolution, no conclusions can be made regarding potential concurrent functioning of both forms.

Questions concerning the function of that hollow within the ditch system or their general use in the settlement of Kakucs-Turján remain unresolved for the present. Considering the fact that sediments filling that cavity are likely to have been deposited in the environment of – at least periodically - stagnant water, the preliminary interpretation which assumed it to have been a well is borne out to a degree. In the case of that particular anomaly, it cannot be ruled out that it actually served as an artificial reservoir which collected ground- or underground water as a hydrogeological depression. However, one should consider the role of the two remaining features which display similar spatial parameters in the magnetometric image. Perhaps the fact that there are as many as three may be accounted for by their varied chronological provenance and/or use, but this requires detailed stratigraphic or chrono-stratigraphic data to be obtained by means of coring and further sampling.

1.5.4. Open spaces

Apart from anomalies which undoubtedly owed to past human activity, the magnetometric picture of the Kakucs-Turján site also demonstrates areas where no deviations from the neutral magnetic gradient were detected or minor negative response was observed (0 – -0.5 nT). Specifically, such areas were encountered at the inner boundary of the ditch system (Fig. 5, Fig. 6). Further such surfaces were identified in the centre of the western part of the settlement, where they surrounded an anomaly indicating remnants of walls (a central building?). Furthermore, elongated, strip-like structures characterized by neutral magnetic gradients extended from that location in various directions. While absence of distinct anomalies beyond the settlement would have been taken as a matter of course, the structures in question were found between areas where the intensity of anomalies was quite considerable.

At the current stage of investigations it cannot be conclusively stated whether those elements are remnants of roads, paths, homestead premises, or other form of communication arrangements in the settlement. Still, since none were determined in the northern part (interpreted as an area dedicated to economic activity, specifically animal husbandry) and the eastern part where hut-like anomalies are very few or occur in much smaller quantities, such an interpretation is by all means viable.

The only means of verification one could employ at this point are the findings from archaeological and sedimentological investigations in trench 1, in the western part of the settlement. As discussed in section 1.5.1., no distinct archaeological features were established in the northern and western section of the trench, with most residential structures found in the remaining sections. Nevertheless, sedimentological indicators for the apparently empty space showed poor grain sorting, pulsative sedimentation environment and presence of metals, phosphorus and other compounds (e.g. $CaCO_3$), which attested to past human activity. Lack of more discernible archaeological features, such as cuts, in that part of the trench may therefore be indicative of another form of exploitation of the area, especially in the light of grain size analysis and geochemical characteristics of the soil. One of the possible explanations for these discrepancies in data is that the area, devoid of structures and immediately adjacent to a house, served as path for instance. Having adopted that explanation of the "empty space" next to the preserved remnants of a dwelling, and extrapolating it to the entirety of the western part of the site, a map of a potential communication network was obtained, covering the residential zone of the Kakucs-Turján settlement. Obviously, these are tentative interpretations which necessitate further studies.

Current work spans geological drillings and analyses of samples thus obtained so as to confront the above conception with the state of affairs in other sections of the western part of the settlement. The investigations consist in analyzing 3 x 1 m plots, with evaluation of samples from locations which in the magnetometric image correspond to empty spaces, hut remnants and ditches. It is expected that the procedures will yield a comprehensive overview of sediment variation across those specific locations and demonstrate their anthropogenic provenance, as in the case of trench 1.

1.6. Environmental characteristics of Kakucs-Turján in the light of the magnetometric view, ERT and GPR prospection.

1.6.1. General outline of anomalies outside the settlement

Thus far, the results of magnetometric prospection were discussed only with regard to the interior of the Bronze Age fortified settlement. As it follows from the analysis of density of occurrence of features with suspected anthropogenic origin for the entire survey (Fig. 4), concentrations of anomalies are also to be found outside the boundaries of the settlement, demarcated by the outer ring of ditches. Archaeological excavations confirmed that they date back to prehistoric periods. In many cases, those were cuts or aggregations of clay, which may be interpreted as floors, hearths or structures associated with oven remnants. It may thus be concluded that economic activity, even habitation, were indeed practiced beyond the fortified settlement as well, though it was inside it that the largest concentration of such remains was expected to be found.

One of such locations is visible in the output magnetometric image to the west, as the survey encompassed the base of a minor incline, along which there was an accumulation of chemical compounds and minerals from higher (westward) terrain, producing an extended, linear anomaly with increased magnetization gradient (Fig. 15).

Apart from isolated anomalies, concentrations of those or linear arrangements at the foot of sloping ground, prospection detected elongated strips aligned SE-NW where magnetization gradient was slightly

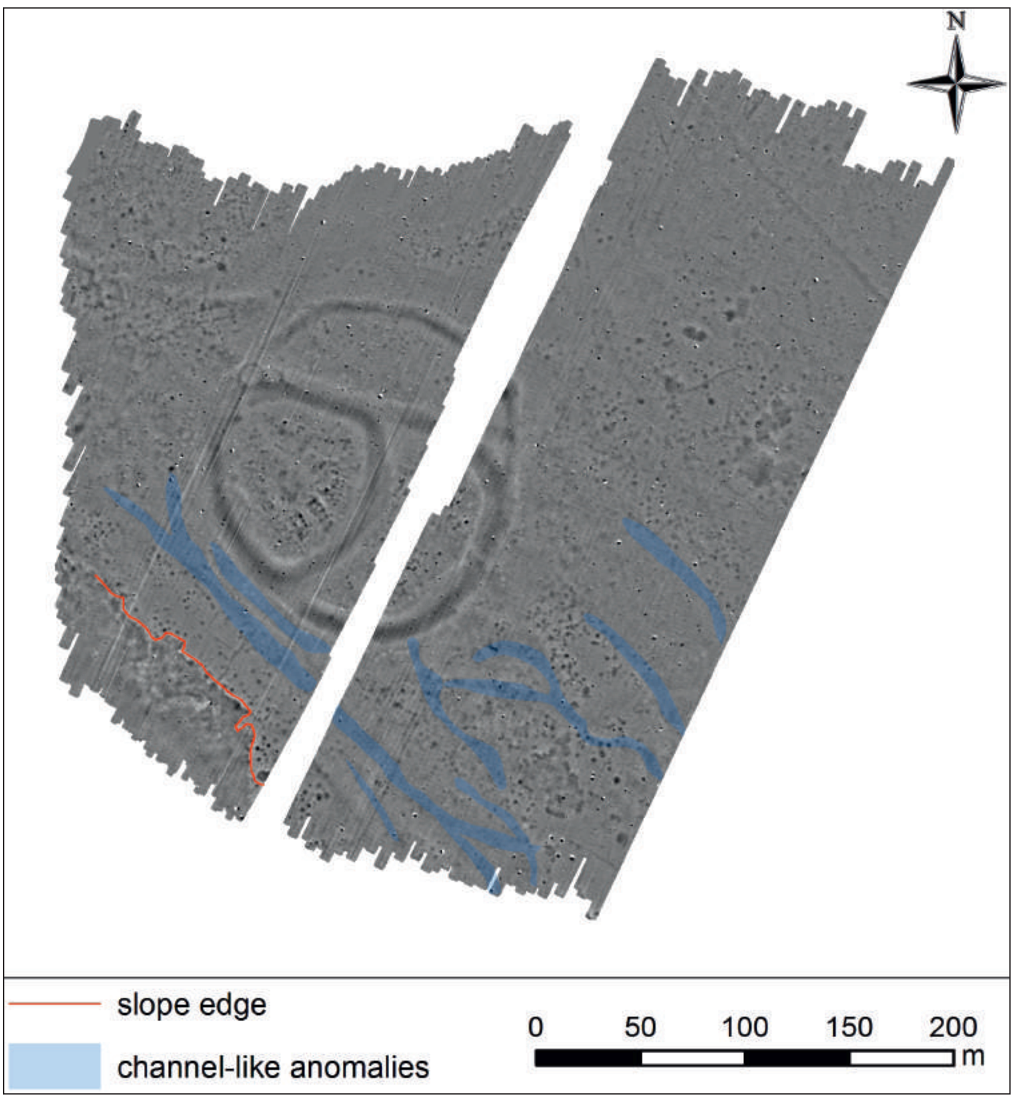


Fig. 15. Interpretation of the magnetometric image outside the fortified settlement.

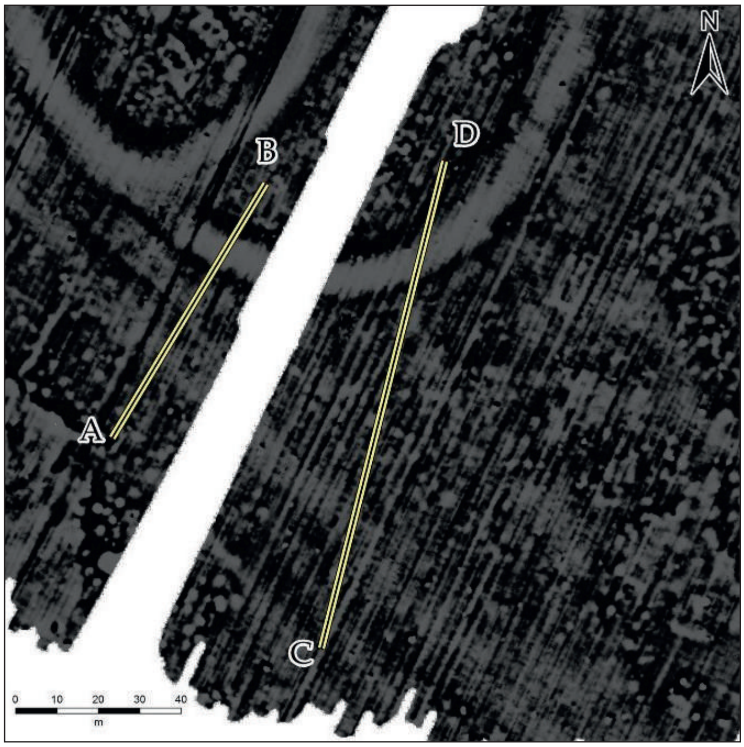


Fig. 16. Two sections (A-B and C-D) over the passes of higher susceptibility outside the settlement.

increased (~ 1 nT) and which varied in width: from 1 m up to 10 m. In the middle of their course, they adjoin the settlement on the west, south and south-east (Fig. 15), occasionally connecting in horizontal view with the outer ditch system. The arrangement of those strips and their spatial interrelationship resemble anastomosing pattern of palaeochannels which may have functioned in the past and supplied water to the ditch system. This might be inferred from the direct horizontal contiguity with the ditch in the south-eastern part of the settlement. In this context, one cannot fail to draw attention yet again to the three features interpreted as wells (see section 1.5.3), which in this case might have served as hydrogeological depression, forming a declivity of terrain that gathered water from a river or a stream.

However a different possible interpretation of those strips should be taken into account; namely, they might constitute features of anthropogenic nature which, admittedly, are less apparent or only partially rendered in the magnetometric plan. These may have been further systems of ditches linked to the settlement in one way or another, or may have functioned as such in a different cultural and chronological context. Particularly in the western and north-western parts of this area, the lines are parallel and reach substantial widths (ca 10 m), which could suggest remnants of deliberate human activity in the past.

The anomalies in question, owing to their complexity and the research prospects occasioned by their interpretation as a river system, prompted further verification work using non-invasive methods, i.e. electrical resistivity tomography and ground-penetrating radar survey.

1.6.2. Verification of magnetometric view by other non-invasive prospections

In order to verify the occurrence of sub-surface archaeological or natural features on the magnetometric plan, two longitudinal resistivity profiles were obtained and a GPR scan was carried out (Fig. 16). The first (section A-B on Fig. 16) was located in the SSW context of the site, partially crossing the ditch section in the north and reaching the colluvial border (Fig. 15 and Fig. 16) to the south (Fig. 17). In the centre,

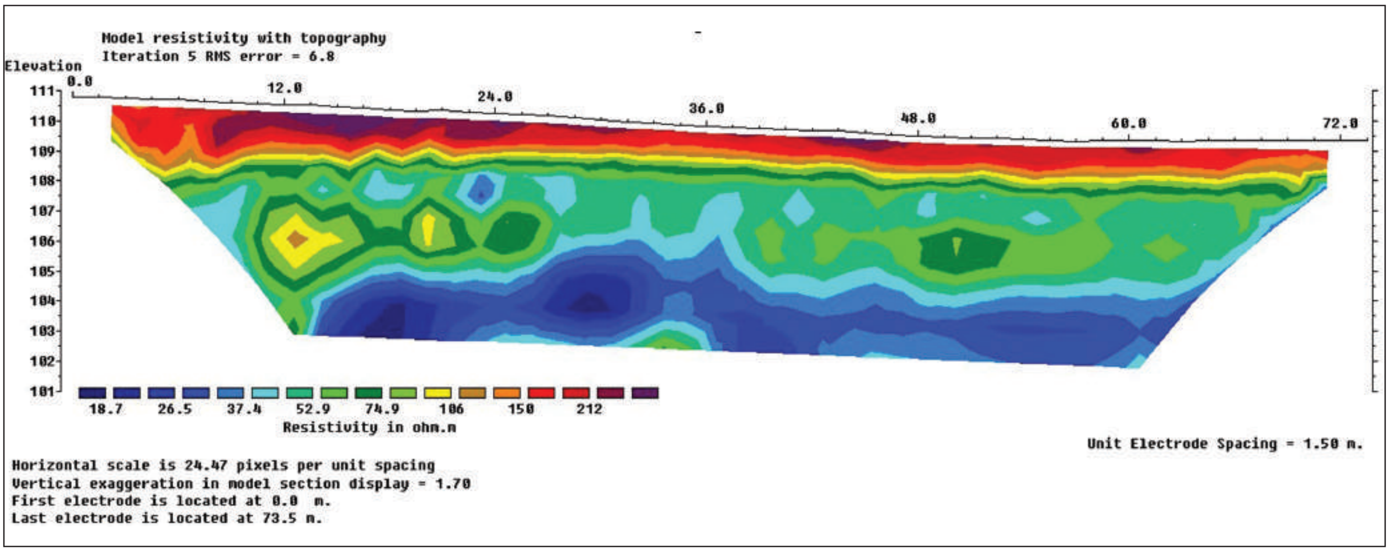


Fig. 17. ERT of section A-B as marked in Fig. 16.

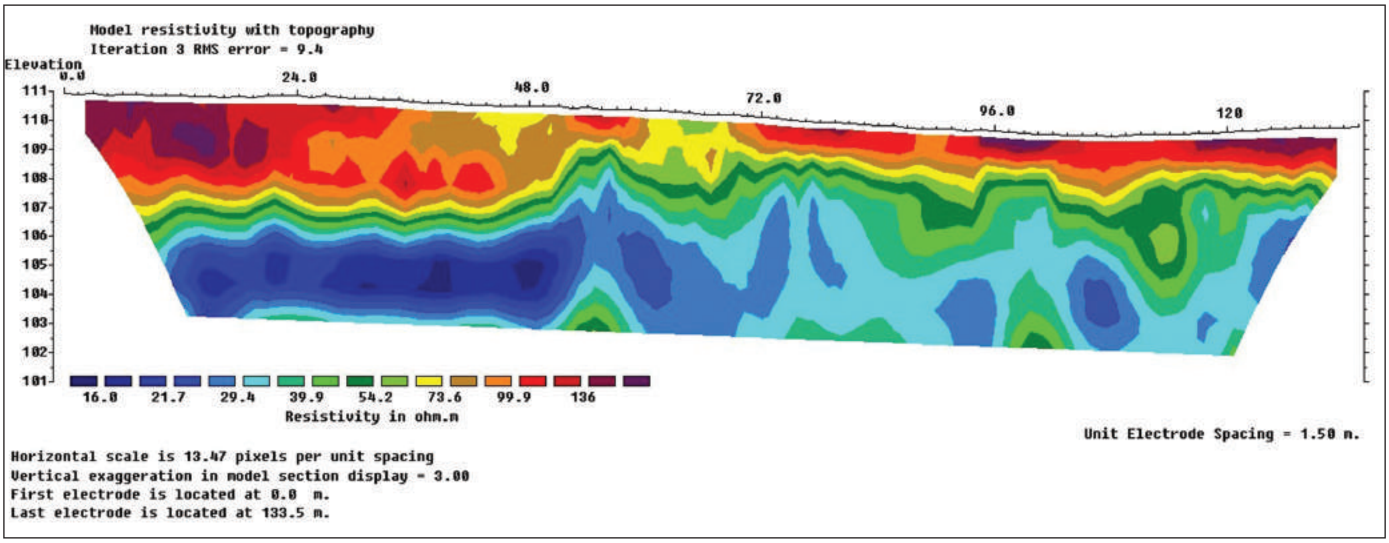


Fig. 18. ERT of section C-D as marked in Fig. 16.

the profile embraced the area of two linear structures interpreted as river channels or additional ditches. The second transect was performed parallel to the former (section C-D on Fig. 17), spanning the ditch in the north, down to the colluvial border on the south. This section covered the minor ditch- or channel-like passes as well as one larger structure of the kind located further southwards.

1.6.3. Electrical resistivity tomography

Electrical resistivity measurements were conducted by applying a direct electrical current into the ground using two current electrodes and measuring the voltage difference at two potential electrodes. Given the voltage difference, the intensity of the direct current and the geometry of the four electrodes, the apparent resultant resistivity can be determined. Having applied a nonlinear, smoothness-constrained least-squares inversion technique in Res2DINV software, true resistivity could be calculated.

The measurements were carried out using a Geotom MK8E1000 high-resolution multi-electrode resistivity, consisting of a data acquisition unit, a computer and two single-shielded 25 cable-trees with

25 takeouts, 4 m each (with 50 steel, 30 cm-long probes per cable). In both cases the injection electrode spacing was 1.5 m along 72 m (Profile 1) and 138 m profile (Profile 2) lengths. A dipole-dipole electrode array was used in both cases, giving a maximum penetration depth of roughly 7.5 m. The coupling with the substrate was very good, and the electric contact with the surface did not have to be enhanced.

Concerning the ERT prospection, the profiles in both sections revealed low resistivity values ranging from 5 Ωm to 200-250 Ωm. The specific resistivities of both profiles can be grouped into three layers.

In the case of Profile 1 (Fig. 16, section A-B and Fig. 17), the uppermost layer is continuous and has a depth of 1-2 m, greater between 0-30 m along the line and resistivity values higher than 120 Ωm. Topsoils usually reveal higher resistivity values. It was inferred that this layer as being drier than the layers below and more heterogeneous, probably because of higher soil porosity resulting from agricultural use of the land. The middle layer is characterized by resistivity values ranging between 50-120 Ωm and extends to a depth of 5 m. At horizontal distance of 27-38 m, a distinct area of lower resistivity occurs. It could be explained by higher moisture content within the substrate or an area infilled with more conductive materials (e.g. clay). Below this layer, resistivity decreases to less than 50 Ωm, occasionally dropping as low as under 25 Ωm, which in this type of soils probably corresponds to the water table. Unfortunately, in this profile no distinct anomalies related to archaeological remains could be determined.

In the case of Profile 2 (Fig. 16, section C-D and Fig. 18), the uppermost layer is discontinuous, and between 58 m and 68 m the values decrease surprisingly, since this is not the lowest area. This layer is again much thicker between 0-45 m, where it reaches 4 m in depth. Some archaeological remains (e.g. buried structures) are likely to occur there, at a depth of 2-3 m, but because of the excess of groundwater within the substrate the resistivity variation is reduced and the environment appears more homogeneous than normal. In our opinion, the most spectacular anomalies occurred in the middle layer between 50 and 120 m. The tomogram revealed an undulating contact between the three layers, between 50 and 120 m, which was not observed in the other profile, or on the left side of Profile 2. We identified at least 2 anomalies (between 85 and 96 m and between 100-115 m), where greater resistivities protrude within the lowermost layer. The second anomaly fits very well with the lowest altitudinal sector of this line, which makes it plausible to interpret it as a possible trench. Looking at the first protrusion and at topography as well, it seems that it was filled with materials mainly from the left side. A possible channel and two artificial trenches or ditches in this area could also account for irregularities of the resistivities.

1.6.4. Results and interpretation GPR

Additionally to the ERT survey, a ground penetrating radar method was used to clarify the section A-B where two large structures outside the ditch showing in the magnetometric plan. The area of investigations was widened by applying 7 additional transects parallel to the initial one, designated as A-B (Fig. 16 and Fig. 19).

Ground penetrating radar (GPR) is a widely used geophysical method based on electromagnetic radiation using high frequency (10-2000 MHz) radar impulses. The basis of the method is that the radiated electromagnetic signal is reflected from the interface of layers with different physical properties. Owing to the high frequency and the high propagation speed large resolution profiles of the subsurface structures and materials can be produced. Consequently, one can detect sediment structures with different composition, archaeological and other subsurface metal and non-metal objects, utilization pipelines, cavities or fissures. Major advantages of the method include its applicability in various environments and its ability to provide infor-

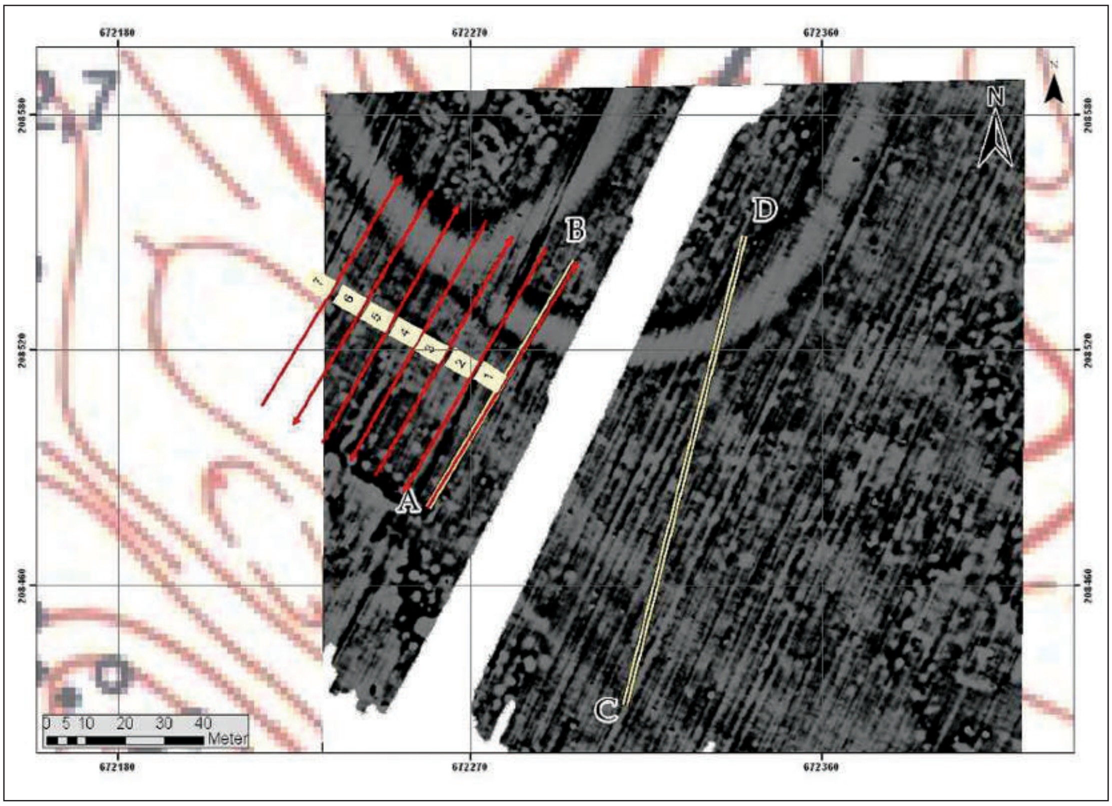


Fig. 19. GPR transects in Kakucs-Turján.

mation about the depth, geometry or even about the physical properties of the subsurface material based on the reflected signals.

Interfaces and other objects could be detected down to 3 m, mostly in the south-western half of the investigated area. The north-eastern part is much more homogenous and it is suspected to be composed of finer grain material as suggested by the ERT profiles as well. If topography is considered, then subsurface anomalies are related mostly to the north-eastern slope of a topographical high, interpreted as an aeolian hummock on the basis of the topographical map (Fig. 7).

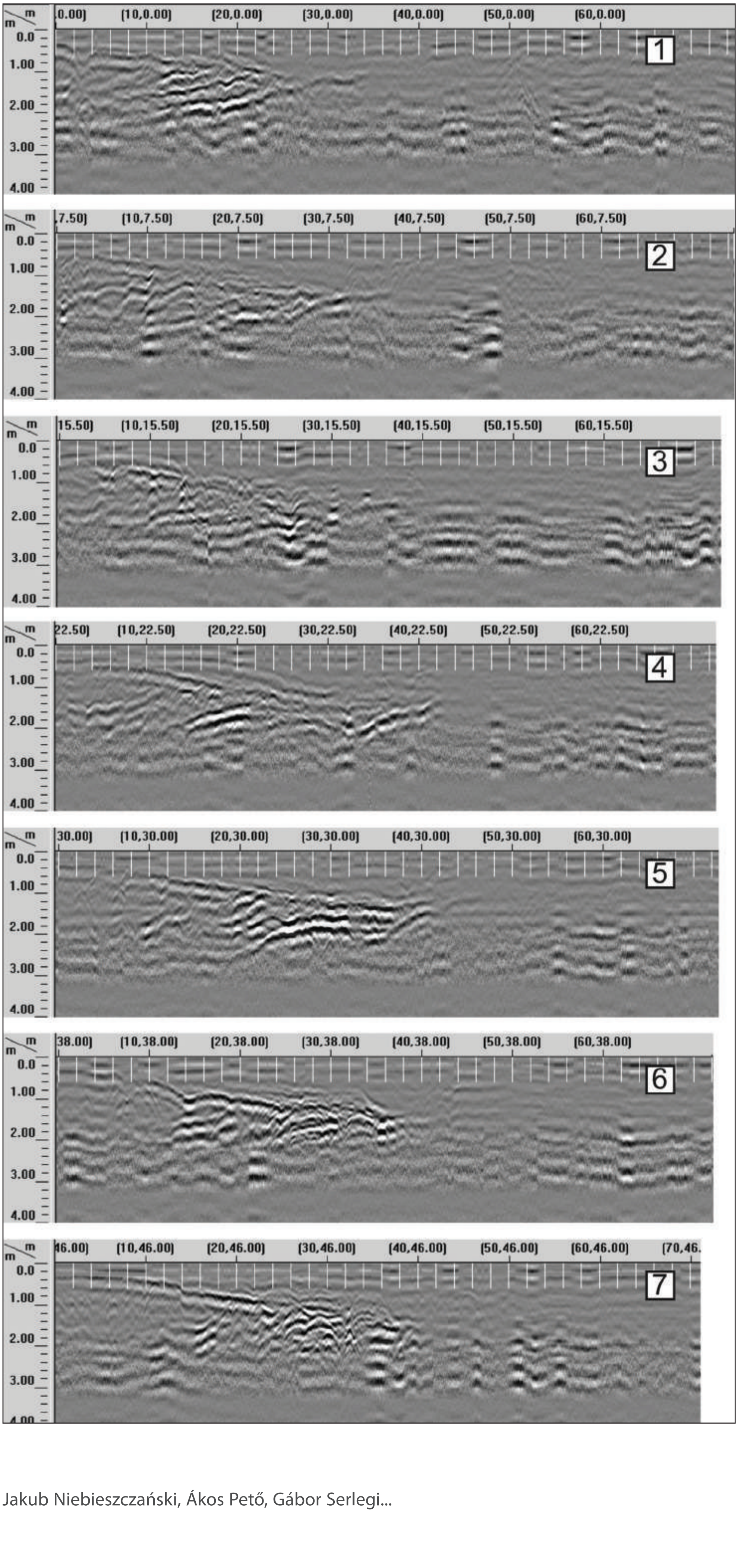
Layers can be clearly discerned when individual GPR profiles are interpreted. The bottommost interface is situated at a depth of 2.5-3.0 m. In GPR profiles No. 1 and 2 (Fig. 20 and Fig. 21) it has a south-western dip, otherwise it is rather horizontal and undulating. The interface can be interpreted as a palaeosurface covered by subsequent sand sheets, most clearly visible in GPR profile No. 4. The dipping of sand sheets is north-eastern, as they fill the topographical lows of the bedding. The overlaid sediment possibly represents the hummock itself.

Besides the obvious stratification, highly reflective infillings can also be detected. These can be identified in each GPR profile. The suspected series of pits, or rather a trench evinced in that form was deepened into the upper, hummock-related layer, and its bottom probably coincides with the bedding layer at 2.5-3.0 m. As visualized in GPR profiles No. 4 and No. 7 (Fig. 20 and Fig. 21), the infillings were covered again by a sand sheet associated with a subsequent aeolian event. Immediately beside the suspected trench much smaller anomalies can also be identified, which might be related to smaller objects.

1.6.5. Summary of the Magnetometric, ERT and GPR survey outside the settlement

Thanks to application of additional non-intrusive tools to verify the magnetometric image, the aforesaid interpretation of the elevated magnetization patches was confirmed: the features proved to be ditch-like structures whose backfill differed from the

Fig. 20. GPR transect vertical profiles (section A-B as depicted in Fig. 19).



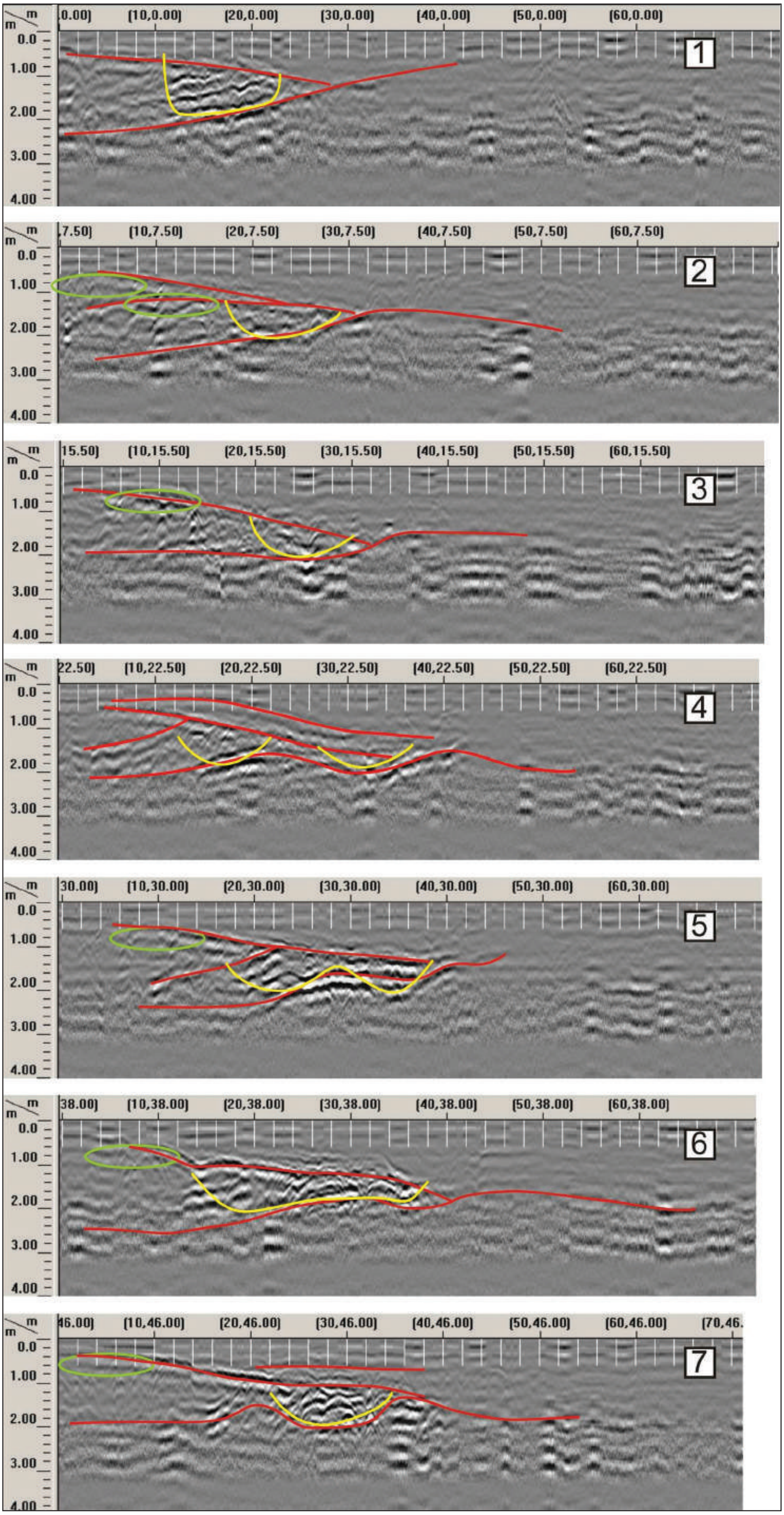


Fig. 21. Interpretation of GPR transect vertical profiles (section A-B as depicted in Fig. 19).

geological background. The issues of the function, however, remains unresolved, both with regard to natural environment and potential remnants of defensive or economy-related structures. Hence none of the concepts formulated hitherto can be validated at this point. Again, further investigations – using high-resolution grid of geological drillings or profile probings – are required to determine the nature of those ditches with a greater degree of probability.

1.7. Geoarchaeological investigations at Kakucs-Turján: a recapitulation

Geoarchaeological works conducted in Kakucs-Turján were focused primary to verify the magnetic and satellite view obtained at the beginning stage of the research. Combination of various methods brought numerous data both of archaeological and palaeoenvironmental value.

First of all the tripartition of the site internal structure was recorded. Each part was separated from another and from the outer area by a ditch infilled with water – most probably a ditch. In the northwestern part of the ditch a three circular objects were interpreted as a possible wells, perhaps serving also as a part of a hydrological system to fill the ditch with water. Only the western part of the site comprised a definite remains of a housing structures which spread concentrically around a central anomaly on a rectangular plan. Houses were built in a form of an elongated rectangles, divided internally with walls.

Excavations of one house in the western part of the site brought also a possibility to investigate the sedimentary environment inside and outside the discussed structure. It appeared that both environs were characterized by high level of anthropopressure resulting in high contamination of anthropogenic indicators like heavy metals or phosphates. Also the sedimentological diagrams shows that the deposition was stimulated by human factor. Outside the house the grain size distribution and other parameters suggest an existence of possible pathway.

The area outside the settlement comprise of an oblong structures similar in plan to the migrating river channels. Their existence was confirmed by the means of non-invasive methods but needs further studies in order to confirm their fluvial origins.

To conclude, the settlement in Kakucs-Turján as well as its closest environment present a variety of archaeological and palaeoenvironmental features. Some aspects were already revealed by the usage of geoarchaeological approach like drillings, laboratory analysis of samples and combined non-invasive surveys. Some question still remains open like the functional aspects of northern and eastern part of the site or the actual function of the circular structures in north of the site. Also it is needed to investigate the stratigraphical position of each ditch part in order to understand the site development and its possible connection to the hydrological net. Therefore, Kakucs-Turján offers a stimulating research perspective which can contribute in our understanding of the Middle Bronze Age societies in the region and their impact on the landscape.

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