2020 IMEKO TC-4 International Conference on
Metrology for Archaeology and Cultural Heritage
Trento, Italy, October 22-24, 2020

Multimethodological Geophysical Investigations to study the Archaeological Site of Norba (Norma, Central Italy)

Piro Salvatore.[1], Quilici Gigli Stefania.[2], Papale Enrico[1] and Zamuner Daniela.[1]
[1] - *ISPC CNR, Institute of Heritage's Sciences, Monterotondo Scalo, Italy (salvatore.piro@cnr.it)*
[2] - *Università della Campania, Luigi Vanvitelli, Caserta, Italy*

***Abstract* – To enhance the knowledge of the unexcavated portions of the archaeological site and to locate the position of the unknown buried structures, geophysical prospections employing the Ground Penetrating Radar method were performed between September and November 2017. For the measurements, a GPR system SIR3000 (GSSI), equipped with a 400 MHz bistatic antenna with constant offset was employed to survey 18 different sectors closing to few excavated area. Taking into account the environmental conditions of the site and the nature of the hypothesized structures, some areas have been surveyed with a spacing interval between parallel profiles of 0.25 m while other areas have been investigated with a spatial interval between closed parallel profiles of 0.50 m. Furthermore, differential magnetic surveys were carried out using the Geoscan FM256 in two areas, overlapping the GPR areas. With the aim to have a better understanding of the subsurface, a qualitative and quantitative integration of the results, have been employed. For the integration process the following techniques: maps overlays and RGB colour composites (graphical integration), binary data analysis and cluster analysis (discrete data integration) and data sum, data product and principal component analysis (continuous data integration) have been used.**

The results obtained from the geophysical surveys were interpreted together with the archaeologists to define the meaning of the individuated structures and to enhance the knowledge of the ancient town's layout and mapping.

I. INTRODUCTION

This study is part of the "*Norba Project*", jointly developed between the University of Campania region "Luigi Vanvitelli", the Municipality of Norma (Latina) and the Institute of Heritage's Sciences (ISPC, exITABC-CNR).
The archaeological site of Norba is located in the Latium Region, about 90 Km south of Rome, in Italy. The ancient town of Norba rises on a high plateau overlooking the Pontine plain. As stated in previous studies, the town has been founded in the archaic age and its most important period was between 450 B.C. and 81 B.C. when it was destroyed. During the Middle Ages, the ancient town was partially inhabited and only for a short period of time. This is one of the reasons for which the archaeological site is still so well preserved today. The city represents one of the best examples of urban town planning, with a regular layout dating back to an ancient age. During the last ten years, the site has undergone many studies, followed by archaeological excavations, which allowed several buildings and other important archaeological features to be brought to light. The conservation of the polygonal walls and other structures, has attracted to Norba, since the beginning of the eighteenth century, the attention of the historians and archaeologists; it has also been used for the experimentation of the first examples of aerophotogrammetric restitution. Thanks to the work of Latium Region and the Municipality of Norma, now the whole site is part of an archaeological Park. The archaeological excavations made in a small portion of the town allowed to recognize a regular urban layout, marked by terraces in polygonal work.
The *Norba Project* started in 2017 with new acquisition and processing of extensive geophysical surveys to investigate unexcavated portions of the archaeological site with the aim to enhance the knowledge of the urban plan of the ancient town [3] and [5]. Ground Penetrating Radar and the Gradiometric methods have been applied to investigate this site. In particular, GPR system SIR 3000 (GSSI), equipped with a 400 MHz antenna with constant offset was employed to survey 18 different areas close to some of the unearthed structures. Furthermore, differential magnetic surveys were carried out using the Geoscan FM256 in few areas investigated with GPR.

II. METHODS

The geophysical surveys were carried out using the Ground Penetrating Radar and the gradiometric methods. For the measurements a SIR3000 GPR system (GSSI) equipped with a 400 MHz (GSSI) bistatic antenna with constant offset was employed. The horizontal spacing between parallel profiles at the site was 0.25 and 0.50 m. In the investigated areas, a total of 1199 adjacent profiles across the site were collected alternatively in forward and reverse directions, employing the GSSI cart system equipped with odometer. All radar reflections within the 90 ns (two-way-travel) time window were recorded in the field as 16-bit data and 512 samples per radar scan.

Part of the area surveyed with GPR has been investigated employing the gradiometric method, Fig. 1. This surface was divided in squares of 20x20 m and of 10x10 m where the vertical gradient of the magnetic field was measured using a fluxgate gradiometer FM256 (GEOSCAN Research, UK) along parallel profiles with a horizontal spacing of 1 m and with a sampling interval of 0.5.

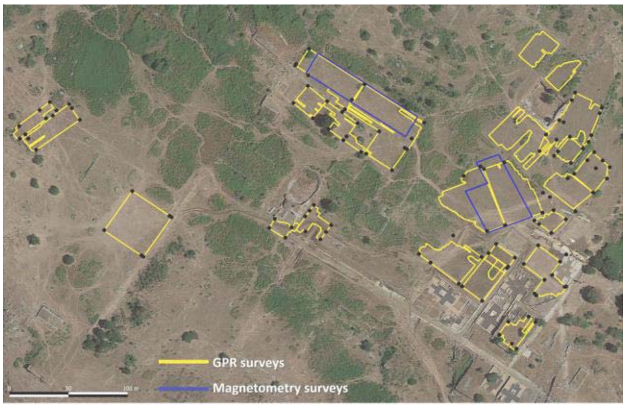

Fig.1. Norba site, location of the investigated area.

III. PROCESSING AND RESULTS

All the GPR data were processed with GPR-SLICE v7.0 Ground Penetrating Radar Imaging Software (Goodman 2017). The basic radargram signal processing steps included: (i) post processing pulse regaining; (ii) DC drift removal; (iii) data resampling, (iv) band pass filtering, (v) background filter and (vi) migration. With the aim of obtaining a planimetric vision of all possible anomalous bodies, the time-slice representation technique was applied using all processed profiles [1]. Time slices for a depth of about 0.90 m and 1.20 m are represented in Fig. 2 and 3.

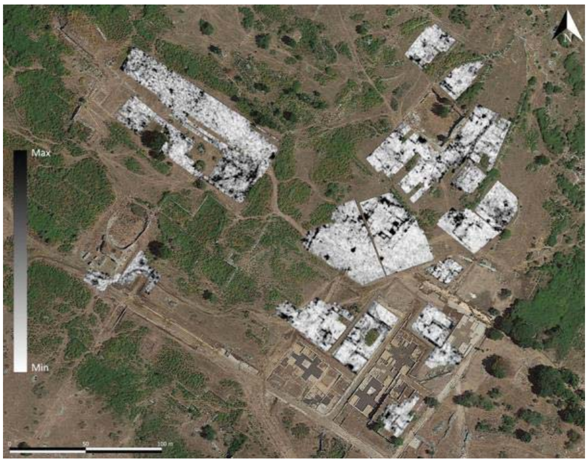

Fig. 2. GPR time slices at the estimated depth of 0.90 m.

The magnetic data was processed with GEOPLOT 3.0 software (GEOSCAN Research). After de-spiking, filtering and rearranging processes, the data was assembled in a contour of the vertical gradient of the total magnetic field, Fig. 4.

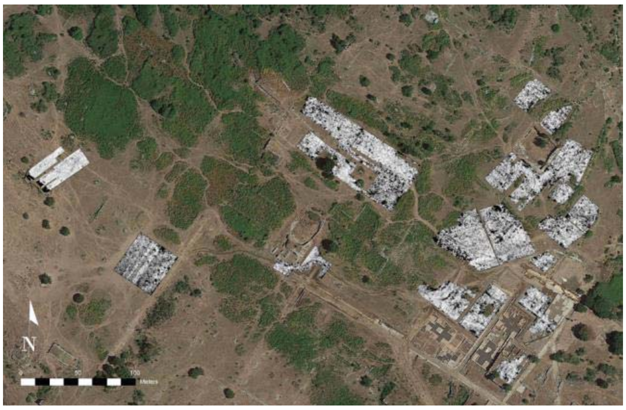

Fig. 3. GPR time slices at the estimated depth of 1.20 m.

The magnetic data was processed using the 2D cross-correlation technique in order to enhance the S/N ratio and to better define the spatial location and orientation of the possible targets [4]. This method is a measure of the similarity between the raw data and calculated synthetic anomalies, Fig. 5 and Fig. 6..

Fig. 4: Gradiometric contour map of the investigated area. Range -300 – +300 nT/m

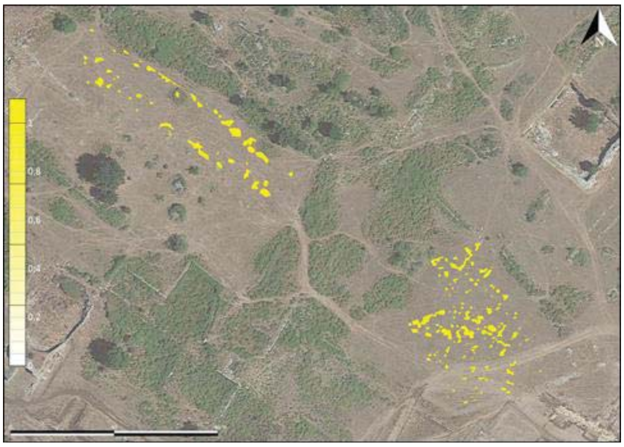

Fig. 5. Contour map of the 2D normalized cross-correlation, at 1 m depth, with negative susceptibility contrast.

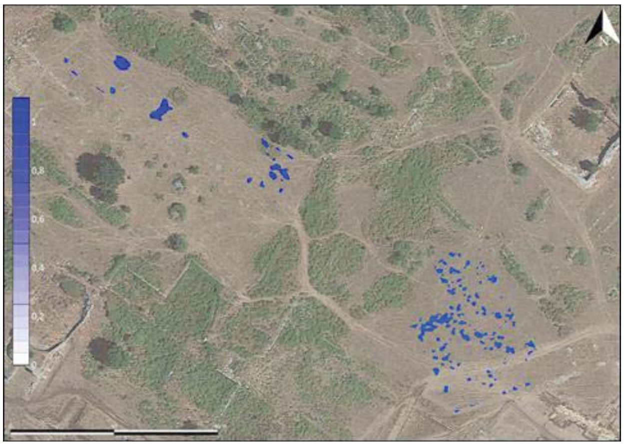

Fig. 6. Contour map of the 2D normalized cross-correlation, at 1 m depth, with positive susceptibility contrast.

With the aim to have a better understanding of the subsurface, qualitative and quantitative integration of the results, has been employed in few investigated areas. For the integration process the following techniques have been applied: map overlays and RGB colour composites (graphical integration), binary data analysis and cluster analysis (discrete data integration) and data sum, data product and principal component analysis (continuous data integration), [2].
The results obtained employing the quantitative discrete integration and the quantitative continuous integration techniques are presented in the Fig. 7 and 8 respectively.

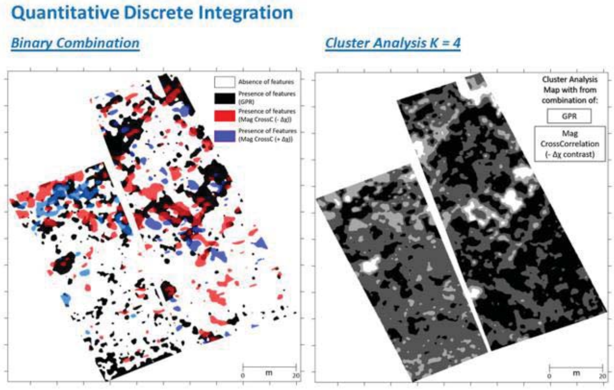

Fig. 7. Norba site, quantitative discrete integration results.

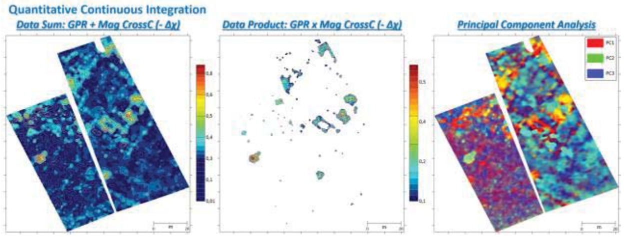

Fig. 8. Norba site, quantitative continuous integration results.

IV. CONCLUSIONS

Employing geophysical methods to investigate unexcavated areas of Norba site allowed us to recognize features which are compatible with the information given by the archeologists in terms of architecture and structure type.
The detailed analysis of the results obtained employing GPR surveys, allowed us to recognize the organization of the sectors of the town.
Taking into account the environmental conditions and the characteristics of the searched structures, the intrinsic high resolution of the employed methods has allowed the identification and recognition of weak anomalies in the internal part of the buildings.
The integration of different geophysical methods and data analysis has provided an enhancement of different types of data, new analysis and visualization capabilities for future interpretations of archaeological and geophysical features at different investigated area.
As expected the integration of different geophysical data sets allow us a high potential to improve the knowledge of the subsurface. As known a single geophysical method might reveal only a portion of the searched buried building. Integrated geophysical data sets may show relationships between the different physical parameters and their contrast between the searched bodies and the surrounding subsoil.
Discrete integrating methods allow application of statistical algorithms to a significant number of

geophysical data sets.

Continuous data integrating methods generally produce a new data set. This is characterized by the simultaneous presence of all anomalies individuated by the different geophysical methods. In these fused data sets, the anomalous conditions, frequently much less visible in a single data set, can be pointed and analysed.

This project is still in progress and new field integrated surveys are planned for the next future.

REFERENCES

[1] Goodman, D., Piro, S. (2013). GPR Remote sensing in Archaeology, Springer: Berlin

[2] Piro S., Papale E., Zamuner D., Kuculdemirci M., 2018. Multimethodological approach to investigate urban and suburban archaeological sites. In "Innovation in Near Surface Geophysics. Instrumentation, application and data processing methods.", Persico R., Piro S., Linford N., Ed.s. pp. 461 – 504, ISBN: 978-0-12-812429-1, pp.1-505, Elsevier.

[3] Piro S., Quilici Gigli S., 2018. Indagini geofisiche per l'integrazione dei dati di scavo a Norba. In "Norba, scavi e ricerche", Atlante Tematico di Topografia Antica, XXII Supplemento 2018. L'Erma di Bretschneider. ISBN 978-88-913-1259-4, pp. 15-27.

[4] Piro, S. and Gabrielli R. (2009). Multimethodological Approach to investigate Chamber Tombs in the Sabine Necropolis at Colle del Forno (CNR, Rome, Italy). *Archaeological Prospection*, **16**: 111-124.

[5] Quilici Gigli, S., Quilici, L. (2000). Sulle mura di Norba. Atlante tematico di topografia antica, 9, 181-244.