Understanding the anomaly: reinterpreting *Porolissum* Roman town with emerging GPR and ER data

Michał Pisz [1, 2*], **Vlad-Andrei Lazarescu** [3], **Alexandru Hegyi** [4]

1 School of Archaeological and Forensic Sciences, University of Bradford, Bradford, United Kingdom
2 Faculty of Geology, University of Warsaw, Warsaw, Poland
3 Institute of Archaeology and History of Art, Romanian Academy – Cluj Branch, Cluj-Napoca, Romania
4 Maritime Asia Heritage Survey, Center for Southeast Asian Studies, Kyoto University, Kyoto, Japan
* Corresponding author: E-mail: m.pisz@bradford.ac.uk; michal.pisz@uw.edu.pl

Abstract
The Roman *Porolissum* (Romania) was first surveyed with magnetics in 2010. Local geology is propitious for magnetic prospection. In 2021 the Polish-Romanian team carried out a complementary ER and GPR survey. Emerging geophysical data allowed reinterpretation of the previous survey results. Complementary survey data and geological setting analysis yet enhanced the archaeological interpretation.

Keywords
archaeological prospection; earth resistance; ground penetrating radar; magnetometer survey; Roman *limes Porolissensis*

Research background

In this paper, we present the case study of a multi-method archaeo-geophysical survey carried out in the extent of a Roman fort and *municipium Porolissum*. The first magnetometer survey carried out in 2008 by a team of geophysicists from Eötvös Loránd University showed very good responsiveness. Hence, investigations were continued in collaboration with multiple teams from different institutions, focusing on the area of the Roman town (Ștefan 2016; Fiedler et al. 2018; Opreanu and Lăzărescu 2018). Captured anomalies clearly outlined buried archaeological structures due to the use of strongly magnetic construction material (andesites and dacites). The Polish-Romanian team carried out supplementary earth resistance (ER) and ground penetrating radar (GPR) surveys in 2021. We argue that despite the seemingly unambiguous results of the magnetic survey, the application of complementary geophysical methods, GPR in particular, allowed improving the analysis, led to emerging discoveries and enhanced the interpretation of previous results.

Porolissum Roman fort and town

The site is located in NW Romania (Salaj county), in the Moigrad-Pomăt-Citera magmatic-volcanic complex. The fort is partly set on and surrounded by several Neogene hillocks, the genesis of which is associated with a phenomenon of hot-spot intrusions into Oligocene deposits, laying magmatic bodies consisting of dacites and andesites that were later brought to the surface by selective erosion (Fig. 1) (Mac 2010).

As a strategic frontier province, *Dacia Porolissensis* was a Roman territory with a strong military presence. The core of the *Porolissum* military complex was the Pomăt Hill fort, the largest auxiliary fort in the Dacian provinces, measuring 230 × 300 m. The civilian settlement at *Porolissum* was located around the fort, and due to its position at the fringes of the Empire, it developed into an important commercial hub allowing for complex connections with the *Barbaricum* (Opreanu and Lăzărescu 2016).

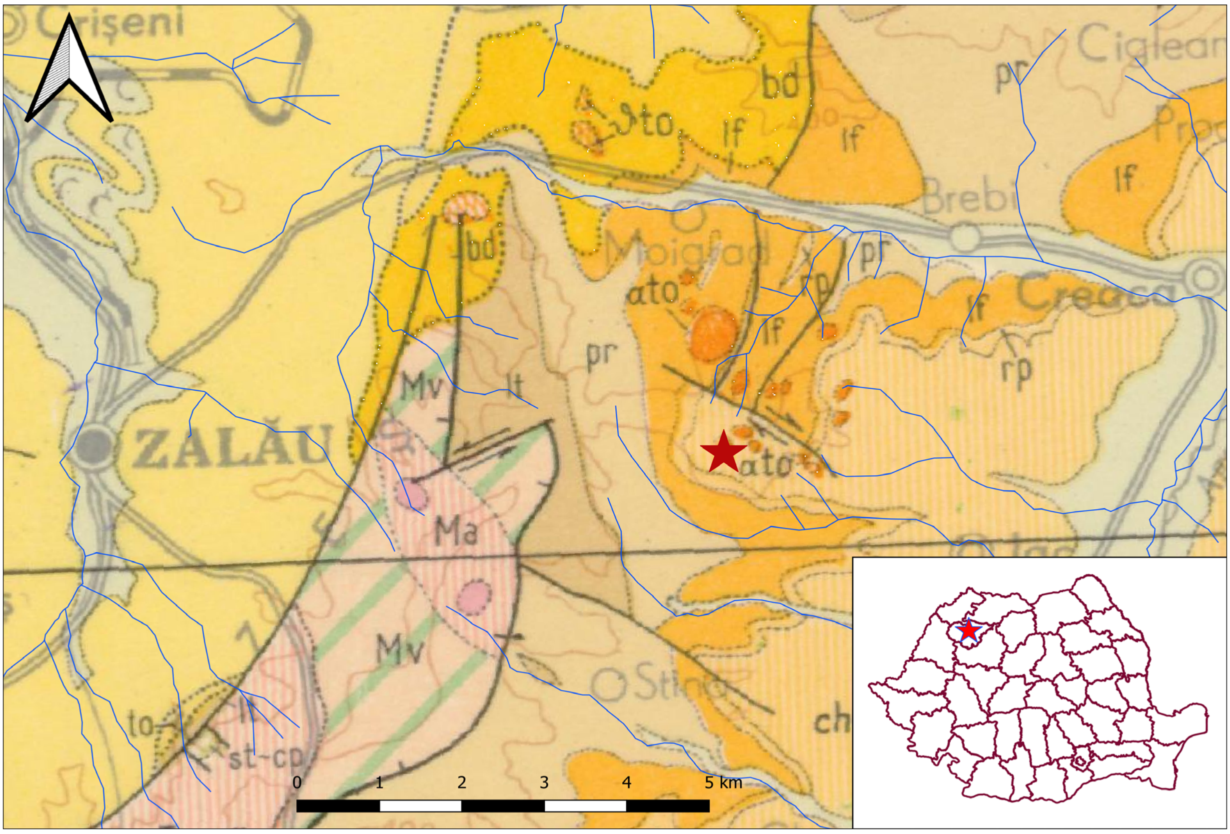

Fig. 1: The location of the Roman fort and town of *Porolissum* on the 1:200000 Geological Map of Romania (Raileanu et al. 1968).

Methods

The magnetic survey in the *municipium* area was carried out between 2010-2016 by Dan Ștefan, with a Bartington Grad601 dual sensor fluxgate gradiometer (Ștefan 2016). In 2021 we carried out a complementary survey with ER and GPR methods (Schmidt et al. 2015).

ER survey was carried out with Geoscan Research RM85 meter in a multiplexed measurements mode. Multi-depth twin probe array has been used with three mobile probes separation distances set at AM = 0.5, 1.0 and 1.5 m. Measurements were carried out within a 20 × 20 m grid, with 1 m crossline and 0.5 m inline. The ER data were processed in Geoplot 4 software. Recorded resistance values have been despiked and multiplied by the value of the K geometry factor relevant for each of multiplexed arrays, to calculate the values of the apparent resistivity for each maximum depth of prospection. Subsequent filtering procedures (e.g. low pass, interpolation) were applied.

GPR survey was carried out with a Malå GX radar with a shielded 450 MHz antenna in the same 20 × 20 m grid, with a 0.5 m crossline and 0.05 m inline. The GPR data was processed in SubGeo WAVE GPR processing software and exported as time slices.

Rendered geophysical maps were georeferenced and uploaded to QGIS along with up-to-date UAV orthophoto, DSM, satellite imagery and Romanian Geological Map 1:200000. In addition, Magnetic Susceptibility readings of the soil surface and materials used for construction have been taken on the site with Bartington MS3 meter and MS2D sensor.

Results

ER (Fig. 2) and GPR (Fig. 3) survey results matched to some extent, GPR being considerably more detailed. Numerous electrical anomalies were captured, high resistant zone and linear being the most commonly encountered. The latter corresponded with highly reflective features detected with the GPR.

 KIEL-UP • DOI: https://doi.org/10.38072/978-3-928794-83-1/p43

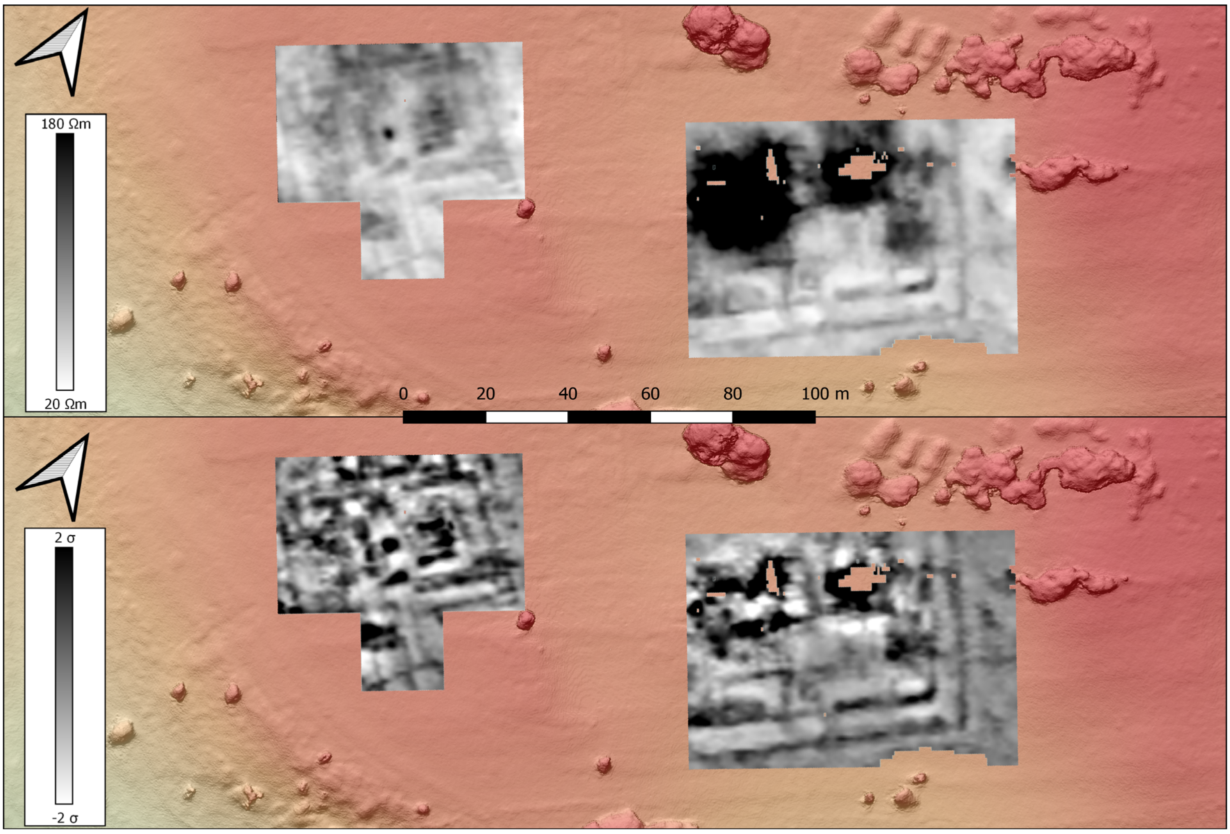

Fig. 2: The results of the 2021 ER survey. Resistivity map at AM=0.5 m (above), and high pass filtered AM=1.0 m (below).

Discussion

The previous geophysical survey results proved magnetics to be very effective in the geological conditions of *Porolissum*. Excellent contrasts triggered by strongly magnetic linear features (i.e. walls built of andesites and dacites) resulted in clearly pronounced structures. On the other hand, magnetic maps looked blurred at spots where building material was scattered above archaeological structures.

The same distortion burdens the shallower and lower-resolution prospection with ER. Scattered highly resistive material prevented us to capture some anomalies of linear structures lying under the rubble in the very low resistive subsoil (Fig. 2).

The latter property of the soil tends to be an obstacle for the GPR survey. Nonetheless, we argue that the GPR survey presented even better effectiveness and satisfyingly complemented magnetic survey results. It was less affected by scattered rubble and clearly depicted preserved structure foundations, providing a such level of detail as preserved *hypocausta* (Fig. 3). This allowed us to improve the existing interpretation and attribute particular functions to structures.

The considerable depth and good state of preservation of buried features, along with a fortunate geological setting of the site, may suggest the magnetic method be applied exclusively in such conditions. However, complementary methods, apparently the GPR being the best choice, should be considered to improve the archaeological interpretation.

Conclusion

A few conclusions might be drawn based on the results of this study.

1. Resurveying the area of the previous apparently unambiguous magnetic survey, with complementary geophysical methods, was very effective in providing additional information about archaeological features and structures.

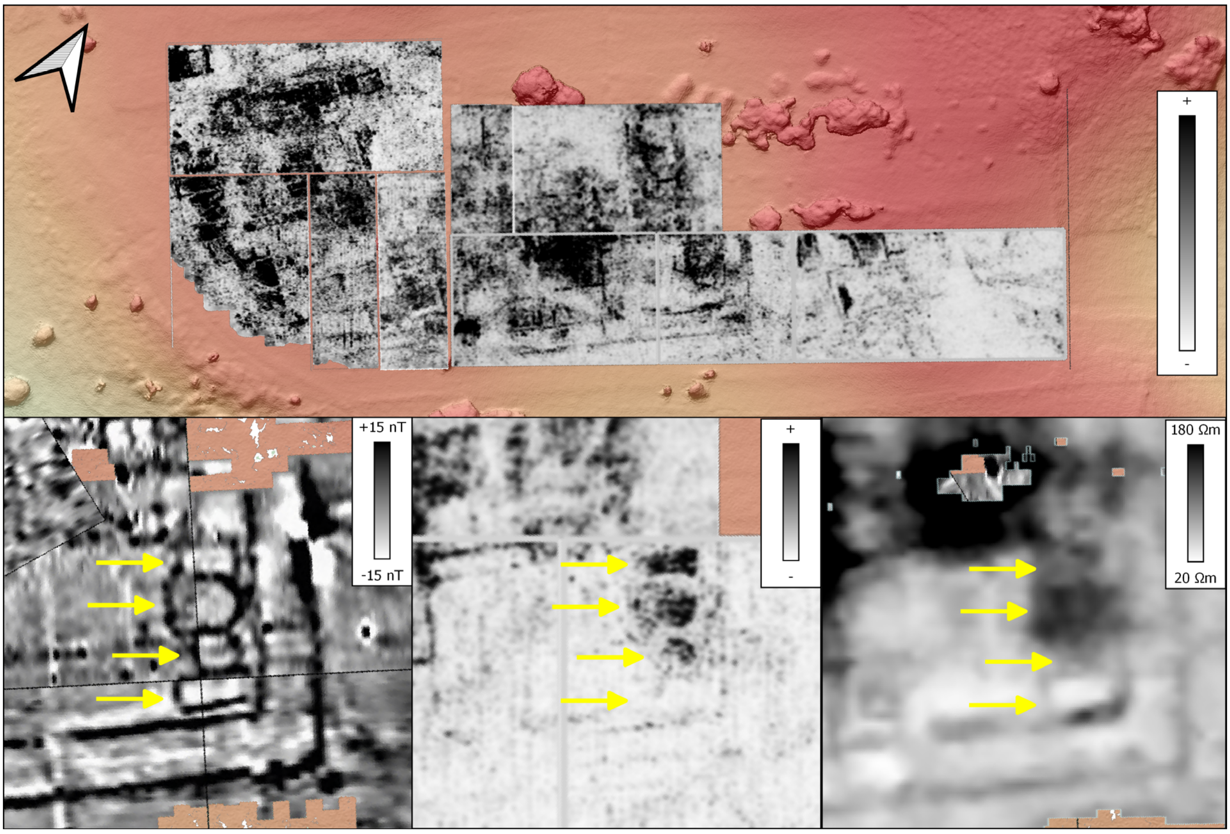

Fig. 3: The results of the 2021 GPR survey (above) and the baths as seen in the magnetic (below left), GPR (below centre) and ER (below right) imaging.

2. Even if applied in theoretically unfavourable conditions, complementary geophysical measurements allowed us to improve the archaeological interpretation, e.g. attribute functions to particular archaeological structures.
3. The analysis of the geological map and Magnetic Susceptibility values of the soil and rocks used on site as a construction material, helped to enhance the interpretation of the existing magnetic survey results and to explain the phenomena recorded in this data. Strongly magnetic rocks, besides feature-related anomalies, produce considerable noise.
4. Strongly magnetic archaeological features may deliver clear results, however, in certain situations, they may also distort the overall image of surveyed features and lead to interpretive pitfalls. Properties of soils and rocks should be tested and taken into account at the stage of analysis and interpretation of archaeo-geophysical data.
5. Based on the results presented in this paper we plan to carry out a further GPR survey with a multi-channel array.

Acknowledgments

This scientific work is financed by the National Science Centre (Poland) within the Preludium 16 programme (grant number 2018/31/N/ST10/01782).

References

Fiedler M, Höpken C, Pánczél SP, Bajusz I, Döhner G, Lenkey L, et al. Porolissum. Forschungen im Kastell auf dem Pomet von 2009 bis 2011. In: Müller L, Schiller B, editors. Von Kreta nach Kuba. Gedenkschrift zu Ehren des Berliner Archäologen Veit Stürmer. Logos Verlag; 2018. German. Available from: https://www.academia.edu/38252634/Porolissum._Forschungen_im_Kastell_auf_dem_Pomet_von_2009_bis_2011_-_Von_Kreta_nach_Kuba.pdf

Mac I. Complexul morfotectonic magmato-vulcanic: Pomăt-Moigrad-Citera, un hot spot unicat în nord-vestul Transilvaniei. In: Irimuș IA, Vescan I, Fodorean I, Moldovan C, editors. Geografia în contextul dezvoltării contemporane Strategii de dezvoltare teritorială. Cluj-Napoca: Editura Universitară Clujeană; 2010. p. 217–23. Romanian.

Opreanu CH, Lăzărescu V-A. Landscape archaeology on the northern frontier of the Roman Empire at Porolissvm. An interdisciplinary research project. In: Opreanu CH, Lăzărescu V-A, editors. Landscape archaeology on the northern frontier of the Roman Empire at Porolissvm. An interdisciplinary research project. Mega Publishing House; 2016.

Răileanu G, Saulea E, Dumitrescu I, Bombiță G, Marinescu F, Borcoș M, cartographers. Harta Geologică a Românei scara 1:200 000. Foaie 10. Cluj, Geological map. București: Comitetul de Stat al Geologiei, Institutul Geologic; 1968; 1 sheet. Romanian.

Schmidt A, Linford P, Linford N, David A, Gaffney C, Sarris A, et al. EAC Guidelines for the Use of Geophysics in Archaeology: Questions to Ask and Points to Consider. EAC Guidelines 2. Namur: European Archaeological Council. 2015; 136:67-88. ISBN 978-963-9911-73-4. uri: http://hdl.handle.net/10454/8129

Ștefan D. Geophysical surveys and the reconstruction of the ancient landscape. In: Opreanu CH, Lăzărescu V-A, editors. Landscape archaeology on the northern frontier of the Roman Empire at Porolissum. An interdisciplinary research project. Mega Publishing House; 2016. p. 115–9.