

# Combining remote sensing and geophysical data to determine Roman structures at Buzovytsia-1 settlement in Ukraine

Kseniia Bondar <sup>1\*</sup>, Oleg Petrauskas <sup>2</sup>, Dmytro Mostovyi <sup>3</sup>, Serhii Didenko <sup>4</sup>, Roman Reida <sup>2</sup>

1 Taras Shevchenko National University of Kyiv, Kyiv, Ukraine

2 Institute of Archaeology of the NAS of Ukraine, Kyiv, Ukraine

3 Scientific Research Centre 'Rescue Archaeological Service' of the Institute of Archaeology of the National Academy of Science of Ukraine, Lviv, Ukraine

4 National Museum of the History of Ukraine, Kyiv, Ukraine

\* Corresponding author: E-mail: [ks\\_bondar@ukr.net](mailto:ks_bondar@ukr.net)

## Abstract

An archaeological map of Buzovitsya-1 Roman time site was obtained based on a combination of geophysical and remote sensing results. The KH-9 Hexagon image reveals Roman structures.

## Keywords

Buzovytsia-1 settlement; GPR; magnetometry; Roman building; satellite image

## Introduction

Application of multiple methods increases the reliability of space reconstructions on archaeological sites. The paper represents an attempt to assemble relevant evidence from magnetometer and ground penetrating radar (GPR) surveys, remote sensing and geospatial investigations, results of limited archaeological excavations to recognize Roman structures on the Buzovytsia-1 settlement recently discovered in Chernivtsi region (Ukraine). It was demonstrated that neither a magnetometer survey nor a GPR survey is able to resolve all the archaeological issues on the sites of the region (Bondar et al. 2022a). Challenging conditions for magnetometry are represented by the use of limestone as a building material for Roman structures, and for GPR by high clay content in the soil causing adsorption of electromagnetic waves, and thus providing poor depth for GPR exploration. However, magnetometry can find baked clay structures and, in some cases, refilled pits, while GPR still can detect shallow stone structures. We involved remote sensing data to obtain additional archaeological information from the color of the topsoil varying with its composition.

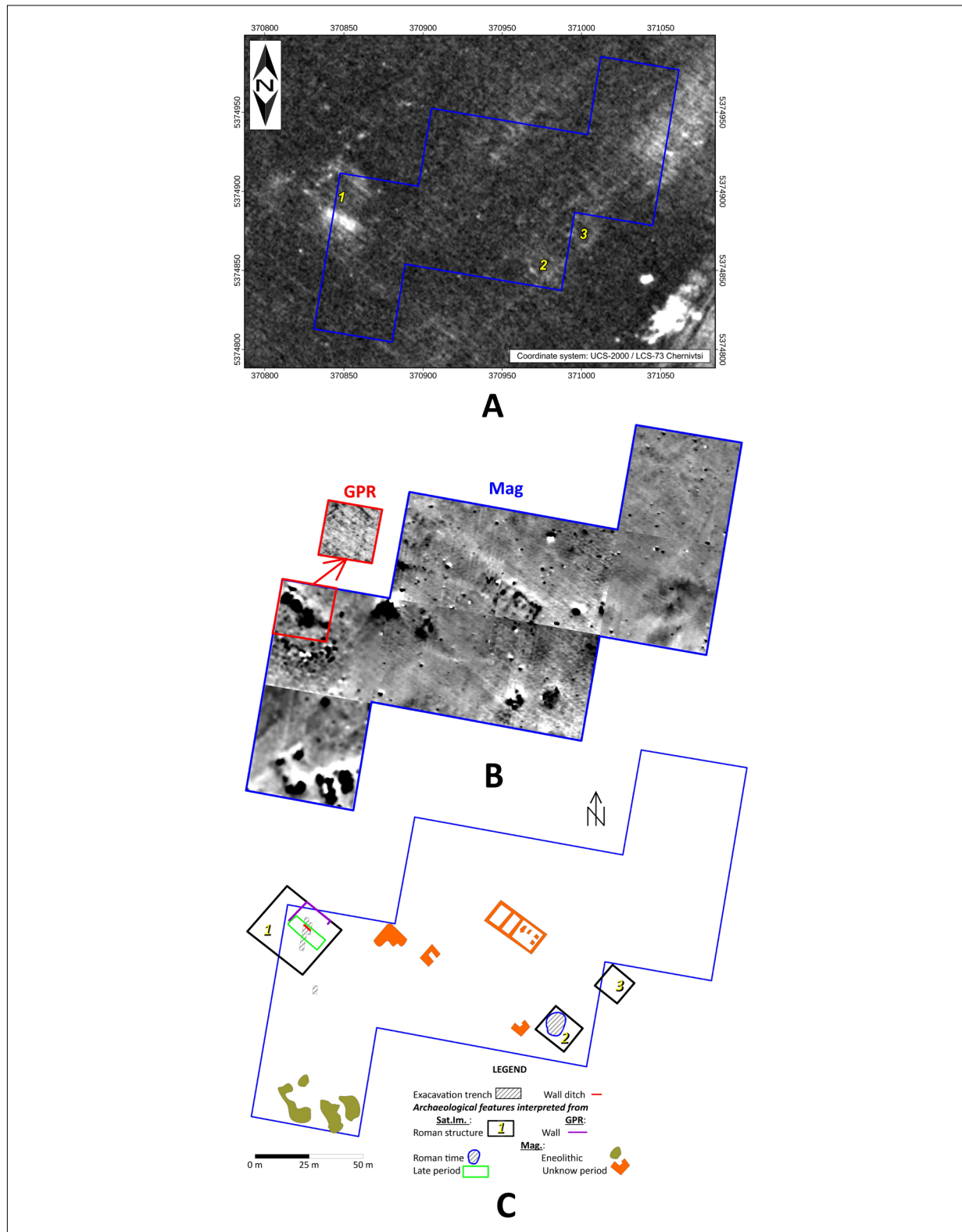
## Materials and methods

Buzovytsia-1 is the largest site of Chernyakhiv - Sântana de Mureş archaeological culture on the territory of Ukraine, which had been functioning during the late 2nd to the middle of the 5th centuries AD. It was discovered due to Roman imports found on the ground surface, as well as material pieces of evidence of Roman construction technologies - fragments of limestone, lime mortar, and bricks.

Geophysical data were collected with the use of total field cesium magnetometer PKM-1 on an area of 2 ha and ground penetrating radar VIY-3 with nominal center frequency 300 MHz antenna on a small plot of 25x25 m.

Declassified analogue panchromatic satellite image from the American reconnaissance program Hexagon (KH-9), taken on 21 May 1974 with the 0.6-1.2 m per pixel resolution has been used to analyse the localization of clusters of construction materials.

Limited archaeological trenching on an area of 48 m<sup>2</sup> has been performed to validate non-invasive results.



**Fig. 1:** Buzovytsia-1 settlement. a) Quasi-rectangular anomalies detected on a satellite image from the American reconnaissance program Hexagon (KH-9), taken at 21 May 1974. b) Geophysical results: magnetogram in greyscale and dynamics of the total magnetic field  $\pm 5.0$  nT, black is high, and GPR C-scan at a time of 12-15 ns, strong reflections are black. c) Interpretation scheme.

## Results

### Remote sensing

The raster obtained as a result of the satellite image classification made it possible to trace three quasi-rectangular spots among the arable agricultural lands (Fig. 1a). The largest one (marked as 1) appeared to be at the place of a building remains cluster. Its approximate area is about 1400 m<sup>2</sup>. The outer parts of the largest spot are whitish, while the inner rectangular-shaped area with dimensions 17x30 m is dark like the background of the field. Two other spots recognized from the image also have a quasi-square shape. We suggest them to be the places of an ancient building. Whitish areas at the edges of the spots correspond to the localization of ploughed building remains available at the moment the image was captured (1974).

### Magnetometry

The area includes several types of magnetic anomalies (Bondar and Petrauskas 2021). Strong ones in the southwest are characteristic of and definitely sourced from Eneolithic buildings of Trypillian archaeological culture. A chain of positive magnetic anomalies with maximum intensities of 10-30 nT appeared at the upper slope within the area of spot 1 (Fig. 1b). However, most of the building's baked clay fragments were lying 10 m down the slope and creating an assembly of small and weak positive anomalies. The oval-shaped positive anomaly coincides with spot 2. A well-preserved building retaining the internal layout is suggested under the anomaly in the center. Quasi-right angles could be recognized in the shapes of some other anomalies.

### Ground penetrating radar

On the C-scan there are two perpendicular linear anomalies in the time interval of 12-15 ns (Fig. 1b). The anomalies are formed by strong reflections, evidencing significant contrast of dielectric permittivity between the source structure and soil. The structure fits well with the northern whitish part of the characteristic spot 1 on the Hexagon image.

### Archaeological excavations

The main excavation trench was laid to the north from the surface cluster of the building remains (Fig. 1c) in order to cut the strong magnetic anomaly. The wall ditch of the ancient building was discovered. A trench from the

late period runs along the wall ditch of the building. To the south of it, rectangular blocks fastened with mortar, sections of concrete fill and four pillars were unearthed.

## Discussion

Excavation data definitely testify to the remains of a building constructed using Roman technologies - building materials (plinth, mortar) and architecture (warm floor - *hypocaustum*). Findings from excavations and walkover surveys are identical. The cylindrical plinth was found in the excavation in situ at a depth of 1.4 m, and 20 m down the slope, the same plinth was found on the surface. Thus, these finds could belong to the same building.

In the 1950s, there was a small quarry on the territory of the settlement, from where limestone was mined by locals. This provides an explanation for the origin of the trench uncovered at the place of the ancient building's wall. We assume a massive stone wall was clearly visible on the surface at that time, and the trench was dug to extract the stone. The chain of magnetic anomalies, obviously, was formed as a result of gradual refill of the abandoned trench with topsoil material, acquiring detrital remanent magnetization (Bondar et al. 2022b).

In the 1970s, intensive ploughing of the settlement territory began, as a result of which building materials of ancient structures appeared on the surface. This is the explanation for the origin of the whitish edgings of spots 1, 2 and 3 recorded in the Hexagon image. The southern edge of spot 1 looks brighter and is located on a terrain with a steeper slope. We assume remains of the southern wall of structure 1 to lie on a smaller depth and, thus, to have been ploughed more intensively. To date, construction remains are concentrated only in the southern part of spot 1. The northern part of structure 1 is supposedly better preserved, which is recognized from GPR data.

Thus, the wall uncovered in the excavation trench is the intrinsic wall of the building separating a room with *hypocaustum*.


## Conclusion

The results of magnetometer and ground penetrating radar surveys, and remote sensing investigations proven by archaeological excavations testify to Roman

architectural structure (presumably, *villa rustica* - style) with an approximate size of 27x32 m.

Putting together all elements interpreted from different surveys allowed us to propose a preliminary archaeological map of the site (Fig. 1c) and define future targets for archaeological excavations.

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