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Integrated Geophysical Prospection at the Roman Villa of Agosta (Comacchio, Italy): first results

Jessica Clementi[1] and Enzo Rizzo[2]

[1] *Sapienza Università di Roma & CERI Research Center, P.le Aldo Moro, 5, 00185 Rome, jessica.clementi@uniroma1.it*

[2] *Università di Ferrara, Dipartimento di Fisica e Scienze della Terra, Via Saragat, 1, 44123 Ferrara, enzo.rizzo@unife.it*

Abstract **– This study presents the first archaeogeophysical results of the investigated area where the geophysical aim was the integratation of geomagnetic, ground-penetrating radar techniques. These environments, characterized by their unique geohydrological challenges, demand a tailored approach to subsurface diagnostics. This research assesses the potential of non-invasive surveys in enhancing archaeological understanding, especially in areas with prior excavation history. We focus on diagnostic sensitivity, data integration, and methodological adaptability under geologically complex conditions. The first results highlighted the multiple zones of magnetic anomalies, providing insights into buried structures and site preservation needs, and contributing tools for preventive archaeology and long-term monitoring. This research is part of a project funded by *Patrum Lumen Sustine*-Stiftung Foundation focused on advancing methodological approaches to archaeological geophysics in water-saturated coastal environments in Comacchio village (Roman Villa of Agosta archaeological site).**

I. INTRODUCTION

The Roman Villa of Agosta, located near the historic wetlands of Comacchio, represents a unique archaeological challenge due to its environmental context. Previously excavated in the 1970s, this site yielded compelling evidence of a luxurious and possibly industrial Roman settlement, yet much of its architectural layout and function remain speculative. Given the poor preservation conditions and patchy excavation history, a non-destructive survey using integrated geophysical methods was proposed. The main aim of the project was to develop and validate a set of geophysical approaches tailored to coastal, water-affected archaeological landscapes. This introduction outlines the historical context, prior findings, and geophysical motivations for the present study. We also emphasize the importance of multi-technique strategies in archaeology for minimizing site disturbance while maximizing interpretative outcomes, particularly in sensitive heritage zones subject to agricultural pressure.

II. CASE STUDY

The archaeological site known as the Villa of Agosta, situated in the reclaimed lands of the Mezzano Valley in the southern Comacchio Lagoon (Ferrara, Italy), constitutes a critical node in the Roman-era landscape of the Po Delta. Strategically located near the hypothesized course of the Fossa Augusta—a major Roman canal engineered to link the Po River system with the port of Ravenna—the site occupies a slightly elevated clay rise within an area historically characterized by lagoonal and fluvial environments.

The site was discovered during drainage works in 1970 and underwent partial rescue excavation between 1971 and 1973, during which approximately 1,000 m² of built-up area were investigated, corresponding to no more than 20–25% of the full extent of the complex [1; 2]. The excavation revealed a multifunctional brick structure with elements of residential, productive, and possibly representative functions, including kilns, drying floors, plastered walls, mosaic fragments, and sculptural debris (Fig.1).

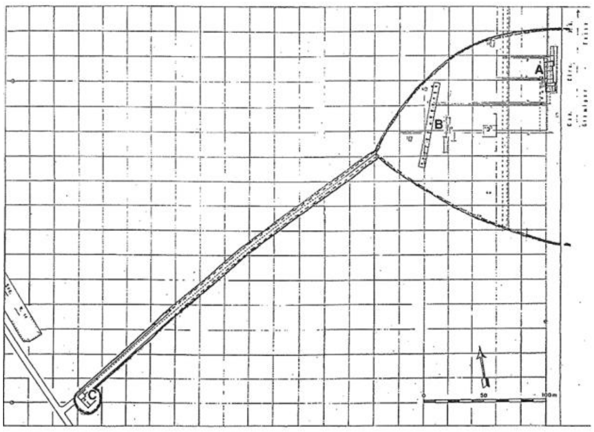

Fig. 1. Plan of the investigated structures of the villa of Agosta, connected by a brick embankment:

A. building with pillars; B. pillars with canopy; C. lagoon house (from Scagliarini 1997: 71)

The presence of figlina-related waste dumps and stamped tiles has led scholars to associate the site with the Officina Pansiana, a known producer of ceramic building materials in Roman northern Italy

More recently, non-invasive investigations at the adjacent Valle Fossa di Porto, conducted using drone-based hydroacoustic technologies, have revealed a submerged paleo-riverbed—likely corresponding to the ancient Vatrenus river (Pliny, Naturalis Historia, III, 119)—as well as structural remains such as post alignments, possible docking platforms, and late Roman material deposits [3]. These findings underscore the area's long-term use as a hydraulically managed, fluvially connected settlement zone, active from the 1st century BCE to at least the 4th century CE, and again during the Renaissance.

Set within the broader geomorphological dynamics of the Po Delta, the Agosta site offers a compelling case study for the intersection of Roman hydraulic engineering, settlement planning, and industrial production. The adaptive strategies observed—both in settlement placement and infrastructure—reflect a high degree of responsiveness to the challenges of marginal, wetland environments. The complex contributes to our understanding of how economic activities such as brick production were integrated into landscape-scale management systems, and how such settlements responded to subsidence, water regime changes, and transport network evolution.

II. METHODOLOGY

The proposed project defines geomagnetic, ground-penetrating radar and electrical resistivity techniques over an area of approximately 20,000 m² (Fig. 2). The geomagnetic prospection employs a GEM GSM-19WG (Fig. 3) magnetometer operating in walking gradiometric mode, with data georeferenced via an integrated GPS system. Magnetic data acquisition followed a 1-meter line spacing grid, resulting in high-resolution coverage. Meanwhile, the GPR survey uses a GSSI UtilityScan DF system with dual antennas at 300 MHz and 800 MHz frequencies, enabling detection of both shallow and deeper features (Fig. 2). GPR data was applied on the geomagnetic anomalies acquiring along orthogonal grids, facilitating 3D reconstruction.

Fig.2. Investigated area with geomagnetic method. The rings indicate the archaeological excavation done in 1970s.

All datasets underwent extensive pre-processing, including dewow filtering, bandpass correction, despiking, and interpolation via kriging [4; 5]. The first results were visualized using composite magnetic maps and radargrams. Special attention was paid to correlating anomalies between the two datasets and evaluating them against known excavation areas from the 1970s. Methodological constraints, such as signal attenuation due to saline groundwater, were carefully documented to inform future applications.

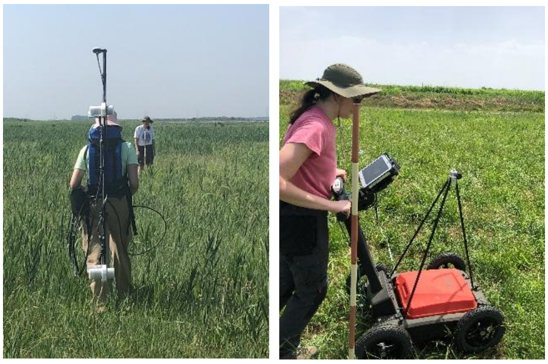

Fig. 3. Magnetometer GEM GSM-19WG in the field (left picture) and GPR GSSI UtilityScan DF system with dual antennas at 300 MHz and 800 MHz (right picture).

III. RESULTS

The geomagnetic survey revealed a series of linear and point anomalies particularly concentrated in the northern and northeastern portions of the site. These were interpreted as potential wall foundations, alignments, and smaller structural features such as kilns or drains. The gradiometric maps showed anomaly ranges between -30 to +30 nT/m, with well-defined geometric features correlating with hypothesized building layouts (Fig. 4).

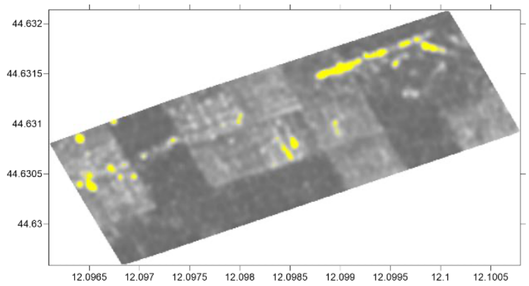

Fig.4. Preliminary gradiometric map of the investigated area.. The scale of magnetic map is in -30 to 30 nT/m. The yellow areas highlight gradient values > 20nT/m.

GPR data, though limited by high conductivity and attenuation due to soil salinity, provided useful subsurface imagery at depths ranging from 0.5 to 1 meter. Radargrams indicated the presence of shallow reflectors with morphologies suggestive of compacted floor levels or foundation trenches (Fig. 5). A composite 3D model synthesized both datasets, supporting the interpretation of an extensive built environment. Notably, the magnetic anomalies aligned with partially excavated areas from the 1970s, validating the geophysical interpretations and underscoring the utility of these methods for heritage monitoring and excavation planning.

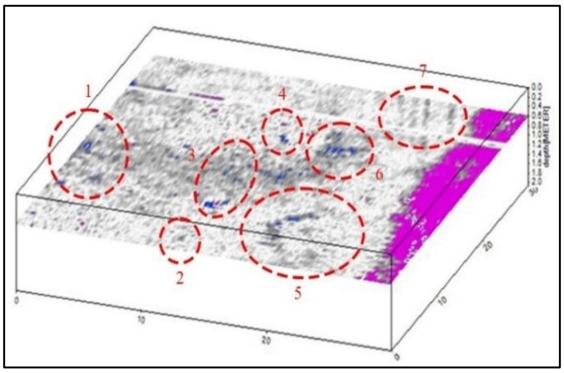

Fig.5. 3D model of the data acquired with the 300mhz antenna and processed with a slice view at t=12ns with an estimated electromagnetic velocity of 0.1m/ns which corresponds to approximately 0.6m.

IV. DISCUSSION

The integration of geomagnetic and GPR methods provided complementary perspectives on the archaeological potential of the Villa of Agosta site. The success of magnetometry in outlining buried architecture highlights its robustness in low-contrast and saturated contexts. In contrast, the limited effectiveness of GPR reflects the challenges posed by high clay content and variable moisture conditions. Nevertheless, even partial radargrams were instrumental in confirming magnetic anomalies and inferring feature depths. This study reinforces the value of multi-method geophysical surveys in archaeological diagnostics. Such integrations not only enhance detection but also improve interpretability across heterogeneous contexts. Furthermore, by linking geophysical data to prior excavation records, our study demonstrates how non-invasive tools can guide heritage management. This has significant implications for developing preventive archaeology frameworks that prioritize conservation over excavation, particularly in environmentally fragile zones.

V. CONCLUSION

This research underscores the efficacy of integrated geophysical surveys in coastal archaeological contexts. The Villa of Agosta survey exemplifies how strategic application of magnetometry and GPR can yield detailed insights into subsurface heritage features. Despite environmental challenges, the methods provided robust datasets that informed both archaeological interpretation and preservation planning. The findings advocate for a wider adoption of such non-invasive diagnostic tools, especially where excavation may pose risks to site integrity. Future work will focus on enhancing signal processing algorithms, integrating remote sensing data, and developing standardized workflows for rapid, field-based archaeological assessments. Ultimately, our approach aligns with the broader goals of sustainable heritage conservation and landscape-scale archaeological modeling.

Given that only an estimated 20–25% of the site has been systematically investigated, future work will focus on extending the survey to the surrounding areas, including the embankments, production zones, and hydraulic features that may have defined the site's economic and functional landscape. This broader coverage is expected to support a more nuanced reconstruction of the villa's development over time and its relationship with the transformed environment of the Roman Po Delta. The continuation of this research will thus contribute not only to the specific understanding of the Agosta complex but also to broader methodological advances in the non-invasive study of wetland archaeological contexts.

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REFERENCES

[1] G. Uggeri, “Un insediamento romano a carattere industriale (Relazione preliminare degli scavi sull’argine d’Agosta, 1971-1973),” Bollettino annuale dei Musei Ferraresi, 1973, pp. 174–186.
[2] D. Scagliarini Corlaita, “Comacchio romana. Strutture edilizie ed emergenze archeologiche urbane”, Guarnieri, C. & Giardini, S. (Eds.), Comacchio, la sua storia e il suo museo, 1997, pp. 65–77
[3] G. Bucci, “Hydrographic Drone Non-Invasive Underwater Investigations: New Archaeological Discoveries in Valle Fossa di Porto (Comacchio—FE, Italy)”, Heritage 6, no. 2, 2023, 1804-1823.
[4] E. Rizzo et al., “Magnetic, GPR and geoelectrical measurements for studying the archaeological site of ‘Masseria Nigro’ (Viggiano, southern Italy). Near Surface Geophysics. Vol 3, No 1, February 2005 pp. 13 -19 DOI: 10.3997/1873-0604.2004025.
[5] C. Neubauer, “GIS and Geophysical Prospection in Archaeology,” Archaeological Prospection, vol. 21, no. 2, 2014, pp. 75–82.