DATA PROCESSING METHODS OF SYSTEMATIC ARTEFACT COLLECTIONS IN MULTI-PERIOD SITES. THE EXAMPLE FROM THE ÉRD-SZÁZHALOMBATTA LOESS PLATEAU

TÖBBKORSZAKÚ LELŐHELYEKEN VÉGZETT SZISZTEMATIKUS LELETGYŰJTÉSEK ADATFELDOLGOZÁSI MÓDSZEREI. AZ ÉRD-SZÁZHALOMBATTAI LÖSZPLATÓ PÉLDÁJA•

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Abstract

The research of multi-period site complexes has several challenges, particularly in topographical investigations where contextual and stratigraphical information is lacking. In such cases, distinguishing the extent of settlements or cemeteries of different periods based on surface artefacts can be challenging. When I was processing the data of the gridded artefact collections gathered from the multi-period site complex of the Érd-Százhalombatta loess plateau between 2017 and 2019, and then in 2023, I encountered several problems regarding this issue. One was related to collection units that could only be partially surveyed, resulting in an incomplete representation of their artefact counts. I have attempted to solve this issue, the problem of not fully researched collection units, with Quantum GIS tools. While this experiment produced better results, it did not solve other difficulties arising from the uncertainty of the findings dating. Since the research area was occupied from the Early Bronze Age to the Late Iron Age utilising the same raw materials for their ceramics, it was challenging to identify the exact period of the sherds. I aimed to deal with this issue by using two different approaches: one using the grid system to display the minimum and maximum number of findings from each chronological period, and the other using a point selection method for displaying differently dated artefacts simultaneously. Through the data management systems developed in this research and the various attempts to address these obstacles, I was able to extract detailed information from the raw data and consequently provide a more comprehensive interpretation of the results.

Kivonat

A többkorszakú (vagy többkorszakos) lelőhely-komplexumok vizsgálatakor számos kihívással szembesülhetünk. Különösen igaz ez a topográfiai kutatásokra, ahol a leletek, jelenségek kontextusa és stratigráfiai adatai nem ismertek, így csak a felszíni leletek alapján nehéz meghatározni a különböző korú telepek és temetők pontos kiterjedését. Amikor az Érd-százhalombattai löszplató több korszakú lelőhely-komplexumának 2017–2019 közti, illetve 2023-as négyzethálós leletgyűjtéseit dolgoztam fel, több nehézségbe ütköztem ebben a témában. Az egyik azokhoz a gyűjtési egységekhez tartozott, amelyek területét csak részlegesen lehetett kutatni és így a felszíni leletek hiányos reprezentációját eredményezték. A nem teljesen kutatott gyűjtési egységek problémájának megoldására a Quantum GIS eszközeivel tettem kísérletet. Habár ezáltal sikerült jobb eredményeket elérni, a leletek bizonytalan keltezéséből fakadó problémák nem oldódtak meg. Mivel a vizsgált területet a kora bronzkortól a késő vaskorig szinte minden korszakban lakták, valamint ugyanazokat a nyersanyagokat használták fel a kerámiáikhoz, meglehetősen nehéz volt különválasztani az egymást követő periódusok leleteit. Ezt a problémát kétféle módon próbáltam megoldani; elsőként a négyzetháló használatával jelenítettem meg az egyes korszakokhoz tartozó leletek legkisebb és legnagyobb számát, míg a második módszer esetében egy GPS pontokon alapuló rendszert használtam a különféleképp datált leletek egyidejű megjelenítésére. A kutatás során kidolgozott adatkezelési rendszerek, illetve a fent említett akadályok megszüntetésére tett kísérletek révén sikerült a nyers adatokból részletesebb információkat kinyerni, és ezáltal lehetővé tenni az eredmények átfogóbb értelmezését.

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KULCSSZAVAK: SZISZTEMATIKUS TEREPBEJÁRÁS, NÉGYZETHÁLÓS LELETGYŰJTÉS, ADATFELDOLGOZÁS, TÉRINFORMATIKA, BRONZKOR, KORA VASKOR

Introduction

In recent decades, the topographical research of archaeological sites has undergone some remarkable advancements. New methods came to the service of archaeologists, such as geophysical prospecting, satellite imagery, or LiDAR, and with the development of technology, old methods also gained some new aspects.

The appearance of handheld GPS devices and the more widespread use of GIS (e.g. see Conolly 2008; Conolly & Lake 2006; García Sánchez 2012; Wheatley & Gillings 2002) have provided new possibilities and perspectives for fieldwalking surveys (e.g. Czajlik & Holl 2011; Gyucha et al. 2015; Koller 2018; Koller 2021; Mesterházy 2013; Mesterházy & Füzesi 2024; Mesterházy & Stibrányi 2012). These tools improved the intensive surveys of large territories, yielding copious amounts of data about the sites and artefacts (Czajlik 2022, 62). Nevertheless, collecting data is only one part of the process; managing, visualising, comparing, and interpreting the results alongside other methods is equally crucial.

In the case of gridded surface collections, the most common method of data management involves linking the numbers or weights of artefacts to the specific collection units for each period. Utilising pre-established collection units, such as grid squares, is a well-established solution as it provides a clear and manageable unit for collecting artefacts and handling their data in GIS (e.g. Campana et al. 2006; Czajlik et al. 2015; Dreslerová & Demján 2019; Mesterházy 2013; Mesterházy & Füzesi 2024; Wroniecki & Barton 2018). Furthermore, a unit like a square can effectively display the artefact density of archaeological sites period by period. However, the incomplete surveying of a collection unit, due to fragmented and mosaic parcels or other obstacles, can lead to misleading density numbers or colours displayed on a map. I call this *the problem of not fully researched collection units*, for which I was seeking a solution while working on my master's thesis.

While the previously mentioned method can effectively show the artefact density of the grid on a period-by-period basis and is useful for many surveys, it can be insufficient for multi-period site complexes. Whereas, in areas where human settlements existed for several periods, the differences in the material culture may not be as apparent. Therefore, this can make it much more difficult to date the collected artefacts. The difficulty of dating can result in the artefacts not being able to be definitively assigned to a particular archaeological period. In these cases, it is not possible to simply indicate the number of artefacts per period on the grid of a map, as a considerable part of the dating data is only partially reliable. Therefore, another data management and displaying method is necessary to address this difficulty.

I faced these issues while I was writing my master's thesis about the systematic surface collection of a multi-period site complex at the loess plateau of Érd-Százhalombatta (for further details and research history see: MRT 7; Czajlik et al. 2016; Czajlik et al. 2019b; Czajlik et al. 2023; T. Németh et al. 2016; Vicze 2004; Vicze 2013). In this area, there are two larger and better-researched sites; *Százhalombatta–Százhalom* is a well-known Early Iron Age tumuli field whose territory contains burials from several periods of the Bronze Age, too; and *Százhalombatta–Földvár* which is a fortified tell settlement inhabited from the Early Bronze Age up to the Late Iron Age. In addition, there are several smaller prehistoric sites on the loess plateau, whose connection with the two large sites is still uncertain (**Fig. 1.**).

The challenges in dating were not the only difficulty I had to face while surveying this area. The loess plateau of Érd-Százhalombatta is mainly cultivated in small parcels with diverse vegetation and many enclosed gardens. As a result, conducting systematic artefact collections was difficult as we had to work within the constraints of the small parcels, and therefore many collection units could only be partially researched.

Between 2017 and 2019, an extensive topographical investigation was conducted in this area as part of the Interreg Iron-Age-Danube (DTP1-1-248-2.2) project. The research focused on exploring the settlements and cemeteries of the Early Iron Age along the Danube and brought together a team of twenty institutes from Austria, Croatia, Hungary, and Slovenia. From 2017 to 2019, several research methods (e.g. aerial and geophysical prospection, LiDAR) were applied on the loess plateau, including the systematic artefact collection discussed in this paper.

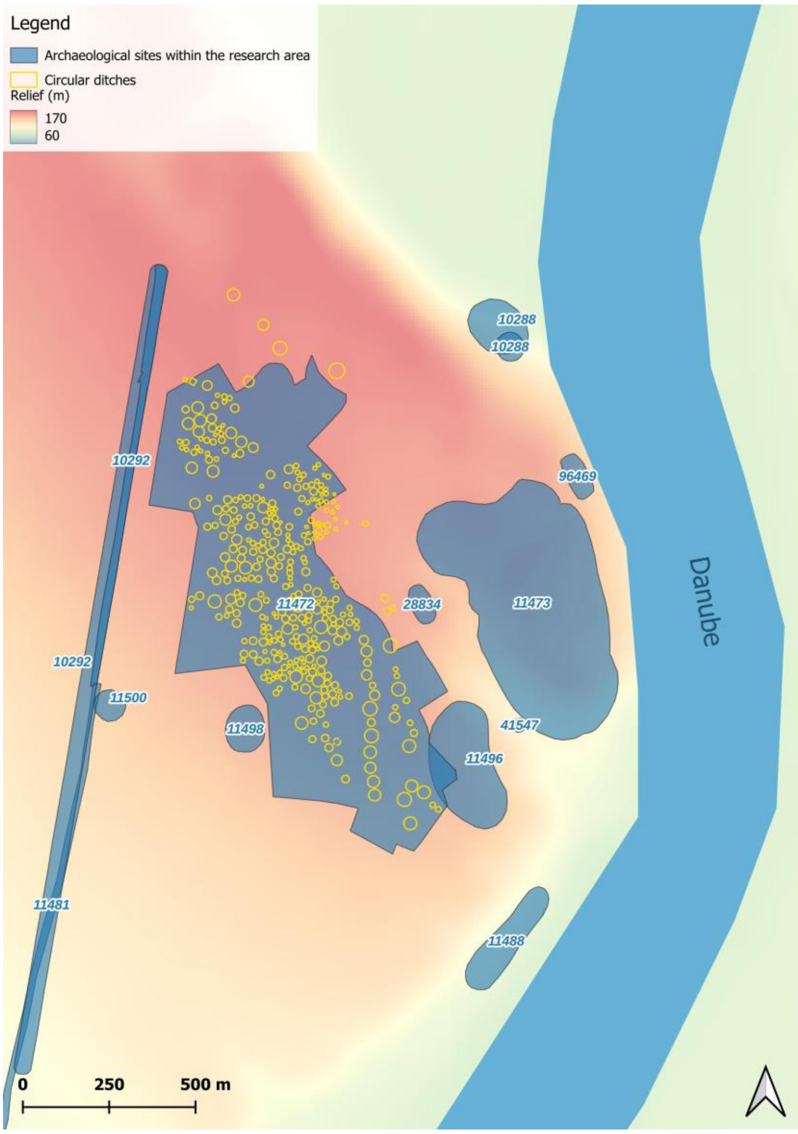

Fig. 1.:
Archaeological sites within the research area with the circular ditches of the Early Iron Age tumuli field. Sites:

1. ábra:
Régészeti lelőhelyek a kutatott területen és a kora vaskori halomsírmező körárkai. Lelőhelyek:

10288: Érd - Téglagyár;
10292: Érd - Római út;
11472: Százhalombatta - Százhalom;
11473: Százhalombatta - Földvár;
11481: Százhalombatta - Római út;
11488: Százhalombatta - Alkotmány utca;
11496: Százhalombatta - Megyunka-dűlő (Kocsányné dombja);
11498: Százhalombatta - Tóthtanya;
11500: Százhalombatta - Stichtanya;
28834: Százhalombatta - Szőlőskert;
41547: Százhalombatta - Turul utca 49-53.;
96469 Érd - Ófalu, Zátony

As a student at the Institute of Archaeological Sciences of Eötvös Loránd University, I had the privilege of joining the Hungarian team, led by Zoltán Czajlik. Related to this project, the topic of my master's thesis (Gergácz 2020) was to process the systematic surface collection data and help to analyse it in the context of further non-invasive research methods. The first conclusions of the research were published in the volume presenting the results of the project (Czajlik et al. 2019b) as well as in a conference volume (Czajlik et al. 2023).

A few years later, in 2023, the systematic artefact collections continued with the support of the Hungarian National Museum. These investigations were crucial for dating the phenomena discovered through previous aerial and geophysical prospection (Czajlik 2008; Czajlik et al. 2016; Czajlik et al. 2017) and for understanding the archaeological topography of the area.

Systematic artefact collections between 2017 and 2023

During the initial planning of the fieldwork, we realised that researching all ~75 hectares of the tumuli field within the timeframe of the Iron-Age-Danube project would be impossible; therefore, we needed to prioritize our research questions. In the first year, the southern part of the tumuli field was in focus to delineate the Early Iron Age finds to the east and west of the known border of the burial mounds. During the second year, to test the hypothesis of the archaeologists of the "Matrica" Museum, we examined the cultivation plots situated northwest of the hillfort settlement for the Early Iron Age horizontal settlement. Our plan for 2019 and 2023 was to explore the area close and in between the two previously investigated territories, but due to the vegetation cover, our efforts were only partially successful (**Fig. 2.**).

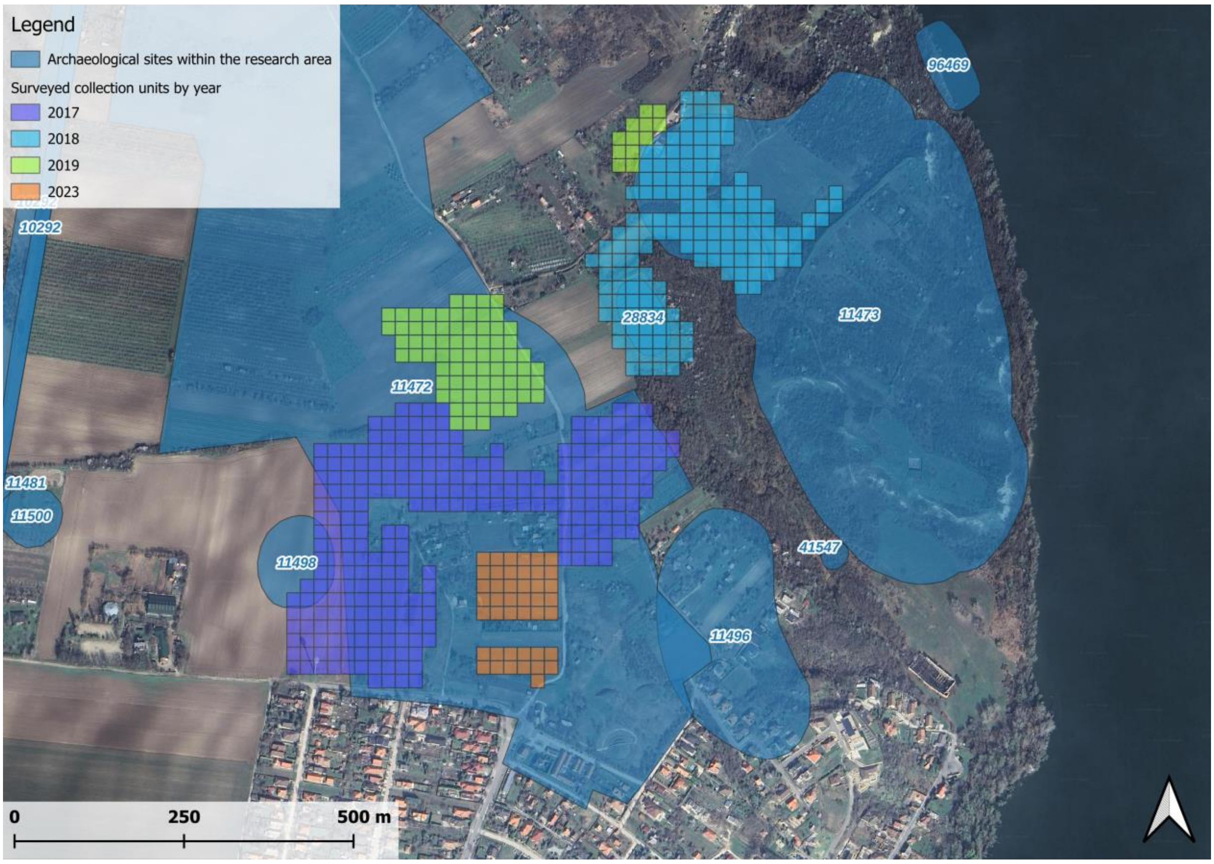

Fig. 2.: Researched collection units between 2017–2023
2. ábra: A vizsgált gyűjtési egységek 2017–2023 között

During our fieldwork, we used a 20 m x 20 m north-south oriented grid corresponding to the EOV (Unified National Projection) coordinate system, created by two colleagues of Eötvös Loránd University, András Bödőcs and László Rupnik. We decided to use the 20 m x 20 m grid system, because this size could provide detailed results, while also be time-effective regarding the fieldwork. In 2017, the fieldwalkers followed the grid on handheld GPS devices, then the edges of the collection units were marked out with wooden stakes using a Trimble GeoX 7 GPS in 2018 and 2019 and a Leica GS07 antenna with a Leica CS20 controller in 2023. A collection unit was examined by one person, usually for 10–15 minutes, the finds were marked on handheld GPS devices and collected by these units. During the four seasons of research, we managed to investigate ~22 hectares with this method in 10 working days.

During the years of the fieldwork, the workflow of washing, dating, and documenting the finds was continuous. The cleaning was done by fellow students and me, while PhD students Kata Novinszki-Groma and Eszter Fejér provided invaluable assistance with the dating. Meanwhile, I started to build the database which grew and evolved organically as I gained more knowledge and experience. The database structure described in this paper represents its latest and most evolved state.

For the data management, I created two Excel files. Both files included unit ID, GPS ID, survey status and survey date. Besides that, one contained the number of finds collected by unit in total and by era, while the other incorporated the weight data of the artefacts of different periods also by unit. By joining these Excel files with the grid's shape file in QGIS, I was able to display the number and weight of artefacts.

However, precisely determining the age of the sherds during dating proved to be a challenging task, often bordering on the impossible. The reason for this is the continuity of human activity on the landscape, spanning from the Early Bronze Age to the Late Iron Age and that the former habitants used the same raw materials for crafting their ceramics. Therefore, the above-mentioned Excel files did not contain just a simple era for most of the sherds. Instead, it featured two columns for each phase, indicating the minimum and maximum artefact number. The minimum represented surely dated artefacts of a period, and the maximum included both certain and potential artefacts.

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Processing the data of the artefact collections

The problem of not fully researched collection units and a solution attempt

Although a grid is frequently used to show the number or weight of collected artefacts in each unit by period (e.g. Czajlik et al. 2015, Fig. 4.; Gruškovnjak et al. 2019, II.4.2. Fig. e-f; Kecheva 2014, Fig. 2.; Mesterházy 2013, Fig. 3.) or with a heatmap (e.g. Czukor et al. 2013, Fig. 14.; P. Fischl & Horváth 2010, Fig. 6.), this figure or colouring alone may not always represent the actual density of artefacts. This display method often fails to consider that the collection units have not been surveyed in the same spatial extent. In places, such as the study area with fragmented and mosaic parcels, *the problem of not fully researched collection units* could have a significant impact on data interpretation.

The techniques developed by Anderson & Negus-Cleary (2018), Burgers et al. (2004), and Dreslerová & Demján (2019) tried to face this type of bias during gridded artefact surveys. Since we strived to do the field surveys in fairly uniform visibility circumstances, I only considered the differences in the extent of the researched units.

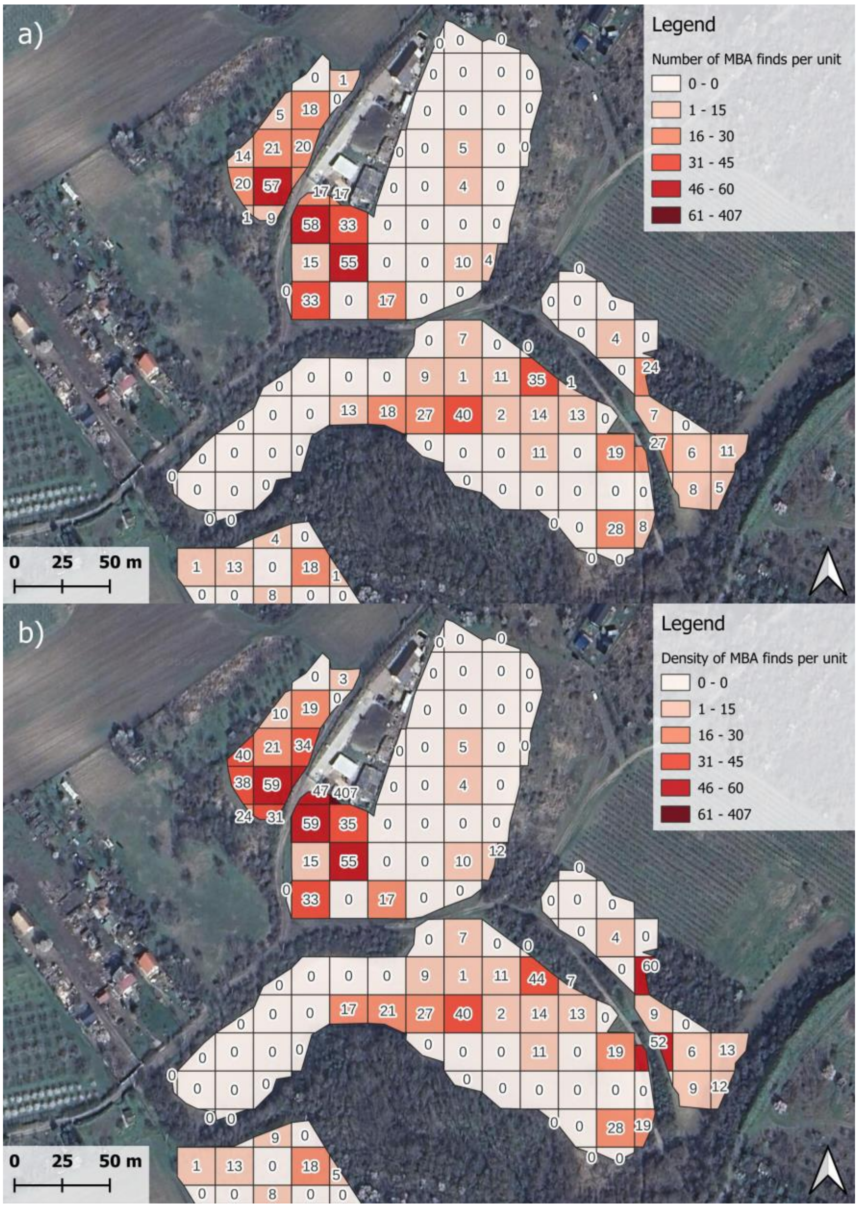

Fig. 3.: a) The minimum number of Middle Bronze Age finds by collection unit, b) The density of Middle Bronze Age finds after the area-based correction, based on their minimum number

3. ábra: a) A középső bronzkori leletek legkisebb száma gyűjtési egységenként, b) A középső bronzkori leletsűrűség a területi alapú arányosítás után, a legkisebb számokat felhasználva

I applied an area-based density-correcting approach (**Fig. 3.**), similar to the one used by Anderson & Negus-Cleary (2018), since that seemed the most suitable for this research. My first step aimed to delineate the surveyed areas within every 20 by 20 metres unit by creating a surface shape file in QGIS to mark out the surveyed areas based on the tracks of the fieldwalkers and then to cut out the indeed studied territories of the grid. Then I joined the cut grid and the Excel files dynamically, enabling the data of the Excel files to be constantly updated in the grid's attribute table in the QGIS software.

Once I had the roughly accurate surveyed area and the number of collected artefacts in each unit, I calculated the area compensated artefact density. The 'number of findings per area' was defined by using the formula: $x = a / b * 400$, where *'x'* is the density, *'a'* is the number of collected finds, *'b'* is the researched area (m^2) of the given unit and the '400' represents the area in m^2 of a fully researched 20 m x 20 m sized collection unit. To obtain the value of *'b'* I used the *'$area'* function in the QGIS field calculator. While the density I received was hypothetical, it proved to be advantageous for determining the concentration of findings, and for later interpretation. However, there are limitations to this method, as it does not alter the values of the squares without findings and can only proportion the number of pieces from periods known from the surface collection, leaving us with no data on other, otherwise present periods. Furthermore, it must be taken into account that the units that were surveyed to a very small extent could also distort the results with too large, compensated artefact numbers.

The effect of chronological uncertainty and a solution attempt

As previously mentioned, it had been challenging to precisely date the collected artefacts. During the fieldwork, we marked a total of 5431 points on the GPS devices, out of which 4020 were sherds from archaeological periods. We were able to date 1887 artefacts to one (e.g. Early Iron Age), 1618 to two (e.g. Late Bronze Age or Early Iron Age) and 528 to three possible periods (e.g. Middle Bronze Age or Late Bronze Age or Early Iron Age). Therefore, only 46% of the archaeological artefacts had a certain dating, while the others could belong to two or even three periods.

By displaying each period on a map and comparing their minimum and maximum densities, I was able to gain more comprehensive information. Since the minimum number would probably signal too few artefacts and the maximum number too many, by examining them together, we can get a better picture of what the actual density could look like. Additionally, applying the area-based density correcting method discussed previously to both cases enables a more precise visualisation. Although this step brings us closer to the real distribution of archaeological finds of different ages, the map display still does not reveal the probability of a finding belonging to a specific period.

A different approach: using point selection for visualising several period categories at the same time

Since we can only visualise the data of one period at a time using grid-based densities, I shifted my focus to analysing GPS points during data processing. Using the latter for spatial analyses proved to be a great approach by multiple studies (e.g. Brooks et al. 2009; De Clercq et al. 2013; Koller 2021; Mesterházy & Füzesi 2024; Terrenato 2000; Trachet et al. 2017) as it can provide more accurate data about specific objects (Gruškovnjak 2019, Fig. 7.) compared to the conventional gridded surveys. Furthermore, by assigning dating data to these points, multiple periods and their dating probabilities can be visualised simultaneously.

In order to achieve this, my first step was to generate unique IDs for the GPS points using the field calculator of QGIS and to add these IDs to a newly created Excel file as well. These IDs contained the date of the fieldwalking in YYMMDD format, the GPS ID, and the point number, such as *"191129_G4_0195"*. It was calculated with a quite simple formula as *'191129_G4' + "name"* in the case of the previous example, where the *name* is the column containing the point numbers. Then I merged all the shape files into one and joined together with the new Excel file utilising the point IDs.

This enabled further analysis of the points. Before I could assign any archaeological phases to the points, it was necessary to address the collected non-archaeological artefacts. As mentioned before, a significant number of non-archaeological sherds were gathered during the fieldwork, making up one-fifth of the items collected. The reason for this was probably the limited expertise of the students participating in the fieldwork and the abundance of modern artefacts on the surface. The points of the latter made the real accumulation of archaeological finds invisible by creating a false homogeneity.

To eliminate this issue, I assigned a "modern" attribute to as many points inside a collection unit as many non-archaeological sherds had been noted during the dating process. I aimed to select points that were evenly distributed within the collection units to prevent any artificial clustering of the fragments. For the selected points I added a "modern" attribute in the Excel file's column containing the types of the finds. Then I repeated this for all find types and assigned any associated field notes to the corresponding point (**Fig. 4.**).

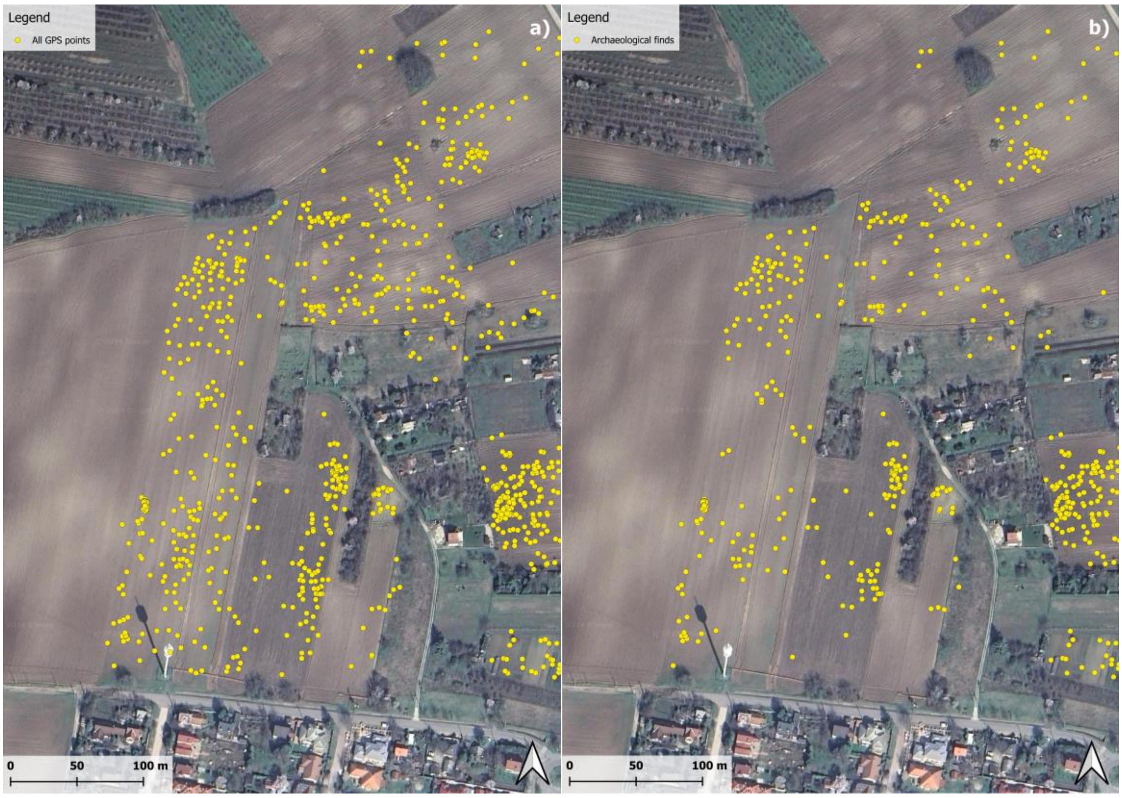

Fig. 4.: a) All GPS points marked during the fieldwork, b) The GPS point of real archaeological finds
4. ábra: a) Minden terepen felvett GPS pont, b) A régészeti korú leleteket jelölő GPS pontok

A similar approach was previously used to display various types of findings such as glass, sherds or *terra sigillata* by utilising field notes data (Bartus et al. 2016, 216, Fig. 5, 12). However, as far as I know, it has not been used to differentiate between time periods, except in surveys where sherds were marked and collected one by one, making the next step of the data processing an interesting methodological experiment. After selecting all the archaeological sherds, I used the point selection method to assign dating data to them using abbreviations, such as *"LBA/EIA"* for the period names in the related column of the Excel file. Whenever I had additional information about a specific point, I was able to link the point to the actual find and its true chronological property. Similar to the non-archaeological finds, I assigned the different eras of the finds to points located mostly evenly within the collection units.

By applying this approach, it has revealed previously hidden accumulations of archaeological artefacts at site-level and I was able to display artefact distribution maps for the different chronological periods. For example, a few Early Iron Age sherd accumulations could be linked to specific burial mounds (**Fig. 5.**) and some of the Middle Bronze Age sherd concentrations showed the ploughed-out burials found during the fieldwork (Czajlik et al. 2019b, 169) (**Fig. 6.**). By using this method not only were we able to see the probability of a finding being from a certain period but – in a few cases – we also could associate some sherd concentrations with specific archaeological objects.

However, it might be worth noting that the distribution of the finds on the surface does not usually represent the distribution of archaeological objects under the surface (Ammerman 1985) and there are lots of factors influencing the results of artefact collections and which periods or site types can be detected (e.g. see Doneus 2013; Gruškovnjak 2019; Noble et al. 2019; Shott et al. 2002). Furthermore, the linking of certain artefact concentrations to archaeological objects is hypothetical and only possible within favourable conditions supported by additional data (e.g. ploughed-out burials with human remains in the case of Middle Bronze Age concentrations).

In addition to the above-mentioned results, this visualising method pointed out how the sherds of different collection units got a diverse dating on the area of the Middle Bronze Age horizontal settlement, even though they were probably from the same period, and how misleading results we could get if using only the grid display (**Fig. 7.**).

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Fig. 5.: The GPS points of all archaeological finds which could belong to the Early Iron Age with the circular ditches of the tumuli

5. ábra: Minden lehetséges kora vaskori lelet GPS pontja az ismert körárkokkal

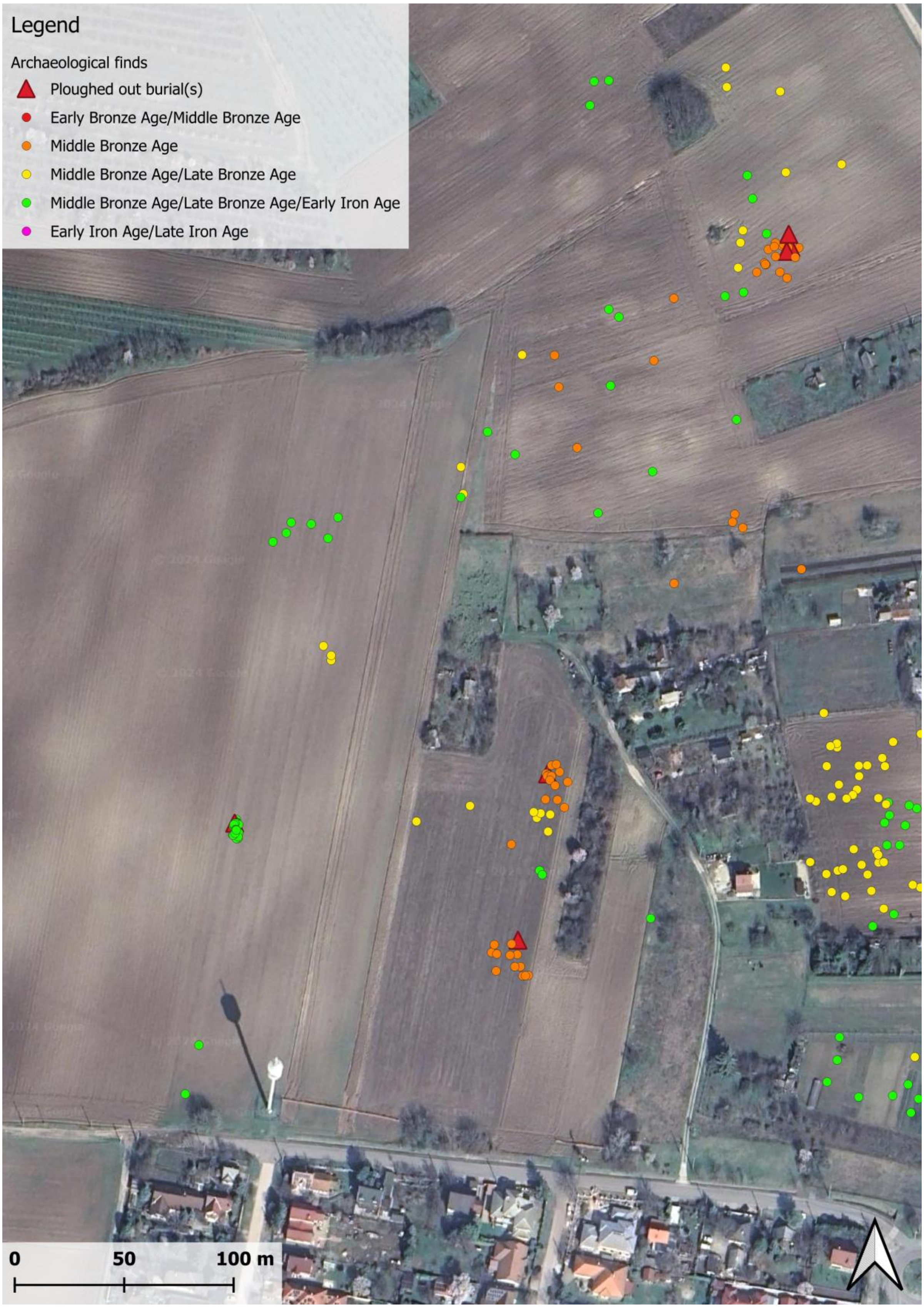

Fig. 6.: The GPS points of all archaeological finds which could belong to the Middle Bronze Age with some ploughed-out burials found on the surface

6. ábra: Minden lehetséges középső bronzkori lelet a felszínen észlelt kiszántott sírokkal

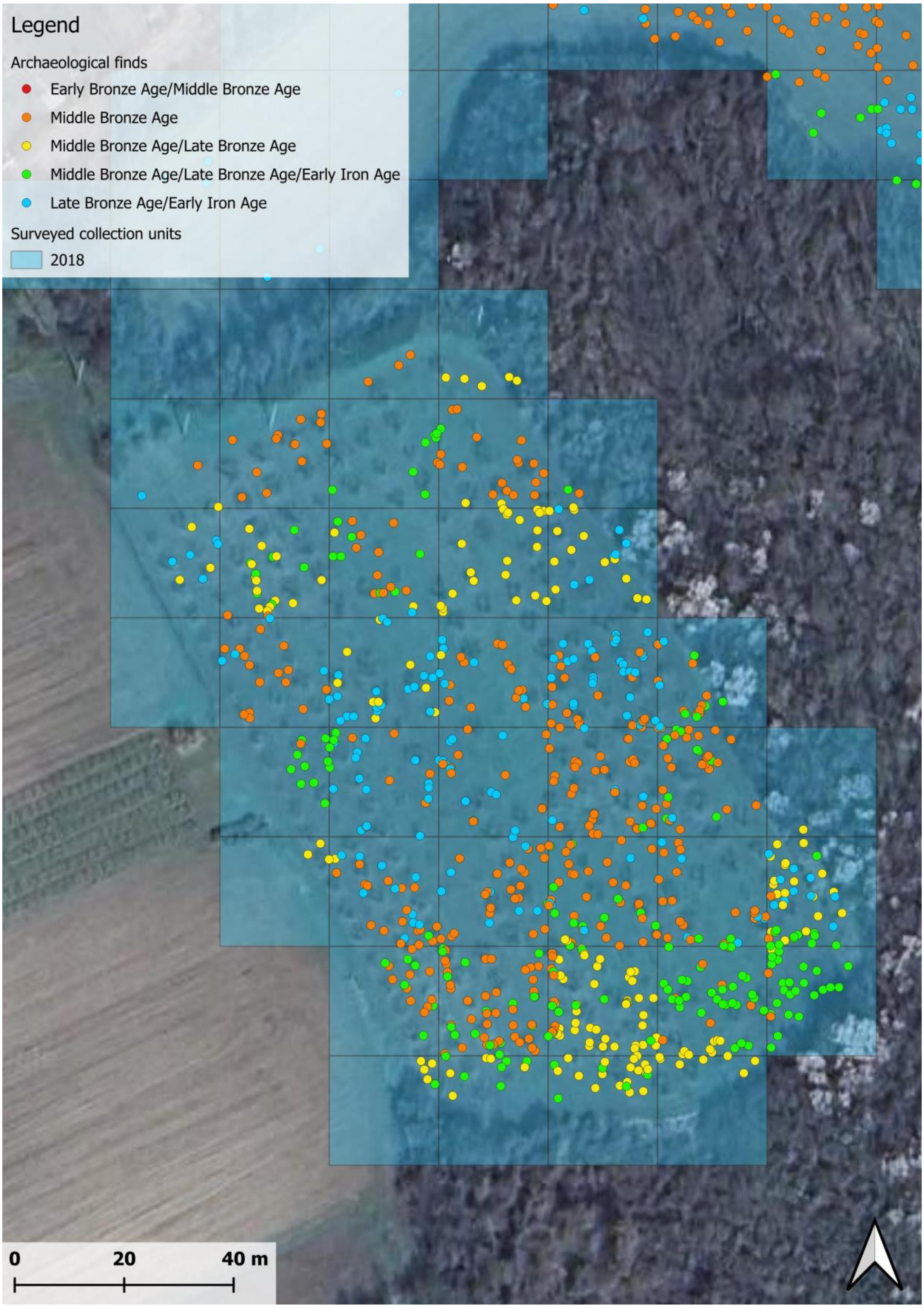

Fig. 7.: The GPS points of differently dated finds by collection units which probably all belong to the Middle Bronze Age

7. ábra: Négyzetenként különbözően datált leleteket jelölő GPS pontok, amelyek valószínűleg mind a középső bronzkorhoz tartoznak

Conclusions

When dealing with archaeological data we likely cannot achieve complete certainty in our results. However, it is crucial to acknowledge the potential biases and strive to find solutions that minimise their impact on our data. The above-mentioned challenges should be considered when dealing with gridded surface collections or any systematic artefact collections located on multi-period sites.

Whereas gridded surface surveys can be conducted without fragmentary units in certain cases, such as when the research area is located on one large or multiple contiguous cultivation plots as in the case of Süttő-Sáncföldek (Czajlik et al. 2019a) or when only a smaller part of a site is being studied (e.g. Czajlik et al. 2015; P. Fischl & Horváth 2010), research circumstances are rarely so optimal. In the case of the loess plateau of Érd-Százhalombatta, the gridded fieldwalking could not have been carried out without investigating the fragmentary collection units, so I had to find acceptable solutions for the data processing, creating a hypothetical density.

While the developed solutions regarding the grid system (hypothetical density correction, using minimum and maximum finding numbers for periods) for the problem of not fully researched collection units and the dating uncertainty produced better results than the usual grid density visualisation, the real break-through was brought about by the applied point selection method.

It is possible that the dates of the finds using the latter method are hypothetical and some sherd accumulations from a certain time period may have become less visible. However, there are certainly no artificial accumulations due to the data processing technique. This method has its flaws and will not show us the real distribution of the artefacts of different periods unless we pack the findings individually. However, keeping these in mind, it can still make a big difference when analysing the data of systematic artefact collections.

The point selection method can be used not only in the case of gridded surface collections but any intensive systematic artefact collections on multi-period sites too, which means we can get more detailed results with less invested time and energy. In addition, in some fortunate cases, some finding accumulations can be associated with specific archaeological objects or phenomena at a site level using this data processing method together with other investigations, for instance, aerial reconnaissance or geophysics.

Contribution of the author

Gergácz Rebeka Writing – Original Draft.

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