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Finding graves in a cemetery: Preliminary forensic GPR investigations in the Non-Catholic Cemetery in Rome (Italy)

P.M. Barone [a,b,*], K.J. Swanger [a], N. Stanley-Price [c], A. Thursfield [c]

[a] Archaeology and Classics Program, The American University of Rome, Via Pietro Roselli, 4, 00153 Rome, Italy
[b] Geoscienze Forensi Italia® – Forensic Geoscience Italy, Italy[1]
[c] The Non-Catholic Cemetery in Rome, Via Caio Cestio, 6, 00153 Rome, Italy

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ABSTRACT

This paper presents partial results of a Ground-Penetrating Radar (GPR) survey conducted in the oldest section of the Non-Catholic Cemetery in Rome (Italy). This cemetery, a unique spot within the walls of Rome, has been the principal burying-ground for non-Catholic foreigners for the past three centuries.

Extensive information exists about the oldest burials in the Cemetery: many were marked by headstones or horizontal stone markers carrying inscriptions; others are recorded in literary sources but their precise locations are unknown. Moreover, the headstones and markers can be lost or misplaced as time passes. GPR survey therefore plays an important role in non-destructively investigating the subsurface of the cemetery. This is the first time that such a geophysical survey has been conducted at this site. Using a GPR system specifically designed for forensic purposes, it has helped to determine whether the grave records for the oldest part of the cemetery are consistent. In the case study reported here, the effectiveness of the technique is demonstrated by reference to a single, anomalous stone monument.

1. Introduction

During recent years, Ground-Penetrating Radar (GPR) has progressively acquired credibility in the field of non-destructive shallow subsurface forensic investigations [13,7,3,4,12,5,6], and literature therein). The major benefits of this geophysical technique are the real-time visualization of the data acquired and the quick data acquisition [2,10]. However, technical complexities have sometimes prevented law enforcement from using this tool to their full advantage.

In particular, mapping unmarked graves in historical cemeteries can present a number of technical challenges that can limit the method's usefulness. There is often no surface expression of the burial location. Even if markers are present, they may be inaccurately positioned. The challenge is to explore the subsurface without disturbing the soil. A grave is a relatively well-defined target; the size is typically 0.5 m by 2 m, and the depth is normally between 1 and 2 m. Furthermore, the act of excavating the soil for burial radically disturbs the natural soil structure [14,15,8,16, and literature therein].

GPR responses vary greatly depending on the target being sought and the host material. The best practice is to review several similar case studies to develop an understanding of variability.

This paper focuses on a single standing stone located in the oldest part of the Non-Catholic Cemetery of Rome. The

* Corresponding author at: Archaeology and Classics Program, The American University of Rome, Via Pietro Roselli, 4, 00153 Rome, Italy.
E-mail address: p.barone@aur.edu (P.M. Barone).
[1] www.geoscienzeforensiitalia.com.

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Old Cemetery (also called the *Parte Antica*) has been affected by several events in the course of its history. Bombs fell on it during the Second World War and in the 1960s the installation of irrigation systems and landscaping projects caused surface alterations. (Fig. 1). A systematic survey carried out in the 1980s provides the essential documentation of the visible standing monuments in the Old Cemetery [11]; see also [18]. The GPR investigations aim to check the association of the stone monuments with underlying graves, and to locate those graves not marked by any stone memorial, avoiding the possibility to be forgotten forever.

Whether geophysical investigation is undertaken for preservation, cemetery management, or research, respect for the dead and for descendant communities is of paramount importance. From a more general point of view, before beginning any kind of project management of such a precious heritage like this monumental cemetery, it is necessary to know its entire history from the surface until the subsurface. Information on historic cemeteries provides an invaluable insight into community practices at known points in history. Using a tool like the GPR is a cost-effective and non-destructive way to ensure the project will not encroach upon any grave sites.

2. Site description

The Non-Catholic Cemetery has approximately 2500 tombs containing more than 5000 sets of human remains that have been buried since the beginning of the 18th century [18,19]. The GPR survey was conducted in its oldest part (the Old Cemetery or *Parte Antica*). Near the entrance to this part there stands a small marble column, less than 1 m high (Fig. 2). It has two inscriptions on different faces, carefully engraved, one of which is larger than the other. Both read 'PO' above and '1875' below. There is no trace of a 'Po' in the Cemetery's burial database or other burial records. In fact, by 1875 (if it is indeed a date) there had been no recorded burials in the *Parte Antica* for almost 40 years (the infant Arthur Severn had been the last person known to have been buried there, in 1837) [18]. Another oddity is that this column is not visible in old photographs of the *Parte Antica*, even in those dating to as late as the 1920s [17].

Fig. 2. The small marble column with the 'PO 1875' inscriptions.

Its top seems to have once been domed and later chiseled flat. High on one side are a pair of holes filled with metal, as if a chain had once been attached to it. Considering this 'chain' hint and ignoring its location in a cemetery, the column looks more like a bollard. Some of the older bollards and chains that surround fountains in Rome look similar to the column [17]. If this is true, it is necessary to answer several questions: what was its purpose? Why was a bollard placed in a cemetery?

3. Data acquisition and processing

The area around the PO 1875 column in the *Parte Antica* was investigated by a GPR system whose compactness, intuitiveness, data acquisition rapidity, portability, and ruggedness were designed specifically for forensic purposes. The system is the FINDAR (Sensors & Software,

Fig. 1. On the left, the location of the Non-Catholic Cemetery in Rome. This satellite image shows the Old Cemetery (*Parte Antica*) in red; the New Cemetery (from 1822) in yellow, and other, adjacent archaeological areas. On the right is the area of the *Parte Antica* from which the GPR data were collected. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Fig. 3. The GPR surveyed area around the 'PO' column and the line spacing parameters. Note the presence of a pine tree inside the area.

Inc.), equipped with 500 MHz bistatic antennas and an odometer. A grid with dimensions of 10 × 10 m for collecting parallel profiles with a line spacing of 0.5 m is acquired by following only the Y orientation. Owing to the presence of the headstone in the middle of the surveyed area, the GPR collection was paused, relocated and restarted with the same profile from the other direction until the headstone was reached again (Fig. 3).

To identify the different targets present at depth, we first analyzed each radar section, applying the basic Dewow time filter and Automatic Gain Control. To convert the two-way travel time into depth, we performed a velocity analysis using the hyperbola calibration technique [2] on all radar sections in which the hyperbolic events were well detectable. The analysis did not reveal variability of the soil electromagnetic properties throughout the area, providing an average velocity of 0.10 m/ns.

To define the lateral continuity and geometry of the buried targets, we interpolated the grid data and generated a series of migrated depth-slice maps, applying the average envelope amplitude algorithm to each trace [1] and using the computed average signal velocity to estimate the target depths.

It is worth noting that all abovementioned processes were performed directly onsite and in real time, immediately after the acquisition of the GPR data. Thus the survey work caused minimal disturbance to those visiting the cemetery.

4. Results and discussion

The GPR survey was able to discern several interesting anomalies under the surface of the Old Cemetery near the PO 1875 column. Many tree roots were discovered throughout the plot, stretching out from a nearby tree. The roots were discovered approximately 0.3 m deep in the soil (Fig. 4) [9].

Normally, in the case of a buried grave, the image would look like two hyperbolic events separated by a horizontal reflector [3,4]. Moreover, when the buried target has a geometrical shape and is partially filled with air, as in a sarcophagus, it is possible to see two different effects: the 'ringing' and the crisscrossing of the hyperbolic tiles [4,16].

It had been previously argued, based on the evidence of the Cemetery's burial database and historic photographs, that the PO 1875 column was unlikely to have marked a burial dating to 1875 [17]. Nevertheless, GPR survey revealed an anomaly resembling a grave in the underlying deposits. Both the radargrams and the depth-slice map show this regular anomaly located approximately 1.5–2 m beneath the current ground level (Fig. 5). Further research must be undertaken to better understand this phenomenon, for instance, whether it represents one of the early burials known to have been made in this area but not marked by a stone monument.

The results obtained from the GPR survey of the entire Old Cemetery will be beneficial to visitors and to the cemetery management by providing a better understanding of what lies beneath. Knowing the location and size of subsurface graves is crucial in managing the cemetery.

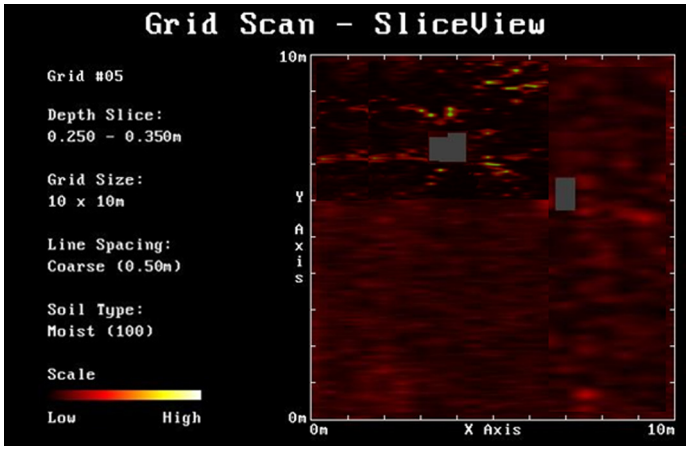

Fig. 4. In the picture, the depth-slice map shows the presence of a tree root architecture at a depth of approximately 0.30 m. Note that the grey area in the middle of the anomalies is the tree, under which it was not possible to collect data.

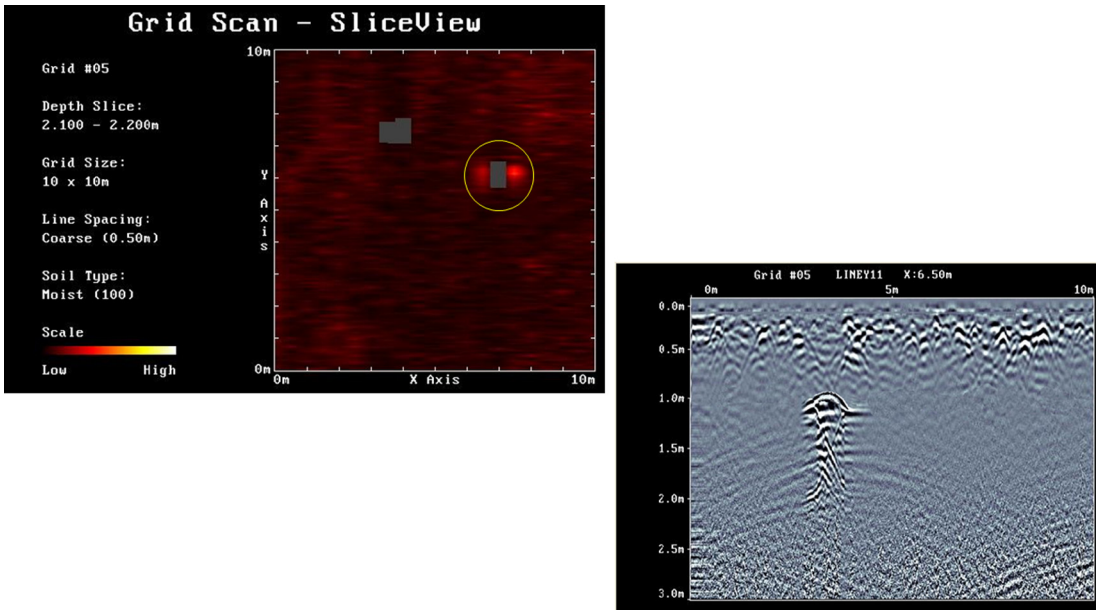

Fig. 5. On the left, the depth-slice map with the anomaly (circled in yellow) related to the grave buried beneath the column. Note that the grey area in the middle of the anomalies is the column, under which it was not possible to collect data. On the right, the radargrams show a typical anomaly related to a buried grave (i.e., two hyperbolic events with a short sub-horizontal reflector in the middle, the two crisscrossed hyperbola tiles, and the 'ringing' effect). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Continuing research throughout the cemetery would reveal any unmarked graves as well as any other anomalies buried underground.

5. Final remarks

There are several reasons that an historic cemetery may require a GPR search: written documentation about these sites may be missing or incorrect, thus providing inaccurate information; headstones or markers may have gone missing or have been moved; the location may be changed due to the overgrowth of the natural environment; human remains may need to be removed due to restoration or exhumation projects.

The cemetery mapping shown here has demonstrated the value of GPR for confirming grave locations. The key benefits of such a geophysical survey are the possibility of using compact, portable, rugged GPR instruments; the rapid acquisition of the data; the onsite and real-time process; and the ability to obtain immediate location and identification information on the zone of interest. A further benefit of the system is that an area which is searched without result can be ignored by future investigators who can then move on to other areas with confidence, knowing that due diligence has been exercised in ruling out an area of concern.

In particular, the geophysical survey of the Non-Catholic Cemetery has helped provide a better interpretation of the subsurface. This undertaking is of paramount importance to facilitate the management of such a historically important site. Furthermore, the GPR survey results could be made available to the many visitors to the cemetery in providing a quite new perspective in seeing it from a subsurface point of view. In fact, if, on the one hand, this study can help to develop an understanding of GPR variability detecting graves in similar forensic cases, on the other hand, the results can give the possibility both to focus precisely the conservation/restoration plans and to enrich the cultural activities of the cemetery augmenting the reality of what you can 'see', always minimizing, if not entirely avoiding, the disturbance to such a respectful site.

Finally, the results have emphasized the importance for this kind of geophysical methods to be part of an integrated program of research that considers historical, archival, and other available data, mitigating possible shortcomings of geophysical survey results.

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