The more, the merrier? A multi-methodological survey at the Roman town of Carnuntum

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Abstract
We have newly discovered the garrison of the governor's guard, the castra singularium, in the Roman Town of Carnuntum. For a more detailed research we decided to apply a multi-method research approach on this important archaeological site. The analysis of the different geophysical prospection methods was carried out prior to an archaeological excavation. By excavating a small area, the interpretations of the non-destructive methods could be evaluated.

Keywords
Carnuntum; evaluation excavation; multi-method survey; Roman archaeology

Introduction

The Roman site of Carnuntum was once a flourishing center on the frontiers of the Roman Empire. Through a large-scale archaeological prospection project, this huge area could be investigated and analyzed in great detail using nondestructive prospection methods (Wallner et al. 2021). One of the main discoveries of the project was observed in the military settlement, where it was possible to identify a military camp, interpreted as the garrison of the governor's guard. Through the archaeological analysis of the immediate surroundings, the Roman fort was determined to be embedded in a large administrative complex related to the seat of the Roman governor at Carnuntum (Gugl et al. 2021).

The garrison of the governor's guard in Carnuntum

In the area between the governor's palace (A) and the military training ground (C) a massive enclosing wall of a large building complex (B) was visible in the archaeological prospection datasets (Fig. 1).

Thanks to the unique situation in Carnuntum, the vast administrative center of a Roman province was not overbuilt by modern structures. This results in an incredible field of activity for the non-destructive investigation of this archaeological site (Fig. 2). We will summarize our efforts made so far and will compare the results of the different applied methods.

Materials and methods

As early as the 1960s, it was possible to derive the first images of the Roman settlement of Carnuntum from aerial photographs. However, it was not until the large-scale geophysical prospections in the 2010s that the entire urban landscape could be explored in detail. Here, mainly motorized magnetics and ground penetrating radar systems were used. However, at the area presented here, additional methods were applied to generate a comparative data set, which should reveal the potential of each individual method (see Fig. 3). All systems were operated with an

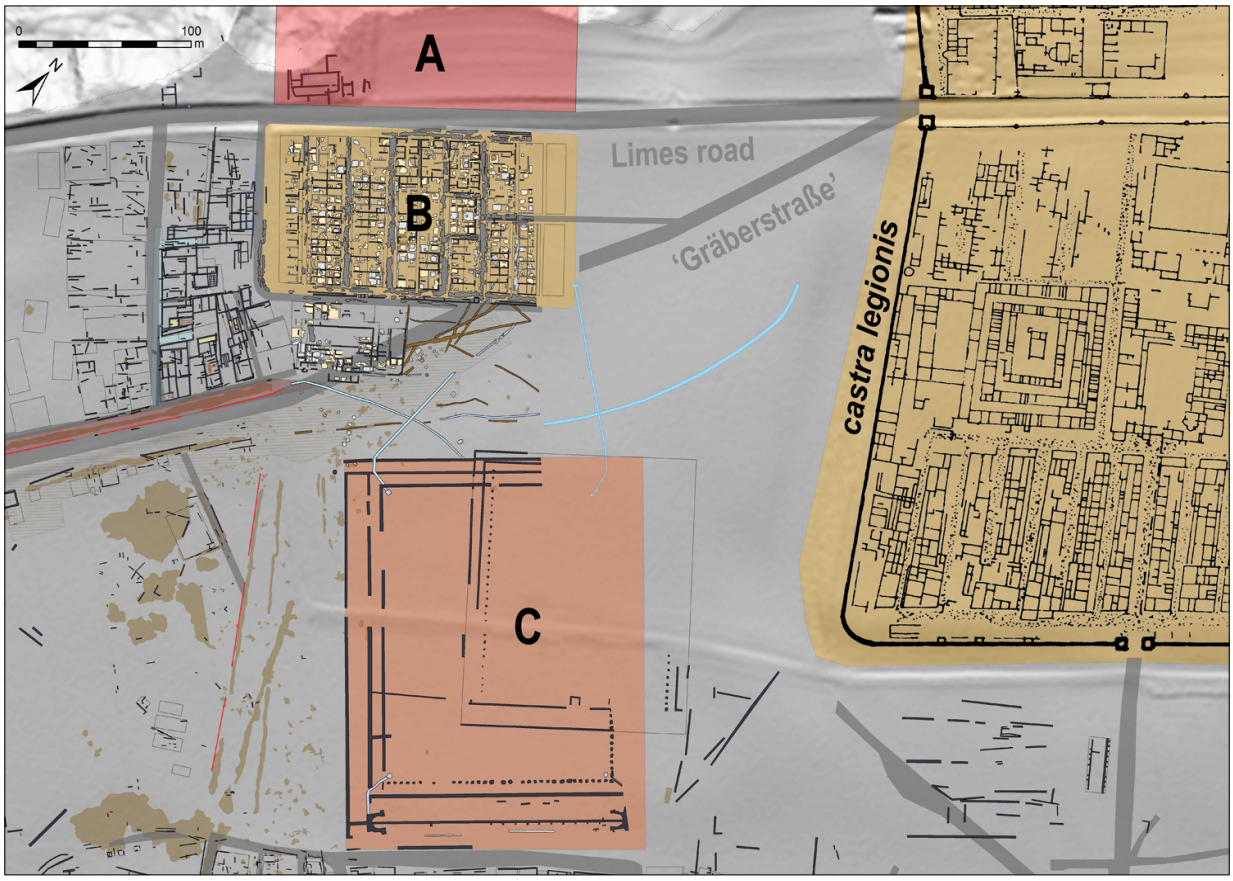

Fig. 1: Current archaeological interpretation of the area southwest of the legionary fortress representing the administrative district of Carnuntum consisting of A = governor's palace (*praetorium*), B = garrison of the governor's guard (*castra singularium*) and the C = military training ground (*campus*).

RTK-GNSS to ensure the accurate georeferencing of the measurements.

Aerial photographs

The development of vegetation marks depends on many factors and therefore the buried remains underneath the surface are not always visible. Unfortunately, the area discussed here did not show clear vegetation mark over many years. Only the extremely dry springs and summers of recent years revealed clearly recognizable structures.

Ground penetrating radar (GPR)

The motorized GPR survey using a Malå 16-channel 400 MHz MIRA system was carried out two times, but with perpendicular surveying directions. The diagonally staggered arrangement of the antennas achieves a measurement resolution of 8 × 4 cm. The dataset was processed using the ZAMG in-house ApRadar software.

Magnetometry

A motorized magnetic survey was conducted using 8 Foerster FEREX CON650 gradiometer probes with a line spacing of 25 cm on a six-meter long custom-built survey cart. The speed of the survey vehicle was adapted not to extend the inline spacing to more than 10 cm. The dataset was processed using the ZAMG in-house ApMag software, resulting in georeferenced grayscale images with a resolution of 10 cm² per pixel.

Electric Resistivity Tomography (ERT)

Measurements were collected with the DAS-M instrument (MPT-IRIS instruments) using 96 stainless electrodes distributed along 8 parallel lines and 12 electrodes in each line, with a separation of 1.5 m between electrodes. To achieve a real 3D configuration, current injections were performed in odd lines with voltage dipoles located in the even lines, and subsequent collections after reversing these. Data were processed using normal-reciprocal analysis (Flores

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Fig. 2: The Garrison of the Governor's Guard (a) aerial photo overlayed with GPR visualization (depth slice 80–200 cm) (orthophoto: M. Wallner), (b) archaeological interpretation of GPR dataset.

Fig. 3: The applied methods: (a) GPR - 16-channel 400 MHz MIRA, (b) Magnetometry – Fluxgate probes, (c) EMI – CMD Explorer, (d) EMI – DUALEM-21HS, (e) EMI - EMD2, (f) ERT – DAS-M, (g) percussive core drilling, (h) stratigraphic excavation.

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Orozco et al. 2012) and ResIPyfor the inversion. A resolution of 30 cm was achieved in the 3D imaging results.

Electromagnetic Induction (EMI)

Lateral changes in subsurface electrical conductivity were mapped using four different instruments: the CMD Explorer and CMD Mini-Explorer (by GF Instruments), the DUALEM-21HS and EMD2 (by Sensys), thus providing apparent conductivity information for a large variety of coil separations and coil orientations.

Targeted percussive core drilling

By targeted percussive core drilling, it is possible to gain a microinvasive insight into the stratigraphic nature of the site. Hereby a metal cylinder, driven into the ground, is used to recover a continuous and, as far as possible, undisturbed sequence of layers of sediments.

Stratigraphical excavation

One of the most challenging areas for the archaeological interpretation of the surveyed area was chosen for an evaluation excavation. The excavated area (10 m x 15 m) is located in the administrative building (*principia*) of the military camp. The excavation was carried out following the stratigraphic method and documented as digital surfaces generated by photogrammetry.

Results

The potential of large-scale, non-invasive prospection methods has been widely recognized in archaeology in recent years. Our study reveals the possibility to extend the details in the investigation when combining high resolution GPR and 3D-ERT. Additionally, EMI maps confirm the structures defined with ERT and increase the resolution, and facilitate quick mapping. The extensive investigation of Roman Carnuntum by the combined application of a wide variety of survey methods resulting in detailed information on its ancient infrastructure.

Through the detailed investigation, by means of various archaeological prospection methods (aerial photography, GPR, magnetometry, ERT, EMI, stratigraphical excavation), it is now possible to gain far-reaching conclusions about the administrative center of a Roman province.

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