GeoScience Engineering

MEASURING MAGNETIC SUSCEPTIBILITY TO DETERMINE DEPOSITS IN FIELD ARCHAEOLOGICAL RESEARCH AT THE MIKULČICE SITE

Jiří ŠINDELÁŘ, Marian MAZUCH, Marek HLADÍK
Institute of Archaeology of the Czech Academy of Sciences, Brno, Czech Republic
E-mails: sindelar@arub.cz, mazuch@arub.cz, hladik@arub.cz

ABSTRACT

The submitted paper presents the possibilities of specific use of a simple geophysical method in the conditions of an ongoing archaeological excavation. It demonstrates an effective (i.e., quick, inexpensive, and beneficial) method that greatly enhances the knowledge gained from archaeological context analysis and thus contributes to a more accurate interpretation of the excavated portion of the historic strata. For example, field measurements of magnetic susceptibility can help to correctly interpret the genesis of individual layers, to distinguish individual phases in a visually indistinguishable stratum, or to indicate layers (and stone walls) that have undergone heating, etc. A detailed geophysical measurement of magnetic susceptibility was carried out on a section with archaeologically excavated relics of fortifications on the outskirts of the early medieval Mikulčice – Valy hillfort and the results were then critically confronted with the archaeological interpretation. This mutual multidisciplinary approach is also methodologically significant. Geophysics reveals certain information that is invisible to the archaeologist's eye, and may provide important clues to the correct interpretation of the archaeological context. Archaeological research, in turn, provides more precise information on the reasons and possible source of changes in magnetic susceptibility values of different layers and materials.

Keywords: Fortification; Magnetic susceptibility; Mikulčice.

1 INTRODUCTION

Magnetic volume susceptibility is a mathematically appropriate expression of the relative permeability of the medium. It is denoted by the Greek letter kappa and indicates the ability of matter to induce a magnetic field in itself at an externally applied magnetic intensity. It is mainly used for low magnetic substances instead of permeability. [1] The soils that form the backfill of individual archaeological objects are among such substances, so the method is a useful adjunct to their visual and structural description. The magnetic susceptibility values of sediments are primarily dependent on the content and concentration of magnetic (mainly ferromagnetic) minerals as well as their size. [2] The value can be reduced by the presence of diamagnetic material such as SiO_2, $NaCO_3$, and organic materials. [2] The increase in values occurs, for example, due to settlement processes and the corresponding physical, chemical, and microbial changes in the soil. Within the framework of the above-mentioned processes, oxidation-reduction changes occur in the iron minerals of the soil and thus alter their magnetic susceptibility. [3] In addition to the influence of former microbiological activity at the surface of the cultural layers, there is a huge increase in the magnetic susceptibility values due to ancient fires (fire pits, rocks that have been subjected to heat, pieces of daub, bricks, and parts of fragmented ceramic vessels in the soil, slag as a result of iron or glass production, remains of furnaces, etc. [4] The measurement of magnetic susceptibility is also used in the analysis of mixtures of topsoil and geological subsoil, where the smoothness or, conversely, a certain chaotic nature of the measured values in the profile may be used to decide whether the object was naturally deposited or whether it may be interpreted as a one-time and deliberately buried object. [5] The authors of the paper have encountered and described all of the above examples during their more than twenty years of experience in the application of the geophysical method in archaeological and historical research at sites in the Czech

Vol. 67 (2021), No. 4
pp. 176–186, ISSN 1802-5420
DOI 10.35180/gse-2021-0063

Republic. Since 2005, the authors of the paper have been using the method in rescue archaeological excavations in the Tábor region. Thanks to magnetic susceptibility measurements in large-scale excavations of prehistoric settlements (Tábor – Tesco, Tábor – Komora, construction of the D3 highway), cultural layers were clearly distinguished from the geological subsoil, which showed identical visual characteristics. [6–8] Documenting a large area research in Ústí nad Labem, the authors of this paper managed to distinguish individual historical horizons within a 1 m thick and visually and structurally uniform stratum using the given method. [9] In building history research, the authors of the paper employed the method of field measurement of magnetic susceptibility to quickly and clearly distinguish between stone and brick walls under a thick layer of plaster (cf. [10]) and it was used to determine the building material (stone) of different provenance for the construction of the tower of the city castle in Tábor in 2012 [11].

In archaeological excavations, the method is mainly used in surface geophysical prospecting. Field measurements in exposed archaeological situations are a significant minority. Even so, the method is coming to the attention of archaeological workers in the world [12, 13] and in the Czech Republic [14], where we may regard Antonín Majer as a pioneer in the application of magnetic susceptibility measurements on exposed archaeological profiles, who has been dealing with the issue for more than 25 years.

Measurements of magnetic susceptibility at the Mikulčice – Valy site were previously carried out in a more systematic way in 2007–2008 during the revision research of Church II (area 84; not yet published) and during archaeological research in the NW section of the acropolis wall R 2012 I, II (areas 91 and 96 [17]). The systematic data collection has yielded a comparative set of information on the magnetic properties of the cultural layers and geological subsoil at this prominent early medieval power centre. [15] During the R 2018 field archaeological investigation in the SW section of the outer foreground wall (Area 119, Fig. 1), we carried out experimental areal mapping of the magnetic susceptibility of the sediments of a nearly 12 m long and 2 m high profile that captures part of the settlement activity at the foreground wall (inside, "behind the wall"), relics of the actual timber-clay fortification with a 9th century front stone wall, and part of the 9th century riverbed immediately outside the wall.

The aim of our project was to independently carry out a classical archaeological interpretation and an interpretation based on the measurement of magnetic susceptibility of one and the same discovery circumstance of the archaeological context without mutual exchange of information or any confrontation or influence and only then to compare the two results.

2 METHODOLOGY AND WORK PROCEDURE

The subject of comparison of the archaeological interpretation and magnetic susceptibility results of individual archaeological contexts is one of the main sections of the above-mentioned research of the fortification at the Mikulčice hillfort from 2018 (Fig. 1). The fortified foreground of the Great Moravian hillfort at Mikulčice is located NW of the power centre's main core, the so-called acropolis. The area of the inner part of the foreground is about 2.4 ha. Here the natural geological subsoil consists mostly of older flood clays on river sandy sediments. In the 9th century, this area was fortified and surrounded from the outside by the branch or the former main stream of the Morava River.

The survey of the R 2018 area was carried out as a preliminary survey due to the construction of the cycle path, which unfortunately also affected the still intact terrain in the castle foreground. The above survey was carried out in the place where the cycle path crosses the likely course of the fortification. The area was orientated as perpendicular as possible to the presumed line of the fortification and included a strip 15 m long (along the fortification) and 10 m wide (perpendicular to it). The survey area is represented by three pairs of standard research squares of 5x5 m, between which control blocks were left. This was the most extensive field survey of the Mikulčice wall since the early 1980s. [16–18] In terms of the complexity of the archaeological context, the technology used to lower the groundwater level by means of drilled wells, and the demands on the methodology of field research and its documentation (difficult recognition of contexts, problematic interpretation of dynamically changing strata), the fortification research ranks among the most demanding operations in the early medieval archaeology in general.

For the above comparison, one of the main sections at the NW outer edge of the study area was chosen (see Fig. 2). From the outside, it ran into the bed of the former course of the Morava River, which bypassed this fortification immediately in front of the front stone wall of the wall in the 9th century, with a projecting stone fortification

Vol. 67 (2021), No. 4
pp. 176–186, ISSN 1802-5420
DOI 10.35180/gse-2021-0063

structure, flanked in front by two or three palisade rows of notched stakes. In the northern part, the cut was extended beyond the presumed rear of the wall to the inner part of the Mikulčice foreground.

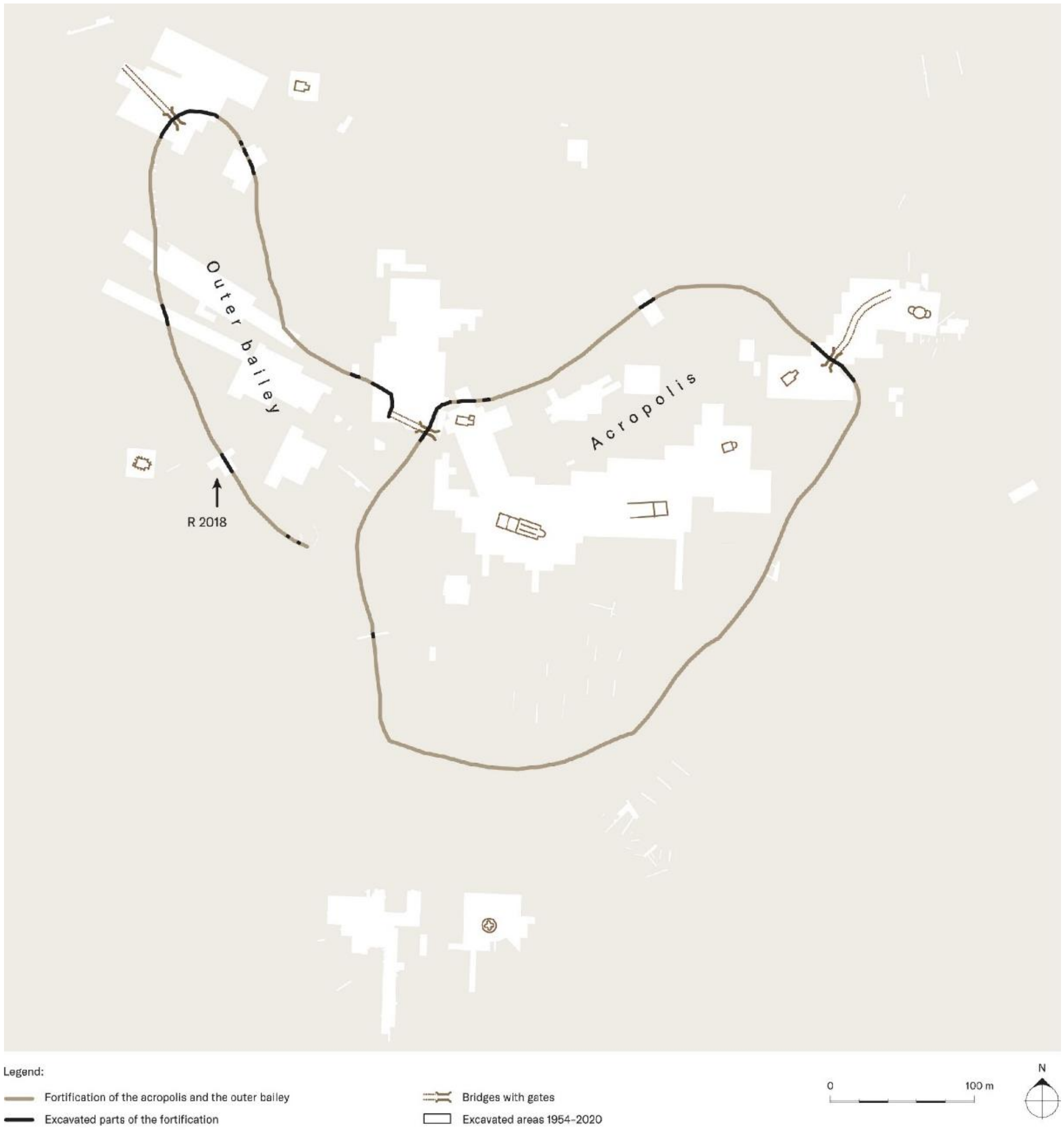


Figure 1. *Mikulčice stronghold. Location of the research area R 2018 (modified according to [18])*

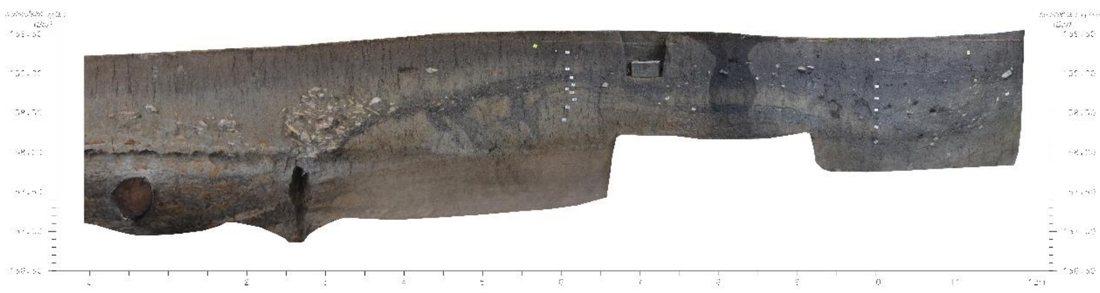


Figure 2. *Photo plan of the NW section in the R 2018 area*

Vol. 67 (2021), No. 4
pp. 176–186, ISSN 1802-5420
DOI 10.35180/gse-2021-0063

The researched archaeological profile was divided horizontally and vertically into 10 cm x 10 cm squares in which repeated measurements of magnetic susceptibility values were carried out. A KT – 5 kappameter with a sensitivity of 1 x 10^{-5} SI units was used for the measurements. The magnetic susceptibility measurements in each square were repeated three times (to exclude gross and random errors) and the average values of the three measurements were entered into the evaluation. The complete square grid was geodetically surveyed and each square was assigned a profile X and Y coordinate. The Z coordinates replaced the average values of the observed magnetic susceptibility. The coordinates were then transferred into the Atlas DMT software, in which the analysis, calculations, and a "3D model" creation of the magnetic values of the studied profile were carried out. The output is 2D plans of the profile in question, on which the magnetic susceptibility is represented in the form of coloured hypsometry, a cartographic technique commonly used to represent terrain relief on maps. The hypsometric representation is suitable for rapid elevation orientation on maps and gives a very good idea of space, thus making the elevation breakdown clearer and allowing the study of relief over large areas. By replacing the height information with another value (magnetic in our case), the originally cartographic method becomes suitable for the study and interpretation of geophysical measurements. Depending on the measured values, three different plans of the studied archaeological profile were created (Figure 3); all at the same scale, but in different hypsometric colour scales. This allows for a more accurate subsequent interpretation of some local inhomogeneities.

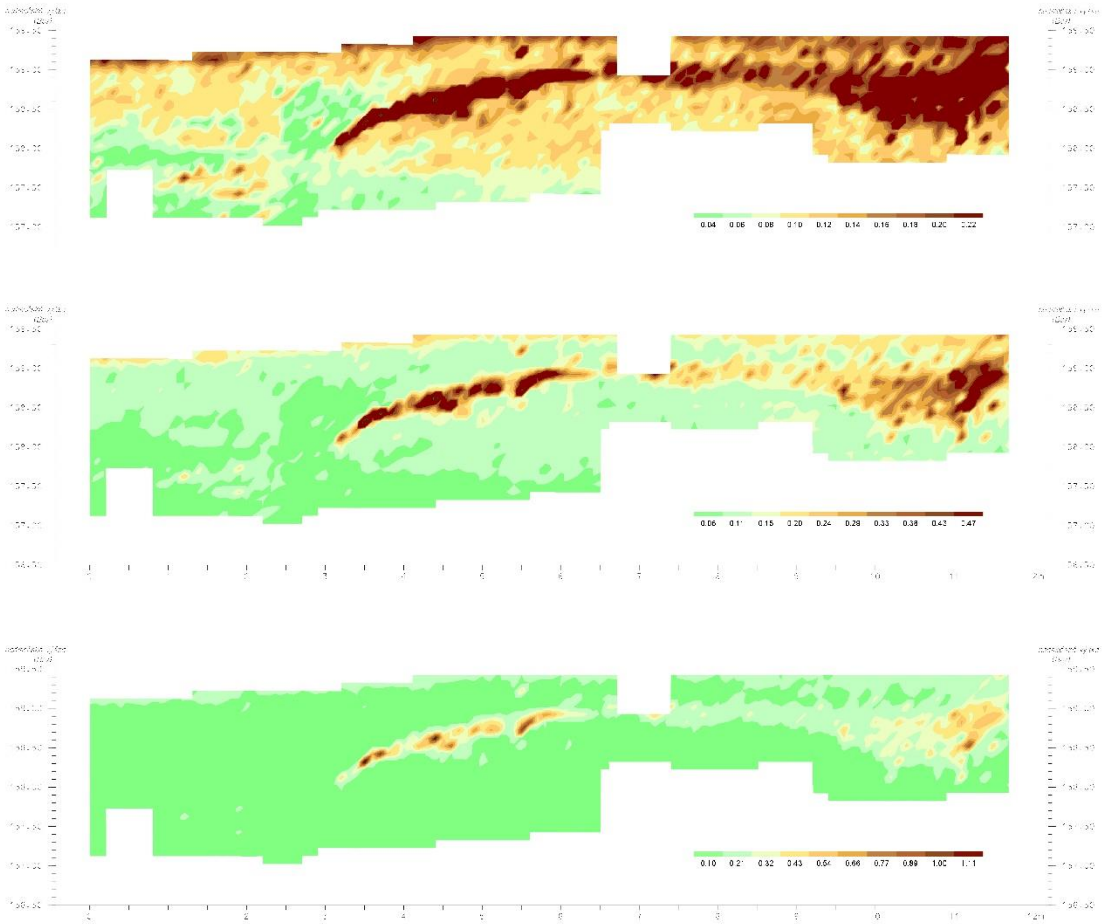


Figure 3. *Hypsometrically plotted magnetic susceptibility values on the subject profile*

Vol. 67 (2021), No. 4
pp. 176–186, ISSN 1802-5420
DOI 10.35180/gse-2021-0063

3 INTERPRETATION OF THE ARCHAEOLOGICAL PROFILE ACCORDING TO MAGNETIC SUSCEPTIBILITY VALUES

Based on the surface magnetic susceptibility measurements and the graphical representation of the resulting values using the hypsometry method, we can distinguish 12 different elements (“layers” or objects) on the profile in question. In all subsequent entity figures, we refer the reader to Fig. 4 (interpretation diagram). The analysis of the results of this measurement was carried out completely independently of the assessment of the archaeological situation, so that we could objectively assess the contribution of this method to interpreting the individual archaeological contexts recognised, and therefore to interpreting the overall archaeological context.

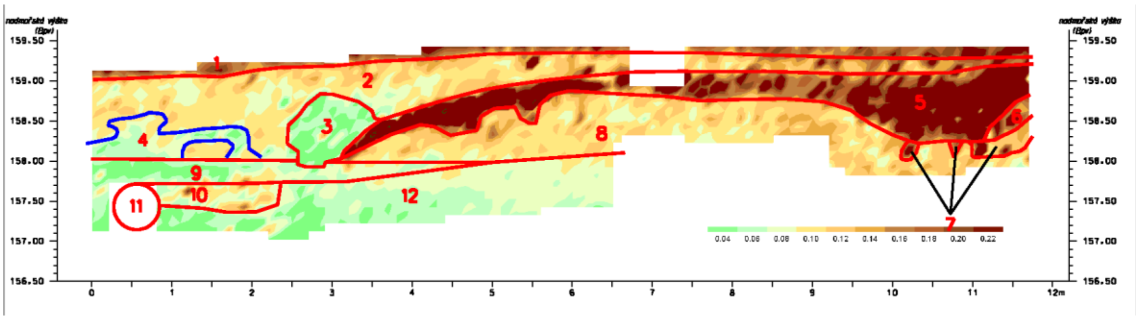


Figure 4. *Interpretation scheme based on magnetic susceptibility (detailed in the text below)*

In the upper part, topsoil with an increased magnetic susceptibility value (**No. 1**) is very well manifested, caused by recent human activity as well as microorganism activity in the soil.

Below the topsoil, the more powerful layer of subsoil and floodplain clay is clearly visible (**No. 2**). **No. 3** indicates a cluster of stones with magnetic susceptibility at the limit of measurability of the instrument used (KT – 5 kappameter with a sensitivity of 1 x 10^{-5} SI units).

The layer with more stones in the left part of the profile, at the lower limit of the flood clay, can be interpreted as a destroyed part of the front wall (**No. 4**). **No. 5** indicates a very distinct layer with very high magnetic susceptibility values. Based on these very high magnetic values and the fact that the normal cultural layer at the site shows values of about 0.20 (1 x 10^{-5} SI units), this is most likely a buffer layer. This is a planer for which the material from the settlement at the bailey was used. High values indicate sediment that may have been subjected to heat, or layers with a high content of pottery, grease, etc. The lower boundary of this layer is irregular and could suggest the backfilling of features that have been buried in the bedrock. The highest values are measured in the area of the actual core of the wall and then in the right part of the profile. On the far right, we can isolate an area within this layer (labelled **No. 6)** which has lower values and could be a relic of the cultural layer or a runoff of the cultural layer into a buried object. **No. 7** indicates three small anomalies in the right part of the profile, below the lower edge of element No. 5. These could be relics of objects buried in the subsoil, or irregularities in the subsoil, clogged by the cultural layer. **No. 8** denotes a more powerful stratum in which there are different alternating values of magnetic susceptibility. The values and areal expression of this stratum most closely correspond to flood clays, i.e. gradually deposited sediments where the activity of microorganisms in the soil has always persisted over a period of time. **No. 9** indicates a layer with a very low magnetic susceptibility value. Such a character and manifestation could correspond to a layer of alluvial sediments. We have separately distinguished the layer below the lower boundary of element No. 9. Here (marked by **No. 10**), the alternation of different sediments is evident. As this is not an area-wide feature, it is not easy to decide whether this can be interpreted as a one-off backfill for which both the over-excavated geology and the cultural layer were used, or whether it is a runoff from the surrounding area.

No. 11 indicates the tree trunk and then **No. 12** indicates the area that may be interpreted as pure geological bedrock.

Interpretation of the archaeological profile according to the magnetic susceptibility values in the presented case of the Mikulčice probe R 2018 allows to distinguish only layers with a minimum thickness of 10 cm. This is due to the methodology of data collection. This fact may therefore cause the aforementioned alternation of measured values in the layer marked as No. 8 in the interpretation sketch. For the purpose of assessing individual small layers (well distinguishable visually), a different data collection methodology would be required.

Comparing the interpretation scheme of the magnetic susceptibility and the orthophoto of the studied profile, we do not find any major discrepancies. Only visually recognisable “wedges” of darker sediment that run from the dark (obviously anthropogenic) layer No. 5 into the bedrock (right, next to a distinct cluster of stones) are interesting. These “wedges” do not appear in the measured magnetic susceptibility values.

Analogous “objects” were observed during the solution of a similar problem within the framework of rescue archaeological research on the route of the D3 highway. An early medieval settlement was investigated near the village of Žíšov in the Tábor region in 2009 and 2010. Historical objects were buried in the geological bedrock, which is made up of Pleistocene fine-grained silty sand. This overlies Pleistocene gravels and gravel-sands (RISS grade). The documentation of the historic objects found during the rescue archaeological investigation of the Žíšov site includes, in addition to the visual description of each backfill layer, the collection of pedological samples and the measurement of magnetic susceptibility. Anthropogenic sediments in the overburden cause solifluction colouring of the sand in the layers deposited below, down to the groundwater level. This creates visually distinguishable “false layers and objects”, which cannot be distinguished from the geological bedrock either structurally or by magnetic susceptibility values. [8]

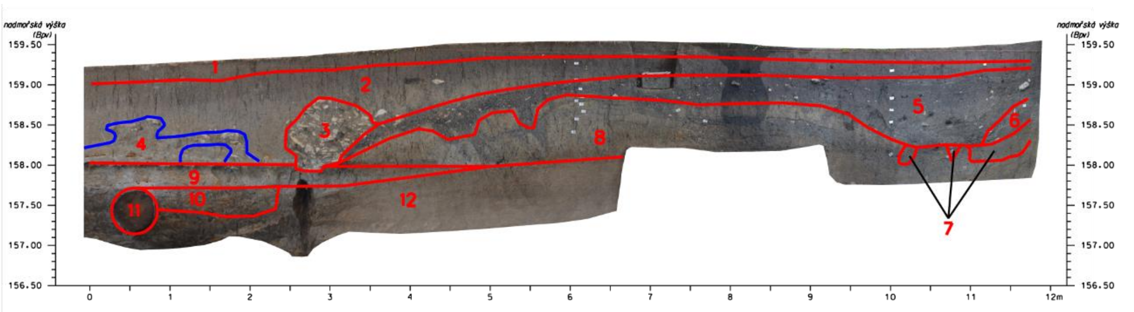
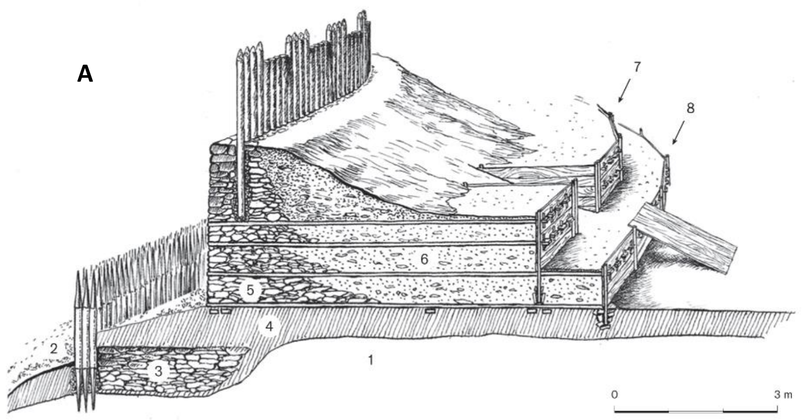


Figure 5. *Interpretation scheme based on the magnetic susceptibility projected onto the photo plane*



Vol. 67 (2021), No. 4
pp. 176–186, ISSN 1802-5420
DOI 10.35180/gse-2021-0063

Figure 6. *Mikulčice stronghold: A – Ideal reconstruction of the rampart based on archaeological context in the excavation area R 2012-II, eastern main section; B – orthophoto of the eastern main section in the R 2012-II excavation area; C – orthophoto of the north-western main section in the* ***R 2018*** *excavation*
Legend: *1 – original terrain; 2 – three rows of stakes; 3 – stone substructure in the slope below the rampart; 4 – clay backfill levelling layer; 5 – stone front wall of the rampart; 6 – wood-and-earth core of the rampart; 7 – rear of the step; 8 – reverse wooden wall of the rampart (modified according to* [17, 18])

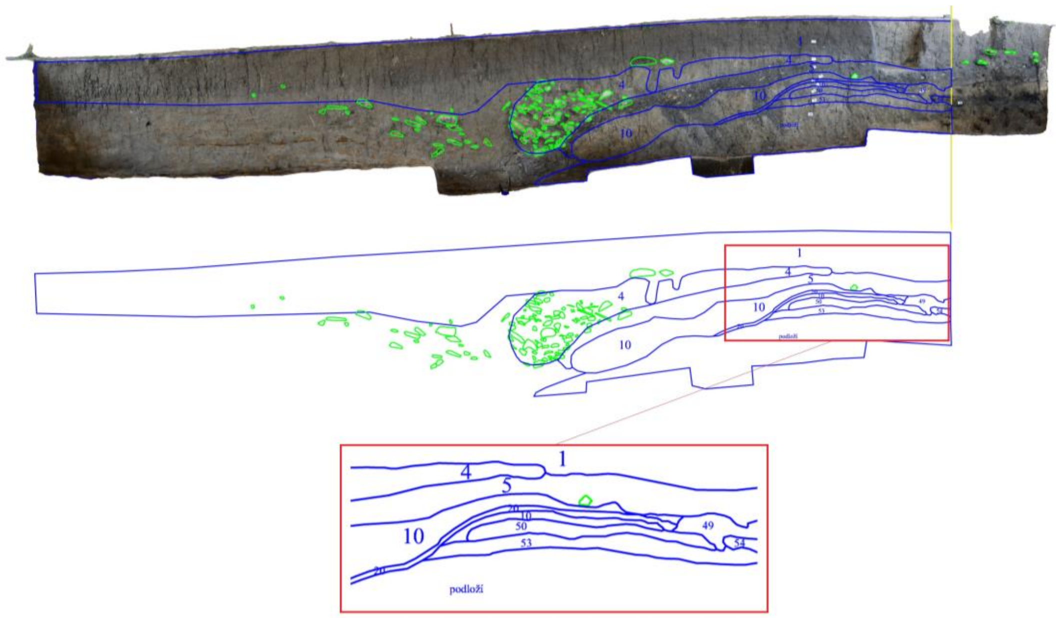


Figure 7. *Archaeological interpretation of the NW profile of the R 2018 area*

Vol. 67 (2021), No. 4
pp. 176–186, ISSN 1802-5420
DOI 10.35180/gse-2021-0063

4 ARCHAEOLOGICAL INTERPRETATION OF THE SUBJECT SECTION

As mentioned in the introduction, along with the evaluation of the results of the magnetic susceptibility measurements, an analysis and subsequent archaeological interpretation of the above-mentioned research on the destruction of the Great Moravian wall at the Mikulčice bailey was carried out independently. In the present paper we do not deal with the part of the researched area behind the wall from the inner side, as it is already part of the settlement on the foreground, which was investigated only by means of a narrow probe and will be the subject of further field research perhaps in 2022 (the research was postponed twice due to the Covid-19 situation). Thus, what follows is a description of the section according to the individual macroscopically distinguishable deposits or structures, from which, with the help of Figs. 6 and 7, the whole archaeological context of the findings can be well understood.

Description of section – contexts stratigraphically from above (see **Fig. 7**):

- **C1** – brownish-black silty clay loam, continuously across the study area, a mixture of flood clay of uncertain age (probably medieval to essentially recent) and ploughed topsoil of the inner development, displaced by agricultural activity over the remains of the lower surviving part of the fortification.
- **C2** – brownish-black sandy clay to clayey sandy across the whole study area; apparently the same interpretation as C1, only the proportion of clay component (new flood clay) is lower, the layer appears lighter when reduced in area.
- **C3** – blackish grey to grey clay (lighter with increasing depth) in the area outside the wall; uppermost fill of the extinct Morava River channel, interpreted as flood clay, similar to C1.
- **C4** – grey-yellow sandy clay, in the upper parts probably still interfered by ploughing – mixed with stratigraphically younger C2 (min. depth of context 4 from the surface of about 35–50 cm). Clay fill – base of the wall – immediate ground preparation (in the plane) with transferred, elsewhere excavated clay from the growing subsoil, before building the actual construction of the wall; the first layer of stones of the front wall was laid on C4, on the surface of the layer dark impressions are also visible – remnants of the transverse slabs in the foundation grid of the wall. The layer is practically devoid of finds.
- **C5** – grey-black sandy loam with clay concretions and a lot of charcoal and daub (with a lot of pottery and bones – the character of the cultural layer). The layer from the presumed rear of the wall passes under C4 further down towards the underlying stone structure. Interpretationally, in our opinion, this is a secondary relocated waste used to raise the ground before the actual fortification construction began. The lower stone structure was founded on this layer, and stakes were driven through this layer, underpinning the front of that structure. Only then was C4 laid, on which the actual wall was founded. C5 would therefore chronologically date from the settlement prior to the construction of the wall. However, the time period in which the waste that forms part of this layer was formed before it was moved during the wall construction is more indeterminable. Exactly the same use of secondary waste in the preparation of the ground for the construction of the wall has been observed both in the investigation of another section of the castle foreground wall and in the excavation of the acropolis wall [17–18].
- **C10** – grey-yellow to yellow sandy clay – a deposit of brought excavated "clean" clay, interpreted as C4; in two thinner layers (between them C20) it increases the terrain before the construction of the wall.
- **C20** – as C5; thin interlayer, inserted into C10; interpreted as C5.
- **C27** – bedrock, clay.
- **C50** – grey sandy, interpreted as C5 and C20.
- **C53** – as C10 – yellow slightly sandy clay, only very difficult to distinguish from the vegetated subsoil; interpreted as C10, C4 – the first clay deposit, or rather the original surface – the level of the riverbank at the time when the area was settled or the wall construction began (trampled and slightly contaminated vegetated subsoil, almost no finds).

5 FINAL DISCUSSION

When comparing the archaeological interpretation of the studied profile with the results of the areal mapping of magnetic susceptibility, we can find a clear agreement in the basic features of the studied cultural stratum. Geophysics carried out during the archaeological excavation can thus help to more accurately support the

Vol. 67 (2021), No. 4
pp. 176–186, ISSN 1802-5420
DOI 10.35180/gse-2021-0063

archaeological interpretation. It therefore provides important clues to understanding the genesis of archaeologically recorded layers, or it may aid in the process of distinguishing natural contexts from those that are separated only by differences in colour or consistency, although they may not reflect distinct intentional acts in reality.

In our particular example it was, as expected, the easiest to identify the relics of the former stone elements of the wall – the destruction of the front wall and the below reinforcement substructure (the actual front stone wall has been almost completely dismantled since the modern period at the latest, so that in the vast majority of Mikulčice excavations only one or a few lines of masonry remain in their original placement from its original height of several metres), characterised by a very low susceptibility value.

From the magnetic susceptibility mapping, the ploughed part of the clay overburden in the upper part of the profile can be well distinguished from the surface of the older floodplain clay, the lower boundary of which is visually and structurally indecipherable. Conversely, in the southern part of the profile (left), there is no visually discernible magnetic boundary between the upper flood clay and the archaeological context C4, which is interpreted as an immediate landscaping prior to the construction of the actual wall structure.

There is absolute agreement in the case of a strong anthropogenic context of C5. Archaeologically, the layer is interpreted as a secondary waste that raised and levelled the terrain before the construction of the fortification began. The very high magnetic susceptibility values are another important clue that confirms the historical interpretation. The chaotic alternation of values indicates a rapid and single build-up with the use and mixing of different materials.

When studying the internal subdivision of this distinctive layer, the magnetic susceptibility values also show a well-defined "sorting" of the individual materials at an angle of about 45° (especially for the backfill of the various terrain depressions), which would again indicate a single backfill and planer (towards the watercourse from the settlement). This is also consistent with the archaeological idea that temporary scarfing of stakes and slabs was used in the construction (raising) of the wall core behind the lower forward substructure in the case of the acropolis fortification, which was subsequently removed [17]; an identical situation is also observed in the case of the R 2018 foreground research – not yet published]. Two depressions (0.2 m to 0.25 m) can be distinguished at the lower boundary of this layer (directly below the wall core, to the right of the lower stone substructure) based on magnetic susceptibility. When fitted to the orthophotoplane, these are locations with distinct dark wedges into the underlying strata. Analogous phenomena have been studied by the authors of this paper at the site of Žíšov in the Tabor region (see [8] above). These aforementioned geophysics findings support the archaeological interpretation that this is a spontaneous drifting of the ballast towards the "outside of the fortification" and a kind of "tearing" of it, most probably following the gradual destruction of the front stone wall into the river bed flowing around the outside of the fortification. In this way, the mass of the ballast was no longer supported by the headwall and, due to soil pressures and climatic changes (frost, rain), the above-mentioned displacement of the clay ballast took place and the dark contaminated layer C5 entered the resulting wedges.

The not very powerful layers, marked in the archaeological documentation as No. 20, 27, 50, and 53, cannot be distinguished using the method of magnetic susceptibility mapping and thus merge into one layer. In the area in front of the wall (on the outside of the front stone wall, or the lower substructure with rows of stakes), layers representing the gradually flooded former riverbed can be clearly documented archaeologically, which is confirmed again by the geophysical method, as the magnetic susceptibility values here clearly rule out the existence of any cultural layers.

6 CONCLUSION

The first test of the geophysical method application (measurement of volumetric magnetic susceptibility) in the complex stratigraphic conditions of an early medieval central site such as Mikulčice has significantly supported the general interpretative possibilities of archaeological research. It has proved to be a very effective (fast, cheap, and beneficial) supplementary tool for describing vertical stratigraphy, which can be used in the field even by trained laymen. With long-term application of the method at the site, the interpretative possibilities should further increase, in direct proportion to the recognition and definition of local patterns. Similarly, after systematic geophysical measurements of the horizontal and vertical stratigraphy in archaeological probes in Tábor over the last 15 years, it has been possible to accumulate a large database, thanks to which, for example, it is possible to distinguish visually and structurally identical layers of two 13th century horizons (the older, settlements before the founding of the royal city and the younger, so-called Přemyslid, i.e., related to the founding of the town of Hradiště) on the basis of magnetic susceptibility alone [17].

ACKNOWLEDGEMENTS

The study is a result of the Ministry of Culture project NAKI II "Virtual Scientific Model of Great Moravian Mikulčice: A System of Interactive Documentation, Presentation, and Archiving of Long-Term Systematic Archaeological Excavations" (No. DG18P02OVV029).

REFERENCES

[1] MAHER, B.A. Magnetic properties of modern soils and Quaternary loessic palaeosols: palaeoclimatics implications. *Palaeogeography Palaeoclimatology Palaeoecology*. 1998, vol. 137(1–2), pp. 25–54. ISSN 0031-0182. DOI: 10.1016/S0031-0182(97)00103-X

[2] KAPLIČKA, A. and E. PETROVSKÝ. Magnetic properties of Soils – Antropogenic and Enviromental Aspects. In: FÜLEKY, G. (ed.). *Soils and Archaeology: Papers of the 1st International Conference on Soils and Archaeology: May 30–June 3, 2001, Százhalombatta, Hungary*. 2003, pp. 1–3. BAR International Series 1163. ISBN 978-1841715315.

[3] HUŠŤÁK, P. and A. MAJER. *Užití geofyzikálních a geochemických metod při interpretaci zánikových horizontů*. Praha: Pueblo-archeologická společnost, o.p.s., 2010.

[4] FRÖHLICH, J., A. MAJER and N. VENCLOVÁ. Archeologická prospekce a průzkum měřením magnetické susceptibility zemin. In: *Ve službách archeologie. 1. sborník k 60. narozeninám RNDr. Vladimíra Haška, DrSc. Příspěvky z konference Přírodovědecké metody v archeologii: March 5–6, 1998, Kravsko, Czech Republic*. Brno: Archeologický ústav AV ČR, 1998, pp. 87–93. ISBN 80-86023-13-3.

[5] BAJER, A. and L. LISÁ. *Metodika odběrů a zpracování vzorků pro geoarcheologický výzkum „Výzkum sedimentárního záznamu" [Methodology of sampling and processing of sedimentary geoarchaeological samples „Sedimentary record research"]*. Brno: Mendel University, Masaryk University, 2016. Available from: http://invenio.nusl.cz/record/374032/files/nusl-374032_1.pdf

[6] KRAJÍC, R. *ZAV Tábor – Tesco [Rescue archaeological research Tábor – Tesco]*. Finding report no C-200406937. 2004. Archived: Archeologický ústav AV ČR, Praha.

[7] KRAJÍC, R. *ZAV Tábor – Komora [Rescue archaeological research Tábor – Komora]*. Finding report no. C-200912864. 2009. Archived: Archeologický ústav AV ČR, Praha.

[8] ŠINDELÁŘ, J. *Magnetická susceptibilita, ZAV D3 – lokalita Žíšov [Magnetic susceptibility, rescue archaeological research D3 – Žíšov]*. Expert report. 2010. Archived: Husitské muzeum v Táboře.

[9] CVRKOVÁ, M. *Nálezová zpráva ZAV Ústí nad Labem – Fórum [Finding report of the rescue archaeological research Ústí nad Labem – Fórum]*. Finding report no. C-200903464. 2009. Archived: Archeologický ústav AV ČR, Praha.

[10] ŠINDELÁŘ, J. and J. TOMEŠEK. *Geofyzikální průzkum klášterního kostela v Českých Budějovicích [Geophysical survey of the monastery in České Budějovice]*. Expert report. 2019. Archived: Jihočeské muzeum v Českých Budějovicích.

[11] ŠINDELÁŘ, J. *Geodetická a geofyzikální dokumentace táborského hradu [Geodetic and geophysical documentation of the Tábor castle]*. Expert report. 2008. Archived: Husitské muzeum v Táboře.

[12] HENRY, E.R. A Multistage Geophysical Approach to Detecting and Interpreting Archaeological Features at the LeBus Circle, Bourbon County, Kentucky. *Archaeological Prospection*. 2011, vol. 18(4), pp. 231–244. ISSN 1099-0763. DOI: 10.1002/arp.418

[13] EPOV, M.I., V.I. MOLODIN, A.K. MANSHTEIN, E.V. BALKOV, P.G. DYAĎKOV, G.G. MATASOVA, A.Yu. KAZANSKY, S.B. BORTNIKOVA, O.A. POZDNYAKOVA, Yu.G. KARIN and D.A. KULESHOV. Integrated archeological and geophysical studies in West Siberia. *Russian Geology and Geophysics*. 2016, vol. 57(3), pp. 473–482. ISSN 1068-7971. DOI: 10.1016/j.rgg.2016.03.009

[14] KŘIVÁNEK, R. Detailní měření magnetické susceptibility v odkrytých archeologických situacích. *Archeologické rozhledy*. 2008, vol. 60(4), pp. 695–724. ISSN 0323-1267.

[15] HLADÍK, M., R. HADACZ, A. DOHNALOVÁ, J. ŠUŠOLOVÁ, M. LÁTKOVÁ and J. KYNICKÝ. Fortification of the suburb of the Great Moravian stronghold at Mikulčice-Valy. *Slavia Antiqua. Rocznik poświęcony starożytnościom słowiańskim*. 2014, vol. 55, pp. 67–124. ISSN 0080-9993. DOI: 10.14746/sa2014LV.2

[16] PROCHÁZKA, R. Otázka předlokačního a lokačního Brna v konfrontaci písemných a archeologických pramenů. *Pamiatky Trnavy a Trnavského kraja*. 2009, vol. 12, pp. 103–112. Available from: https://www.trnava.sk/userfiles/download/attachment/ourak_KPU-Zbornik-pamiatky_12-2009.pdf

[17] MAZUCH, M. Findings about the early medieval fortification of the Mikulčice – Valy acropolis. *Slavia Antiqua. Rocznik poświęcony starożytnościom słowiańskim*. 2014, vol. 55, pp. 7–65. ISSN 0080-9993. DOI: 10.14746/sa2014LV.1

[18] POLÁČEK, L. et al. *Great Moravian Elites from Mikulčice*. Brno: Archeologický ústav AV ČR, 2021. ISBN 978-80-7524-032-3.

[19] ŠINDELÁŘ, J. *Měření magnetické susceptibility na ZAV v Táboře [Measurement of magnetic susceptibility in rescue archaeological research in Tábor]*. Expert report. 2015. Archived: Husitské muzeum v Táboře.