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APPLICATION OF NON-DESTRUCTIVE METHODS ON THE TVRDOŠOVCE SITE (PRELIMINARY RESULTS)[1]

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Keywords: *south-west Slovakia, Tvrdošovce, polycultural site, La Tène period, Roman period, settlement, non-destructive archaeology, settlement pattern analysis.*

Abstract: Application of non-destructive methods on the Tvrdošovce site (preliminary results). *The paper presents the application of non-destructive methods on the Tvrdošovce site. The goal of the paper is to inform about the latest results of a non-destructive survey at the Včelíny site in the village of Tvrdošovce. The case study of this site aims to present a combination of various non-destructive methods such as geophysical survey, LiDAR, aerial, and satellite photos with a subsequent comparison with features that previously underwent a process of archaeological excavation. This polycultural site has primarily the character of a settlement. Based on metal prospection, the largest settlement scope may be dated to the Roman period; based on archaeological excavation, the largest period of the settlement may be the middle La Tène period in LTB2/LTC1 and LTC2. An archaeological excavation was performed on the site from 2017 to 2019. Prior to this, an intense surface prospecting using metal detectors had been carried out on this site since 2015. This prospection showed significant Roman, and, to a lesser extent, Bronze Age, Hallstatt, La Tène, and Middle Age settlements. In addition, two geophysical surveys were carried out here in 2017 and 2022. Non-destructive methods are often considered ineffective in the case of lowland sites. Nevertheless, we will try to present a successful example of a combination of these different approaches in the presented article.*

1 INTRODUCTION

In recent years, it is possible to observe a progress in the research on La Tène lowland settlement in the Central European area. An accompanying phenomenon of this is the frequent use of non-destructive methods. This approach was followed – e.g. – in Roseldorf (*Holzer 2007*), Nemčice na Hané (*Křivánek 2014*), Drnholec (*Komoróczy et al. 2019*) or in Haselbach, Etzersdorf,

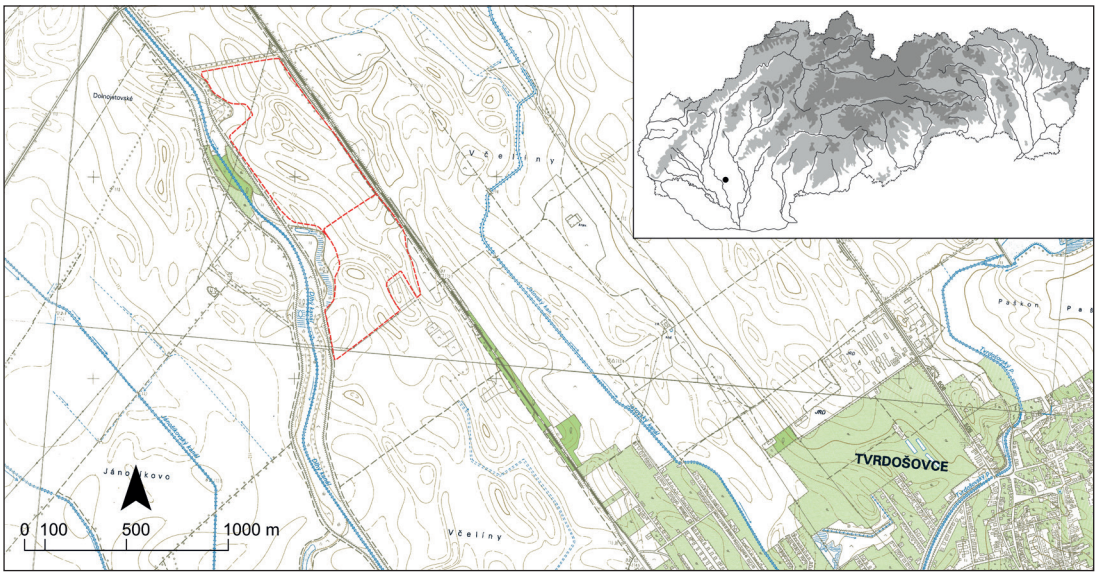

Fig. 1. Tvrdošovce – Včelíny. Site localisation in the base map. Studied area in red (author: R. Čambal).
Obr. 1. Tvrdošovce – Včelíny. Lokalizácia náleziska na základnej mape. Skúmaná oblasť červenou (vyhotovil: R. Čambal).

[1] Our special acknowledgement for their help with geophysical surveys goes to Mgr. Dávid Šálka and Mgr. Jakub Benech.

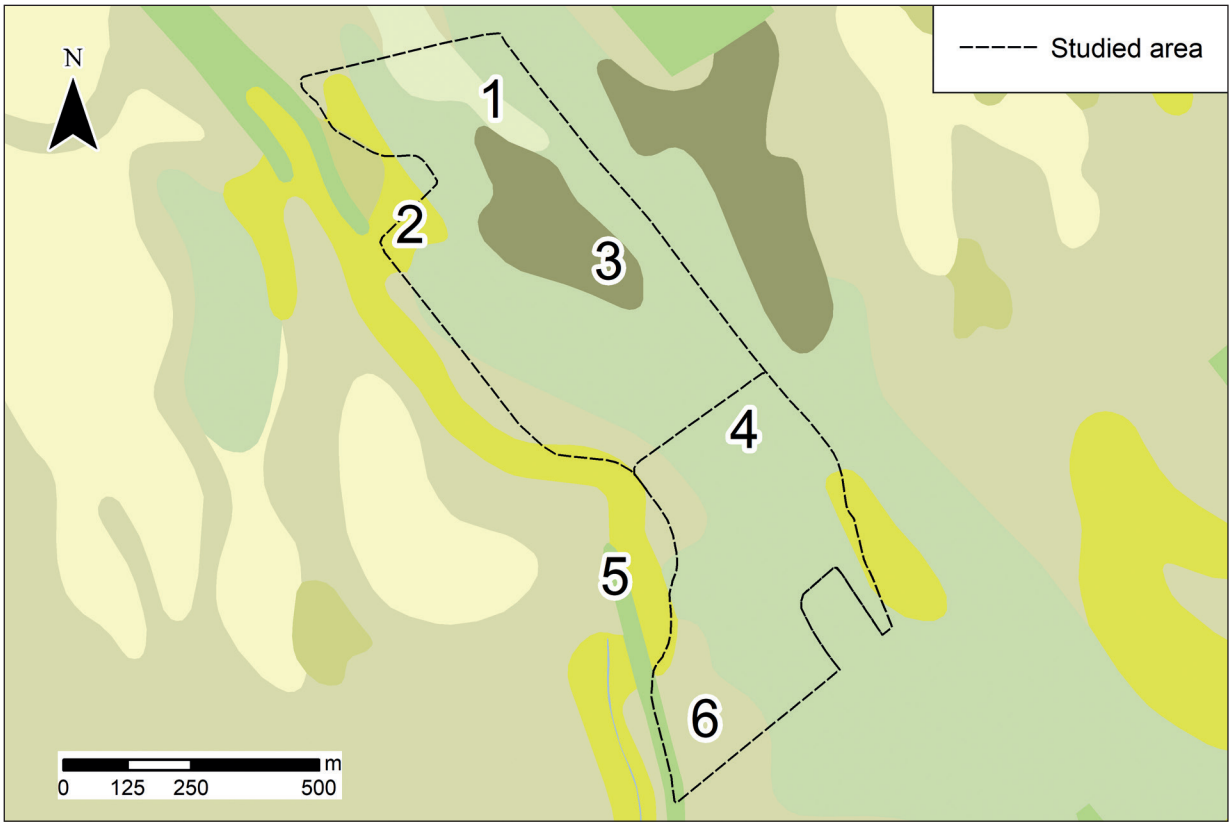

Fig. 2. Tvrdošovce – Včelíny. Geological background of the studied area. Legend: 1 – fluvio-organic sediments: fine-grained sandy, clayey to muddy humous loams of dead channels and swamps; 2 – fluvio-organic sediments: fine-grained sandy, clayey to muddy humous clays of dead channels and swamps; 3 – fluvial sediments: gravel, sandy gravel and sands in low terraces with coverage of eolian sands; 4 – fluvial sediments: mostly sands or gravel sands of floodplain bottom accumulations and low terraces; 5 – anthropogenic sediments: dumps, heaps and piles; 6 – fluvial sedimets: non-articulated floodplain loams or sandy to gravel loams of valley floodplains and floodplains of mountain streams (source: https://www.geology.sk/2018/02/28/geologicka-mapa-slovenska-150-000/; author: A. M. Rekemová).

Obr. 2. Tvrdošovce – Včelíny. Geologické podložie skúmanej oblasti. Legenda: 1 – fluviálno-organické sedimenty: jemnopiesčité, ílovité až hnilokalové humózne hliny mŕtvych ramien a močiarov; 2 – fluviálno-organické sedimenty: jemnopiesčité, ílovité až hnilokalové humózne hliny mŕtvych ramien a močiarov; 3 – fluviálne sedimenty: štrky, piesčité štrky a piesky v nízkych terasách s pokryvom eolických pieskov; 4 – fluviálne sedimenty: prevažne piesky až štrkovité piesky dnových akumulácií v nivách a nízkych terasách; 5 – antropogénne sedimenty: navážky, haldy a skládky; 6 – fluviálne sedimenty: litofaciálne nečlenené nivné hliny, alebo piesčité až štrkovité hliny dolinných nív a nív horských potokov (zdroj: https://www.geology.sk/2018/02/28/geologicka-mapa-slovenska-150-000/; vyhotovil: A. M. Rekemová).

and Stripfing (*Trebsche 2016*). Non-destructive methods may significantly help study much larger areas, but in many cases they don't allow a completely clear interpretation. For this reason, it is necessary to define research questions with regard to the concrete site.

Between 2017 and 2019, a systematic archaeological research was carried out in the polycultural site of Tvrdošovce – Včelíny (Fig. 1; *Furugláš et al. 2019*). At the same time, here they also performed surface prospecting activities and two geophysical surveys. This situation allows us presenting an example of combination of non-destructive archaeological methods and subsequent archaeological verification in the field.

The studied site has a polycultural character, with main settling activities dating to La Tène and Roman period. Since 2015, they have carried out intensive surface prospection with the help of metal detectors. This prospection showed remarkable signs of settlements from the Roman period and – to a lesser extent – from Bronze, Hallstatt, La Tène, and Middle Age periods. Between 2017 and 2019, archaeological research

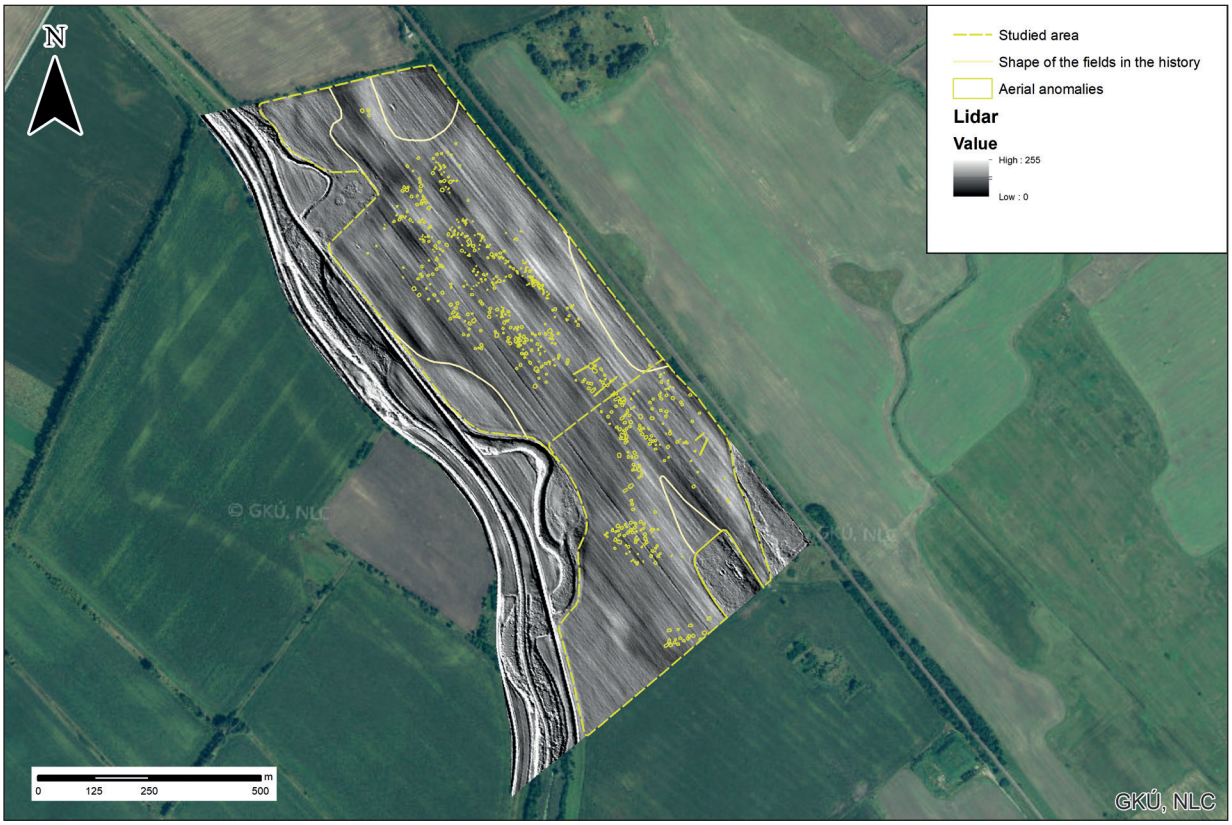

Fig. 3. Tvrdošovce – Včelíny. Interpretation of anomalies from aerial signs in the digital model of the relief (source: Geodetic and Cartographic Institute Bratislava, National Forest Centre, Geodesy, Cartography and Cadastre Authority of the Slovak Republic, mapy.cz, Google Earth Pro; author: A. M. Rekemová).

Obr. 3. Tvrdošovce – Včelíny. Interpretácia anomálií z leteckých príznakov na digitálnom modeli reliéfu (zdroje: Geodetický a kartografický ústav Bratislava, Národné lesnícke centrum, Úrad geodézie, kartografie a katastra SR, mapy.cz, Google Earth Pro; vyhotovil: A. M. Rekemová).

was carried out in this place. During archaeological research operations, they examined nine settlement-related features from middle La Tène, Roman, and Middle Age periods.

2 TOPOGRAPHIC FEATURES

The area is mainly characterised by fluvial sediments (Fig. 2), mostly sands or gravel sands of floodplain bottom accumulations and low terraces. It also shows presence of gravel, sandy gravel and sands in low terraces with coverage of eolian sands, non-articulated floodplain loams or sandy to gravel loams of valley floodplains and floodplains of mountain streams (*Geologická mapa SR*).

Thanks to freely accessible data in form of digital relief model (DMR 5.0), it is possible to observe the current shape of terrain.[2] As for the topography of the site, data from freely available sources were used with an area of about 91,6 ha (Fig. 3). Subsequently, they were elaborated with the help of the Relief Visualization Toolbox software (*Kokalj/Somrak 2019*; *Zakšek/Oštir/Kokalj 2011*).[3] The principal component analysis (PCA) resulted to be the most suitable amongst the available calculations. The results show ground irregularities, which warn about moderate height differences in the studied area. When watching the older aerial images from 2013[4] it is possible to observe a change in the delimitation of single fields that is not corresponding to current status

[2] https://www.geoportal.sk/sk/zbgis/lls-dmr/ (source LLS: Geodesy, Cartography and Cadastre Authority of the Slovak Republic).
[3] Relief Visualisation Toolbox – https://www.zrc-sazu.si/en/rvt, cit. 12.06.2023.
[4] Google Earth Pro year 2013 SE part. In 2020, it is possible to observe a change in the shape also in the NW area of the analysed field.

Fig. 4. Tvrdošovce – Včelíny. Site with geophysically studied territory in 2017 and 2022 (sources: Geodetic and Cartographic Institute Bratislava, National Forest Centre; measurement: D. Šálka, A. M. Rekemová, J. Benech; author: A. M. Rekemová).

Obr. 4. Tvrdošovce – Včelíny. Lokalita s geofyzikálne skúmaným územím v rokoch 2017 a 2022 (zdroje: Geodetický a kartografický ústav Bratislava, Národné lesnícke centrum; meranie: D. Šálka, A. M. Rekemová, J. Benech; vyhotovil: A. M. Rekemová).

and is partially reflecting the results of the geophysical surveys. The presence of the water source in this area is well known. It is located along the south-western border of the analysed field.

3 NON-DESTRUCTIVE SURVEY METHODS

Non-destructive archaeology includes a wide range of methods. Each method has its limits and optimal results may be achieved by combining the various methods. In the case of Včelíny, it was suitable to connect geophysical survey, aerial images[5], satellite pictures, and airborne laser scanning – from freely accessible sources. One of the aims of this non-destructive measurement is to ascertain the presence of positive and negative anomalies. Another goal is to identify the territorial range of the area.

The main method of the non-destructive survey was magnetometry (Fig. 4). Magnetometry is an integral and irreplaceable part of the entire set of non-destructive methods (*Clark 1990*; *Linford 2006*). Satellite and aerial images also result from airborne laser scanning are from freely accessible sources. The first measurement in the concerned area was carried out in March 2017 and it consisted of magnetometry survey (Fig. 5). An area with an extension of 1,38 ha was covered by a five-probe magnetometer – Magneto MXPDA (SENSYS, Germany) – measuring the vertical gradient of earth magnetic field. The area was divided in six independent smaller fields (G1–G6). The density of the measured points was 0,1

[5] https://sk.mapy.cz, cit. 3.3.2023.

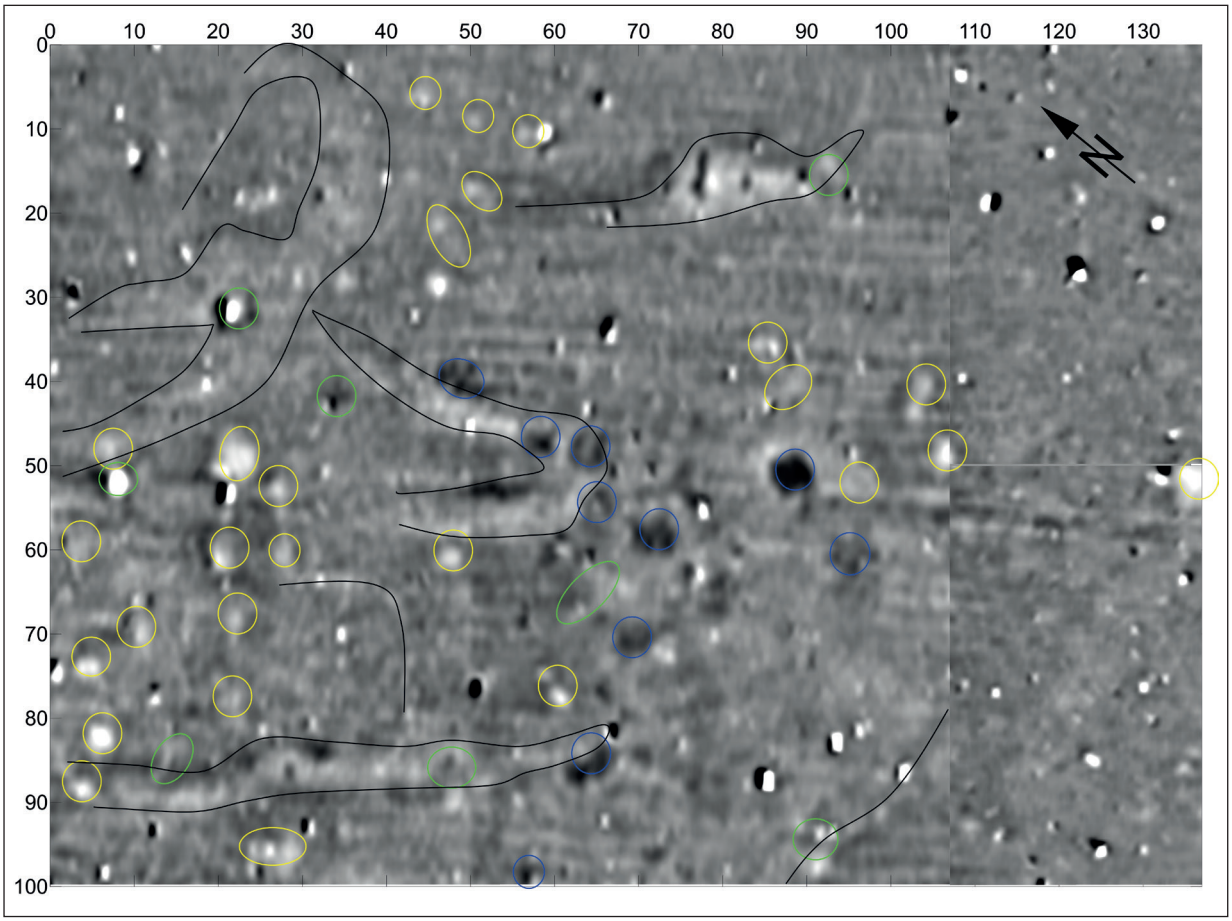

Fig. 5. Tvrdošovce – Včelíny. Geophysical survey carried out in 2017 with indication of potential anomalies. Legend: yellow – positive anomalies, blue – negative anomalies, green – hardly identifiable anomalies, black – linear structures of unknown origin (according to *Murín 2017*).

Obr. 5. Tvrdošovce – Včelíny. Geofyzikálny prieskum z roku 2017 s vyznačením potenciálnych anomálií. Legenda: žlta farba – pozitívne anomálie, modrá farba – negatívne anomálie, zelená farba – ťažko čitateľné anomálie, čierna – lineárne štruktúry neznámej genézy (podľa *Murín 2017*).

x 0,25 m. The number of potential archaeological features recorded was 44; 26 of them were positive, 10 negative, and 8 scarcely readable (*Murín 2017*).

The second survey was carried out on 24 and 25 November 2022. The instrument used was the magnetometer fluxgate LEA MAX (Eastern Atlas, Germany) with ten probes (Fig. 6). The probes (FEREX CON 650, Foerster, Germany) were placed at a mutual distance of 0,5 m. This gradiometer executes measurements with a density of 0,5 x 0,1 m. The results were directly localised by means of a GNNS receiver – Trimble R-10 model 2 (Trimble, USA). The prospection was carried out in ATV mode, i.e. with the use of quad (*Milo et al. 2020*, 185). The data were interpreted in the ArcMap 10. 8. 2 programme; during the second survey, an area of 23 ha was measured.

4 ARCHAEOLOGICAL RESEARCH

Between 2017 and 2019, an archaeological research was carried out in the location of Včelíny for scientific and documentary purposes. Nine settlement features were analysed. Six of them were from middle La Tène period (LTB2/LTC1–LTC2). In four cases, they were pit-houses with two or three posts in framework, with the posts located in the centre of the shorter sides and one post in the centre of the axis between them (Obj. 1/2017, 3/2018, 4/2019, 5/2019). In the remaining two cases, we have storage pits from La Tène period (Obj. 4A/2019 and 4B/2019). One

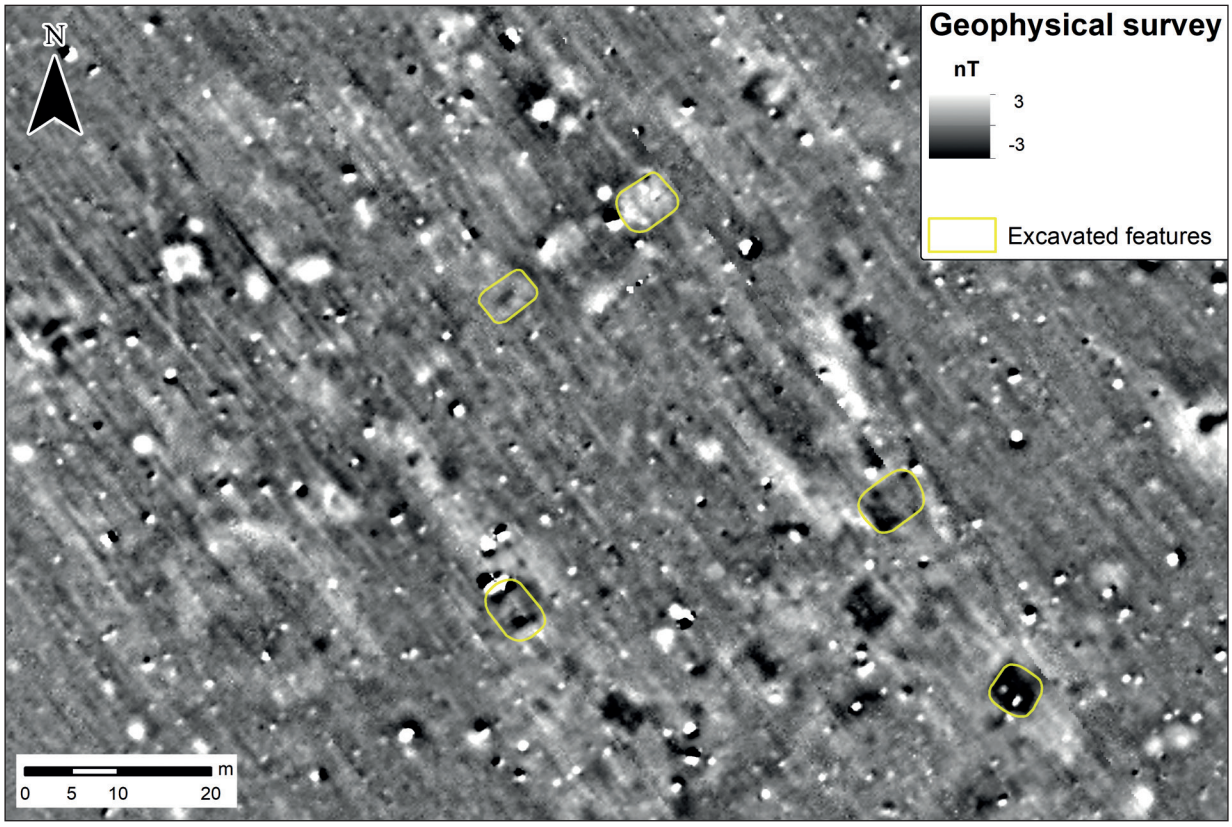

Fig. 6. Tvrdošovce – Včelíny. Results of magnetometry from 2022 on the area of the 2017 survey and on the places of the archaeologically analysed features in 2017 – 2019 (measurement: D. Šálka, A. M. Rekemová, J. Benech; author: A. M. Rekemová).

Obr. 6. Tvrdošovce – Včelíny. Výsledky magnetometrie z roku 2022 na ploche prieskumu z roku 2017 a na mieste archeologicky skúmaných objektov v rokoch 2017 až 2019 (meranie: D. Šálka, A. M. Rekemová, J. Benech; vyhotovil: A. M. Rekemová).

pit-house (Obj. 2/2017) belongs to early Roman period (C2–C3). Two features in the shape of settlement pits, analysed in superposition with La Tène features 5/2019 date back to the Middle Ages (13th century).

Feature 1/2017 (Fig. 7: 1) – rectangular pit-house with three post structure, with a pair of post in the centre of the shorter sides. The third post was shallowly deepened in the bottom of the feature and was placed in the centre of axes (in between). The feature was filled with soil, with a layer of orange burnt daub. Underneath this layer, in the lower part, there was a strong ash layer of about 0.4 m. La Tène shards, animal bones, and small fragments of iron objects were found in the filling. Feature orientation: NE-SW. Dimensions: 4.7 x 2.7 m; depth: 1.2–1.3 m from ground level.

Feature 2/2017 (Fig. 8) – Germanic square-shaped pit-house with seven post structure, with central post. In the southern side there was an entrance niche. It belongs to the early Roman period (C2–C3). The feature was filled with a compact backfill coat of grey-brown soil, without layers. The filling includes Germanic shards, a bronze brooch with ligated stem, copper Roman coins, a golden wire, bronze decoration, a tip of an iron sickle, bronze and bone needles, and animal bones. Feature orientation: N–S. Dimensions: 5.1 x 5.1 m; depth: 0,6 m from ground level.

Feature 3/2018 (fig. 7: 2) – rectangular pit-house with two post structure, with posts in the centre of the shorter sides. Along the southern wall there was an earthen bench. The filling of the feature consisted of soil layers. Underneath these layers, there was a destroyed wall made up of burnt orange daub. Underneath the wall, there were layers of soil mixed with ash and charcoal.

Fig. 7. Tvrdošovce – Včelíny. Pit-houses from middle La Tène period: 1 – feature 1/2017, 2 – feature 3/2018, 3 – feature 4/2019, 4 – feature 5/2019 (photograph: R. Čambal).

Obr. 7. Tvrdošovce – Včelíny. Zemnice zo strednej doby laténskej: 1 – objekt 1/2017, 2 – objekt 3/2018, 3 – objekt 4/2019, 4 – objekt 5/2019 (foto: R. Čambal).

The feature contained La Tène shards, iron slag, and animal bones. Two almost complete vessels were located on the bottom. Feature orientation: NNE–SSW Dimensions: 5.05 x 3.7 m; depth: 1,5 m from ground level.

Feature 4/2019 (fig. 7: 3) – rectangular pit-house hut with two post structure, with a pair of posts in the centre of the shorter sides. The filling of the feature consisted in a layer of black soil. Above the bottom, there was a layer of burnt orange daub and ash, lying on a layer of charcoal. The floor was daubed with clay. The filling included La Tène shards, two bronze wire brooches, small fragments of iron objects, and animal bones. Feature orientation: NW–SE. Dimensions: 5 x 4,1 m, bottom: 4.45 x 2.85 m; depth:

Fig. 8. Tvrdošovce – Včelíny. Feature 2/2017 – Germanic pit-house (photograph: I. Bazovský).

Obr. 8. Tvrdošovce – Včelíny. Objekt 2/2017 – germánska chata (foto: I. Bazovský).

1,15 m from ground level. The feature was located in superposition with a pair of La Tène storage pits (features 4A and 4B), located at both sides of its southern half. Both of them were filled with a uniform backfill of soil containing shard material from La Tène period.

Feature 5/2019 (fig. 7: 4) – rectangular pit-house with two post structure, with posts in the centre of the shorter sides. The filling of the feature consisted of a compact layer of thick black soil. The floor was daubed with clay and made up of several layers with a size of 1–2 cm. The feature included La Tène shards, small iron objects, two fragments of sapropelite bracelets, and animal bones. Feature orientation: NE-SW. Dimensions: 7 x 5,25 m, depth 1,35 m from ground level. The feature was lying in superposition with a pair of medieval storage pits (features 5A and 5B), located in its south-western part. Both of them were filled with a uniform backfill of soil containing innumerable medieval shard material. In the feature 5A, they also found an iron bell clapper together with pottery, which can be dated to the 13th century.

5 RESULTS

Already in 2017, at times of the early survey, it was clear that it was necessary to compare the geophysical survey results with the anomalies in the aerial images. It has been shown that not all geophysical anomalies can be reliably identified with weaker vegetation signs on aerial photographs (*Murín 2017*). By comparing the second measurement from 2022 with aerial images, the same phenomenon can be observed (Fig. 9). Nevertheless, even the reverse situation occurred; and it was possible to follow the archaeological features in the form of vegetation signs in the aerial imagery (whereas their expression in the magnetic data is not clear). By looking at the monitored area, it is possible to interpret a total of 726 anomalies from freely available images. They are in relation with the elevated places that were identified on the basis of the airborne laser scanning data. Unfortunately, potential anthropogenic signs were displayed in the aerial photographs only in 2/3 of the possible range of the site. We know that the site continues even in the south-eastern direction. Nevertheless, for the purposes of aerial imagery, the unsuitable vegetation inhibits the identification of whatsoever structure.

Another useful element was the comparison between the magnetogram and the airborne laser scanning. Even in this case, it is as though the anomalies correspond to the terrain irregularities. It is possible to observe a significant (although not exclusive) absence in the lowest parts of the studied area (Fig. 3 and 4). In the concerned area, the settlement is concentrated in some clusters. With regard to the central part, it is possible to observe that the settlement continues in north-west direction (Fig. 3). The question is whether this is due to the way the settlement was organised in the past (and it is therefore a deliberate urban form) or whether we are observing the absence of anomalies, for example due to overlaying with sediments. By taking into consideration the surrounding terrain, we can observe a direct connection between the settlement and the water course. At the same time, it can be argued that this is not an uncommon phenomenon. Even J. Waldhauser (*1976*, 297, 298) informed about a similar situation. We also

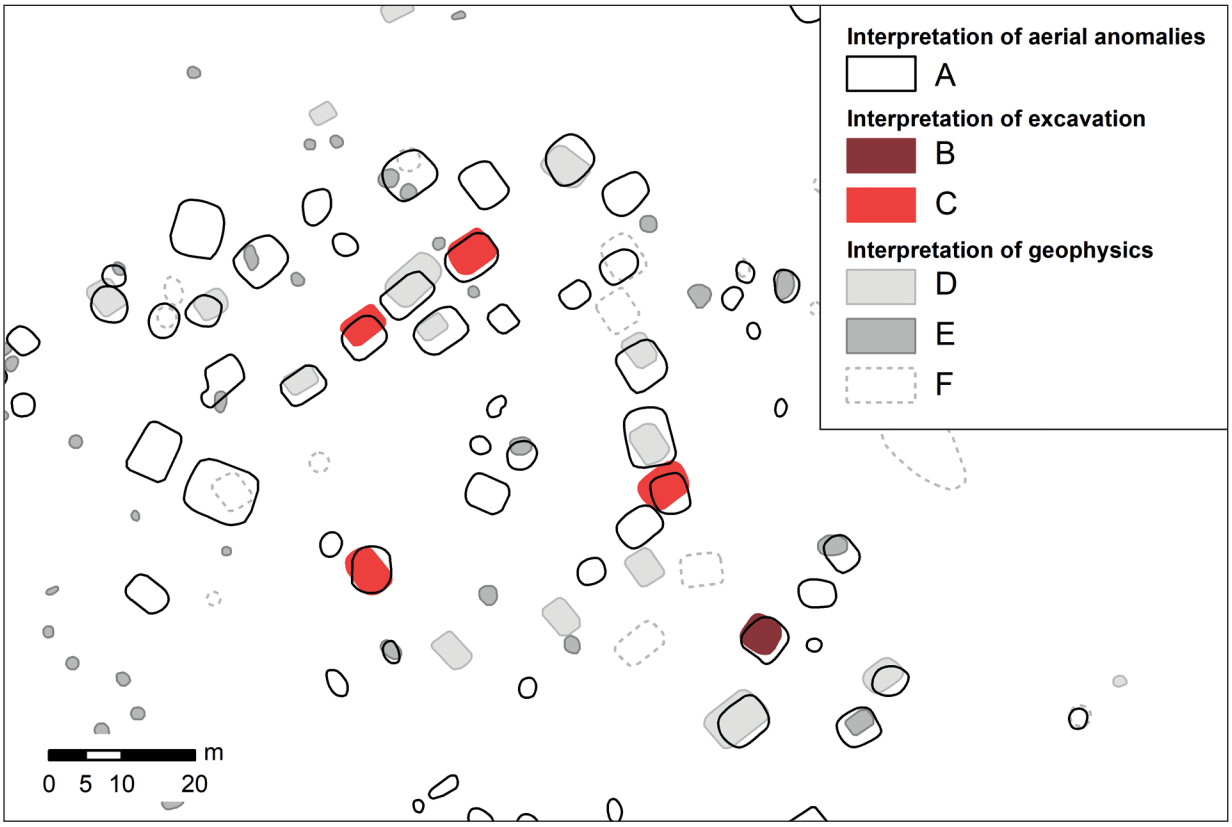

Fig. 9. Tvrdošovce – Včelíny. Geophysically studied area in 2017 with interpreted anomalies according to geophysics in 2022, aerial images and defined position of archaeologically analysed features in 2017 – 2019. Legend: a – vegetation signs, b – pit-house (Roman period), c – pit-house (La Tène period), d – potential pit-houses, e – features, f – questionable features (source for aerial indications: mapy.cz, author: A. M. Rekemová).

Obr. 9. Tvrdošovce – Včelíny. Plocha geofyzikálne skúmaná v roku 2017 s interpretovanými anomáliami podľa geofyziky z roku 2022, leteckých snímok a s vyznačenou polohou archeologicky preskúmaných objektov v rokoch 2017 až 2019. Legenda: a – porastové príznaky, b – zemnica (doba rímska), c – zemnica (doba laténska), d – možné zemnice, e –objekty, f – otázne objekty (zdroj pre letecké príznaky: mapy.cz, autor: A. M. Rekemová).

know some other similar topographic sites – e.g. Berching-Pollanten (*Fischer et al. 1984*, 316), Radovesice (*Waldhauser et al. 1993*, 5), Drnholec (*Čižmář/Jelínková 1985*, 21).

According to freely available aerial images[6], the site extension is of about 50 ha.[7] The geophysical survey focused on a surface of 23 ha. Therefore, it is possible to observe and analyse only part of the total extent of the site. The prospection revealed 417 anomalies. Here, a vast majority of anomalies (340 cases) can be identified as anomalies with positive magnetic values. There were 62 negative anomalies (Fig. 10).

If we focus on the shape comparison of the results of magnetometry and aerial survey, then we find out that a given shape of an anomaly detected on aerial photographs may not correspond to the same anomaly that is visible on a geophysical survey. For this reason, all anomalies were taken into account, incl. the smaller ones. The area surveyed with the magnetometer presented about 201 vegetation signs (in 123 cases we have an overlapping with the results of the geophysical survey). In 78 cases, we have anomalies that are visible in the vegetation signs, but not in the geophysical survey (Fig. 11).

The function of the single features recorded by the geophysical survey is unclear and it can be re-interpreted through subsequent archaeological research. Preliminarily, 102 of the rectangular

[6] https://sk.mapy.cz

[7] On the basis of vegetation signs, features are observed also in the eastern part, beyond the railways, but no geophysical surveys were carried out in this zone.

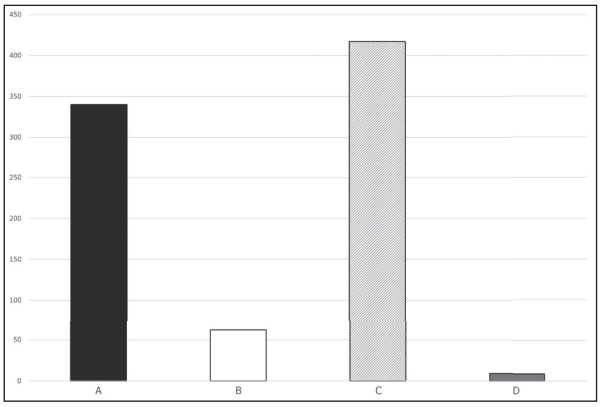

Fig. 10. Tvrdošovce – Včelíny. Approximate number of anomalies in the 2022 geophysical survey and known features according to archaeological research. Legend: a – positive anomalies, b – negative anomalies, c – all geophysical anomalies, d – excavated features (author: A. M. Rekemová).

Obr. 10. Tvrdošovce – Včelíny. Približný počet anomálií na geofyzikálnom meraní z roku 2022 a objekty známe z archeologického výskumu. Legenda: a – pozitívne anomálie, b – negatívne anomálie, c – všetky geofyzikálne anomálie, d – vykopané objekty (autor: A. M. Rekemová).

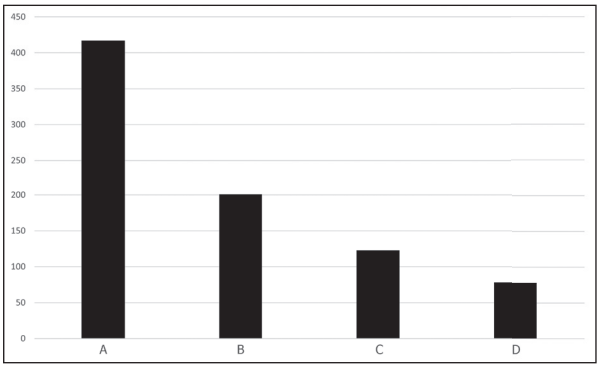

Fig. 11. Tvrdošovce – Včelíny. Comparison between aerial indications and geophysical survey in the space of the 2022 geophysical survey. Legend: a – geophysical anomalies, b – indications on aerial images, c – indications and anomalies visible both in the aerial images and in the geophysical survey, d – aerial indications not captured by geophysical survey (author: A. M. Rekemová).

Obr. 11. Tvrdošovce – Včelíny. Porovnanie leteckých príznakov a geofyzikálneho merania v priestore geofyzikálnej prospekcie z roku 2022. Legenda: a – geofyzikálne anomálie, b – príznaky na leteckých snímkach, c – príznaky a anomálie zároveň viditeľné na leteckých snímkach a geofyzikálnom meraní, d – letecké príznaky nezachytené geofyzikálnym meraním (autor: A. M. Rekemová).

anomalies can be identified as possible pit-houses with residential, manufacturing or housekeeping functions. As for the remaining features, the total number of anomalies is 252. They may be pits of various kinds or not clearly identifiable pit-houses, clay pits or other types of features. Some anomalies show high magnetic values that are typical for pyrotechnological features and objects (*Fassbinder 2015*, 87).

In terms of internal space arrangement, an interesting element is represented by the group of structures partly confirmed also by the archaeological research. Here, the identified features constitute a certain form of closed farmstead (Fig. 9). Moreover, on the basis of two archaeological studied features, we can assume similar or simultaneous dating also for spatially close anomalies. Preliminarily, they belong to the earliest stage of the area settlement in the La Tène period (end of LTC1 – years between LTC1 and LTC2). Analogous arrangements of features with internally almost intact space creating a farmstead are also known from other locations (Fig. 12) as for example Nitra-Šindolka (*Březinová 2000*, Abb. 4), Milonice (*Lečbych/Mikulová 2014*, Fig. 3) and it is possible also to think about the site of Michelstetten (*Trebsche 2010*, Abb. 57a–d; *2020*, Abb. 3.24).

One of the possible explanations of the occurrence of positive anomalies also resides in the fact that the topsoil shows magnetically strong values; and the feature with such a filling may show positive values (*Clark 1990*, 65, 66; *Fassbinder 2015*, 88). Later if the filling of the feature is compact topsoil, then this situation presented in anomaly can reliably reflect the form of of archaeologicised activity (*Fassbinder 2015*, 88).

Negative anomalies are usually appearing in some concrete situations. They can originate from the material which was used for the given feature and has lower magnetic values; and – therefore – they can differ from topsoil where they were deposited. They could also be related to situations in which the dug feature was filled in a short time with its own filling. Another essential factor may also be water. If in the given area there is the same humidity of soils, but the level of groundwater is varying, there could be influences on the magnetic value of the anomaly. Consequently, a positive

Fig. 12. Sites with analogous arrangement of settlement structures: A – Tvrdošovce – Včelíny (source: mapy.cz, drawn up by: A. M. Rekemová), B – Nitra-Šindolka – without settlement sequences (according to *Březinová 2000*, Abb. 4), C – Milonice – Nivky – without settlement sequences (according to *Lečbych/Mikulová 2014*, obr. 3), D – Michelstetten (according to *Trebsche 2020*, Abb. 3.24). Red colour – potential spatial organisation. All plans were adjusted.

Obr. 12. Lokality s analogickou organizáciou sídliskových štruktúr: A – Tvrdošovce – Včelíny (zdroj: mapy.cz, vyhotovil: A. M. Rekemová), B – Nitra-Šindolka – bez fáz osídlenia (podľa *Březinová 2000*, Abb. 4), C – Milonice – Nivky – bez fáz osídlenia (podľa *Lečbych/Mikulová 2014*, obr. 3), D – Michelstetten (podľa *Trebsche 2020*, Abb. 3.24). Červenou farba – potencionálna priestorová organizácia. Všetky plány boli upravené.

anomaly might become negative. The origin can be searched in the geochemical reaction in connection with ferromagnetic particles and iron oxides (*Fassbinder 2015*, 88, 89).

By looking at the features studied by the first geophysical survey in 2017 (Fig. 5) and subsequently confirmed by the archaeological research, it is possible to observe the following results: two anomalies had positive values before excavation, two anomalies had negative values, and one anomaly cannot be clearly specified (*Murín 2017*). If we compare this status with the results obtained in 2022 (Fig. 6) – i.e. after the archaeological survey – the situation appears partially changed. On the basis of results, we can observe two positive and two negative anomalies. Compared to the first survey, the anomaly no. 4 appears slightly more significantly negative than before (see Fig. 6, 9). In some other cases, the filling is not so clearly identifiable as before excavation. We assume that the cause of this lies in the fact that the features were subsequently filled not only with their soil, but also with fillings partially mixed with topsoil – which might have partially modified the final magnetic values on magnetogram.

According to archaeological research, we know that features 1/2017, 3/2018, and 4/2019 contained layers with burnt daub and ash; and in features 3/2018 and 4/2019 also charcoal (Fig. 7, 8). Clay floors were documented in features 4/2019 and 5/2019. Nevertheless, these factors (concerning the results themselves) did not really differentiate the features from each other. Similarly, with regard to features 4/2019 and 5/2019, there was no visible superposition with the storage pits. Before the research, the

features 2/2017 and 3/2018 presented negative values (Fig. 5; *Murín 2017*); based on our knowledge of their archaeological filling, we are not currently capable of assessing the cause of such a phenomenon.

6 DISCUSSION AND CONCLUSIONS

The difference in the first geophysical survey – which in the course of three days covered an area of 1,38 ha (*Murín 2017*) – cannot be compared to the range of the second survey, whose measurement covered an area of 23 ha in just two days. Furthermore, it was shown reasonable to complement information by adding the results of the airborne laser scanning, satellite photographs, and aerial images (with consequent comparison of their outputs). Thanks to such a way of proceeding, it was possible to warn about one limit of the studied site. The laser scanning method helped map terrain prominences and irregularities in the studied area. Thanks to geophysical surveys we know that the observed anomalies are concentrated exactly in certain places.

Further research and discussion might focus on the absence of features or signs of their occurrence in the lower parts of the site. It is possible (albeit not sure) that there are features located under the layers of hardly readable sediments. Another relevant limit lies in the polycultural character of this site. This factor represents a significant bias for the interpretation of single structures. Comparison of aerial and satellite imagery from several years proved to be efficient. It showed the changing shape of fields and their delimitation. In some parts, the aerial/satellite images didn't show vegetation signs.

One of the aims of the research was to ascertain the possibility of observing negative/positive anomalies in a location with larger range. This fact was well confirmed, which gave rise to the question about the origin of the different magnetism of the features. For the purpose of further comparison, it shall be convenient to carry out a prospection even in other sites with similar dating.

On the basis of archaeological research, we know the contents of five features. The different character of their fillings cannot be reflected in the last results of magnetometry. Therefore, the question remains about how to methodically approach the study of this issue. A standard part of future research procedures shall be the measurement of magnetic susceptibility.

On the basis of a general assessment of outputs, it is possible to state that about 78 potential archaeological features recorded by the aerial images were not captured by the geophysical survey. This doesn't necessarily mean that they are not present. It just shows that there are more difficult to identify in the surrounding soil or in the potential cultural layer.

It proved reasonable to focus on the dating of a specific settlement structure consisting of several features. Analogies show that this mode of space arrangement is not an isolated case. We have signs of possible intended organisational and urbanistic planning of the settlement, at least during a certain phase of settling (in this case, during the La Tène period). Analogous sites were also archaeologically studied. That's why it was possible to identify their various phases of construction. The absence of features in some parts of the analysed space is all the more striking. As for Tvrdošovce, we cannot state with certainty that this central area was not built up. However, thanks to magnetometry, we can at least assume it.

It is clear that the Tvrdošovce site offers space for further non-destructive surveys in close cooperation with field archaeological research. On the basis of aerial images, we can observe that the settlement could continue also in the north-east direction, towards the railway line. Moreover, the results of the previous detector prospection show that the findings are concentrated also south-east of the border of the area that was subject to geophysical survey. Future research activities will have to focus on the total extension of the given site and on possibilities of dating the features ascertained through geophysical methods.

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APLIKÁCIA NEDEŠTRUKTÍVNYCH METÓD NA LOKALITE TVRDOŠOVCE (PREDBEŽNÉ VÝSLEDKY)

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Polykultúrna lokalita Včelíny v Tvrdošovciach (okr. Nové Zámky) je známa vďaka detektorovej prospekcii a niekoľkoročnému systematickému archeologickému výskum (2017–2019). Počas archeologického výskumu tu bolo odkrytých deväť objektov, medzi ktorými boli štyri zemnice a dve zásobné jamy datované do doby laténskej (LTB2/LTC1–LTC2), jedna polozemnica datovaná do doby rímskej (C2–C3). Okrem toho zo stredoveku pochádzajú ďalšie dve sídliskové jamy (13. storočie; obr. 7, 8).

Terénnu situáciu na lokalite bolo možné vyhodnotiť na základe voľne prístupného digitálneho modelu (DMR 5.0). Bola analyzovaná plocha 91,6 ha (obr. 3). Pre výpočet bol použitý software Relief Visualization Toolbox (RVT). Prínosná bola primárne analýza hlavných komponentov (principal component analysis – PCA). To umožnilo sledovať terénne nerovnosti zapríčinené odlišnou výškou.

Z rôznych metód nedeštruktívnej archeológie bolo použité geofyzikálne meranie, letecké snímky, satelitné snímky a letecké laserové skenovanie (LLS). Mimo geofyzikálne meranie pochádzajú tieto dáta z verejne dostupných zdrojov.

Hlavnou nedeštruktívnou metódou použitou na lokalite bola magnetometria. Realizovali sa tu dve merania. Prvé prebehlo v roku 2017 a pokrylo 1,38 ha (obr. 5). Druhé meranie sa uskutočnilo v roku 2022 v rozsahu 23 ha (obr. 4). Na celej ploche bolo možné pozorovať pozitívne a negatívne anomálie.

Pri analýze leteckých/satelitných snímok bolo identifikovaných približne 726 porastových príznakov. Pri porovnaní z LLS, možno konštatovať priamu nadväznosť na vyvýšené polohy. Geofyzikálne meranie identifikovalo približne 417 anomálií. Magneticky pozitívne anomálie sa objavili v počte 340 a magneticky negatívne v počte 62 (obr. 10). Pričom v priestore geofyzikálneho meranie možno určiť približne 201 porastových prejavov. Z toho sa s magnetickými anomáliami podarilo stotožniť cca 123 objektov, 78 anomálií nebolo možné pozorovať na výsledkoch z magnetometru (obr. 11).

Ak spojíme výsledky dvoch prieskumov s archeologickým výskumom, tak môžeme sledovať objekty, ktoré vytvárajú štruktúru potencionálneho dvora (obr. 9). Podobne organizované zoskupenia objektov rešpektujúcich možné usporiadanie do podoby dvora (obr. 12) nachádzame aj v Nitre-Šindolke, Miloniciach (ČR) a možno uvažovať aj o lokalite Michelstetten (AT).

Prvé geofyzikálne meranie prebehlo pred archeologickým výskumom v roku 2017 (obr. 5). Bolo možné pozorovať dve magneticky pozitívne anomálie, dve negatívne a jednu ťažko charakterizovateľnú.

Druhé meranie na lokalite prebehlo po archeologickom výskume v roku 2022 (obr. 6). To v určitej miere ovplyvnilo namerané hodnoty. Podarilo sa identifikovať dve pozitívne a dve negatívne anomálie. Pri objekte 4/2019 možno aspoň vizuálne konštatovať silnejší negatívny magnetický prejav (porovnaj obr. 6 a 9).

Z archeologického výskumu vieme, že objekty 1/2017, 3/2018 a 4/2019 obsahovali vrstvy s prepálenou mazanicou, popolom a pri objektoch 3/2018 a 4/2019 aj uhlíky (obr. 7, 8). Ílové dlážky boli doložené v objektoch 4/2019 a 5/2019. Tieto faktory na samotných výsledkoch meraní ale dané objekty od seba nediferencovali. Rovnako ani v objektoch 4/2019 a 5/2019 neboli zreteľné viditeľné superpozície so zásobnými jamami. Pred výskumom mali objekty 2/2017 a 3/2018 negatívne hodnoty (obr. 5), na základe našej vedomosti ich archeologickej výplne, ale nie sme momentálne schopní vyhodnotiť príčinu tohto javu.

Komparácia všetkých spomínaných metód a podkladov poukázala na slabú viditeľnosť niektorých geofyzikálnych anomálií na leteckých

snímkach. Dáta z LIDAR-u upozornili na terénne nerovnosti, ktoré majú pozorované anomálie indikujúce historické osídlenie tendenciu kopírovať. Neprítomnosť anomálií v niektorých oblastiach ale môže byť zapríčinená vrstvami sedimentov, ktoré znemožňujú ich čitateľnosť. V budúcnosti bude získané poznatky potrebné overiť ďalším archeologickým výskumom. Pre porovnanie bude zmysluplné vykonať prospekciu aj na iných lokalitách s podobným datovaním.

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