

DOI: 10.15584/anarres.2017.12.5

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## Barrows from the Late Neolithic and Bronze Age in the Upper Dniester River Basin in Ukraine. Geophysical Research and Archaeological Verification<sup>2</sup>

### ABSTRACT

Makarowicz P., Cwaliński M., Niebieszczański J., Romaniszyn J. 2017. Barrows from the Late Neolithic and Bronze Age in the Upper Dniester River Basin in Ukraine. Geophysical Research and Archaeological Verification. *Analecta Archaeologica Ressoiviensia* 12, 59–74

This article evaluates the potential of magnetometry to establish the internal structure of three mounds in the barrow cemetery of Bukivna in the Upper Dniester River Basin in Ukraine. We also evaluate the effects of geomorphological processes on the magnetometric results. The three-stage research method we applied comprises the preparation of a digital elevation model of the mounds, conducting geomagnetic surveys and, finally, targeted excavations, the latter enabling the verification of previously detected magnetic anomalies.

In effect our studies show exceptionally complex geophysical anomalies, difficult to interpret with any certainty. In the peculiar case of the barrows 6 and 7 in group I, partly connected by an earthen mantle, the overlapping magnetic fields did not allow the two mounds to be distinguished from each other; it was possible to achieve only through subsequent excavations. In both barrows, a series of ritual and sepulchral structures were discovered that provided clear magnetic signals. The arrangement of the anomalies in the mound 1, group II, potentially reflects various aspects of the barrow's structure and its state of preservation, beginning with postdepositional processes related to erosion or to the run-off of material down the slope, and ending with the mound's stratigraphy, formed over the course of two phases. In turn, in the case of mounds 6 and 7, it can be assumed that the effects of these processes have been

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<sup>1</sup> The author is the recipient of a scholarship of the Foundation for Polish Science, awarded within the framework of the 2017 START programme.

<sup>2</sup> The article is the result of project no. NCN 2011/03/B/HS3/00839 "Bukivna. Elitarna nekropola kultury komarowskiej nad Dniestrem" [Bukivna. An Elite Komarów Culture Necropolis by the Dniestr River] and project NPRH 12H 12 001981 "Katalog cmentarzy kurhanowych kultury komarowskiej w dorzeczu górnego Dniestru. Dawne województwo stanisławowskie" [Catalogue of Komarów Culture Barrow Cemeteries in the Upper Dniestr River Basin. The Former Stanisławów Province].

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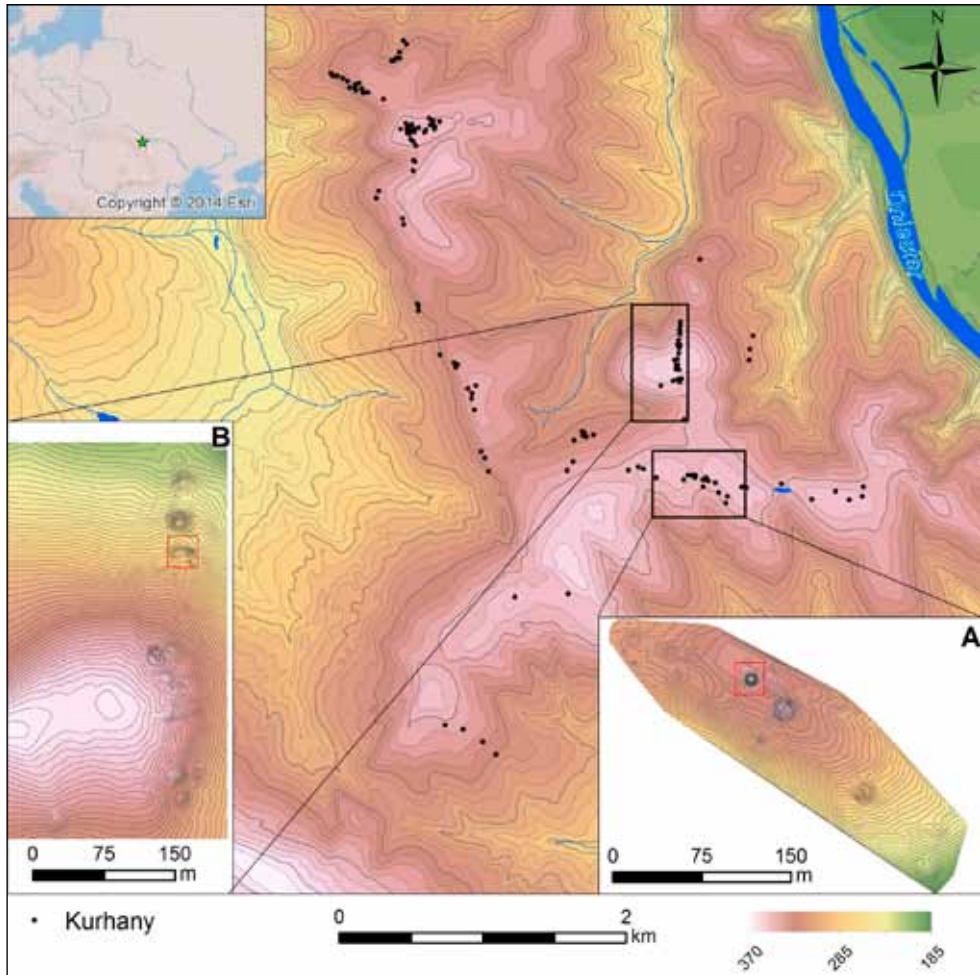
somewhat “suppressed” in the magnetometric image, due to the strong impact of the burnt wooden structures located underneath the features

**Key words:** barrow, mound, magnetometric survey, stratigraphy, Komarów culture, Corded Ware culture, magnetic anomalies, slope processes, burnt structures

**Received:** 03.10.2017; **Revised:** 23.11.2017; **Accepted:** 01.12.2017

## Introduction

The presented article is one of the results of two Polish-Ukrainian research projects focusing on Middle Bronze Age barrow cemeteries in the Upper



**Fig. 1.** The cemetery complex in Bukivna and Milovania (Western Ukraine). A – Research grid I; B – Research grid II

Dniester River Basin. One of the objectives in common for both projects involved preparing records of the discussed sites and characterising the Corded Ware and Komarów cultural landscape shaped by the barrows (Makarowicz *et al.* 2013a; 2013b; Lysenko *et al.* 2015; Makarowicz *et al.* 2016a; 2016b). About 700 mounds were documented at 17 sites in the course of our research. Non-invasive surveys were conducted at several dozen barrows, while five were studied by excavation. Simultaneously, an analysis of the cultural landscape was undertaken using geographical information system (GIS) tools, in order to understand – among other things – how the cemeteries were organized and which geomorphological preferences conditioned their location. Duplicated linear system or group-linear arrangements of mounds have been observed at all of the cemeteries situated on the plateaus of major watersheds, therefore can be regarded as typical for the Dniester River Basin (Makarowicz *et al.* 2016a).

In this article, we will evaluate the potential of magnetometry for identifying the internal structure of the barrows at the cemetery in Bukivna. Among the 19 prospected mounds, three were later explored by excavation, making it possible to verify the results of the non-invasive surveys. Observations in this regard provide the basis for interpretation of geophysical anomalies as a reflection of certain features in the barrows' structure and the effects of geomorphological processes occurring within the mounds. The three mounds discussed here are: Komarów culture barrows nos. 6 and 7 from group I and the Corded Ware culture mound no. 1 from group II, located within two survey grids respectively (Fig. 1; Makarowicz *et al.* 2016a).

The aim of this contribution is therefore to evoke a discussion concerning the issue of using non-invasive methods in the studies of barrows – archaeological features with distinctive landscape form. Simultaneously, the text highlights the need for a multifaceted verification of the results of such activities.

## 1. Research methodology

### 1.1. Magnetometric surveys

Magnetometry, which measures the variability of the Earth's magnetic field, has been applied in the course of geophysical research at the cemetery of Bukivna (cf. e.g. Weymouth, Huggins 1985; Kvamme 2006;

Schmidt 2007; Pospieszny 2011). To this end, the Bartington FluxGate Grad 601 gradiometer was used, equipped with a single probe containing two sensors. The measurements were carried out manually due to the density of forest coverage in the analysed area (a dense beech forest). The measuring accuracy was set by the technical parameters of the gradiometer model and oscillated at the level of 0.1 nT [nanotesla]. The survey was conducted within the framework of two areas (measurement surfaces) delimited by geodetic instruments (a tachimeter and GNSS RTK). In the case of both research areas, a 10×10 m grid was set up. The measurements were effected using the parallel transect method, with transects spaced at a distance of 0.5 m from each other, oriented on the north–south magnetic axis. Along both transects, readings of the magnetic field's gradient were taken every 0.25 m. The acquired data were processed using Geoplot 3.0 software with the application of the interpolation function, noise reduction and the limitation of the scope of values displayed in the image within the range from -5 to 5 nT, in order to restrict the effect of extreme values linked, for example, to metal waste.

#### 1.1.1. Geodetic documentation and the creation of elevation models

An important aspect of the interpretation of magnetometric images involved juxtaposition of mapped anomalies on digital elevation models previously prepared for the studied barrows (Makarowicz *et al.* 2016a, 25ff.). The elevation measurements intended to make these models were taken using Leica TCR407 laser total stations. On average, the measurement density amounted to four points per m<sup>2</sup>. Afterwards, recorded elevation data was interpolated into a model in the ESRI ArcInfo software, with the use of the *TopoToRaster* function.

#### 1.1.2. Verification methods – excavations

The excavations provided some insight into the structure and stratigraphy of the mounds, including architectural elements located underneath the earthen mantle (various types of sepulchral features). The barrows were divided into quarters and explored in artificial spits, each documented graphically (Makarowicz *et al.* 2013a; 2013b; Lysenko *et al.* 2015). In addition, a total station survey was also conducted in order to register distribution (planography) of the finds in the mounds' layers, including the original ground level on which the barrows were

heaped up. In this way, it was possible to display the created plans within the same geodetic coordinate system, in respect to which the elevation and magnetometric measurements were also taken.

### 1.1.3. Geographical information systems and data synthesis

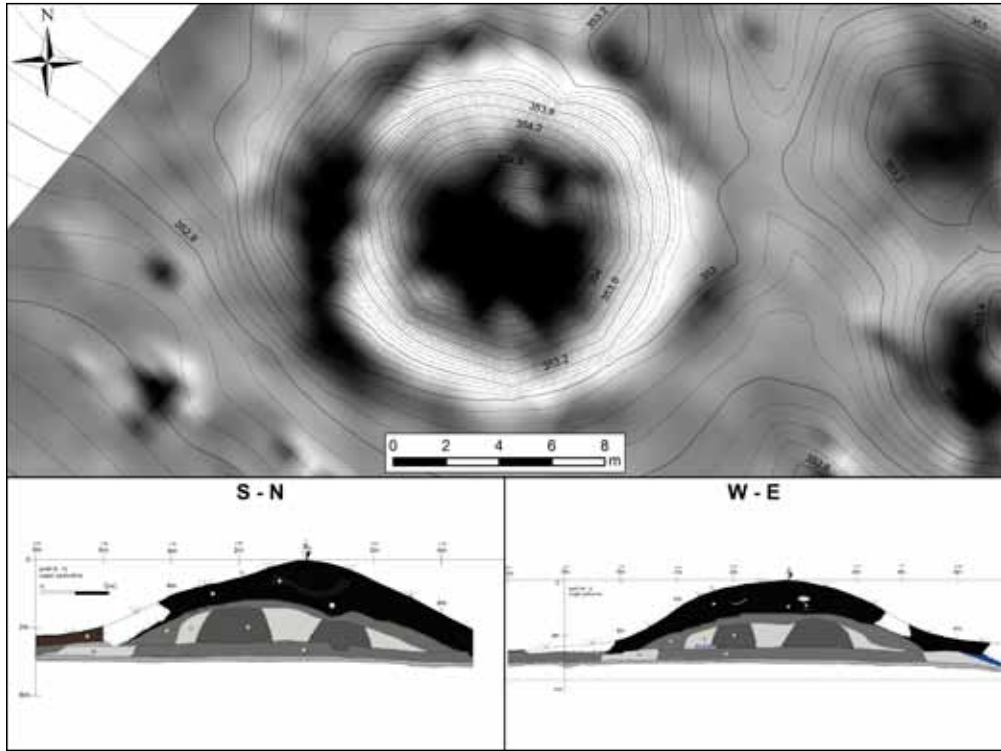
The final step involved integration of the acquired information on magnetic field variability, elevation, the distribution of archaeological finds and features in the internal structure of the barrows into the data 'geobase' using ArcInfo software. The integration of all the available information into one display and information processing platform made it possible to conduct comparative analyses of the individual research stages.

## 2. The results

### 2.1. Research grid I

The research grid encompassing barrow 1 from group II measured 35×16 m, i.e. 560 m<sup>2</sup> (Fig. 2). This section was part of a larger area subjected to magnetometric prospection in the scope of the aforementioned barrow group; this method allowed for the identification of six mounds (Makarowicz *et al.* 2016a; Fig. IV.285 & IV.286). Barrow 1 had the shape of a truncated cone measuring ca. 2.5 m in height and 12 m in diameter. The gradient of the mound's slopes was irregular. A fundamental difference was observed in the N–S section, in which the southern slopes are gentler than the ones on the opposite side. In addition, in the E–W section the western boundary between slope and terrain is located at a lower absolute height than the eastern one. This can be observed in the elevation of the barrow on sloping terrain, which dips gradually to the west.

The magnetometric image of the discussed barrow indicates the significant variability of the magnetic field induction within it. It is possible to distinguish a few successive magnetisation zones, beginning from the peak, through the slopes and down to the barrow's immediate surroundings. The peak has extremely high values (following compression to fit the range -5–5 nT), forming an irregularly outlined concentration that encompasses the entire plateau. A concentric belt of negative readings extends from just beneath the threshold of the flat area down to the lowest parts of the slope. This ring-like (in terms of its arrangement)



**Fig. 2.** Results of non-invasive surveys and excavations of barrow 1 from group II at the cemetery in Bukivna. In the upper part of the illustration, the magnetometric prospection results have been placed onto a hypsometric plan. The stratigraphic sections of the excavated part of the barrow are included in the left and right bottom corners (Lysenko *et al.* 2015, for explanation of layers, see: Makarowicz *et al.* 2016a)

anomaly differs in width depending on the section of the slope. In the western part of the barrow it clearly narrows to 1.5 m, which differs from the remaining course of the signal, generally measuring from 2.5 up to 4 m in diameter. Where the lower parts of the slope merge into the flat surrounding area, yet another concentric anomaly was registered, reminiscent of a ring, but this time with a positive magnetisation level. This structure is also asymmetrical. The most visible and widest section is the ca. two-metre long belt situated on the western side of the barrow. In turn, its width amounts to only a dozen or so centimetres on the northern, southern and eastern sides. In places, the anomaly disappears, taking on the value of the magnetic background at 0 nT.

The excavations of barrow 1 have provided some information about its stratigraphy and lithology. In light of these results, it can be stated

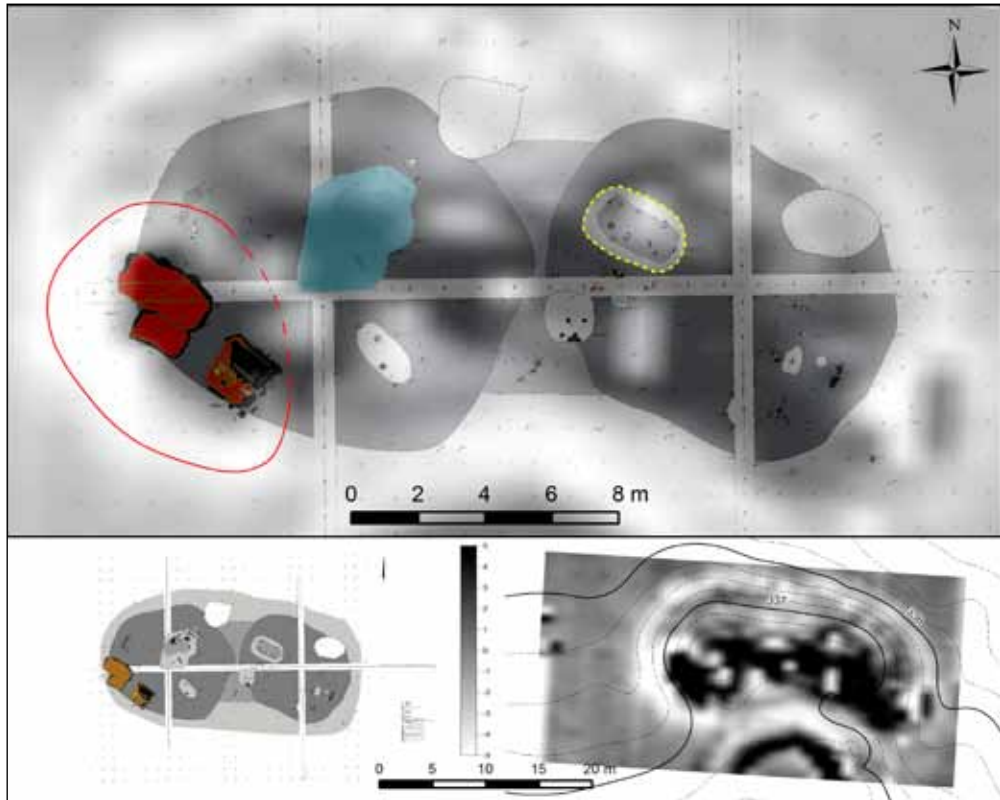
that the mound consisted of two layers – construction horizons (Fig. 2). The stratigraphically older one was built from organic material, most probably cut turf pieces arranged with the growth side facing downwards (Makarowicz *et al.* 2013a; Lysenko *et al.* 2015). It was built at the time of the Corded Ware culture, as the radiocarbon dates point to the second half of the 3<sup>rd</sup> millennium cal BC (Makarowicz *et al.* 2016b, Tab. 2). The second, overlying layer was built up from much thicker loess deposits, up to 1.5 m thick in the accumulation zone at the base of the slope. This layer was also clearly younger than the one below, with numerous modern vessel sherds discovered within. It should be noted that the grave pit was dug directly into the natural soil, beneath the original humus layer.

## 2.2. Research grid II

Within barrow group I at the cemetery in Bukivna, a “double mound” was identified, consisting of two mounds connected by an earthen mantle, with a kidney-shaped outline and two peaks (Fig. 3). This funerary structure has the following dimensions: ca. 30 m along the W–E axis and 14 m along the N–S axis. The average height of the barrows amounted to 1.5 m; however, it should be emphasized that the western peak was a few centimetres higher. There was a small plateau located between the two peaks, which was an element shared by both mounds.

The geophysical prospection undertaken within the framework of this project covers a rectangular area measuring 28×18 m. It is part of a larger magnetometric plan prepared for group I (Makarowicz *et al.* 2016a, 168–172). The magnetometric image does not enable a clear separation of the two barrows. It distinctly shows a complex of anomalies, an element of which was a strip of negative readings with a kidney-shaped outline, surrounding an area characterised by considerable gradient variability, with positive values predominant on the southern side of the elevation (Fig. 3).

The magnetometric imaging shows an extensive anomaly with an oval contour, consisting of an internal maximum positive and external negative, located at the western edge of mound 6 (Fig. 3). At the opposite side of the elevation, a strongly polarized anomaly is visible, probably caused by an object made of iron. Due to the presence of trees overgrowing both mounds, it was impossible to take measurements in certain spots – these are marked as white strips in the westernmost part of the area (Fig. 3).



**Fig. 3.** The results of non-invasive surveys and excavations of barrows 6 and 7 from group I. In the upper part of the illustration, the magnetometric results are superimposed onto the horizontal projection of the explored layers. The bottom left illustration shows the generalized planography. The structures marked in brown represent wooden chambers of the “mortuary house” type. The magnetometric image is placed in the bottom right corner of the figure, along with a hypsometric model (Makarowicz *et al.* 2016a)

At the southern foot of the elevation, a pronounced and complicated anomaly was observed with a semi-circular outline, formed by concentric, adjacent rings of magnetisation: outer negative and inner positive (Fig. 3). In the course of excavation, it turned out that they belong to yet another, smaller barrow (Makarowicz *et al.* [eds] 2018).

After completion of geophysical survey, barrows 6 and 7 were excavated. The methodology was adapted to their specific spatial arrangement. The research area was divided into six parts or “quarters” (Fig. 3). The upstanding remains enabled us to distinguish two separate mounds, with a distinct stratigraphy and planography, constructed



from turf layers covered by thin loess deposits. Several structures and features were encountered within the barrows. In barrow 6, two graves of the “mortuary house” type, i.e. funerary wood-daub structures, were documented in the western part (Fig. 3), while mound no. 7 contained two cenotaphs consisting of fired wooden elements and stone enclosures. Both barrows also yielded abundant deposits of vessels and other items. The absolute dates indicate that the two mounds were not erected at the same time. Barrow 7 is older, while barrow 6 younger (Makarowicz *et al.* 2016b). Nonetheless, they can both be attributed to the Komarów culture (Makarowicz *et al.* [eds] 2018).

### 3. Discussion

In light of the results presented here, we would like to draw attention to the differences in the shape and construction of the barrows located in the discussed survey grids, as these factors clearly influence the results of the magnetometric prospection. When interpreting the results, it is necessary to determine the natural lithography of the research area, i.e. the peripheries of the Podolian Upland and Subcarpathia. The sediments that formed the watershed on which the barrows in Bukivna are concentrated primarily consist of silt fractions, deposited here in the Pleistocene due to the effects of weathering processes in the Carpathian Mountains (Matoshko 2004; Łańczot *et al.* 2002). As a result of aeolian accumulations, lithologically homogeneous layers of loess cover were formed, which make up the uppermost stratum within the studied area. In consequence, we can expect uniform magnetic background readings in the resulting images. Even though the use of a gradiometer did not make it possible to read the absolute values of the magnetic field strength of these sediments, in each case it was expressed as a constant zone of neutral values approximately amounting to  $0 \text{ nT m}^{-1}$  (the relative value adopted during instrument calibration). In consequence, it is possible to show that the natural stratigraphy in the cemetery area in Bukivna is uniform, especially within the area of research grids I and II.

In the case of barrow 1 from group II (grid I), a comparison of the magnetometric, hypsometric and excavation results (Fig. 1) allows for an in-depth discussion and consideration of the coherence of the results provided by the individual methods. Still, the unique layout of the magnetic anomalies does not allow for an unambiguous explanation

in reference to terrain morphology or the stratigraphy documented during excavations.

The observed anomalies take a form of concentric ring-like signals with alternating degree of magnetisation, covering the entire mound and its immediate vicinity. The magnetisation values reach the positive maximum of the scale at the mound's flattened top, then decrease below 0 nT near the slopes, and become positive again in the flat areas adjoining the slopes. One possible explanation would be the geomorphology of this funerary structure. Assuming that the arrangement of the anomalies corresponds to or reflects the morphology of the terrain, the effects of denudation processes should also be taken into account. In this context, we can distinguish three zones roughly coinciding with abovementioned distribution of the anomalies: a – the flattened barrow top (a relatively stable zone), b – the slopes (where erosion processes are clearly observable), and c – the foot of the barrow (the accumulation zone). This interpretation is justified if we assume an originally higher magnetic susceptibility of the barrow (resulting from the use of turf as a building material) in relation to the subsurface layers in its vicinity. In this way, the denudation processes would over time contribute to the mineral depletion (of ferrous compounds) of the slopes compared to the foot of the barrow, while the top remains intact. This hypothesis is very probable, especially if we look at the mound's morphological profile. The westernmost part of the barrow and its base have an increased magnetisation value. This corresponds to the main direction in which the area slopes. As already mentioned, the barrow was constructed on terrain that gently dips towards the west, as a result of which the largest accumulation of material should be located at that side of the mound.

Yet another idea concerning the specific layout of the anomalies has been put forward based on the comparison of the magnetometric image with the results of the archaeological excavations. It can be assumed that the distribution of the anomalies reflects the conical arrangement of the layers forming the barrow, taking into account the high level of ferromagnetic minerals which increase the magnetic susceptibility of the lowest layer (turf blocks) in relation to the secondary layer (loess). This difference contributed to the creation of a characteristic dipolar anomaly with a positive maximum in the spot with the highest concentration of material (the peak zone) and the negative maximum around it (the slopes). In this case, the centre of the anomaly would

correspond to the original feature made of turf, and the external one to the secondary loess cover. However, the question remains whether the magnetic field anomaly generated by this layering of material (turf blocks) is strong enough for the magnetometer to register, despite the presence of the overlying layers of loess which are between 0.7 and 1.4 m thick.

Considering the magnetisation of the material forming the body of the barrows, it should be noted that the turf mantel could have constituted a distinct layer of reduced permeability. At this stratigraphic level, magnetically susceptible iron or manganese minerals would accumulate from the water run-off, thus contributing to the increase magnetisation degree of the layer. In an alternative approach, it could be assumed that the ring-like signals showing positive or negative values are parts a single normally-polarized, dipolar anomaly resulting from induced magnetization including both the secondary and original layers.

In the case of research grid I, the specific features of the area should also be noted that possibly affected the final outcome of the research. First and foremost, the identified barrow was relatively high (2.5 m) – a factor which in combination with dense forest overgrowing the site hindered the conduct of magnetometric survey. The steep slopes of the barrow caused that the probe had to be raised and carried at the varying height above the ground level while ascending and descending, which in turn contributed to possible sampling irregularity. As the mound flattened out towards the top, the probe was lowered again and the regularity of the measurements was regained. In comparison with magnetically positive peak, the barrow's slopes provided lower values, thus it would be interesting to consider whether observed spatial structure of magnetisation is indirectly also an effect of applied methodology.

All of the presented hypotheses concerning the interpretation of the magnetometric results regarding the structure of the barrow and the morphology of the terrain require thorough verification in the course of further research. Until more data is collected, an indication of the most probable explanation of observed anomalies is impossible.

The magnetometric image from the second research grid, encompassing barrows 6 and 7 in group I, was no less complicated. The first important observation was the lack of an anomaly suggesting the run-off of material rich in ferromagnetic minerals, despite the fact that the mound has quite a significant height (ca. 1.4 m). The second

observation is that certain archaeological structures overlapped with the anomalies registered in the magnetometric survey.

To propose an explanation for the complicated distribution of magnetic anomalies, we should consider the stratigraphy of both monuments. The barrows were covered by a layer of modern humus up to 0.2 m thick, underneath which there was a layer of light grey loess ca. 0.2–0.25 m thick. The original body of the mounds, formed by layers of turf arranged with the vegetation facing downward, was present at a depth of 0.4 m from the mound tops. It consisted of two levels that differed in colour. The original humus, dark brown or black in colour, was located at a depth of 1.5–1.6 m and was ca. 0.25–0.3 m thick, while the natural (i.e. light grey loess characteristic for the region) lay beneath the humus. It is therefore possible that the accumulation of turf rich in iron compounds contributed to raising the magnetic susceptibility of the barrows in relation to the soil in their vicinity. This is probably the reason behind the increased magnetisation of the mound surfaces (the peak and the slopes), which are reminiscent in shape of a normally polarised dipolar anomaly with a positive maximum on the southern side of the slopes and a negative on the northern one.

In addition, in the western part of barrow 6 (the western one), graves of the “mortuary house” type were discovered, constructed from wood, clay and earth (Fig. 3). An analysis of the features’ stratigraphy has revealed that they were built before the construction of the mound, at a depth of about 0.9–1.3 m from the top of the barrow, on the original ground. One of the structures was made from oak trunks, of which part was hewn horizontally and cut vertically, while the other – also built from oak – consisted of wooden framing that gave it a chamber-like appearance. Both features were hardened using clay, applied with great precision to the crevices between the tree trunks. Before the structures were fully covered with earth, they were ritually burned, as a consequence of which a distinct anomaly is emitted in this sector. As an effect of high-temperature combustion, the soil took on an orange or brick-red colour, and acquired new magnetic properties. The increased magnetic susceptibility of the burnt organic material or overheated mineral sediments is a frequently observed phenomenon, explained as the Le Borgne effect (Le Borgne 1955; 1960; Schmidt 2007). In both mounds, other structures, including cenotaphs, small wooden buildings and vessel deposits, were situated in the original humus strata or virgin

soil strata (up to a depth of 1.8 m). Even though these features consisted of fragments of burnt wood, charcoal and overheated soil (signs of the intentional use of fire at those spots), they did not form a single, planographically legible, consistent anomaly in the magnetometric image. These structures did not produce any distinctive signals as in the case of the “mortuary houses” (probably due to the depth at which they were located); nonetheless, the spots where they are present always indicate a positive gradient value.

In contrast to barrow 1 from group II, where magnetisation structure is a consequence of mound morphology (namely its height, steepness and thickness of the layers) and denudation processes on the slopes, the geophysical survey of the barrows 6 and 7 from group I managed to partially reveal inner features concealed under topsoil. A number of structures and graves with magnetically strong and clearly discernible signals has been discovered in the latter mounds, whereas they were not attested in the case of barrow 1 from group II. Due to intense anomalies originating from these features, it can be presumed that any effects of natural pedological processes occurring in the barrows 6 and 7 that could alter original magnetic susceptibility of the soil were somewhat “suppressed” on the magnetometric image. Nonetheless, one should pay attention to kidney-shaped streak consisting of negative values at the circumference of the “double mound”, possibly a residue of denudation on the slopes.

## Conclusions

Our research has allowed us to observe some exceptionally complex magnetisation structures, the nature of which cannot be determined with complete certainty. The overlapping magnetic fields of the adjacent barrows 6 and 7 from group I, together forming the so-called “double mound”, made it impossible to separate them solely on the basis of magnetometric imagery. Only subsequent excavations allowed to distinguish the two individual mounds from each other. In the case of the mound 1 from group II, the arrangement of the anomalies potentially reflects a number of different aspects related to the mound’s stratigraphy and state of preservation, beginning with postdepositional processes connected to erosion and the run-off of material down the slope, and ending with the two stages of the mound’s development. Barrows 6 and 7, partly

connected by earthen mantle, are a special case due to the accumulations of burnt organic material with strong magnetic properties. On the other hand, the considerable size of barrow 1 from group II, which is higher than most of the mounds at the cemetery, arguably had some influence on the results of magnetometric survey. This in turn draws attention to the problems facing application of geophysical methods in the studies of archaeological features of distinctive landscape form.

The main conclusion stemming from presented research is the need for a multifaceted consideration of potential sources of magnetic anomalies occurring within the prehistoric earthen mounds, in the light of available data collected i.a. on the cemetery in Bukivna. Due to the possibility that residues of various processes (both natural and anthropogenic) end up being superimposed onto the two-dimensional magnetometric image, in each case the results of interdisciplinary studies have to be verified and subjected to comparative analysis. Recommended methodology to achieve this goal could be the three-stage approach as applied at Bukivna, involving the following steps: preparation of a digital elevation model of the site, conducting geophysical survey e.g. using magnetometry, and verification of the results with direct exploration techniques of a varying degree of invasiveness, e.g. drillings, test trenches or full-scope excavations, depending on the circumstances. Nevertheless, it has to be kept in mind that due to the structural heterogeneity of barrows and variety of postdepositional processes affecting them, establishing the general conditions governing the occurrence of magnetic anomalies in this regard might be impossible. Hence, every case should be considered individually with respect to observations and experiences hitherto gathered during similar surveys.

A research perspective that would enable a more precise determination of the nature of the geomagnetic anomalies, as well as providing a reliable interpretation of this phenomenon, would require further interdisciplinary work and discussion. One promising step seem to be laboratory tests determining the magnetic susceptibility of samples taken from the sediments in various zones of the barrows affected by erosion. In addition, it would be useful to develop a database containing information on magnetometric prospectations at other sites with distinctive landscape form – in particular other barrows – and their verification through excavations (or drilling). The authors have already carried out a number of geophysical surveys of mounds within the scope of the project devoted to cataloguing

barrow cemeteries in the Upper Dniester River Basin (Makarowicz *et al.* 2016a), while at present they are conducting comparative analyses focusing on explaining the nature of the anomalies detected within the barrows.

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