AKADÉMIAI KIADÓ

Archaeologiai Értesítő

DOI:
10.1556/0208.2024.00084
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RESEARCH ARTICLE

Non-destructive investigations at Neolithic tell-centered settlement complexes on the Great Hungarian Plain

A case study from Battonya-Parázs-tanya

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Received: August 21, 2024 • Accepted: September 3, 2024

ABSTRACT

In Southeast Europe, recent years have witnessed a notable shift in scholarly focus related to prehistoric tell sites, expanding to encompass both their immediate surroundings and broader contexts. This shift has coincided with, and to a large extent has been generated by, significant methodological advancements in an array of non-invasive methods, including particularly magnetic prospection. This paper presents the methodology and results of an integrated set of non-destructive investigations conducted at Battonya-Parázs-tanya, a Middle/Late Neolithic settlement located in the southeastern part of the Great Hungarian Plain. In addition to various map sources, magnetometry, LiDAR, thermal and multispectral imaging, and surface survey were utilized at this tell-centered settlement complex to locate old excavation blocks and gain insights into settlement size, layout, and land use. Our data indicates that Battonya-Parázs-tanya spanned approximately 110 ha, with two primary ditches surrounding the tell and indications of a possible third enclosure, suggesting significant human alterations to the local landscape. This study underscores the importance of integrating multiple non-invasive techniques to achieve a more comprehensive understanding of the organizational complexities of and variations in large Neolithic settlements, thereby shedding light on socio-cultural dynamics that shaped them.

KEYWORDS

Neolithic, tell, settlement structure, non-destructive investigations, Great Hungarian Plain

ABSZTRAKT

A délkelet-európai őskorkutatás érdeklődése az elmúlt években a lelőhelyek közvetlen kutatásáról tágabb környezetük megismerésére is kiterjedt. A kutatás fókuszának ez a változása egybeesett, és egyben nagymértékben összefügg, a roncsolásmentes módszerek, különösen a geomágneses felmérések jelentős módszertani fejlődésével. Ez a tanulmány az Alföld délkeleti részén található középső/késő neolitikus Battonya-Parázs-tanya lelőhelyen végzett roncsolásmentes kutatások módszertanát és eredményeit mutatja be. Munkánk során mágneses geofizikai felmérést, LiDAR felmérést, termális infravörös és multispektrális képalkotást, valamint felszíni leletgyűjtést végeztünk a tell-központú

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településkomplexum területén. Célunk a régi ásatási szelvények lokalizálása, valamint a település méretének, belső struktúrájának és tájhasználati sajátosságainak megismerése volt. A vizsgálatok alapján megállapítható, hogy a lelőhely körülbelül 110 hektáron terül el. A központi tellt két árok veszi körül, és egy feltételezhető harmadik árok a táj jelentős emberi átalakítására utal. Tanulmányunk rámutat a roncsolásmentes technikák együttes alkalmazásának fontosságára annak érdekében, hogy pontosabb ismereteket szerezhessünk a nagyméretű újkőkori települések szerkezetének változatosságáról, valamint az azok létrejöttéhez vezető társadalmi folyamatokról.

KULCSSZAVAK

neolitikum, tell, településszerkezet, roncsolásmentes vizsgálatok, Nagyalföld

INTRODUCTION

Tell sites on the Great Hungarian Plain have garnered attention and have been the focus of excavations since the late 19th century. These prehistoric monuments, with their dense spatial concentration of materials, initially captured the interest of amateur archaeologists and collectors. Due to their stratigraphic sequences, representing long-term developments at a single geographic location, professional archaeologists became interested in tells primarily to understand shifts in material culture and practices over long periods of time. By extrapolating broader trends from the findings, these studies played a key role in outlining cultural transformations within the regions surrounding the tell sites, ultimately contributing to the reconstruction of Neolithic and Bronze Age cultural history across the Great Hungarian Plain.

For many decades, as in other parts of Southeast Europe, archaeological research predominantly concentrated on the tells themselves, often neglecting to consider them within a broader contextual framework. Although external sites were recognized,[1] systematic archaeological investigations of the areas adjacent to tell sites were rarely conducted.[2] On the Great Hungarian Plain, excavations at the Late Neolithic site of Polgár-Csőszhalom marked a turning point, fundamentally altering the scope of archaeological research and introducing a new perspective and interpretive framework for understanding tells at the local scale.[3] Initially, the project focused on the tell itself, but beginning in 1995, extensive development-led excavations were conducted in the surrounding area due to highway construction. Beyond merely recognizing the existence of off-tell occupations, these investigations exposed for the first time the abundant and diverse features of a large, intensively occupied village that was contemporaneous with a focal tell.

While pioneering geomagnetic research conducted at Polgár-Csőszhalom as early as 1990 produced one of the most iconic images of an enclosed tell in Southeast Europe,[4] the expansion of geophysical prospection into the surroundings of tells on the Great Hungarian Plain did not occur until two decades later. In this context, the extensive magnetometry survey performed with a single-sensor, handheld device at the Late Neolithic site of Szeghalom-Kovácshalom stands out as a particularly significant early effort.[5] This research demonstrated the effectiveness of geophysical investigations in revealing settlement layout and organization at large Late Neolithic sites on the Great Hungarian Plain. The identification of one of the largest known Neolithic villages in Europe, spanning approximately 90 ha, prompted the introduction of the term 'tell-centered settlement complex' for sites where tells were surrounded by extensive and intricate villages.

Like at other large sites in Europe, such as the Tripolye megasites,[6] the application of multisensor magnetometry profoundly expanded research possibilities on the Great Hungarian Plain. The ability to rapidly survey vast areas, at a decreasing cost over time, has opened new avenues for exploring Late Neolithic tell-centered settlement complexes. Over the past more than a decade, several of these large settlements have been extensively investigated using magnetometry.[7]

Although during the past decades, magnetometric survey has emerged as the foremost and most extensively employed method to identify subsurface archaeological features and understand settlement organization, a variety of additional non-destructive and minimally invasive methods also have been utilized to explore these matters. These methods, including surface surveys, soil coring for stratigraphic and geochemical analyses, various forms of geophysical prospection beyond magnetometry (such as Electrical Resistivity Tomography and Ground Penetration Radar), as well as aerial and remote sensing imagery of various kinds, complement each other, with an ever-growing potential to offer more comprehensive insights into settlement layout and use.

Depending on the research goals, different combinations of these methods have been employed at large Late Neolithic sites on the Great Hungarian Plain (see cited works above). For example, the *Late Neolithic tells and their landscape along the Lower Tisza River between 5000 and 4500 BC* project, the most prominent regional-scale, comprehensive archaeological investigation on large villages to date, focuses

[1] Kalicz and Raczky (1987).

[2] e.g., Kalicz and Raczky (1984).

[3] Raczky et al. (2002).

[4] Raczky et al. (1994).

[5] Gyucha et al. (2015); Parkinson et al. (2018).

[6] Chapman et al. (2014); Rassmann et al. (2016).

[7] e.g., Mesterházy et al. (2019); Parkinson et al. (2018); Füzesi et al. (2020a,b); Raczky and Anders (2009); Raczky and Anders (2016); Raczky et al. (2022); Riebe et al. (2023); Sarris et al. (2013).

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on five tell sites and their immediate surroundings in the Hódmezővásárhely microregion. The program combines data on previous excavations at the tells, systematic surface surveys, as well as magnetometry and soil coring to understand the spatial organization of and stratigraphic sequences at these sites.[8]

In line with this and other referenced examples, we employed a range of non-destructive methods to investigate the Middle and Late Neolithic Battonya-Parázs-tanya site, situated on the Maros Fan in the southeastern Great Hungarian Plain. Our approach involves consulting available data from previous excavations at the tell, examining historic maps, analyzing aerial and satellite imagery, and conducting surface surveys, LiDAR, thermal and multispectral imaging, and magnetometry to make inferences about settlement size, organization, and use at this tell-centered complex. Additionally, we sought to identify the locations of previously excavated trenches on the tell.

THE SITE AND ITS RESEARCH HISTORY

The archaeological site known as Battonya-Parázs-tanya in the archaeological literature (officially registered as Battonya-Száraz ér, Battonya 14; ID: 28950) is situated northwest of the town of Battonya, specifically in the Kis-Tompa-dűlő area, on the left bank of a large bend of the Királyhegyesi-Száraz ér river (*Figs 1 and 2*).

Excavations at the site were carried out by Júlia G. Szénászky and György Goldman during the late 1970s and early 1980s. Based on the results, they described the site as a tell settlement, with initial occupation dating back to the early period of the Middle Neolithic Szakálhát culture (ca. 5500–5000 BC), and with the uppermost layers representing the Late Neolithic Tisza culture (ca. 5000–4600/4500 BC).

The methods and results of each excavation season were summarized in the annual issues of the journal titled *Régészeti Füzetek*.[9] According to the excavation reports held

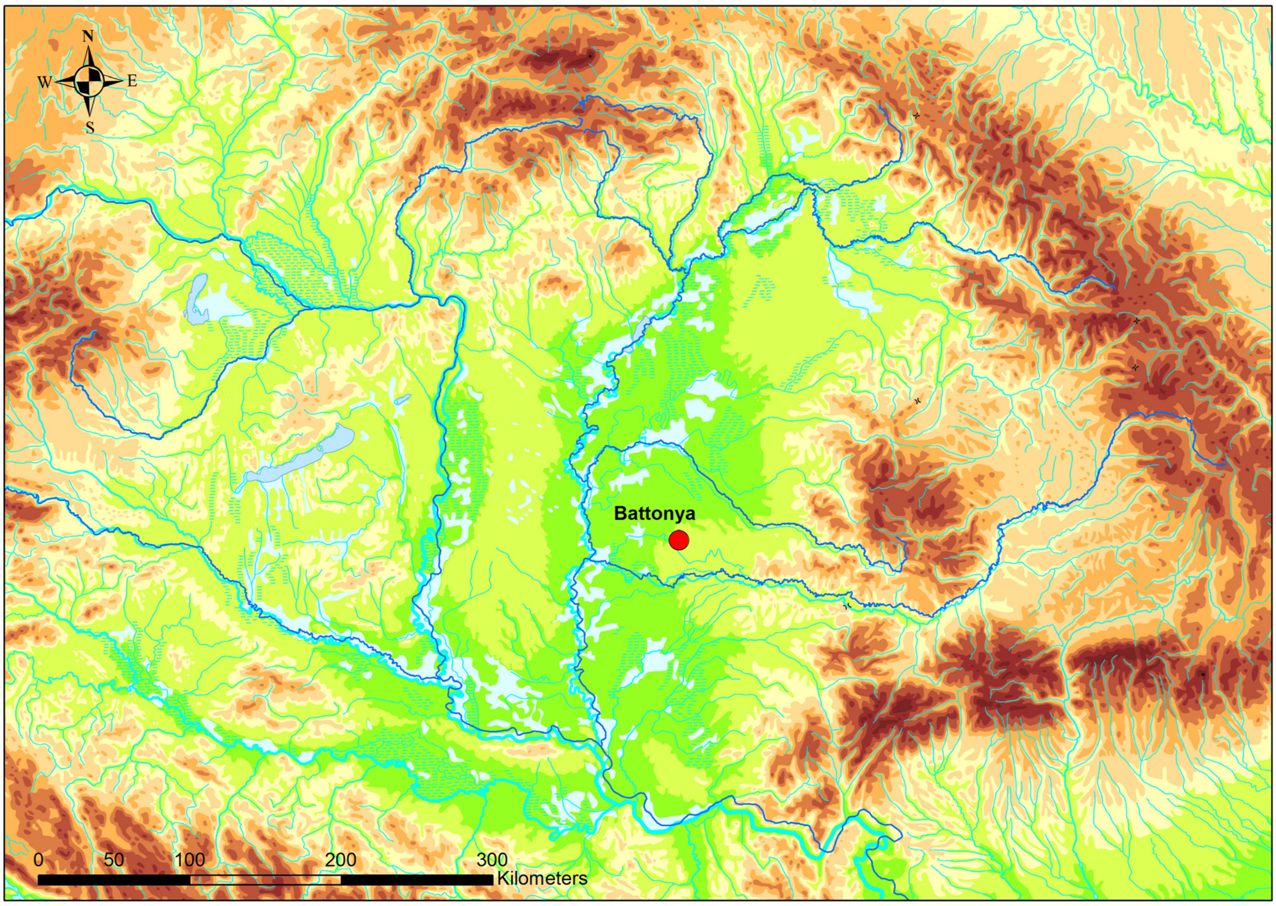

Fig. 1. Location of Battonya-Parázs tanya in the Carpathian Basin
1. kép. Battonya-Parázs tanya elhelyezkedése Kárpát-medencében

[8]Raczky et al. (2021); Raczky et al. (2022).

[9]G. Szénászky (1976) 5; G. Szénászky (1977a) 4; G. Szénászky (1978a) 5; G. Szénászky (1979) 4–5; G. Szénászky (1980) 4; G. Szénászky (1982) 4.

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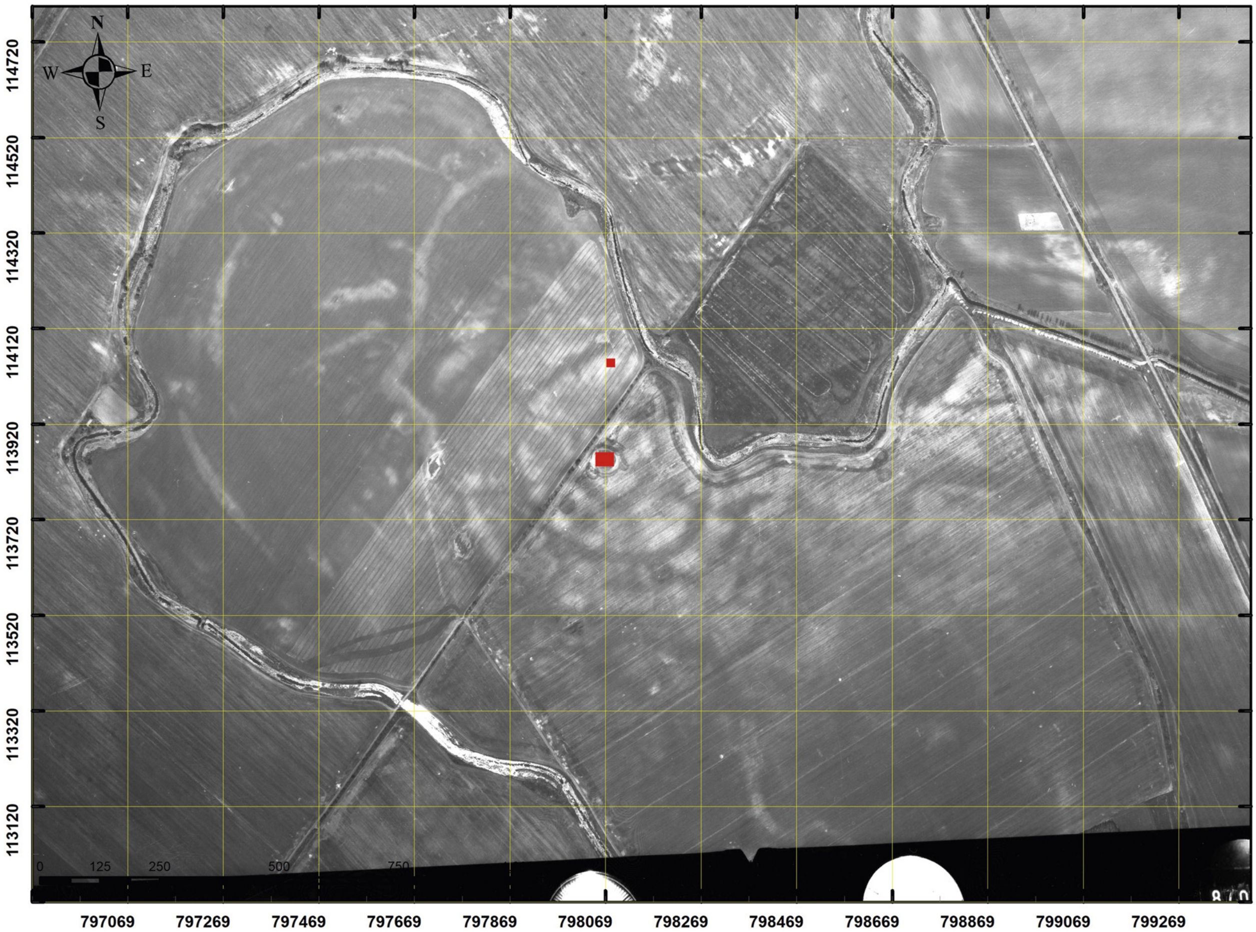

Fig. 2. The reconstructed locations of the two main excavation blocks (Blocks I–VI and VII) in the aerial photograph taken in 1987
2. kép. Az 1987. évi légifelvétel a két ásatási terület (I–VI. és VII. szelvények) megjelölésével

in the archival of the Hungarian National Museum,[10] the first archaeological operations were prompted by land improvement works, as a branch of the local canal system was planned to pass through the site. During initial excavations, thick layers and several house structures dating to the Szakálhát culture were uncovered beneath Medieval Age buildings. To explore the Middle Neolithic layers, which prompted attention as they yielded a remarkably large number of Vinča ceramics, archaeological research continued at Battonya-Parázs-tanya. From 1975 to 1981, a total of seven blocks were exposed. However, the excavation reports and summaries do not provide information about the exact locations of these blocks.

Two 6 × 6-m blocks (Blocks I and II) opened in 1975 and were connected in the following year (Block III), creating a single block of 20 m in length. In this trench, artifacts from the early and late phases of the Szakálhát culture were recovered, and finds representing the Late Neolithic Tisza culture were also unearthed.

Excavations continued in Blocks II and III in 1977. In 1978, with the opening of the 9.6 × 5-m Block IV, the excavated area reached 200 square meters. In 1979, Block V, measuring 6 × 18 m, was exposed immediately north of Blocks I–III. In the final excavation year of 1981, Block VI was opened, transforming the excavated area into a regular rectangle and increasing it to 450 square meters. Additionally, Block VII, a 4 × 4-m trench, was exposed on a more elevated area closer to the Királyhegyesi-Száraz ér. In this block, early Szakálhát artifacts were not found, and superimposing the late Szakálhát layers, a thick stratigraphy belonging to the Tisza culture was documented.

Concerning publications, two brief reports on a ceramic figurine, which became a trademark of the site, were published, as well as a study on ^{14}C results.[11] A more extensive study, that is, a published version of Júlia G. Szénászky's doctoral dissertation, includes the descriptions and detailed evaluations of two structures (Houses 5 and 9) and two pits (Pits 13 and 26), all dating to the Szakálhát period.[12]

[10]Hungarian National Museum Archaeological Archive: V. 40/1976, VI. 70/1977, VIII. 82/1978, XX. 241/1979, IX. 6123/81, IV. 50/1982.

[11]G. Szénászky (1977b); G. Szénászky (1978b); G. Szénászky (1983).

[12]G. Szénászky (1981); G. Szénászky (1988).

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Additionally, the scientific evaluation of the site's "mineral and rock artifact collection" was published, however, the contexts of these findings remain unclear.[13]

LOCALIZING THE EXCAVATION BLOCKS

As noted above, prior to this research, no information was available regarding the locations of the blocks excavated between 1975 and 1981. To identify them, we scrutinized non-digitized archival aerial photographs of the Battonya-Parázs-tanya area stored at the Lechner Knowledge Center's Remote Sensing and Surveying Institute (formerly, Földmérési és Távérzékelési Intézet, or FÖMI). The main excavation area—measuring 26.5 × 17 m in total—is clearly identifiable in aerial photographs taken in 1981 and 1987 (*Fig. 2*).[14] However, we could not locate the 4 × 4 m block opened in 1981 in any of the images. According to the excavation journal, this block was situated "in the elevated, tell-like area closest to the Száraz ér". Based on the available aerial photographs and the LiDAR survey detailed below, the possible location of Block VII north of Blocks I–VI was marked in *Fig. 2*.

INVESTIGATING THE EXTENT AND LAYOUT OF THE NEOLITHIC VILLAGE AT BATTONYA-PARÁZS TANYA

Surface surveys

To delineate the extent of the Neolithic settlement at Battonya-Parázs-tanya and identify contemporaneous structures based on the spatial distribution of surface finds, we conducted a non-systematic pedestrian survey. A treeline divides the site into two sections, both of which are cultivated fields (Areas A and B, *Fig. 3*). In April 2022, the surface survey was limited to the east of the treeline (Area A) and the field to the west (Area B) was not surveyed due to vegetation coverage at that time. In August 2022, following the crop harvest, we were able to extend the survey to include Area B.

Over the course of our surface surveys, we identified the tell area and an extensive, contemporaneous external settlement. The spatial distribution of datable ceramics indicates that the Neolithic village at Battonya-Parázs-tanya may have covered as much as 110 ha. Across Area A, we recorded 40 Neolithic buildings, indicated by spatially well-distinguished clusters of burned daub and other finds, particularly ceramics (see below, *Fig. 7. Element 2)*. Plowing at the time of the survey primarily exposed traces of buildings on the tell and in the northern and southern parts of the external settlement. The diagnostic artifacts collected date to the end of the Szakálhát and the Tisza period. As a result of the surveys, fragments of three anthropomorphic figurines were also uncovered. The details of these findings will be presented in a separate paper.

Historic maps

To gather potential additional information about the internal structure and broader environment of the Battonya-Parázs-tanya site, we consulted historical maps. The cadastral maps of Battonya, Mezőkovácsháza, and Mezőhegyes did not provide any insights that would enhance our understanding of these matters.[15] The site is depicted only on a map sheet from the *Second Austrian–Hungarian Military Survey*, compiled between 1806 and 1869, where it is referred to as Csigan-halom *(Fig. 3)*.[16] This map shows the highest area of the site, along with a deep, ring-like ditch to its southeast.

Satellite and aerial imagery

Satellite and aerial imagery were utilized to collect information about the settlement layout prior to employing ground-based remote sensing techniques. These resources were particularly effective in identifying major man-made features. An aerial image from September 21, 1961, available on fentrol.hu,[17] along with a 1960 photograph taken by the CORONA satellite (*Fig. 4*),[18] both captured before excavations took place, revealed a double-ditch system encircling the tell at Battonya-Parázs-tanya. Furthermore, a Google Earth™ image from September 2018 *(Fig. 5)* provides insights into the current state of this enclosure system.

GEOMAGNETIC PROSPECTION

Data from the surface surveys, as well as the satellite and aerial images, were instrumental in identifying the principal target area for geophysical prospection at Battonya-Parázs-tanya. In April 2022, we conducted a magnetometry survey over an area of 24.5 ha in Area A using a quad-driven, 15-channel Sensys device. Given the estimated size of the site based on the surface collections, the geophysical survey covered about one-fourth of the site, with the remaining areas occupied by grain crops at the time of the prospection *(Fig. 6)*.

In the northwestern part of the surveyed area, the geomagnetic map reveals an area of approximately 140 × 115 m that is densely packed with house anomalies and surrounded

[13]Baranyi (2003).

[14]IDs: 1981–02187816049, 1987–00597231050.

[15]https://maps.arcanum.com/hu/map/cadastral/?layers=3%2C4&bbox=1805863.1921667943%2C6135470.091152103%2C1834890.15365809%2C6145540.669628675 (accessed on July 18, 2024).

[16]https://maps.arcanum.com/hu/map/secondsurvey-hungary/?layers=5&bbox=2326665.982135731%2C5835169.17713013%2C2341341.8915664842%2C5840204.466368415 (accessed on July 18, 2024).

[17]https://www.fentrol.hu/hu: 1961-0869-5957 (accessed on July 18, 2024).

[18]https://maps.arcanum.com/hu/map/corona-hungary/?bbox=2331457.2975404714%2C5835873.320157597%2C2338714.037913295%2C5838515.174947703&map-list=1&layers=173 (accessed on July 18, 2024).

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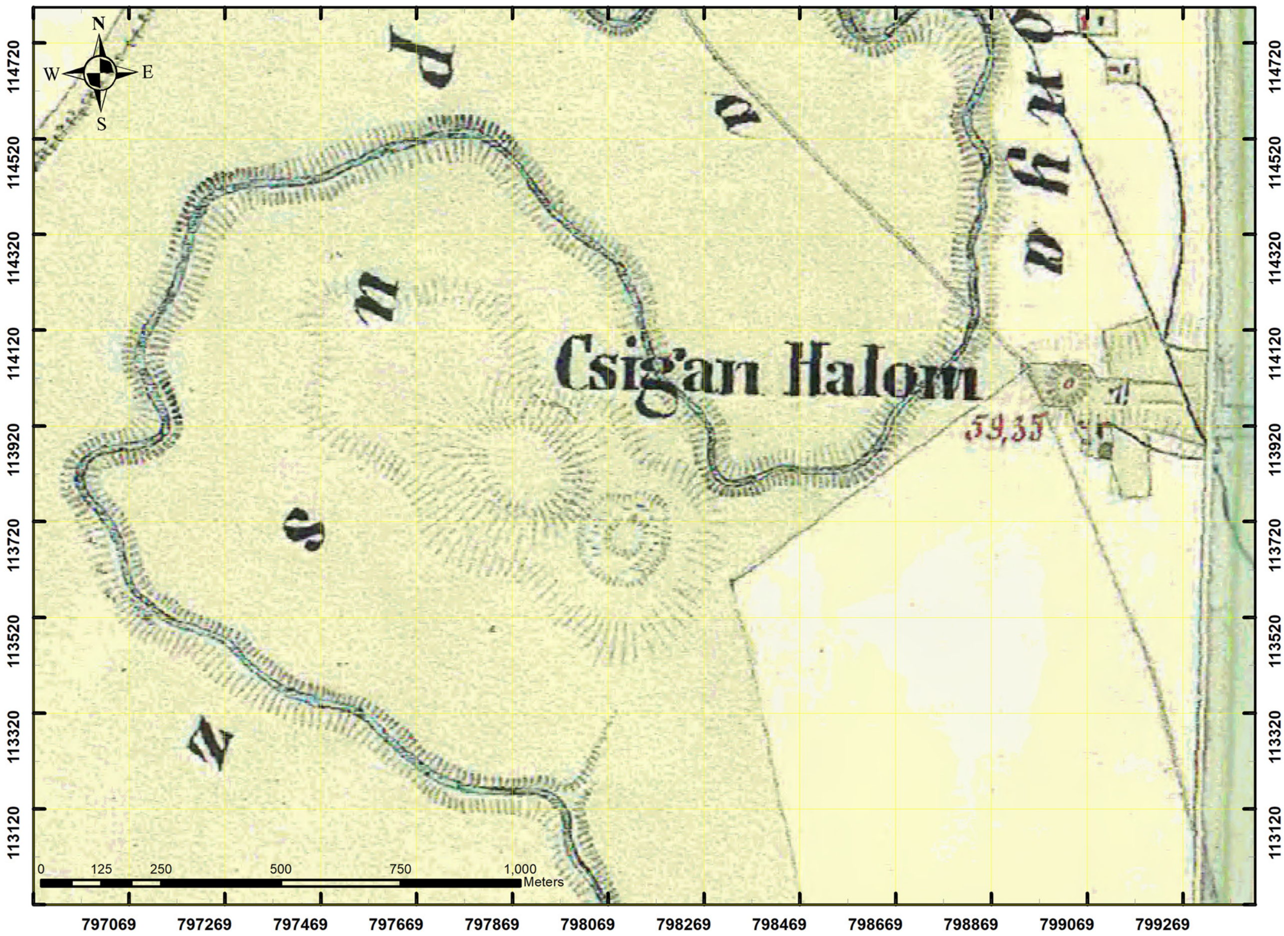

Fig. 3. The vicinity of the site on the *Second Austrian–Hungarian Military Survey* map
3. kép. A *II. katonai felmérés* kivágata a lelőhely környezetével

by a kidney-shaped ditch; this ditch is also visible on the satellite and aerial images noted above. This area represents the tell at Battonya-Parázs tanya, where the excavations between 1975 and 1981 were carried out. The structure anomalies on the tell are oriented toward two or three empty spaces, with a noticeable gap in the row of houses in the southeastern quarter *(Fig. 7. Element 1)*. The kidney-shaped ditch measures about 170 m in diameter in a NE–SW direction and is approximately 10 m wide *(Fig. 7. Element 2)*.

A second, circular ditch, which is also visible on the aforementioned satellite and aerial images, was identified during the magnetometric survey *(Fig. 7. Element 5)*. This enclosure is situated approximately 125–130 m away from the inner ditch. The anomaly of this outer ditch is weaker than that of the inner ditch. The ring-like ditch identifiable on the *Second Austrian–Hungarian Military Survey* map (see above, *Fig. 3*) corresponds to this outer enclosure.

The area between the inner and outer ditches is characterized by relatively few and generally weaker magnetic anomalies. However, there are instances of stronger anomalies, such as those associated with two houses *(Fig. 7. Element 3)*.

Additionally, the magnetic map prominently displays structures and other archaeological features in the southeastern section of the external settlement. The buildings are arranged in radial rows along their longitudinal axis, with the houses' shorter sides aligned along arc lines *(Fig. 7. Element 7)*. The innermost structures, located closest to the tell, are spatially aligned with the outer ditch. The magnetic map shows an abrupt cessation of buildings approximately 430 m southeast of the tell's central point. To the southwest, structures appear to largely terminate at the northern bank of a canal-like feature *(Fig. 7. Element 6)*.

The magnetic anomalies representing structures can be classified into two main groups based on their nanotesla values (scale: -3 nT/m - 3 nT/m) *(Fig. 8)*. Burned buildings exhibit stronger magnetic anomalies of about 2.5-3 nT/m, while non-burned structures, as well as possibly older ones situated deeper in the stratigraphy, show lower values of about 0.5 nT/m. The magnetic map reveals superpositions among several buildings, indicating that not all houses identified during the geomagnetic survey represent the same time horizon. In some areas, structures with lower and higher nanotesla values are alternately located. In these cases, the later, higher-lying house remains might have emitted stronger magnetic signals.

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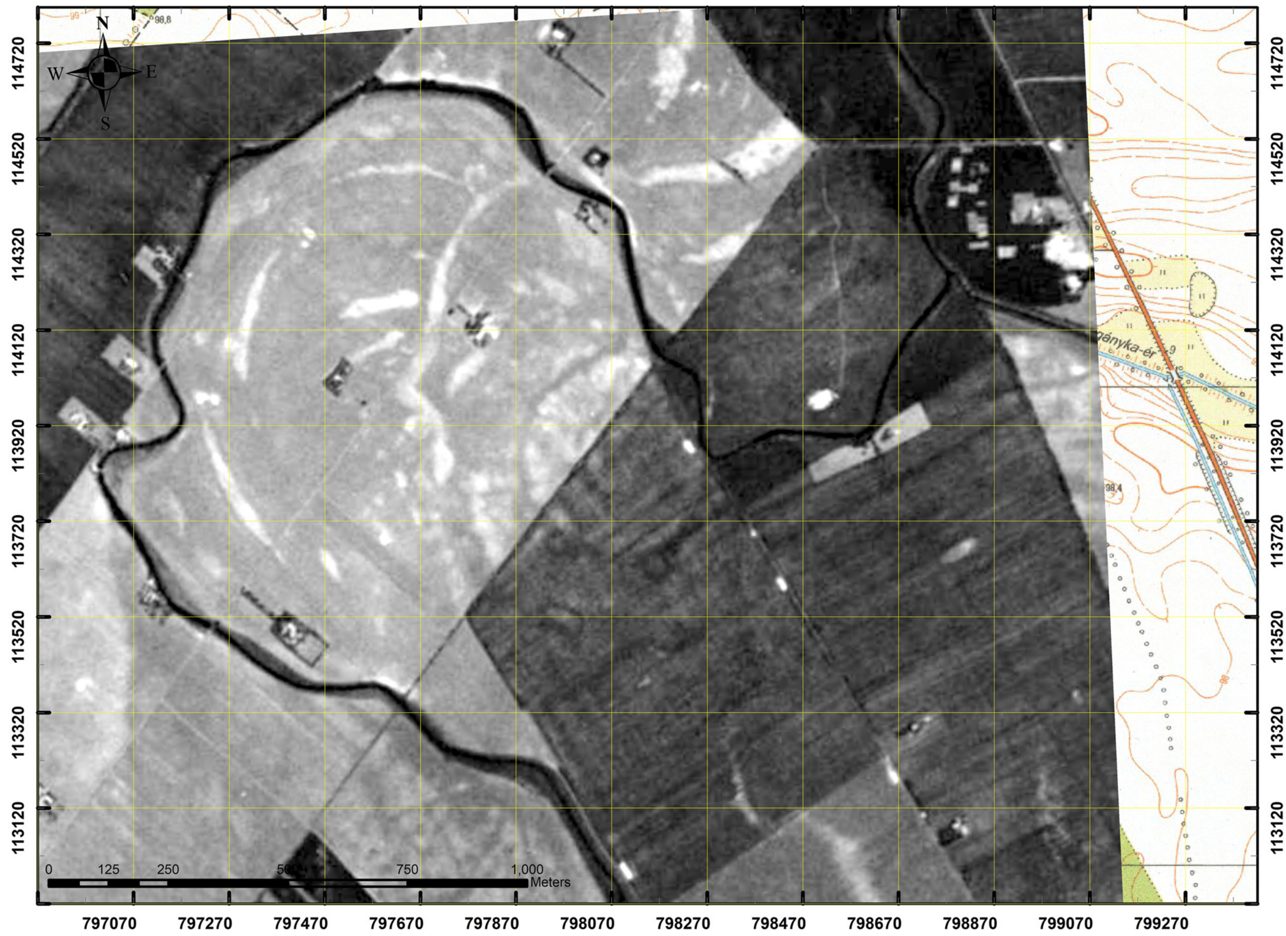

Fig. 4. CORONA satellite image taken in 1960 with the site
4. kép. 1960. évi CORONA műholdfelvétel a lelőhelyről

Finally, it is notable that the magnetic survey also revealed anomalies indicating burials encircled by ditches dating to the Sarmatian period (second to fifth centuries AD) in the eastern strip of the surveyed area *(Fig. 7. Element 8)*.

AIRBORNE PROSPECTION

We performed a LiDAR survey and captured multispectral and thermal infrared images. By incorporating these new layers of information into our analysis and comparing the results with the outcomes of the geophysical prospection, we sought to gain deeper insights into settlement organization and its relationship with the local topography.

LiDAR

The drone-mounted LiDAR survey was carried out with a DJI Zenmuse L2 in December 2023, and covered a total of 180 ha (for technical specifics, see *Table 1*). The data was processed using a DJI Terra photogrammetric software, and the analysis was carried out using ArcGIS Desktop software. The terrain model created from the LiDAR data provided the reference within centimeter-level accuracy.

Table 1. Technical specifications used for the research
1. táblázat. A kutatáshoz használt technikai specifikációk

Method	Drone	Sensor
LiDAR	DJI Matrice M350	DJI L2
Multispectral and RGB images	DJI Mavic 3M	DJI built-in multispectral camera 4 × 5Mp RGB 20Mp resolution
Thermal Infrared	DJI Matrice M30T	DJI built-in camera 1,280 × 1,024 thermal resolution

The Digital Elevation Model (DEM) created using LiDAR, along with the elevation contour map and the slope gradient layer, enhances our understanding of the settlement structure and its relationship to local landscape, in particular the oxbows of the Királyhegyesi-Száraz ér *(Figs 9 and 10)*. In the DEM, the inner ditch around the tell, well detected in satellite and aerial images and by our magnetometry survey, is less perceptible *(Fig. 9. 1)*. However, a significant contribution of the DEM is that it revealed alternating

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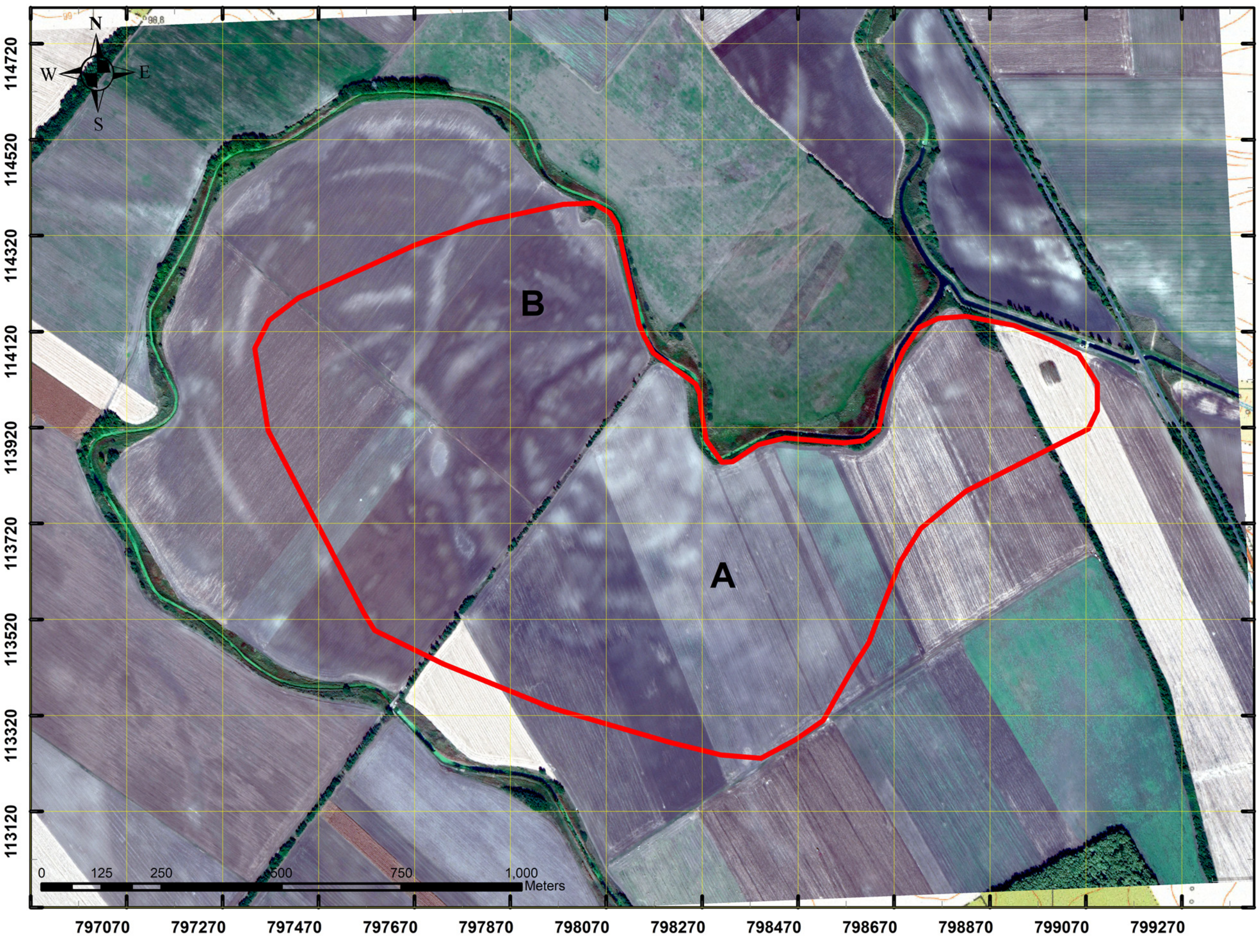

Fig. 5. A 2018 Google Earth™ image showing the site area, research areas A and B, and the extent of the Neolithic settlement
5. kép. A lelőhely területét ábrázoló 2018-as Google Earth™ felvétel az A és B kutatási területek megjelölésével és az újkőkori település kiterjedésével

deeper and shallower sections within the outer ditch, which were undetectable through satellite and aerial images or the magnetic map.

Another important observation drawing on the DEM is that a strong anomaly can be observed at the kidney-shaped indentation of the inner ditch, and by connecting the line of the hiatus observed between the outer houses, a clear depression can be detected in the central zone (*Fig. 9. 1–2*). Initially, we interpreted this line (see above, *Fig. 7. Element 4)* as a road leading to the tell, similar to what was observed at Polgár-Csőszhalom.[19] However, due to the nature of the depression, its function as a road is highly questionable.

Another important result of our LiDAR imagery is the identification of a potential third enclosure at Battonya-Parázs-tanya. The DEM suggests that this enclosure runs concentrically and in an arc south and southwest of the tell, parallel to the lines of the inner and outer ditches, and is composed of deeper and shallower sections similar to the outer ditch. The inverted image from the LiDAR survey (*Fig. 10. 2)* shows that, like the outer ditch, the artificial section of this third ditch displays sections of equal length with identical depth breakpoints.

The LiDAR also provided valuable information about Area B, which has not been subjected to geophysical prospection. Based on the DEM (*Fig. 9. 1–2*), a plateau of similar elevation to the settlement core can be distinguished to the north of the tell, extending in a NE–SW direction (*Fig. 13. 9*). However, this plateau does not align with the enclosure lines. The outer ditch is interrupted within the plateau area (*Fig. 13. Element 9.1)*, while the elevated terrain (*Fig. 13. Element 9.2)* continues southwest beyond the third, potential enclosure.

Multispectral imaging

Multispectral images can detect the remains of buried structures based on surface vegetation index values.[20] Data collection at Battonya-Parázs-tanya with a DJI built-in multispectral camera was conducted in June 2024 over the same area as the LiDAR survey.

The vegetation index revealed some multispectral anomalies on the highest elevation area to the west of the tell

[19] Mesterházy et al. (2019).

[20] Moriarty et al. (2018).

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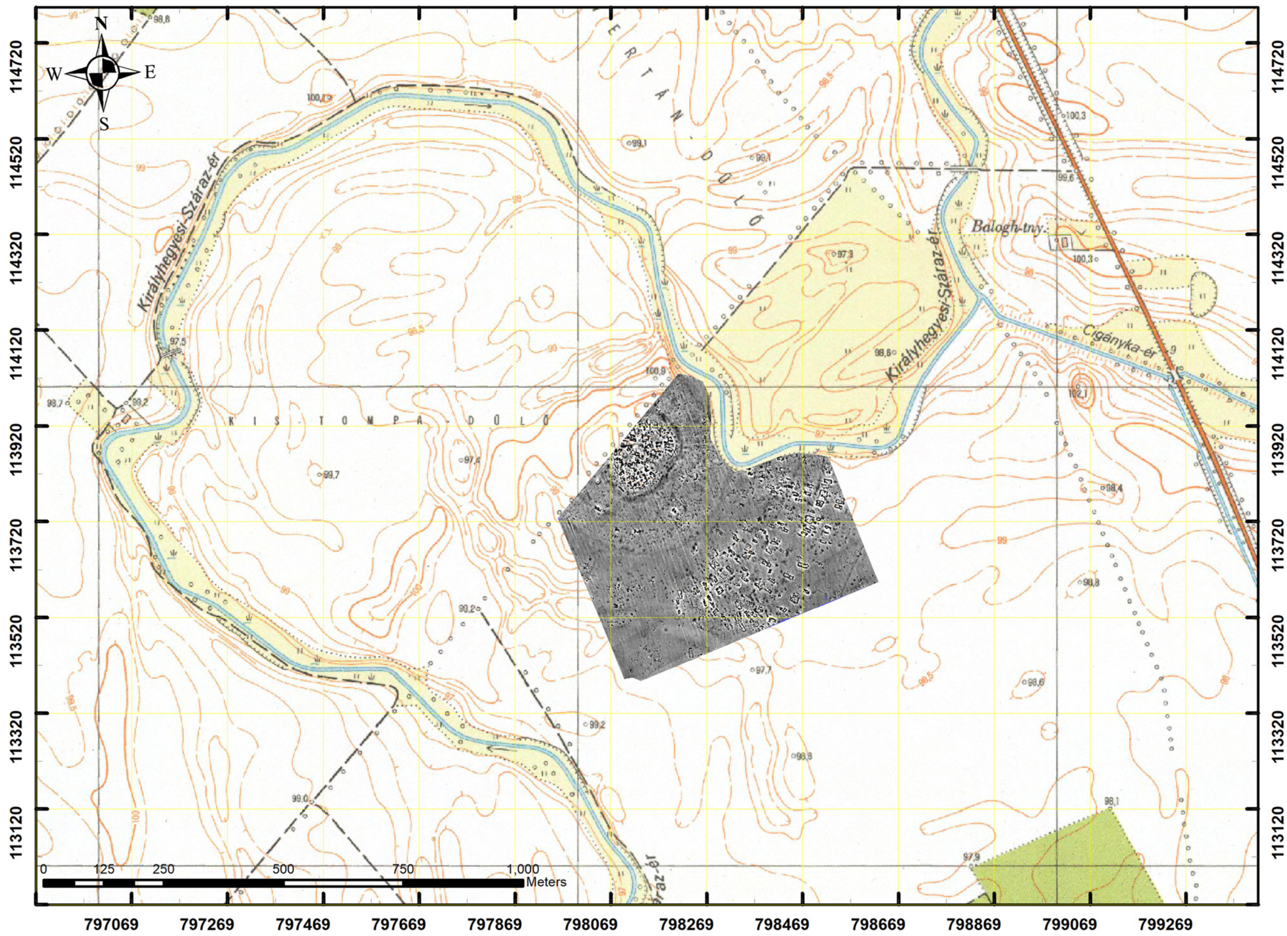

Fig. 6. The broader area of the site on the 1:10,000 topographic map and the extent and results of the geophysical survey
6. kép. A lelőhely tágabb környezete az 1:10 000-es topográfiai térképen és a geofizikai felmérés területe és eredménye

(*Fig. 11*). However, since these multispectral anomalies are linked to variations in soil composition that influence vegetation, and because recent agricultural practices can also alter soil composition, interpreting the current results is challenging. Our surface surveys confirmed the presence of Neolithic features in this area, but further research is necessary to confidently connect the multispectral anomalies with archaeological features.

Thermal imaging

Thermal infrared images can reveal buried structures and other man-made elements in the landscape.[21] The thermal infrared radiation of archaeological features is impacted by various factors, including the composition of the soil, its moisture levels, and the vegetation cover. Similar to multispectral imaging, we conducted the survey in June 2024, utilizing a DJI built-in camera and covering an area of 180 ha at Battonya-Parázs-tanya. Our investigations align with earlier findings by Casana et al. (2017), demonstrating that thermal infrared imaging performed at the right time can reveal artificial soil disturbances, enabling us to differentiate between man-made and naturally formed topographical features.

In the thermal infrared image *(Fig. 12)*, the debris cones next to the northern section of the third enclosure are well distinguishable. This section of the enclosure is thus likely the result of natural processes. However, in its middle section, no radiation or reflection characteristic of natural formations was detected in the thermal infrared image. Therefore, we concluded that this section, which displays a segmented structure similar to the outer ditch based on the DEM, might be a man-made feature. This is further supported by the fact that this enclosure cuts through the abovementioned, NE–SW oriented plateau located northwest of the tell. The enclosure continues southward in a curve, but its exact path cannot be reconstructed based on our investigations. However, the magnetic map clearly shows a break, perhaps an entrance or gate, in it (see above, *Fig. 7. Element 6*). The exact time of the enclosure's construction is unknown to date, however, due to its alignment with the other two ditches, it is likely associated with the Neolithic settlement at Battonya-Parázs-tanya.

[21] Casana et al. (2017).

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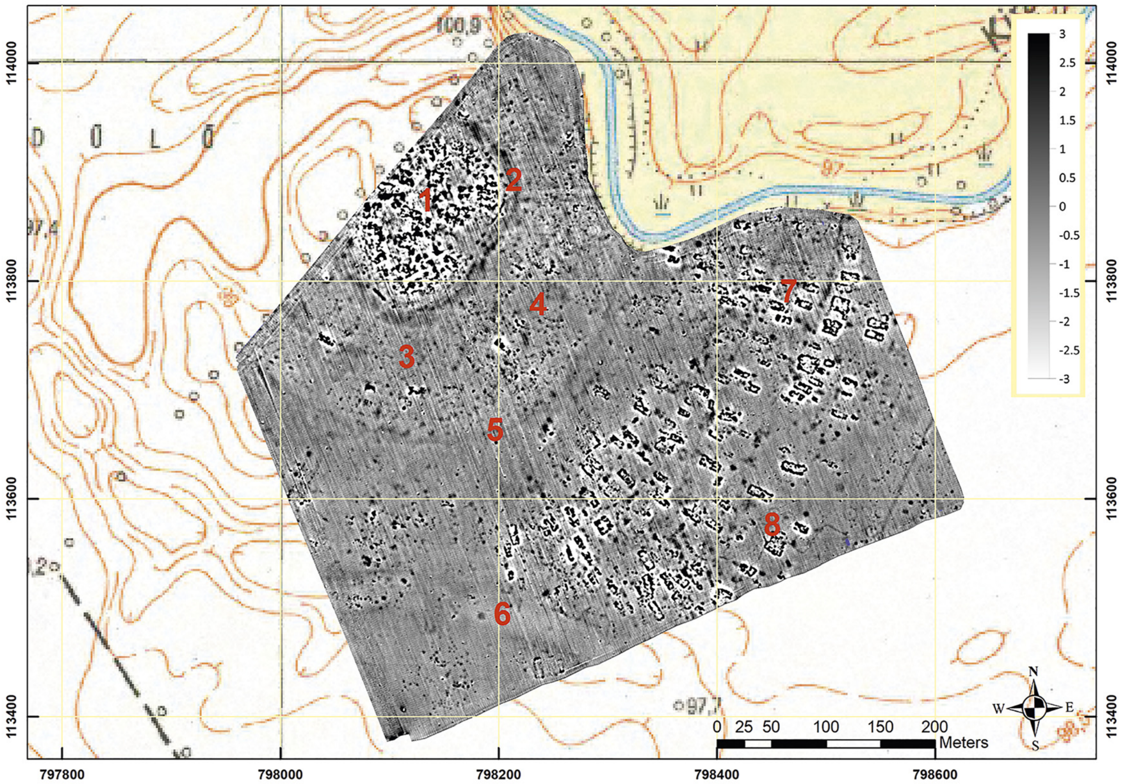

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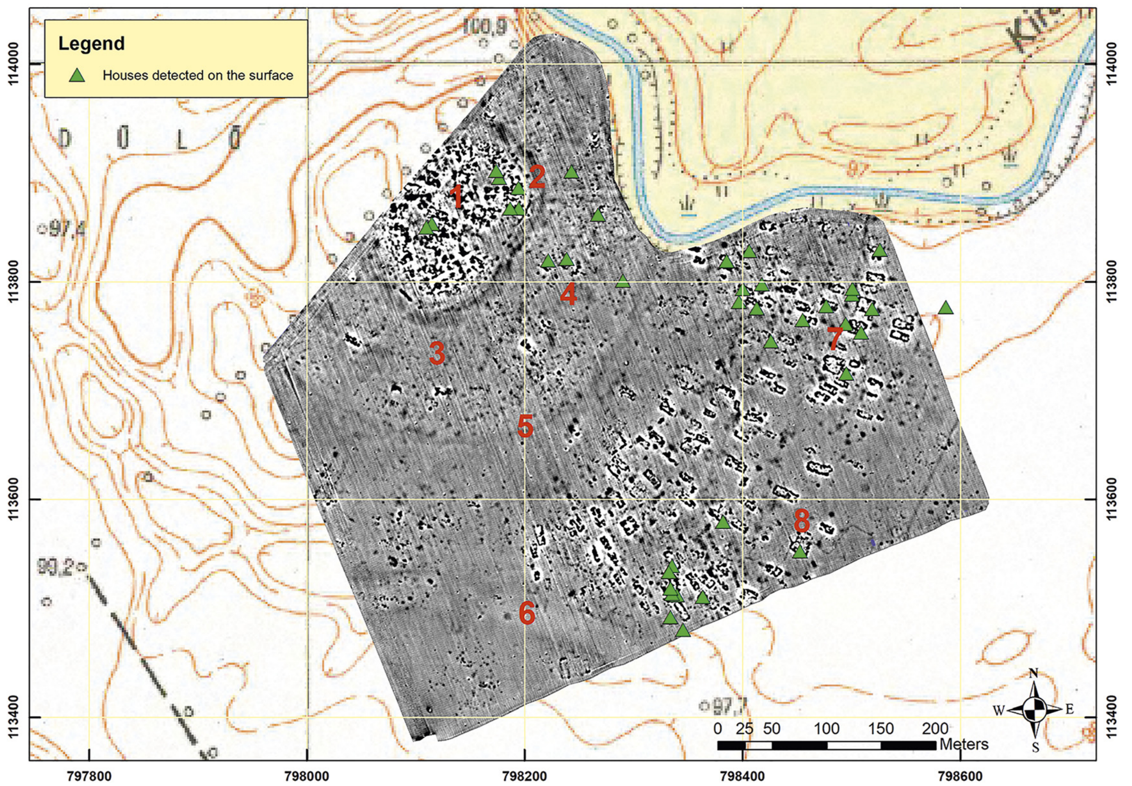

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Fig. 7. 1: The results of the geophysical survey and identifiable settlement and landscape elements (1: tell; 2: inner ditch; 3: area between the outer and inner ditches; 4: low-lying area; 5: third enclosure; 6: natural watercourse; 7: external settlement zone; 8: area of Sarmatian graves with encircling ditches); 2: The results of the geophysical survey with the Neolithic buildings identified during surface surveys

7. kép. 1: A geofizikai felmérés eredménye és az azonosítható településrészek és tájelemek (1: belső tell-mag; 2: belső árok; 3: a külső és a belső árok közötti alacsony intenzitású zóna; 4: mélyen fekvő terület, 5: külső árok vonala; 6: vízfolyás vonala; 7: külső települési zóna; 8: szarmata körárkos sírok területe); 2: A geofizikai felmérés eredménye és a terepbejárással azonosított újkőkori épületek

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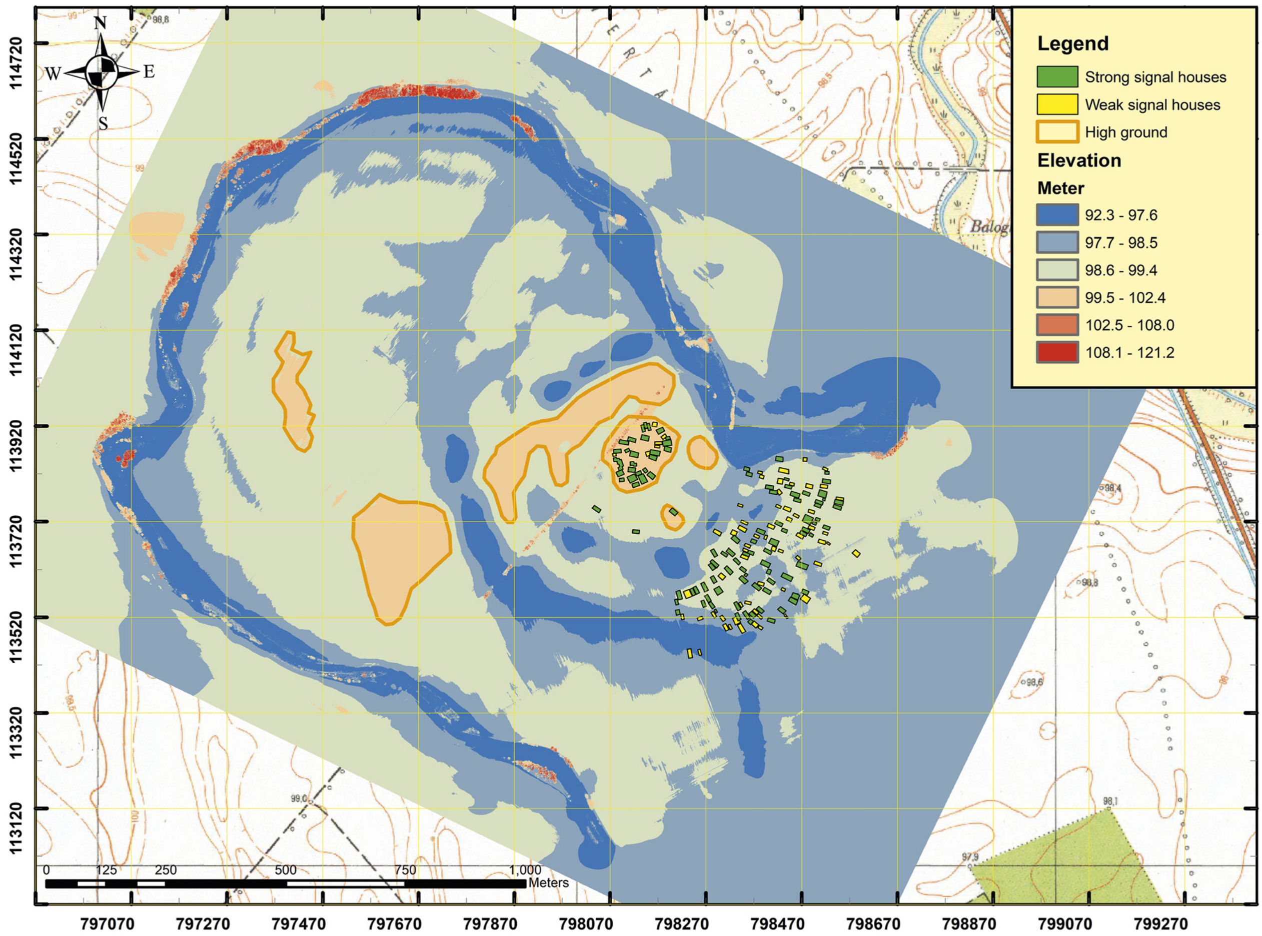

Fig. 8. House anomalies with lower (yellow) and higher (green) nanotesla values on the digital elevation model of the study area
8. kép. Az alacsonyabb (sárga) és a magasabb (zöld) nanotesla értékű házanomáliák a vizsgált terület digitális domborzatmodelljén

DISCUSSION

The research of Late Neolithic sites on the Great Hungarian Plain is currently in its third major phase. The early excavations (for instance, by János Banner, Ferenc Tompa, Lajos Zoltai, János Sőregi, József Korek, Gyula Gazdapusztai, and Nándor Kalicz) was followed by systematic research in the 1970s and 1980s.[22] Both of these phases focused on tells and played pivotal roles in establishing regional typologies and relative chronologies.[23] The past decade has seen the expansion of non-destructive investigations encompassing the immediate vicinities of tell sites. Analyses of aerial and satellite images, the introduction and rapid development of geophysical techniques, soil corings, and surface surveys now allow for collecting substantial amounts of information regarding the extent and internal structure of settlement sites, all without excavation.

As with other Neolithic tell-centered settlement complexes studied using similar methods, the series of non-destructive investigations conducted at Battonya-Parázs-tanya does not offer chronological depth. The results should rather be viewed as a palimpsest, reflecting processes and resultant features that developed at the site over centuries of habitation from the early Szakálhát to the Tisza periods. The separation of the Middle and Late Neolithic components of the site, as well as the comparison with other settlement complexes dating to the Late Neolithic, is rather difficult because different areas might have experienced different developments over time. The excavation results on the tell reflect this complexity: a single, relatively thin Late Neolithic layer was found above the early and late Szakálhát layers in Blocks I–VI, whereas in Block VII, the early Szakálhát layers were absent and the Tisza sequence was much thicker.

On the Great Hungarian Plain, multi-layered sites occupied for a longer period of time than typical settlements developed already in the Szakálhát period; however, residential activities in this phase largely concentrated on small areas. Apart from Battonya-Parázs-tanya, there is currently one other known site where a tell sequence

[22]Kalicz and Raczky (1987).

[23]For a summary, see Raczky et al. (2022).

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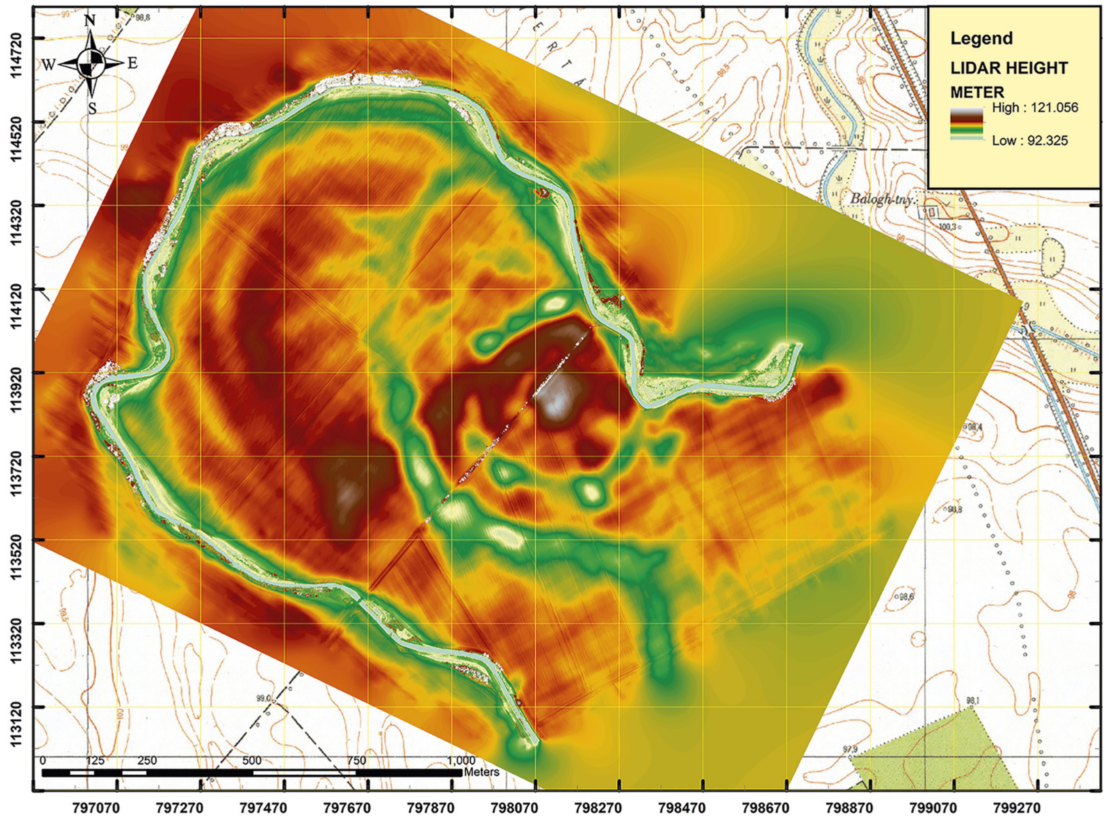

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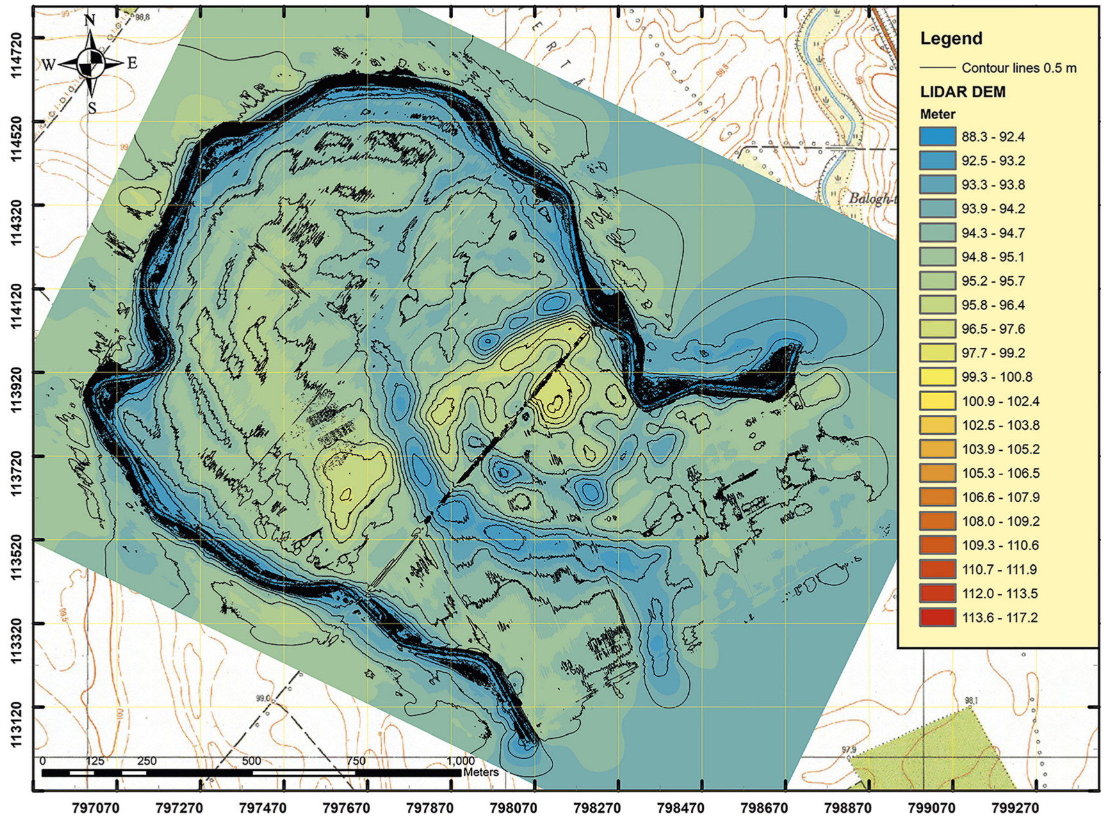

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Fig. 9. 1: the digital elevation model of the study area; 2: the resulting contour map
9. kép. 1: a vizsgált terület digitális domborzatmodellje; 2: a digitális domborzatmodellből generált szintvonalas felmérés

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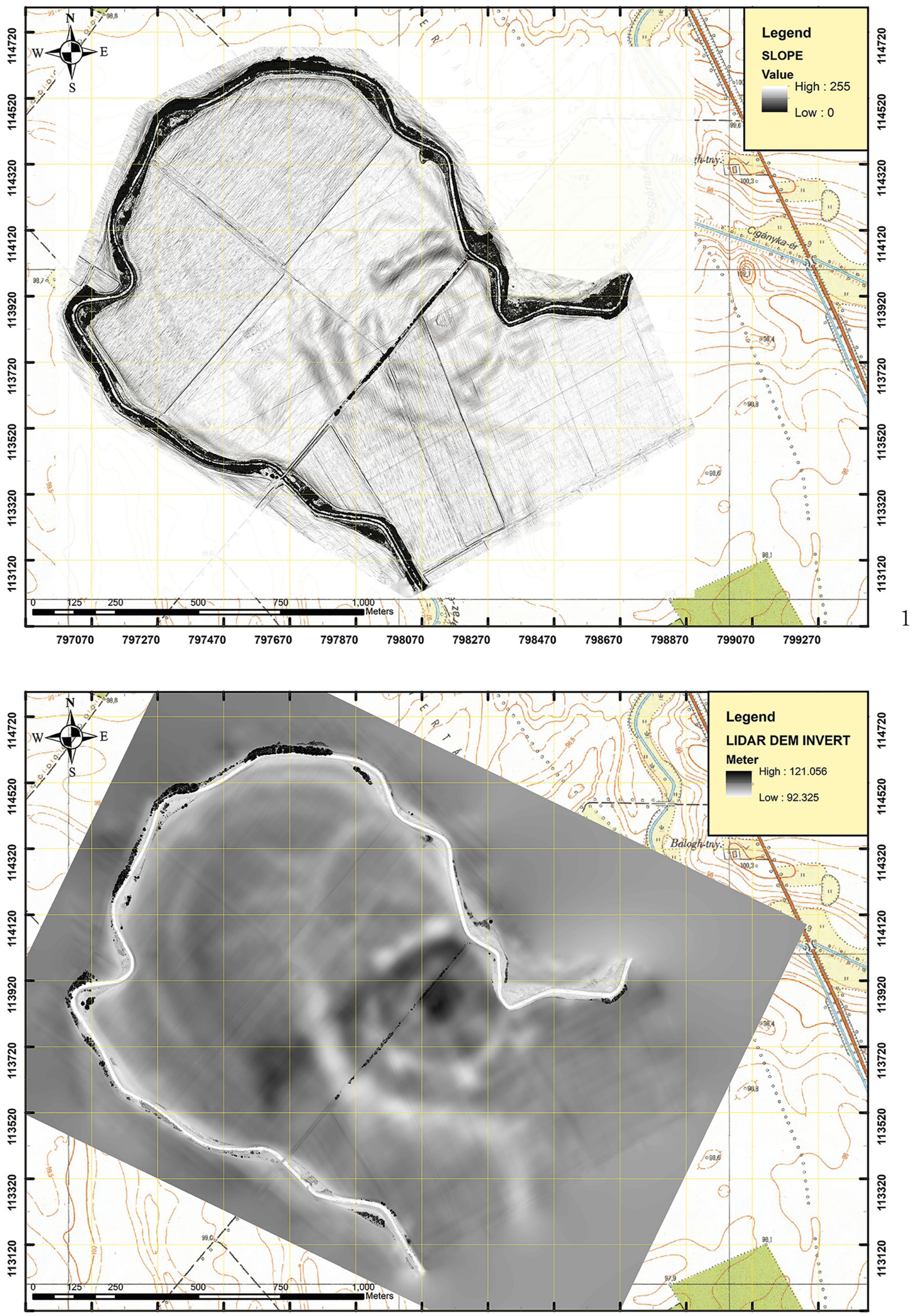

Fig. 10. 1: slope model of the study area; 2: inverse image of the digital elevation model
10. kép. 1: a vizsgált terület lejtőmeredekség modellje; 2: a digitális domborzatmodell invert képe

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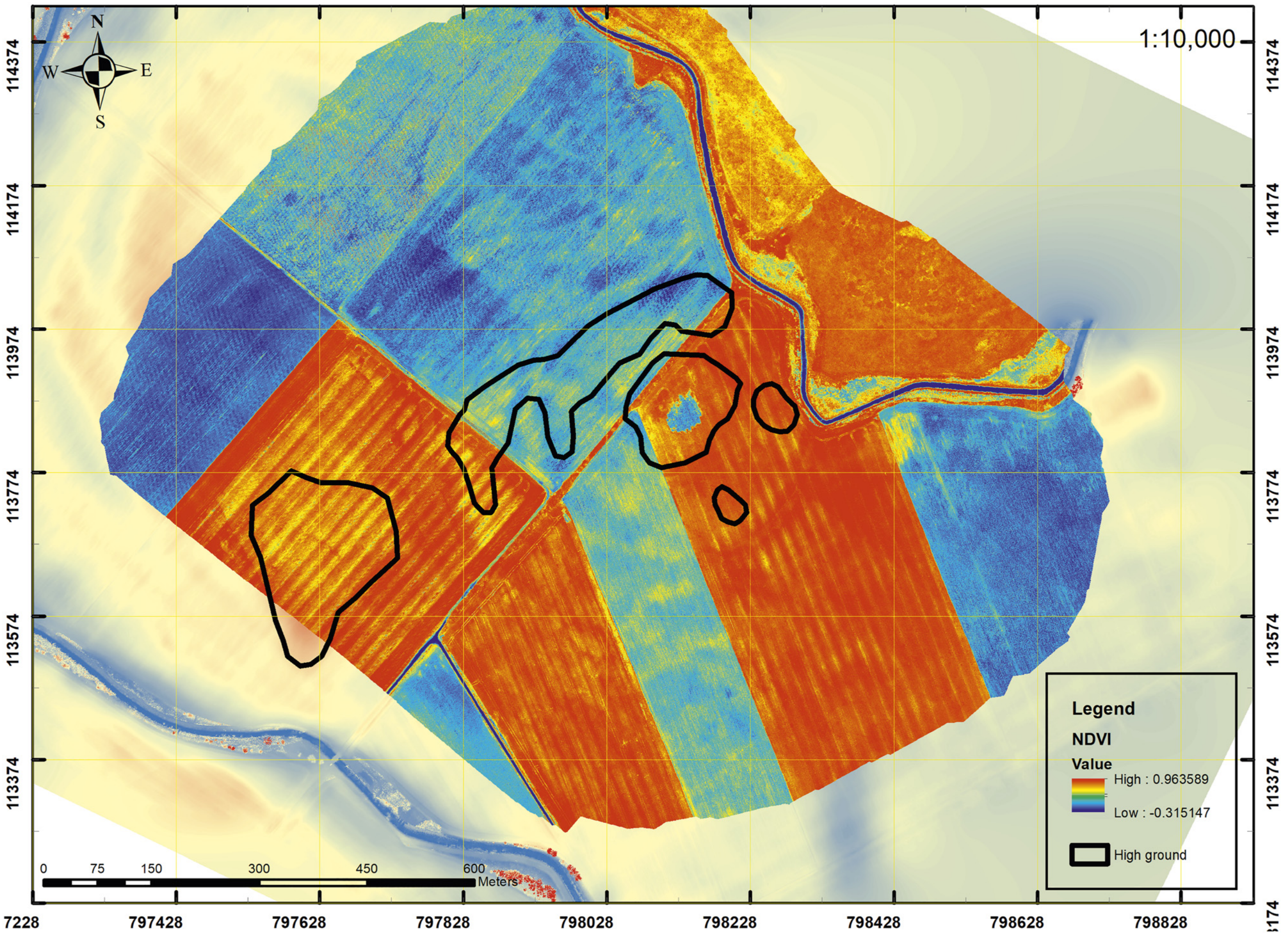

Fig. 11. The multispectral image of the study area, highlighting areas of higher elevations (≥99.5 m asl)
11. kép. A vizsgált terület multispektrális felvétele a magasan fekvő (≥99.5 m tfm) térszínek kiemelésével

accumulated already during the Middle Neolithic. At Mezőkeresztes-Lapos halom, located on the northern periphery of the Szakálhát culture, a geophysical survey revealed a ditch-palisade system surrounding an area of 0.97 ha, within which the stratigraphic sequence measures 1.7 m in thickness.[24] Sites with late Szakálhát occupational layers of varying depth, which developed continuously into tells during the Late Neolithic, have been documented in the nearby Körös region, including Szeghalom-Kovácshalom and Vésztő-Mágor.[25] Like at Mezőkeresztes-Lapos halom, data from Szeghalom-Kovácshalom indicates that domestic activities were confined to an area of less than one ha.

Recent studies, with the intensification of research focusing on areas beyond the confines of tells, have pointed out that the tells many times are not standalone features but parts of extensive settlement complexes. These settlement complexes developed as a result of aggregation processes that peaked during the Late Neolithic across the Great Hungarian Plain.[26] The coming together of smaller village communities around specific sites in the landscape from ca. 5000 BC resulted in some of the largest settlements in Neolithic Europe, such as Szeghalom-Kovácshalom, Polgár-Csőszhalom, and Csökmő-Káposztás domb.[27] The currently available data from our surface surveys indicates that Battonya-Parázs-tanya belongs to the size category of these extensive Late Neolithic sites.

This is of significance from the point of view of the interpretation concerning the temporal development of the external settlement at Battonya-Parázs-tanya. Although radiocarbon dates are not yet available for the outer village in this stage of research, the reconstructed chronological developments at the well-studied sites mentioned above suggest a similar trend toward aggregation at the beginning of the Late Neolithic at Battonya-Parázs-tanya as well. Based on this argument, the results of the non-destructive investigations may represent a much shorter period of Neolithic habitation—perhaps just a few generations—in the external settlement, whereas tell occupation spanned several hundred years.

[24]Csengeri et al. (2021).

[25]Gyucha et al. (2019); Parkinson et al. (2018).

[26]Gyucha (2022).

[27]Gyucha et al. (2019); Mesterházy et al. (2019); Riebe et al. (2023).

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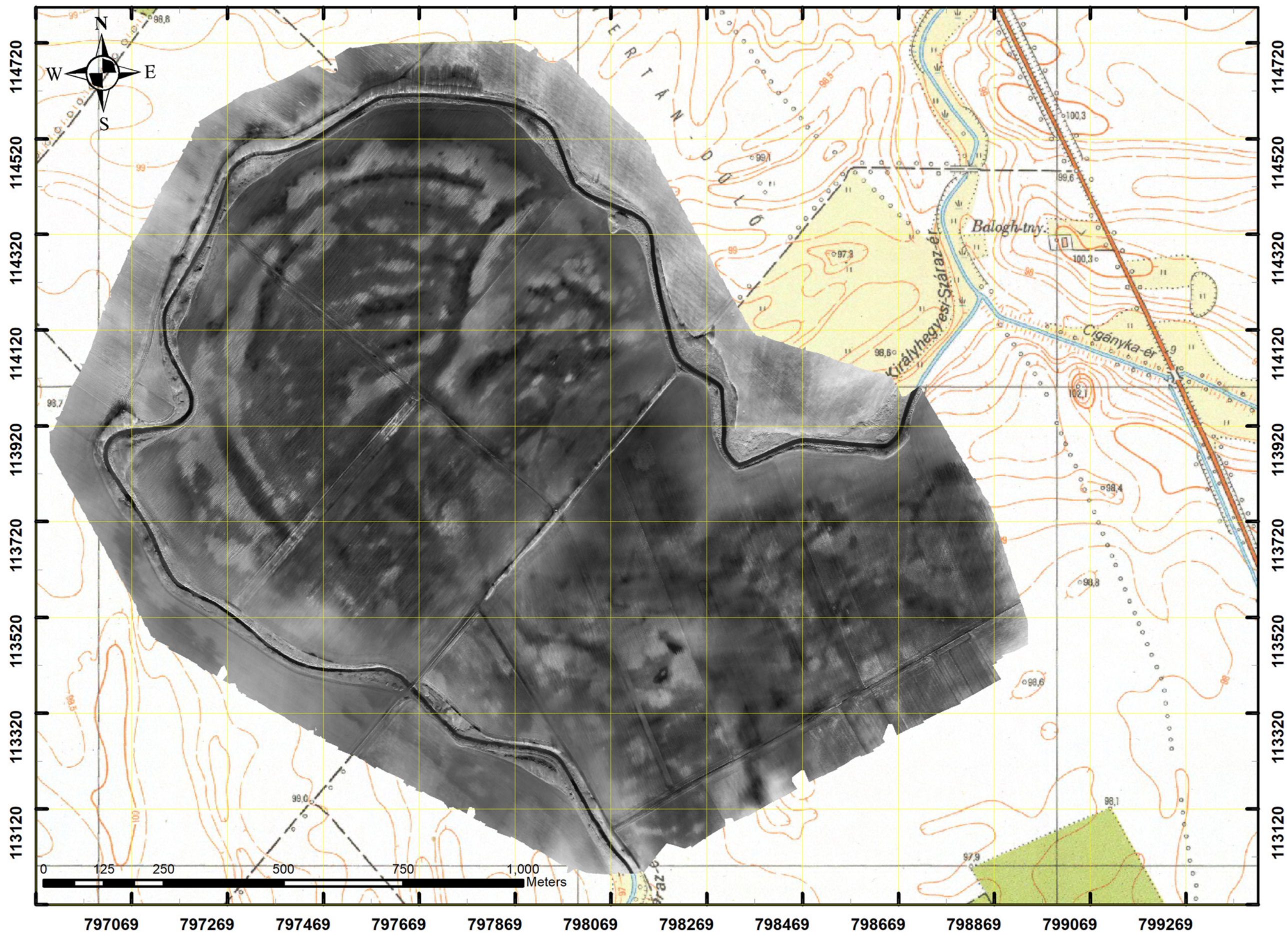

Fig. 12. The infrared image of the study area
12. kép. A vizsgált terület infravörös felvétele

Battonya-Parázs-tanya fits into the general structural pattern of Late Neolithic tell-centered settlement complexes on the Great Hungarian Plain, encompassing a central tell or tell-like settlement, single or multiple ditches or a ditch-palisade system surrounding this core, and an external settlement. However, the more than 100-m distance between the inner and outer ditches makes Battonya-Parázs-tanya stand out among the enclosed Late Neolithic sites in the region. This gap is especially notable for its near-complete absence of structures, in stark contrast to the densely built-up areas of the tell and external settlement. Only a few magnetic anomalies were detected within this zone, all of which are located on elevated ground identified through the DEM (see above, *Fig. 7. Element 1, Fig. 8*). Since several unburnt buildings appear in the magnetogram, the lack of structural anomalies cannot be attributed to unburnt and undetectable buildings in this area. The reasons for this largely uninhabited zone and the activities that may have taken place here remain subjects for further investigation.

The double internal ditch system at Battonya-Parázs-tanya might have been complemented by a third enclosure. Based on the currently available data, we assume that at first, a channel had been formed as a result of natural processes, followed by a deliberate human intervention to deepen this channel directly south and southwest of the tell, and a gate or bridge was constructed through it. The temporal relationship between the three ditches is currently unknown, however, because they align spatially with one another, they may have been created during the Neolithic. The analysis of the LiDAR data regarding the outer ditch and the third enclosure indicates that they may have composed smaller segments connected by deeper sections, similar to the pseudo-ditch system proposed for Öcsöd-Kováshalom.[28]

Concerning their functions, the ditches at Battonya-Parázs-tanya might not have been primarily defensive. The remarkable distance between the inner and outer ditches, along with the alignment of the third enclosure, argues against a defensive role. Instead, the ditch system at this site can be classified among the enclosure systems that delineated areas of differing use and function, which first appeared in the Carpathian Basin during the Middle Neolithic and continued into the Late Neolithic.[29]

[28]Raczky et al. (2018); Füzesi et al. (2020a); Füzesi et al. (2020b); Füzesi et al. (2023).

[29]Raczky and Anders (2012).

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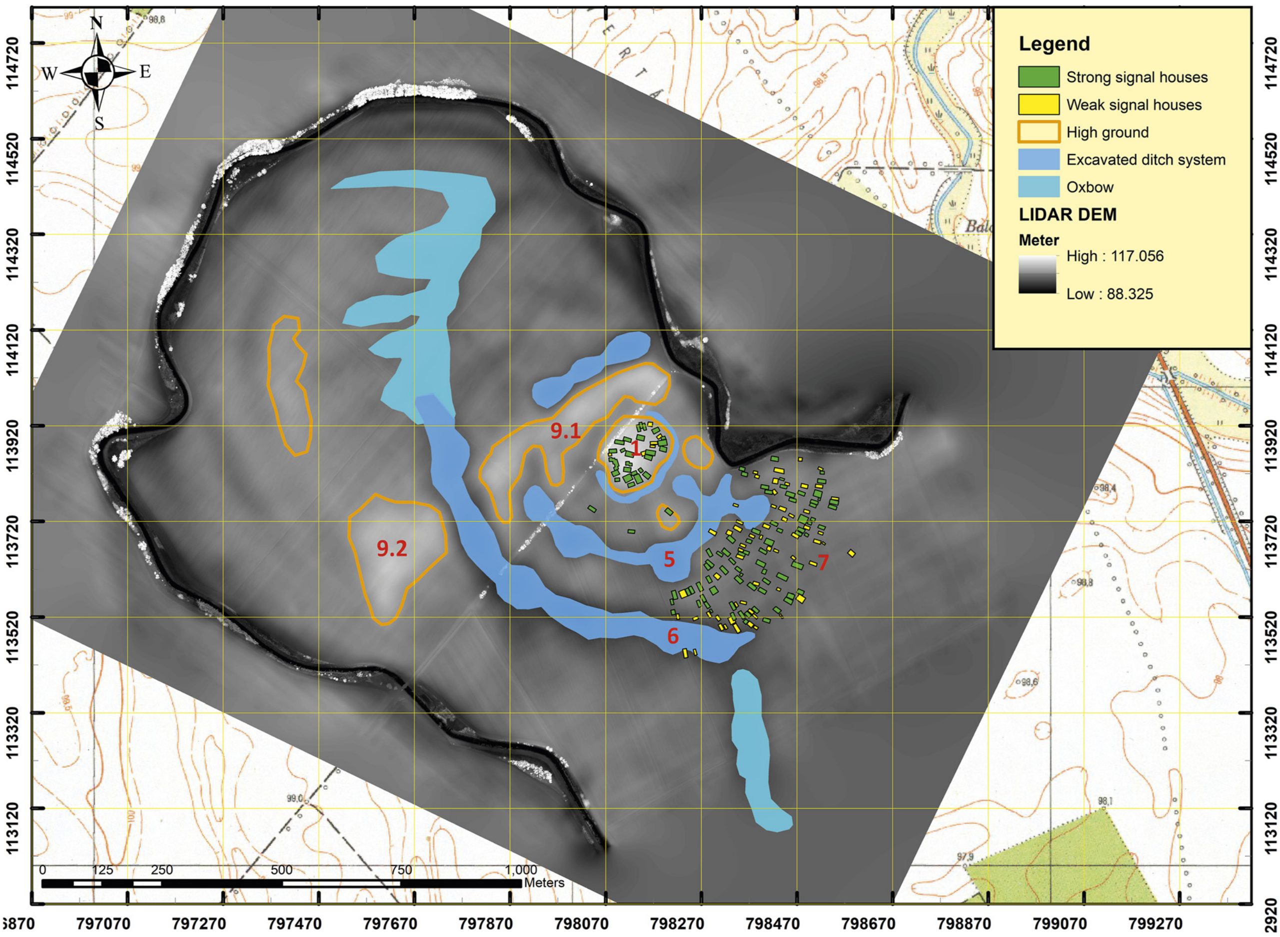

Fig. 13. The internal structure of the Neolithic settlement in relation to the ditches and settlement areas at higher elevations (≥99.5 m asl). 1: tell; 5: third enclosure; 6: natural watercourse; 7: external settlement zone; 9.1: NW elevated plateau; 9.2: SW elevated plateau
13. kép. Az újkőkori település belső struktúrája az árkok és a magasan fekvő területek (≥99.5 m tfm) viszonylatában. 1: belső tell-mag; 5: külső árok vonala; 6: vízfolyás vonala; 7: külső települési zóna; 9.1: ÉNy-i magaslat; 9.2: DNy-i magaslat

The plausibility of interpreting the expanded channel at Battonya-Parázs-tanya as an anthropogenic feature is strengthened by the increasing evidence of significant human efforts to alter watercourses during the Neolithic on the Great Hungarian Plain. Notable examples include the artificial modification of a natural riverbed at the above-mentioned Mezőkeresztes-Lapos halom Szakálhát site,[30] the redirection of the ancient Sebes-Körös river at the Late Neolithic Tisza site of Szeghalom-Kovácshalom to create a moat around the central tell,[31] and the connection of two nearby rivers with ditch sections to form an island at the Late Neolithic Herpály site of Csökmő-Káposztás domb.[32]

Regarding the buildings identified by the magnetometry survey, several of which were verified during our surface surveys, there seems to have been a notable similarity in the orientation of structures between the tell and the external settlement. The magnetic anomalies of burnt houses on the tell, which represent the final Late Neolithic Tisza occupation phase, were arranged in a radial pattern encircling small empty areas. A similar layout was observed on the tell at Polgár-Csőszhalom.[33] The external settlement at Battonya-Parázs-tanya featured houses of varying sizes all oriented toward the tell in a radial pattern. A similar overall spatial organization was documented at the Late Neolithic Hódmezővásárhely-Kökénydomb site.[34]

It is also notable that regarding the locations of structures, the outcomes of the geomagnetic prospection align closely with the spatially distinct clusters of burned daub remains observed during the surface surveys. In each case, the daub debris recorded corresponded to strong structure anomalies. This correlation between surface findings and geophysical data suggests a high level of accuracy in the identification of structures. Additionally, the consistency between these two sets of data enhances our assurance in the overall interpretation of the site's layout and use.

[30] Csengeri et al. (2021).
[31] Gyucha et al. (2019).
[32] Riebe et al. (2023).
[33] Raczky and Anders (2008).
[34] Raczky et al. (2021); Raczky et al. (2022).

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As for Area B research at Battonya-Parázs-tanya, the relationship between the enclosure system and the intensively used parts of the settlement remains unclear due to the limited available data. LiDAR data reveals a high plateau in Area B, comparable in height to the tell, and preliminary surface surveys have identified burned structures there. Drawing on data from other large Late Neolithic sites such as Öcsöd-Kováshalom,[35] Szeghalom-Kovácshalom[36] and possibly Csökmő-Káposztás domb,[37] it is possible that the settlement structure consisted of household clusters arranged with consideration of local geographical features.

CONCLUSION

The integration of multiple remote mapping techniques, as Salisbury noted "the art and science of exploring archaeological sites without digging them",[38] yielded valuable insights into the locations of previously excavated trenches, settlement organization and layout, and land use at Battonya-Parázs tanya during the Neolithic.

Overall, the results indicate that Battonya-Parázs-tanya was one of the most extensive and longest-lasting Neolithic sites on the Great Hungarian Plain. Considering major features and organizational characteristics, the village shares similarities with other Late Neolithic tell-centered settlement complexes that have been studied using similar non-invasive techniques on the Plain. However, in addition to microtopographical features that impacted the site's unique layout, a notable difference is the considerable, more than 100-m distance between the inner and outer ditches surrounding the central part of the village. If, as suggested by the data from the magnetic prospection, this area was indeed sparse or largely devoid of structures, it may have lent a sense of monumentality to the space between the densely built areas of the tell and the external settlement. This distinct characteristic underscores that, as previously noted by Gyucha,[39] while an architectural canon may have existed across the Plain during the Late Neolithic, individual village communities deliberately chose which elements to adopt and how to adapt them as they evolved, resulting in different settlement biographies.

Methodologically, one of the major outcomes of our study is that the layers created through the further analysis of the DEM from the LiDAR survey *(Figs 9 and 10)* and the thermal infrared imagery *(Fig. 12)* highlighted elements in the studied area that would have been unidentifiable without these techniques. These findings enhanced our understanding of both natural and human-made features at Battonya-Parázs-tanya. Notably, one of these features is an enclosure formed by manipulating a natural watercourse. If this feature dates back to the Neolithic, it provides an important example of large-scale construction projects by Neolithic communities that significantly modified their natural environment.

Finally, this study employed a range of methods that have rarely been used in the research of tell-centered settlement complexes in Hungary before, demonstrating the potential of non-destructive methodologies to explore several key aspects of large prehistoric settlements. This is especially crucial given the challenges in determining where and to what extent further targeted, destructive methods should be applied in these extensive sites, where investigations are constrained by limited time and resources.

[35] Raczky and Füzesi (2016); Füzesi and Raczky (2018).

[36] Gyucha et al. (2019).

[37] Riebe et al. (2023).

[38] Salisbury (2012) 178.

[39] Gyucha (2022).

ACKNOWLEDGMENT

The geophysical survey was carried out in the framework of the Körös Regional Archaeological Project. The airborne surveys were conducted by Planta Drone Ltd. The results of the research were first summarized in János Győri's BA thesis at the University of Miskolc. We thank András Füzesi for his comments and help.

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Roncsolásmentes kutatási módszerek alkalmazása egy alföldi, késő neolitikus, tell-központú településkomplexum vizsgálatára. Esettanulmány: Battonya-Parázs-tanya

Győri János – Gyucha Attila – Szalma Bence – Szalma Elemér – Stibrányi Máté – Pethe Mihály – P. Fischl Klára

A késő neolitikus tell-központú településkomplexumok kutatása a roncsolásmentes módszerek egyre bővülő tárházának alkalmazásával új irányt vett. A dolgozatban tárgyalt Battonya-Parázs-tanya lelőhely már ismert a kutatás számára G. Szénászky Júlia és Goldman György a központi tellen folytatott ásatásai nyomán.[40] A középső neolitikum időszakában a szakálháti kultúra, majd a késő neolitikumben a tiszai kultúra népessége által lakott település Battonyától ÉNy-ra, a Királyhegyesi-Száraz-ér Kis-Tompa-dűlőnek nevezett nagy kanyarulatában található, az ér bal partján *(1. kép)*. A közhiteles régészeti nyilvántartásban jelenleg Battonya, Száraz-ér 14 (azonosító sz.: 28950) néven rögzített. A lelőhely és a korábbi ásatási szelvények pontos helyének azonosítása egy 1987-es légifelvétel segítségével 2024-ben történt meg *(2. kép)*.

Archív térképek és légifelvételek tanulmányozása során a tell környezetében összetett szerkezetű települést azonosítottunk *(3–5. kép)*. Ennek további vizsgálatára geofizikai felmérés, LiDAR felmérés adataiból kinyert digitális domborzatmodell, lejtőmeredekség analízis, multispektrális és termális infravörös felvételek, valamint terepbejárás segítségével került sor *(6–12. kép)*. Az alkalmazott módszerek által nyert adatok együttes értékelésével a komplex település belső szerkezetéről részletes képet sikerült kialakítanunk.

A tellt egy vesealakú árok veszi körül *(7. kép 1.2)*, melyen belül az épületek több üres tér köré szerveződve, koncentrikusan helyezkednek el *(7. kép 1.1)*. A belső árkon túl, mintegy 110 méter távolságra egy újabb kerítőárok vonalát azonosítottuk *(7. kép 1.5)*. A két árok közötti terület *(7. kép 1.3)* használatára csak kevés adat áll rendelkezésre, azok is inkább a magasabban fekvő térszínekhez köthetőek. A település területét ÉNy–DK-i irányban a Királyhegyesi-Száraz-ér egy egykori természetes medre zárja. A mederszakasz felső részét kísérő hordalékkúpok a meder természetes eredetét támasztják alá *(12. kép)*. A középső szakaszt a településtől délre azonban mesterséges módon átalakították és a belső két árok vonalához igazították *(9. kép 1, 10. kép 1, 13. kép 6)*. A második árok vonalától K-re és DK-re egy radiális elrendezésű, igen intenzív külső települési zónát térképeztünk fel terepbejárásaink és geofizikai felmérésünk során *(7. kép 1.7, 7. kép 2)*.

Az újkőkori település területét jelenleg egy fasor osztja keleti (A) és nyugati (B) területekre *(5. kép)*. A nyugati területen a vegetációs borítottság miatt nem készült geofizikai felmérés *(6. kép)*. Itt a domborzatmodell, a multispektrális felvételek *(9–11. kép)* és terepbejárásaink adatai segítségével szintén meg tudtuk állapítani a település kiterjedésének határait. A központi magtól Ny–DNy-i irányban egy magas térszín található ezen a területen. Ezt a térszínt nem vágja a második árok vonala, a dombhát azonban nem összefüggő a külső, természetes eredetű árok bevágódása miatt *(13. kép)*. Ezeken a magas térszíneken a felszíni régészeti leletanyag szintén intenzív megtelepedési zónát jelez.

Az összesített adatok alapján a neolitikus település kiterjedése 110 ha. A település belső szerkezete a tájhoz illeszkedik, alapstruktúráját tekintve azonban beleillik a legfrissebb kutatások által általánosnak mondható késő neolitikus települési mintázatba, melynek legfontosabb ismertetőjegye a központi magterületen kívüli strukturált térhasználat, a nagy kiterjedésű horizontális települések létrejötte és árkok alkalmazása a települési tér belső tagolása érdekében.[41]

Jelen dolgozat a battonyai esettanulmányon keresztül a roncsolásmentes módszerek együttes alkalmazásának fontosságára hívja fel a figyelmet. A bemutatott struktúra egyes elemei hangsúlyosabban vagy éppen alig detektálhatók egy-egy felmérési módszerrel, míg azokat más módszerek eltérő megvilágításba helyezik. A battonyai kutatásaink során alkalmazott módszerek együttes használatára a korábbiakban ritkán került sor a hazai őskorkutatásban.

[40] G. Szénászky (1976, 1977a, 1977b, 1978a, 1978b, 1979, 1980, 1981, 1982, 1983, 1988).

[41] Füzesi and Raczky (2018), Füzesi et al. (2020a, 2020b, 2023); Gyucha et al. (2015, 2019); Gyucha (2022); Mesterházy et al. (2019); Parkinson et al. (2018); Raczky és Anders (2008, 2009, 2012, 2016); Raczky és Füzesi (2016); Raczky et al. (2018, 2021, 2022); Riebe et al. (2023); Salisbury (2012).

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