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# Ground Penetrating Radar investigation at Roman Villas of Sabina Tiberina: the case of the villas of Montebuono and Cottanello (Rieti, Italy)

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**Abstract** – The development of geophysical exploration and techniques have proven to be of great help in identifying and classifying buried surfaces and for planning future excavation strategies. The purpose of this work is to detect the presence of buried structures (walls, floors, etc.) in unexplored areas of the Villa of St. Pietro ad Muricentum (Montebuono, Italy) and the Villa of Collesecco (Cottanello, Italy). Both areas were investigated with the Ground Penetrating Radar (GPR). The preliminary results show anomalies a few meters deep attributable to buried archaeological structures. These anomalies seem to be attributable, due to their shape and dimensions, to the presence of wall structures. Moreover, the maps obtained from the planimetric representation (time slices) of the Georadar reflections made it possible to follow the development, as the depth increased, of these structures and to reconstruct their reciprocal geometric correlation. This provides an overall view of the structures under investigation and provide useful guidance to archaeologists for the planning of excavation investigations.

## I. INTRODUCTION

This paper presents the preliminary results of a new Ground Penetrating Radar (GPR) survey at some ancient Roman villas in the Sabina Tiberina region. (Figure 1).

The geophysical survey is part of the collaboration between the Geophysics Group of ISPC-CNR of Naples and the research Group Archeology in the Lazio (GRAL) of ISPC-CNR of Rome for the study of the Roman villas in the territory of the *municipium* of *Forum Novum* in the Sabina tiberina area. This research is carried out within the project: *Economia e produzioni nel Lazio*

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The area of our interest is included in the current Rieti province between the Tevere river and Salaria, in the northwestern sector that corresponds to the territory of the *Forum Novum municipium* [1]. A first acquisition was carried out near the remains of Roman structures found at the church of St. Pietro ad Muricentum or "ad Centum Muros", about 600 meters from the town center of Montebuono. The church stands on top of Grignano Hill, overlooked by the Sabine mountains. The name would derive from the conspicuous remnants of walls of a Roman villa by which it is surrounded. That villa, dating to the early imperial age, is called the "Terme di Agrippa", due to a fragment of a marble epigraph probably found among the ruins, which highlighted the name of Marcus Vipsanius Agrippa, son-in-law of the emperor Augustus, who died in Campania in 12 B.C [1].

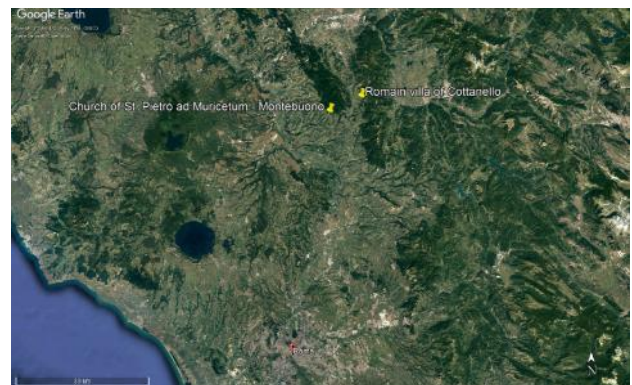


Fig. 1. Satellite image from Google Earth showing the Church of San Pietro ad Muricentum in Montebuono and the Roman villa of Cottanello

A second survey was carried out in the area of the Roman villa of Collesecco in Cottanello. The “villa of Cottanello”, partially excavated [2, 3], was built in the early Imperial age, on a first building of the late republican age. The villa shows remakes and changes related to a period between the end of the 1st century and the 2nd century AD [1]. From the 3rd century the villa was partly abandoned and later occupied from the 4th century AD [4]. At this time, several changes were made in the western part of the building [5].

Previously, Piro and Zamuner (2017) have already studied the area by GPR and Magnetic survey [6]. The results of the acquisition are represented in two-dimensional (2D) and three-dimensional (3D) deep maps. The GPR results obtained allowed the identification of remains of buried structures and surfaces of archaeological interest.

## II. FIELD INSTRUMENTATION AND DATA ACQUISITION

The GPR is a non-invasive geophysical method that is based on the transmission of radio pulses (radar) at high frequency in the underground and on the measurement of the time elapsed between the transmission and the reception on the surface [7]. These impulses reflect on the presence of an archaeological object (discontinuity surface) or cavity [8,9]. The correlation and analysis of these reflections on 2D profiles allow to reconstruct an accurate 3D image of buried bodies.

The GPR SIR System-3000 of Geophysical Survey System Inc., equipped with a 270 MHz monostatic antenna was used, allowing to investigate the soil to a depth of about 4 m. The following acquisition parameters were selected: Scans/sec: 100; Scans/Unit (m): 50; Samps/Scan: 516; Bits/Sample: 16. The GPR processing procedure defined for this study includes the following steps: (1) static data removal, (2) time-zero correction, (3) distance normalization, (4) data filtering, (5) deconvolution and (6) migration. These processing steps are used to remove in-significant portions of the data, correct the y- and x-axes, remove unwanted noise, and improve signal-to-noise ratios.

In Montebuono site two areas were explored (A and B, Figure 2). In area A (1265 m<sup>2</sup>), we acquired 40 profiles: 12 lines in the SW-NE direction and 28 lines in NE-SW direction.



Fig. 2. Ortophoto image (from Google Earth) showing GPR acquisition Area (A and B) in Montebuono.

A line spacing of 1 m were used. Area B (330 m<sup>2</sup>) was investigated (Figure 3) by 16 parallel profiles in the SE-NW direction with a length of about 30 m and a line spacing of 2 m.



Fig. 3. GPR data acquisition in Montebuono (Area B).

The area of the Roman villa of Collesecco (Cottanello) has been divided into three areas of investigation (A, B, C, Figure 4). Area A (4140 m<sup>2</sup>) was investigated with 61 parallel profiles with a length variable between 25 m and 50 m and with a line spacing of 2 m. In area B (250 m<sup>2</sup>), 9 profiles of about 15 m and a line spacing of 2 m were acquired. Area C (1000 m<sup>2</sup>) was covered by 5 profiles of length about 45 m and an equal distance of 2 m. Radar tracks were acquired in distance scan mode.





Fig. 4. Ortophoto image (from Google Earth) showing GPR acquisition Area (A, B and C) in Cottanello's villa.

### III. RESULTS

For each acquired profile, an elaborated 2D Georadar section has been obtained in which the values of the electromagnetic wave amplitudes as a function of time are reported. The parallel profiles obtained were developed to obtain a volume of subsoil. Within this volume, horizontal time segments (2D maps) have been calculated corresponding to different depths from ground level.

Line 02 e line 30 GPR profiles for area A of Montebuono are show in figure 5. These profiles show many shallow reflections. However, Area B does not show significant reflections (Figure 6).

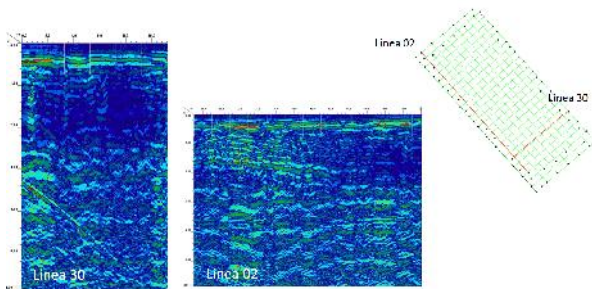


Fig. 5. Example of GPR 2D sections in Area A of Montebuono.

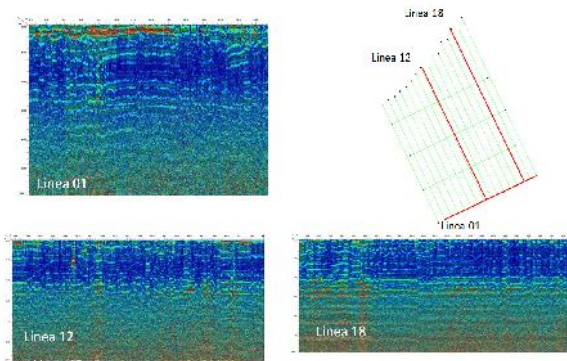


Fig. 6. Line 01, line 12 and line 18 GPR profiles for area B of Montebuono.

The preliminary time slice GPR map show for area A of Montebuono (figure 7) two anomalies (a1 and a2) characterized by a rectangular shape with dimensions 15 x 1,40 m (a1) and 5 x 1,40 m (a2). The anomaly a1 is present from a depth of -0.5 m up to -2.5 m. While the anomaly a2 is present from a depth of -1.2 m up to -2.2 m. These anomalies are probably attributable to the walls of the Roman villa.

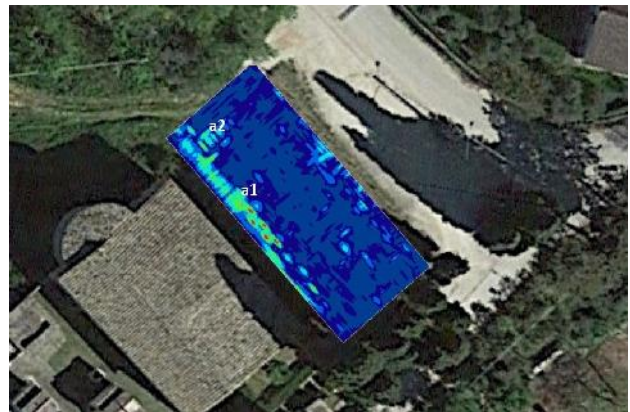


Fig. 7. - 2 m horizontal GPR time slice in area A (Montebuono site).

For the Roman villa of Cottanello, it is reported the preliminary elaborations of area B and C. Some recorded GPR profiles for area B, after the processing, are shown in figure 8. These profiles show shallow reflections located at 2 m depth.

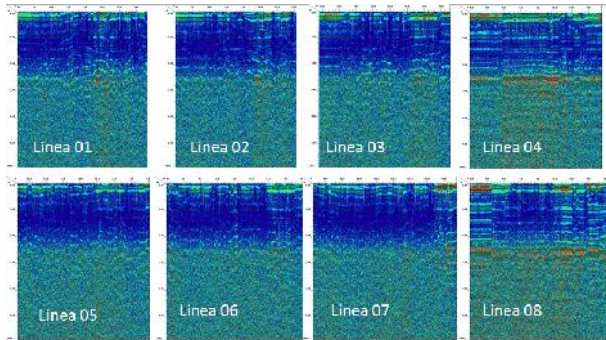


Fig. 8. Example of GPR 2D sections in Area B of Cottanello

The time slice GPR map (Figure 9) permits to highlight two anomalies (a1 and a2). The anomalies a1 and a2 are present from a depth of -2 m up to -4 m with dimension about 15 x 2 m. The rectangular shape suggests the presence in depth of the walls Cottanello's Villa.



Fig. 9. - 2,5 m horizontal GPR time -slice in Area B (Cottanello site).

Figure 10 show a line04 acquired in Area C. In this profile, two high amplitude hyperbolas, at a depth varying from 1 at 1.5 m, are present.

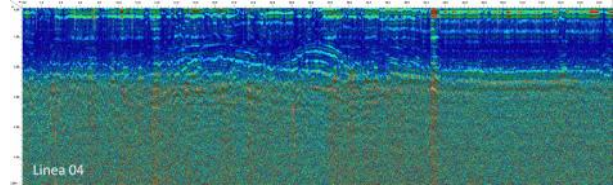


Fig. 10. Example of GPR 2D sections in Area C of Cottanello.

The preliminary time slice GPR map show for area C of Cottanello (Figure 11) one anomaly (a1 and a2) characterized by a rectangular shape with dimensions 10 x 1,40 m. The anomaly is present from a depth of -0.5 m up to -2 m. This anomaly is probably attributable to the walls of the Roman villa.

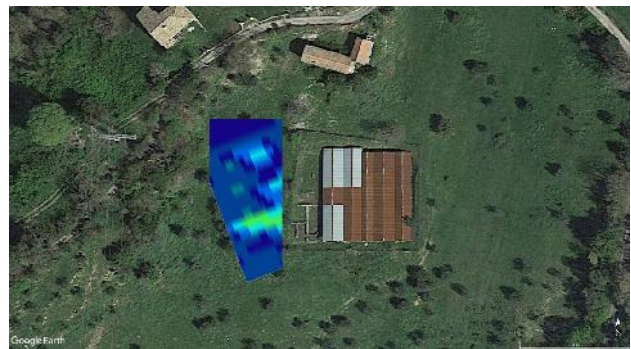


Fig. 11. - 1,4 m horizontal GPR time -slice in Area C (Cottanello site)

#### IV. CONCLUSIONS

The investigations carried out in the area of the Montebuono and Cottanello shows the feasibility of Ground Penetrating Radar (GPR) method as a high resolution non-destructive geophysical survey for detection of shallow subsurface structures. The surveys carried out in areas A and B of Montebuono suggest clearly the presence of an ancient surface (Area A) at depths ranging from about 0.5 m to 2.5 m. The shape and alignment of the anomalies found in the survey carried out in area A suggest that they are related to the probable presence of archaeological structures as walls.

For Cottanello site, areas B and C were analyzed. Structures were found in both areas.

The shape and alignment of the anomalies found in the survey carried out in area B and C suggest that they are related to the probable presence of the walls that delimited the ancient Roman villa

The maps obtained from the planimetric representation (time-slices) made it possible to follow the development,

as depth increases, of these structures and to reconstruct their mutual geometric correlation. The arrangement of these amplitude slices in horizontal layers, representing real depths, is in a visual format familiar to archaeologists, analogous to that of excavation levels.

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