ЕТНО-КУЛТУРОЛОШКИ ЗБОРНИК
Књига XXVI

Book XXVI

ETHNO-CULTURAL ANNALS

for the study of the culture of eastern Serbia and the adjacent areas

EASTERN SERBIA AS AN INSPIRATION AND RESEARCH CHALLENGE

a collection of works in honor of Prof. Dr. Sreten Petrović

Editors
Vojislav Filipović
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Svrljig
2023

Књига XXVI

ЕТНО-КУЛТУРОЛОШКИ ЗБОРНИК

за проучавање културе источне Србије и суседних области

ИСТОЧНА СРБИЈА КАО НАДАХНУЋЕ И ИСТРАЖИВАЧКИ ИЗАЗОВ

зборник радова у част проф. др Сретена Петровића

Уредници
Војислав Филиповић
Ивица Тодоровић

Сврљиг
2023

УДК 008:39(082.1)

ЕТНО-КУЛТУРОЛОШКИ ЗБОРНИК

Зборник је покренут 1995. године на иницијативу проф. др Сретена Петровића и Етно-културолошке радионице Сврљиг

Издавач: Центар за туризам, културу и спорт, Боре Прице 2, Сврљиг

За издавача: Драган Савић

Рецензенти: др Ана Савић-Грујић, академик др Јелена Јовановић, др Милина Ивановић Баришић, др Јована Бајовић Јоксимовић, др Александра Павићевић, др Татјана Трајковић, др Биљана Савић, др Ивица Тодоровић, др Александар Булатовић, др Александар Капуран, др Владимир Петровић, др Војислав Филиповић

Припрема и штампа: Галаксијанис, Ниш

Тираж: 150

ISBN 978-86-6233-555-5

APPLICATION OF REMOTE SENSING IN RESCUE ARCHAEOLOGY: THE RESULTS OF THE TEST GEOMAGNETIC SURVEY ON THE SITE OF MARJANSKO BRDO IN 2023

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Abstract: *During the 2022-2023. rescue excavation campaign on the route of the future Požarevac-Veliko Gradište-Golubac motorway, conducted by the Institute of Archaeology from Belgrade, standard practice included geophysical survey preceding excavations. This strategy proved to be time and cost efficient, improving decision making in opening trenches. Shortly before the start of the three-month-long large-scale excavations at the site of Marjansko brdo, the team from Institute of Archaeology, Belgrade, acquired a Bartington Grad601 fluxgate magnetic gradiometer and immediately began testing the device. Several testing grids were surveyed in the zones that were not previously prospected or excavated. The following article presents the data recorded in the survey compared with the results of the subsequent excavations in an attempt to better understand basic interpretative principles of magnetogram.*

Key words: *remote sensing, geophysics, rescue archaeology, magnetometry, magnetic prospecting.*

Апстракт: *Током кампање заштитних ископавања на траси будуће брзе саобраћајнице Пожаревац-Велико Градиште-Голубац 2022-2023. године, коју је спровео Археолошки институт Београда, стандардна пракса укључивала је геофизичка снимања која претходе ископавањима. Ова стратегија се показала као ефикасна, у смислу времена и новца, побољшавајући одлучивање при отварању сонди. Непосредно пред почетак обимних тромесечних ископавања на локалитету Марјанско брдо, екипа Археолошког института Београд је набавила Bartington Grad601 флуксни магнетни градиометар и одмах започела тестирање уређаја. Неколико тест поља је снимљено у зонама које нису раније снимане или ископаване. У раду ће бити представљени подаци снимљени магнетометром у поређењу са резултатима ископавања у покушају да се боље разумеју основни принципи тумачења магнетограма.*

Кључне речи: *даљинска детекција, геофизика, заштитна археологија, магнетометрија, магнетна снимања.*

Introduction

Rescue excavation campaign on the route of the future Požarevac-Veliko Gradište-Golubac motorway managed by the Institute of Archaeology from Belgrade lasted thorough most of 2022-2023, during which 14 locations with possible archaeological remains were investigated. Before the excavations would start, geophysical prospection was applied on every location, in cooperation with Center for New Technologies Viminacium, including mostly magnetometry, but also GPR method on several locations. Application of remote sensing proved to be both cost-effective and time-saving, facilitating excavation strategy development process, as well as productivity of digging. Even though these methods are nothing new for archaeology and plenty of work has been written and published (Aitken 1958; Aitken 1974; Fassbinder et al. 1999; Schmidt 2002; Aspinall, et al. 2008; David et al. 2008; Bevan 2012; Hahn et al. 2022; Bevan, Smekalova 2023), remote sensing services are becoming more readily available in our country.

In the wake of these favorable experiences, the team from the Institute acquired a Bartington Grad601 fluxgate magnetic gradiometer and testing of the new device was planed for the excavations on the site of Marjansko brdo (Fig. 1). Test trenches done the previous winter confirmed a multilayered archaeological settlement on the location,

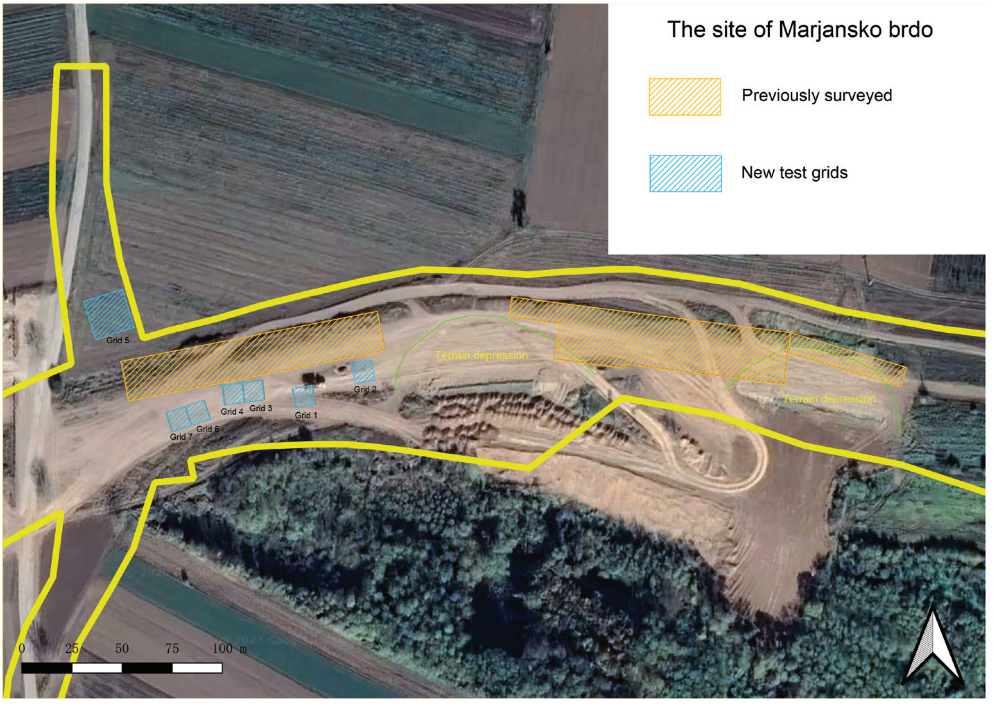

Fig. 1 – Site of Marjansko brdo with previously surveyed zones and new test grids.

though, due to the specific nature of rescue excavations, it was only possible to investigate within the narrow plot of the road-to-be. Total length of the site was, therefore, close to 500 m, but width of the expropriated area was mostly 65-75 m, with some wider stretches, especially on the eastern part, where an intersection was planned. Since magnetometry was previously done on large portions of the site, mostly northern strip, the device was tested on the southern parts, with six smaller grids, as well as one on the northern arm of the intersection. It is important to note that the core of the site is probably situated north of the expropriated area, on the level ground with the highest elevation, where numerous pottery shards were discovered by the accounts of the local people. Terrain elevation drops gradually southwards, ending with ravine just south of the plotted road route. Another essential factor for the survey is the multilayered nature of the site, starting with the Roman layer below the surface and ending with the Neolithic stratum up to 3.40 m deep. Additional features and contexts from Eneolithic, Bronze and Iron Age were also documented, making stratigraphic sequence rather complex and challenging for magnetometric data interpretation.

Methodology

Instrument used in the survey was Bartington Grad 601 fluxgate gradiometer hand-carried system, which utilizes two sensors mounted on a carrying bar. Gradiometers use two or more spatially separated sensors to measure the gradient of the magnetic field i.e, the difference between two sensors (Clark 1996: 70; Gaffney, Gater J 2003: 40; Witten 2014: 88). Measured gradient represents intensity of the vertical downward direction of the Earth's magnetic field, classifying Bartington Grad 601 as a vector magnetometer, which are typically insensitive to the diurnal variations of the Earth's magnetic field (Witten 2014: 87-88; Fassbinder 2016: 2), with vertical gradient being the most commonly measured gradient in the vector magnetometer practice (Bevan 2006: 21). Spacing of the dual sensor layout is 1 m, with an overall sensitivity of 0.03 nT/m. Positioning of the survey grids was done using a South Galaxy G1 GNSS Rover device with an accuracy of <0.03 m and presented in the coordinate reference system WGS84 UTM Zone 34N (EPSG: 32634).

Surveys were done in a total of seven grids. Device used requires setup of regular 10x10, 20x20, 30x30 or 40x40 m grid squares, and due to limited space available, both because of the expropriation restrictions and the fact that a large portion of the site was previously surveyed, six grids were done in 10x10 m configuration (Grids 1-4, 6-7) and only one in 20x20 m (Grid 5), where space allowed. Surveying was done by walking along the grids in a parallel pattern with 2 m intervals between the traverses to align with the dual sensor spacing fixed at 1 m and record data at 1 line/m.

Results of the survey

Seven surveyed grids were setup with intention to prospect site zones that were not done earlier. Acquiring magnetometric image would then allow prioritization of certain areas in terms of excavating, which would in turn economize resource and time expenditure. These zones include cultivated land in the NW part of the site, where intersection of the road will be, and southern strip of the road axis, where the terrain gradually drops in elevation close to 2 m compared to the northern part. Around 20 m from the southern edge of the plotted route, there is a ravine stretching in the NW-SE direction. Terrain configuration is very important in this case since erosion and accumulation of underground water could affect magnetometric image. Flooding with water can cause pits that would normally appear as positive anomalies to leave a negative signal, or to be undetectable entirely. Erosion, on the other hand, can cause detrital or depositional remanent magnetization by filing pits and ditches with foreign material mixed with water, which could randomize the magnetic signature of the feature (Witten 2014: 85; Fassbinder 2016: 7-9). Another important aspect of this particular survey is the complex heterogenous nature of the cultural stratigraphy. Simply put, magnetometry depends on the magnetic contrast between the archaeological feature and the adjacent soil, ideally, archaeologically sterile ground (Fassbinder 2016: 12-13). Distinguishing features on a multilayered site where human presence through several millennia left its footprint on the magnetic image can be more of a challenge, as it will be presented in further text.

Out of seven surveyed grids, three displayed interesting anomalies in the magnetic image, with potential for archaeological investigation, while others revealed a more or less homogeneous environment. Grids 4, 6 and 7 were therefore selected for test trenches in order to determine the origin of anomalies, revealing a total of eight archaeological features. These grids will be analyzed in further text mostly by anomaly description and archaeological description, and by analytical interpretation to a lesser extent. Archaeological features will be described only in basic terms, leaving the more detailed analysis for the site excavation publication.

Grid 4

Values of the magnetic vertical gradient of the Grid 4 range from -10 nT to +11 nT (Fig. 2). In the middle eastern part of the grid there is a positive magnetic anomaly with an epicentre of approximate size of 1.5x1 m, where measured vertical gradient is around 11 nT (Fig. 3). Rest of the anomaly spreads unevenly westwards. It could have been caused by thermoremanent magnetization that occurs in archaeological kilns, fireplaces and other instances where soil is exposed to high temperature (Fassbinder 2016: 7). In this case, according to the size and uneven spread-out shape, it could have been caused by dislocated pieces of Roman period burned ground from a fireplace, that were common on the site in the layers close to surface. Another anomaly cluster, almost 4 m in diameter, is located in the SW part of the grid, with measured vertical gradient around -10 nT. Southern part of the grid was chosen to be further investigated by excavating with a 10x3 m trench (Trench 6), that was additionally expanded westward by 4 m, and 1 m southward, from the 2 m mark measuring from the SW corner. In the zone of the anomaly excavations uncovered two Roman period and two prehistoric features, while the eastern part of the trench revealed none whatso-

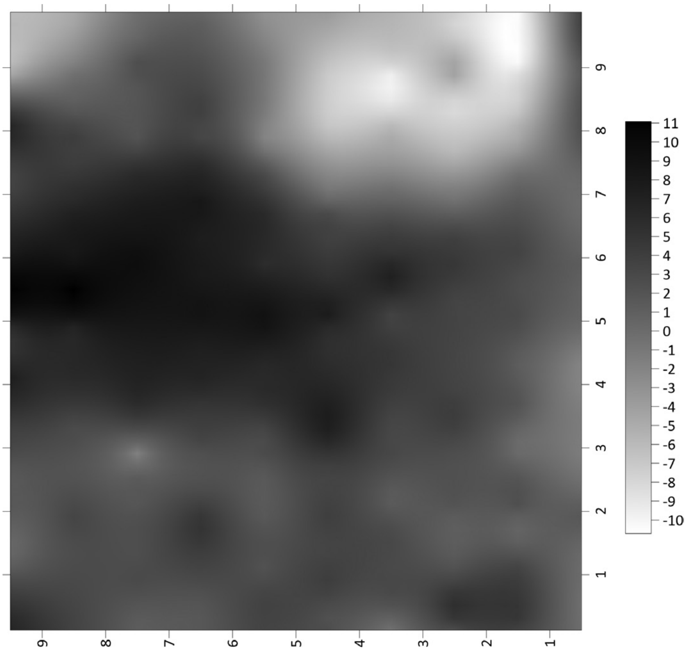

Fig.2 – Magnetogram of the Grid 4.

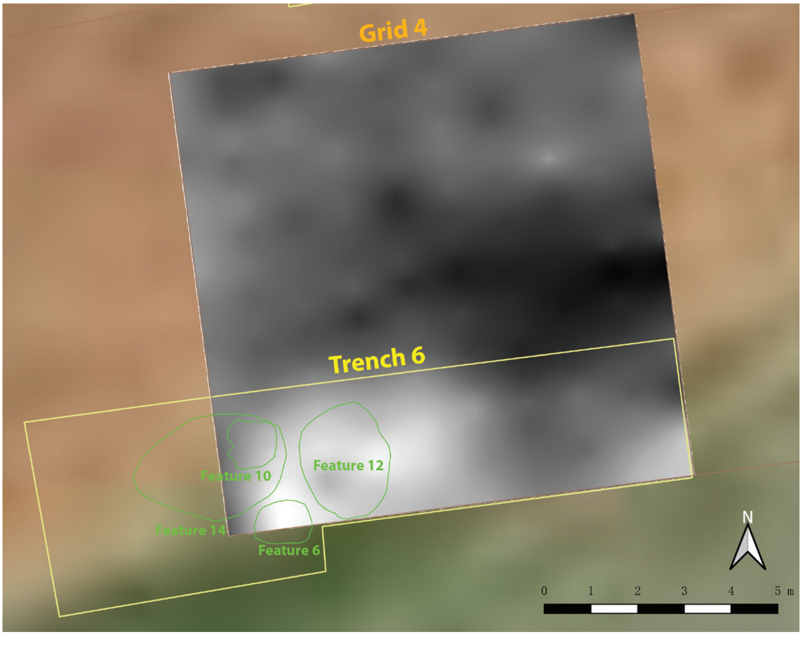

Fig. 3 – Grid 4 overlaid with Trench 6 and excavated features.

Fig.4 – Features 6 and 10 (Archive, Institute of Archaeology, Belgrade).

ever. Both Roman period features were close to the surface: remains of a kiln floor with a renewal layer (Feature 6), and a stone horseshoe shaped structure, approximately 1x1 m in size (Feature 10) (Fig. 4). Feature 12 was a large (≈2x2.3 m) Bronze Age pit with ceramic material that disturbed the remains of burned house daub of an older Neolithic period house (Feature 14) (Fig. 5). All of these features should have left a positive magnetic signature (Fassbinder 2016: 7-9), though they are covered with a zone of negative magnetization, which can be associated with erosion and accumulation of water. Once again it needs to be emphasized that terrain gradually drops southwards, thus the elevation difference between the northern and

Fig. 5 – Features 12 and 14
(Archive, Institute of Archaeology, Belgrade).

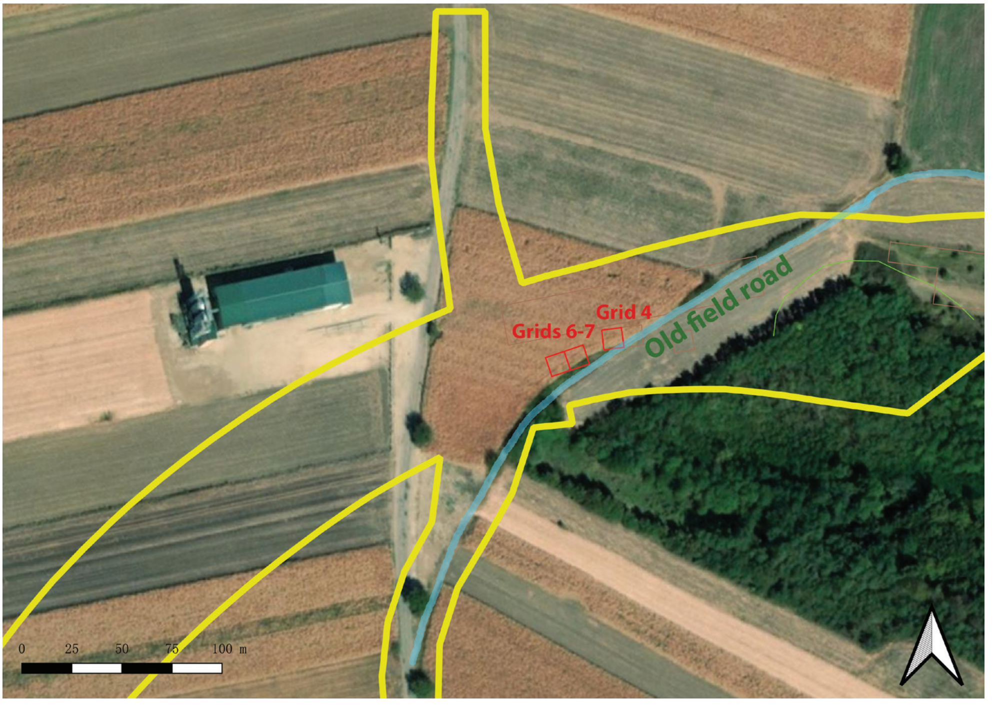

Fig. 6 – Route of the old field road.

southern part of the gird is close to 0.5 m. Furthermore, SW corner of the grid is around 0.1 lower than the SE corner. Negative magnetization could also have been related to the field road that ran just south of the Grid 4 (Fig. 6), but was leveled during the land clearing in preparation for the road works.

Grids 6 and 7

Values of the magnetic vertical gradient of the Grids 6 and 7 range from -6 nT to +11 nT (Fig. 7). As it is visible on the grid image, high intensity anomalies are mostly on the Grid 6, reaching only easternmost edges of Grid 7. Rest of the Grid 7 is largely homogenous in magnetic signature, save for some negative signals further west. Test trench (7x7 m) was, therefore, set up covering western and central part of the Grid 6 and eastern part of the Grid 7 (Fig. 8). Large positive magnetization anomaly in the NW part of the grid corresponds perfectly in size and shape to a prehistoric pit (Feature 35) discovered during excavation. It is expected for pits, ditches etc. that are refilled by topsoil to generate positive magnetic anomaly (Fassbinder 2016: 8). Feature 35 is a large Bronze Age pit (≈2.5x1.8 m) filled with pottery, traces of ash and soot (Fig. 9).

Large negative anomaly in the SW corner of the grid (≈3.3x2.7 m), irregular in shape, roughly corresponds to Feature 36. Inside the feature that is roughly 2.5 m deep

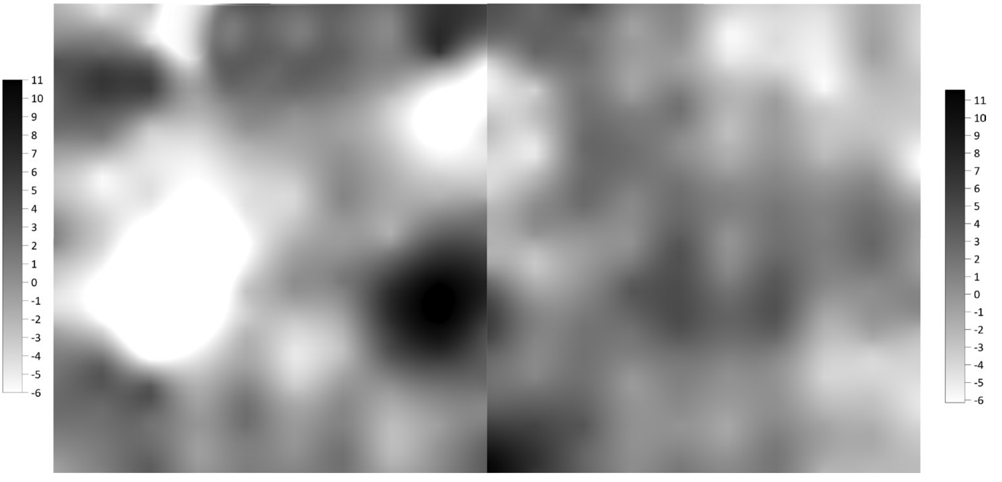

Fig. 7 - Magnetogram of the Grids 6 and 7.

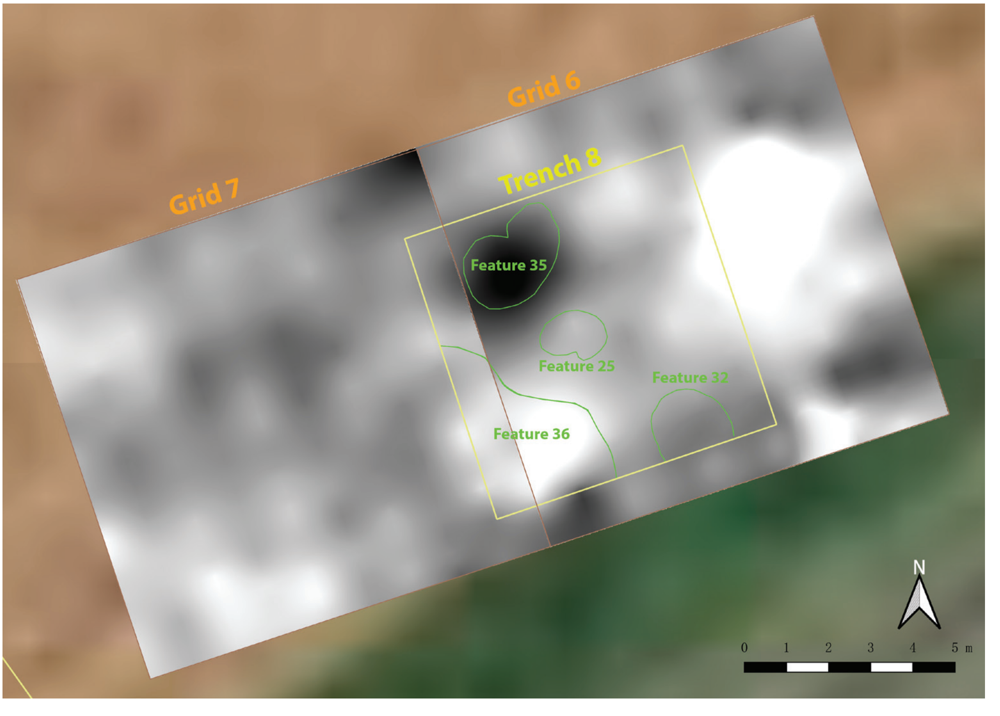

Fig. 8 – Grids 6 and 7 overlaid with Trench 8 and excavated features.

from the surface level, Neolithic period pottery was discovered, as well some dislocated animal bones. Feature 25, on the other hand is a much smaller oval shaped feature, approximately 1.20x1.25 m, and could be associated with a weak negative signal. The feature

Fig. 9 – Cross section of the Feature 35 (Archive, Institute of Archaeology, Belgrade).

contained dark soil with traces of soot and some late La Tene pottery along with dislocated animal bones. Negative magnetic vertical gradient values could be a result of accumulating water that changes the magnetization of the pit, especially in the case of a rather large Feature 36. Similar to the situation in Grid 4, terrain elevation drops from north to the south around 0.70 m.

Feature 32 can't be associated with any anomaly in the magnetic image. Oval feature is a Bronze Age pit that stretches into the southern cross section of the trench, with an approximate size of 1.7x1.6 m. Bronze Age pottery, soot and remains of burned soil, along with a few dislocated animal bones were discovered in the pit. Difficulties in correlating Feature 32 with any anomalies could be attributed to the complex stratigraphy of the site, or even to the temporary soil wetness that has be proven to render pits or ditches magnetically untraceable (Fassbinder 2016: 9).

Large irregular shaped, almost rectangular, negative anomaly that was cut by the eastern edge of the trench did not reveal archaeological features. Similar is the case of the oval negative anomaly in the NE corner of the trench. Failure to register any features in these zones could be due complex stratigraphy of the site, aggravating differentiation of certain archaeological features and layers, but also due to some other unknown magnetization process. Especially interesting is the larger, almost rectangular anomaly, that could indicate a spot of digging that was almost immediately refilled with the same soil; a scenario that should generate a negative anomaly (Fassbinder 2016: 9).

Conclusion

Additional magnetometric test surveys done during the excavations on the Marjansko brdo site proved to be useful in prioritizing digging in the zones where previous prospecting has not been done. Grids allowed for zones to be more precisely investigated with trenches, or even to be skipped if the magnetogram displayed a homogenous environment, in order to put priority on a more promising section. Utilization of remote sensing in this manner treats excavating as the last means of archaeological investigation. Nevertheless, magnetometry as a method is not without its own shortcomings, as it was attested after comparing survey data with excavated trenches.

Two trenches excavated over three test grids uncovered a total of eight archaeological features. Feature 35, a Bronze Age pit, is the most prominent one, since it not only corresponded perfectly with the size and shape of the anomaly, but also generated a positive magnetic signal, as expected for a pit or a ditch. Features 6, 10, 12, 14, 25 and 36 seemed to be obscured by negative magnetic signals, while Feature 32 is untraceable on the magnetogram. Negative magnetic signals, as well as the invisible feature, could be attributed to the erosion and accumulation of water in the zones with the elevation drop. Additional factor complicating interpretation of the magnetogram is the rather complex site stratigraphy ranging from the Neolithic to Roman period. Regardless, utilization of a remote sensing method such as magnetometry gave useful results, as well as valuable experience for future prospection.

Acknowledgements

Author of this text would like to thank his colleagues Aleksandar Bulatović, Aleksandar Kapuran, Vojislav Filipović and Ognjen Mladenović for providing means, opportunity and support needed to realize the implementation of the new magnetometer. A special thanks goes to the team from the Center for New Technologies Viminacium, Vladimir Miletić, Igor Milošević and Ivan Marjanović, for providing technical support, help and advice.

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ПРИМЕНА ДАЉИНСКЕ ДЕТЕКЦИЈЕ У ЗАШТИТНОЈ АРХЕОЛОГИЈИ: РЕЗУЛТАТИ ГЕОМАГНЕТСКОГ СНИМАЊА НА ЛОКАЛИТЕТУ МАРЈАНСКО БРДО 2023. ГОДИНЕ

Примена даљинске детекције показала се исплативом у смислу уштеде времена и средстава, олакшавајући процес израде стратегије ископавања и продуктивност копања, током кампање заштитних археолошких истраживања на траси будућег аутопута Пожаревац-Велико Градиште-Голубац, којом је руководио Археолошки институт Београд током 2022-2023. Водећи се повољним искуствима, тим Института набавио је флуксни магнетни градиометар *Bartington Grad 601*, чије је тестирање планирано током ископавања на локалитету Марјанско брдо. Седам поља је постављено са намером да се процене зоне локалитета које нису раније истраживане, од којих су три показале занимљиве аномалије. Вредности магнетног вертикалног градијента у пољу 4 и пољима 6-7 кретале су се од -10 nT до +11 nT, односно -6 nT до +11 nT. Тест сонде у овим пољима откриле су укупно осам археолошких објеката. Објекат 35, јама из бронзаног доба, је најупечатљивија, јер не само да је савршено одговарала величини и облику аномалије, већ је генерисала и позитиван магнетни сигнал, као што се очекивано за јаму или ров. Под пећи из римског периода, камена конструкција, јаме из периода латена и бронзаног доба, као и кућа и јама из неолита делују прикривено негативним магнетним сигналима, док се објекат 32 не може уочити на магнетограму. Негативни магнетни сигнали, као и невидљивост објеката, могу се приписати ерозији и акумулацији воде у зонама са падом надморске висине. Додатни фактор који отежава тумачење магнетограма је прилично сложена стратиграфија локалитета у распону од неолита до римског периода. Примена методе даљинске детекције, ипак, донела је корисне резултате, као и вредно искуство за будуће проспекције.