Burial Detection Using Ground-Penetrating Radar in Southern Illinois

A Comparison of Historic Cemeteries

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The implementation of ground-based geophysical methods for the detection of human burials has become increasingly common in archaeological fieldwork. Ground penetrating radar (GPR) appears to be a useful instrument for cemetery investigations, but the effectiveness of equipment varies by region due to soil differences and other environmental factors. Few region-specific examples are available for comparative purposes, which presents problems for the interpretation of remote sensing data. Here, we present GPR data from three historic cemeteries in southern Illinois to illustrate the effectiveness of this method for burial identification. Using a scoring system developed for detecting interments, our results indicate that two-thirds of known burials in the sample produced a signal that allowed for positive identification. The implications of this study suggest that regional soil types and geology must be accounted for when utilizing GPR; however, the potential exists to remotely detect interments despite challenging factors.

Introduction

The hills of southern Illinois are dotted with hundreds of partially documented historic cemeteries containing unmarked graves, the proveniences of which have been lost to history. Developing sound methods to identify the location of these graves is vital for those engaged in cultural resource management, cemetery maintenance and preservation, and forensic science. Traditional methods for locating graves involve destructive testing of these sacred landscapes. Using heavy equipment to expose burial features by mechanically stripping away the upper soil horizons is an effective and commonly used

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method when unmarked burials are suspected, but this practice is extremely invasive and requires the destruction of large portions of the site. Ground-based geophysical methods, like surveys conducted with ground-penetrating radar (GPR), provide promising nondestructive alternatives to stripping sites, but the effectiveness of such techniques depends on the soil conditions and the types of interments under investigation (Conyers 2013:53).

In order to provide researchers with confident interpretations of their data, it is crucial to have region-specific examples of the effectiveness of radar as a tool for burial detection. This study aims to provide information regarding the effectiveness of radar as a burial-detection tool in southern Illinois soils by examining recorded burials with markers. Only a few published studies have attempted to utilize geophysical methods for burial detection in southern Illinois, and none have attempted to quantify the effectiveness of GPR in the region (e.g., Henson 2005; Henson et al. 2008; Wagner and Campbell 2016). Thus, this study highlights some of the potential applications of GPR through an examination of three cemeteries dating from the end of the Civil War to the mid-twentieth century located in Jackson County.

Background

The detection of graves using geophysical applications has long been a subject of promise and scrutiny for archaeologists and forensic anthropologists. Advantages of GPR in bioarchaeological applications include its accuracy in the production of three-dimensional maps, its relative ease of use, its cost-effectiveness, and its ability to produce expedited results. Numerous studies have sought to refine the use of GPR as a practical and reliable application for the discovery of burials (Aziz et al. 2016; Conyers 2006; Doolittle and Bellantoni 2010; Fiedler et al. 2009). It is increasingly clear that several variables must be considered in data collection, including (but not limited to) soil type and moisture content (Aziz et al. 2016:395–397; Conyers and Cameron 1998; Doolittle et al. 2007; Fiedler et al. 2009:381); burial methods that account for the presence or absence of a coffin (Conyers 2006:65); overall burial depth (Doolittle and Bellantoni 2010:944); and amount of time since original interment (Pringle et al. 2016).

Due to these variables, researchers have produced a mosaic of literature that is often highly site specific and sensitive to local conditions and depositional processes. For example, using two-dimensional GPR for historic period burial identification in Connecticut has had mixed accuracy despite generally favorable soils (Doolittle and Bellantoni 2010:945). In this same study, the addition of three-dimensional GPR imaging and the analysis of time slices appeared to improve the quality and accuracy of burial identification (Doolittle and Bellantoni 2010:946, 949). Systematic reconnaissance studies in Germany demonstrated that GPR was able to detect burials with a high degree of accuracy (97.9 percent) despite soils that tended to be wet and clay rich (Fiedler et al.

2009:380–385). However, it should be noted that this study focused largely on burials between 30 and 35 years old (Fiedler et al. 2009:381), so variables like resting time and coffin construction almost certainly contributed to the higher success rate.

Burial practices in the southern part of Illinois during the nineteenth and the twentieth centuries have followed a pattern similar to that of the rest of the eastern United States. Cemeteries in the region fall into one of three categories: farmstead, church, or community burial ground (Mytum 2004:18). Cemeteries associated with farmsteads tend to be small family plots with tens of interments. Church cemeteries and community cemeteries are generally much larger, containing hundreds if not thousands of burials. Each of these burial locations shares a commonality in that it represents a ritualized landscape (Rugg 2000:260). Cemeteries are planned locations where burial practices are performed time and again.

Rural cemeteries, like those found in the southern Illinois region, are arranged with regular rows of burials and plots that may be defined by walls or fences. Grave orientation is not always uniform, but an east–west orientation of the burials is generally maintained in Christian cemeteries (Mytum 2004:48). Although grave goods in African American burial grounds tend to be different than those found in Euro-American cemeteries, the orientation of burials tends to follow the same east–west pattern (Mytum 2004:39). These types of patterned cemeteries make excellent testing grounds for GPR equipment since the orientation of the burials is rather reliable.

Beyond the predictability of grave orientation, there is little that can be prognosticated about what actually remains in the ground at most historic cemeteries. GPR analysis is generally biased toward objects that reflect a stronger signal (Conyers 2013:190). The material properties of coffins can have a significant effect on the signal amplitude returned to the machine, with metal coffins or air-filled voids returning higher amplitude values than collapsed wooden coffins. Additionally, under certain conditions, wooden coffins can decay rapidly, leaving little material for the radar to interface with during the survey. Most of the coffins constructed in the nineteenth century, especially in rural areas, were made from local wood (Mytum 2004:37). By the mid-nineteenth century, glass viewing windows became popular additions to some coffins, and lead coffins became fashionable among wealthier individuals during the latter part of the century (Mytum 2004:37). For the current survey, there was no a priori knowledge of coffin types that might be present in the cemeteries.

Three historic cemeteries from Jackson County with preserved burial markers were chosen for this study: the Murphysboro City Cemetery (Murphysboro, Illinois), the Bostick Cemetery (Murphysboro, Illinois), and the Winchester Cemetery (Carbondale, Illinois). These sites were specifically chosen for the current study due to variability in soil types in addition to differences in cultural burial patterns and dates of interment.

The Murphysboro City Cemetery is a community burial ground, with the earliest interments beginning in 1868 (Decker 1923:33). Today, the cemetery is maintained by the City of Murphysboro, and many of the grave markers have been preserved, making it an excellent location to test the equipment. The Bostick Cemetery is a small community cemetery located in rural Jackson County. The cemetery is associated with a freed African American community known as the Bostick Settlement. The earliest interments at the Bostick Cemetery occurred shortly after the founding of the community in 1865. The Winchester Cemetery is a farmstead burial ground located on the campus of Southern Illinois University in Carbondale. Burials at the cemetery began sometime after James Winchester moved to the region in 1870. Many of the markers at the Winchester Cemetery likely represent relatives of an extended family associated with the adjacent farmstead. Unlike the Murphysboro City Cemetery, which is well documented, there are no records that indicate the original location of burial plots at the Bostick and Winchester cemeteries, although each has many intact burial markers.

Methods

Data for this project were collected using a ground-penetrating radar system from Geophysical Survey Systems, Inc. (GSSI). For the survey, GSSI's SIR® 4000 control unit was connected to a 400 MHz antenna, which allowed for effective radar penetration up to 3 m below the ground surface (Figure 1). The control unit was operated in 3-D data collection mode for this project to maximize the interpretive power of the data set. This mode allows the user to collect a series of two-dimensional line-scan profiles within a defined survey grid, which the control unit combines into a three-dimensional model (Figure 2). The three-dimensional model can be sectioned into different planes

Figure 1. GSSI's SIR® 4000 control unit and 400 MHz antenna attached to a three-wheel cart.

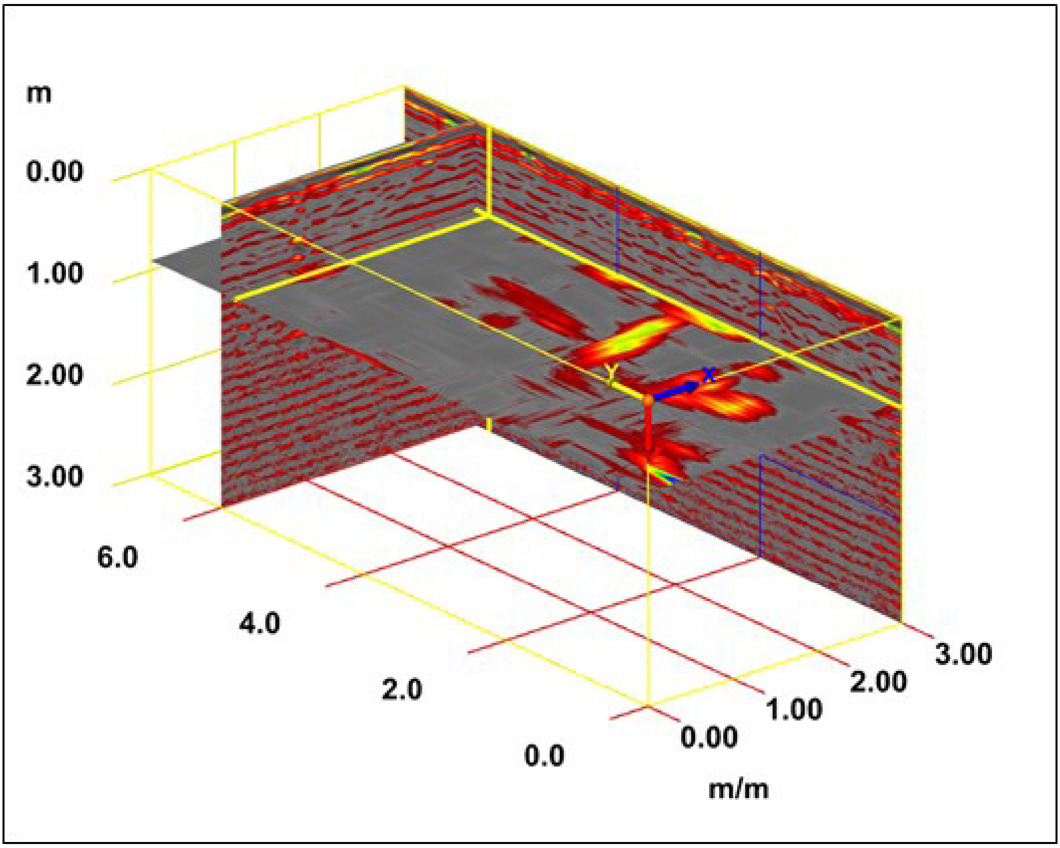

Figure 2. Example of 3-D amplitude time-slice data from Bostick Cemetery Block 1.

for analysis, allowing the user to move through the data in plan view (horizontally) and identify patterns present in the amplitude values. The horizontal image is referred to as an amplitude time slice, indicating that distance (depth in this case) is calculated from the velocity with which the radar reflection returns to the machine.

Postprocessing of the data was performed using GSSI's RADAN® software. The software was used to reduce background noise from the samples and apply color maps highlighting areas of positive and negative amplitude within the time slices. RADAN® was utilized as the primary tool for visualizing the data set and for producing the figures used in this article.

For this analysis, six survey blocks were targeted in the cemeteries: the Murphysboro City Cemetery (*n* = 3 blocks); the Bostick Cemetery (*n* = 1 block); and the Winchester Cemetery (*n* = 2 blocks). Survey blocks were 3 m wide and 7 m long and located on the east side of burial markers in locations that spanned multiple interments. The locations of the survey blocks were specifically chosen to include mid-nineteenth to mid-twentieth century burials with relatively intact markers and few physical obstructions within the survey block. For the collection of three-dimensional grid data, transects were spaced at 50 cm intervals and collected in a crisscross pattern, resulting in grids comprised of 22 line-scan profiles.

Small blocks were intentionally targeted in order to collect a sufficient sample on the same day to minimize any variation in environmental factors, such as soil moisture content. In terms of soil type in the survey area, the Murphysboro City Cemetery consisted of Alvin fine sandy loam. Soil at the Bostick Cemetery was identified as Menfro silt loam, and the Winchester Cemetery had Hosmer silt loam soil (USDA NRCS Soil Survey 2016). Soil moisture content was minimal at the time of the survey. The work was conducted in October 2016, four days after any previous trace of precipitation (.58 cm) recorded by the National Weather Service. The observed rainfall total for the entire year was 99.64 cm (39.23 in), slightly higher than the average 88.08 cm (34.68 in) expected for that time of the season.

Anomalies were categorized within the horizontal amplitude time-slice data on the basis of pattern recognition. Because ground truth measurement of anomalies was not possible for this study, a scoring system was developed to determine the likelihood of intact burials. The subjective nature of such methods is not without its problems, especially because the method relies heavily on the experience of the analyst. Currently, purely objective methods for distinguishing burials from other anomalies have yet to be developed. A multitiered scoring system is proposed here and consists of the following:

0 – No evidence of interment
1 – Evidence of a burial shaft, but no evidence of a coffin
2 – Presence of a small nonlinear anomaly appearing above 50 cm
3 – Presence of a small nonlinear anomaly appearing below 50 cm
4 – Presence of a linear or roughly rectangular anomaly appearing below 50 cm
5 – Presence of a well-defined rectangular anomaly appearing below 50 cm

For a burial location to receive an anomaly score, the anomaly had to be located roughly east and within 2 m of the marker. Potential burials that fell outside the marked locations are discussed but were not included in the data used in the analysis.

Results and Discussion

In total, 21 graves are represented in the data set, some with multiple markers, including footstones. Interment dates were legible on all the markers except for three and range from A.D. 1868 to 1962. In addition to the marked burial plots, survey blocks often included spaces between markers that may contain unmarked burials. Beyond the grave markers, there was no existing information regarding the actual location of burials within the cemeteries.

The results of the anomaly scoring system are presented in Table 1. Of the 21 marked burial plots, three exhibited near-surface anomalies located in areas considered

Table 1. Ranked Anomaly Scores, Soil Types, and Interment Dates for Each Burial Plot.

Cemetery	Soil	Interment Date	Anomaly Score
Murphysboro	Alvin fine sandy loam	1939	5
Murphysboro	Alvin fine sandy loam	1949	1
Murphysboro	Alvin fine sandy loam	1962	0
Murphysboro	Alvin fine sandy loam	1947	1
Murphysboro	Alvin fine sandy loam	1886	4
Murphysboro	Alvin fine sandy loam	1872	3
Murphysboro	Alvin fine sandy loam	1936	3
Murphysboro	Alvin fine sandy loam	1885	0
Murphysboro	Alvin fine sandy loam	1904	0
Murphysboro	Alvin fine sandy loam	1868	2
Murphysboro	Alvin fine sandy loam	?	0
Murphysboro	Alvin fine sandy loam	1908	0
Bostick	Manfro silt loam	1920	3
Bostick	Manfro silt loam	?	0
Bostick	Manfro silt loam	1891	2
Bostick	Manfro silt loam	1911	4
Winchester	Hosmer silt loam soil	1902	3
Winchester	Hosmer silt loam soil	1896	0
Winchester	Hosmer silt loam soil	1909	4
Winchester	Hosmer silt loam soil	1885	3
Winchester	Hosmer silt loam soil	?	3

to be highly probable locations for grave shafts (Figure 3). These areas of relatively low positive amplitude were only visible in the data set within the first few centimeters of soil and appear to indicate a difference in the matrix in those locations. It is likely that variation in soil moisture content near the surface within the boundary of the grave shaft caused the machine to detect a difference in amplitude from the surrounding soil. The only interments with this type of near-surface anomaly were mid-twentieth-century burials from the Murphysboro City Cemetery.

On the basis of the scoring system, only one of the marked burial locations—an interment from 1939 (Figure 4)—produced a strong pattern in the amplitude time-slice data. The location east of the 1939 marker produced a series of radar reflections

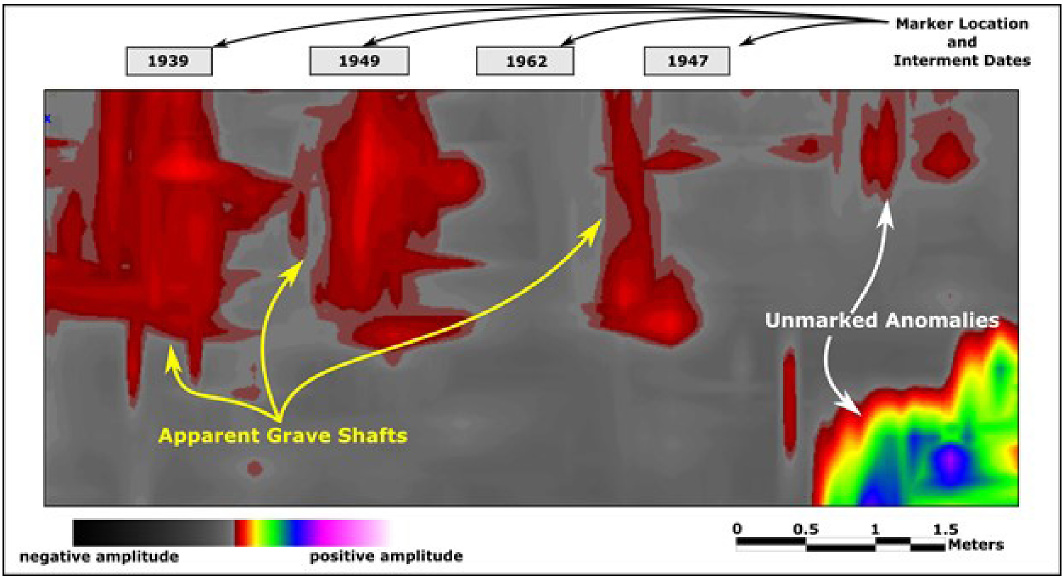

Figure 3. Murphysboro City Cemetery Block 1 amplitude time slice at ground surface.

originating around 75 cm below the ground surface. When viewed as a horizontal slice, it appears as an east–west oriented rectangular anomaly that is strongly suggestive of a coffin. This anomaly produced a strong reflection that is also visible as a distinct hyperbola in the line-scan profile in Figure 5.

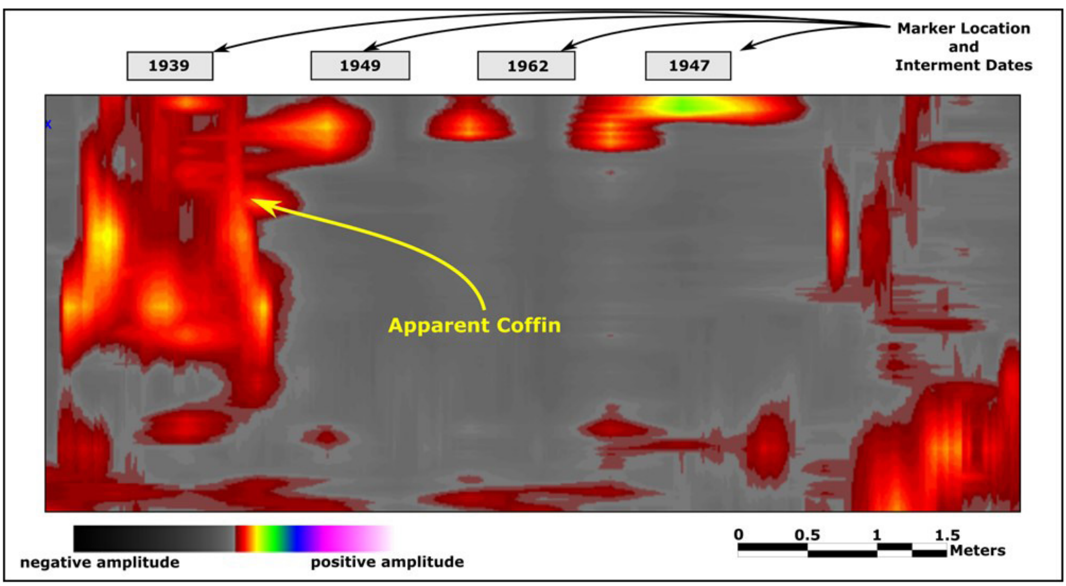

Figure 4. Murphysboro City Cemetery Block 1 amplitude time slice at 75 cm below the ground surface.

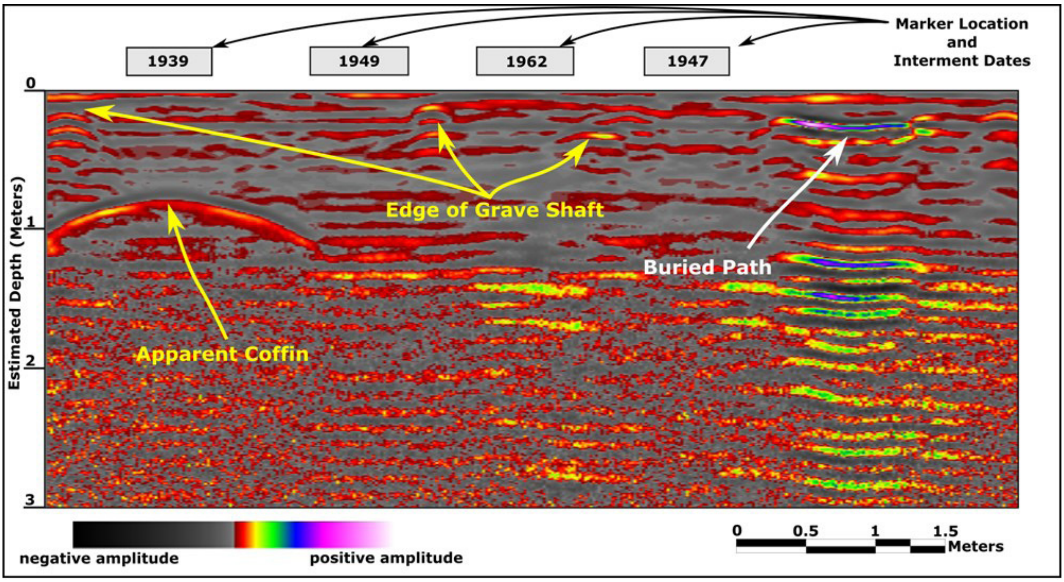

Figure 5. Murphysboro City Cemetery Block 1 line-scan profile.

Including the apparent coffin listed above, 14 (67.0 percent) of the burial plots exhibited radar reflections in patterns that were suggestive enough to label them as possible coffins. Their size, their shape, and the depth at which these possible coffins originated in the data set varied considerably. If our interpretations are limited to anomalies that originate 50 cm below the surface or deeper (which would be a more reasonable depth for a burial), then the number of possible coffins drops to 10 (48.0 percent). An example of how one of these possible coffins appears in the radar data is presented in Figure 6, which shows a linear anomaly originating at 65 cm below the ground surface directly east of a 1909 grave marker in the Winchester Cemetery.

There are no reliable indicators that burials exist in seven (33.0 percent) of the marked plots. These consist of: five plots from Murphysboro City Cemetery with headstone dates of 1885, 1904, 1908, 1962, and one unknown; one from a plot of an unknown date in Bostick Cemetery; and one from a plot dating to 1896 in Winchester Cemetery. Since there is no reason to suspect that any of the burials have been exhumed from the cemeteries, these results suggest that ground-penetrating radar is unable to detect burial remains under certain conditions.

An interpretation of the data set also reveals that plots lacking grave markers may actually contain graves. Several unmarked plots returned radar signals that were congruent in scoring with signals from marked plots. For example, Block 3 from Murphysboro City Cemetery exhibited the reflection of an apparent coffin in an unmarked location at a depth of 95 cm (Figure 7).

A Spearman's rank correlation test ($r_s = -.0084635$ $p = .97341$) was performed and revealed no correlation between date of interment and anomaly scores. This suggests

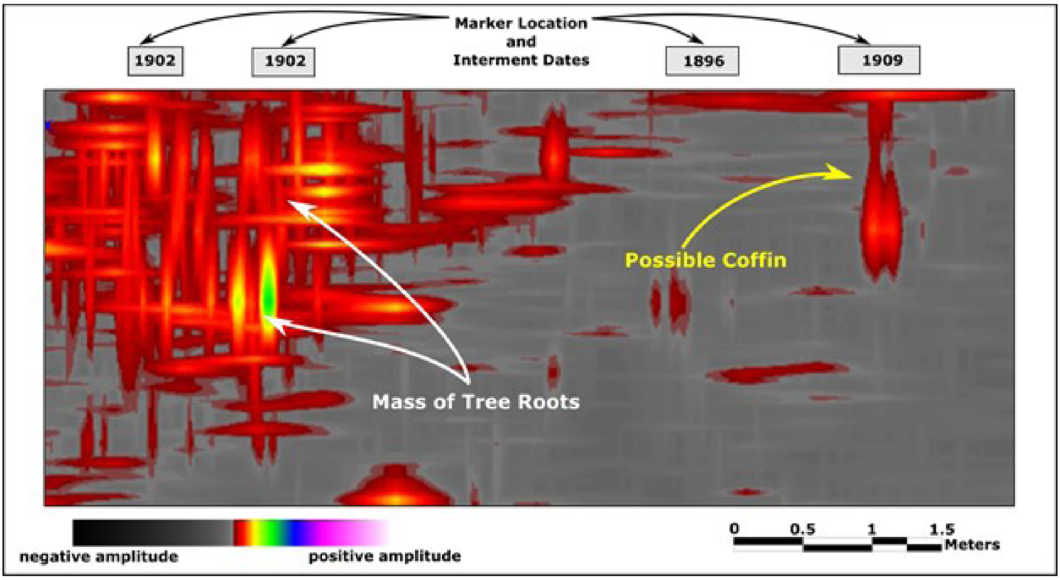

Figure 6. Winchester Cemetery Block 1 amplitude time slice at 65 cm below the ground surface.

that date of interment is not a reliable predictor of the effectiveness of ground-penetrating radar in southern Illinois soils. Relatively strong signals from burials dating to the late nineteenth century and to the mid-twentieth century were found. Some burials

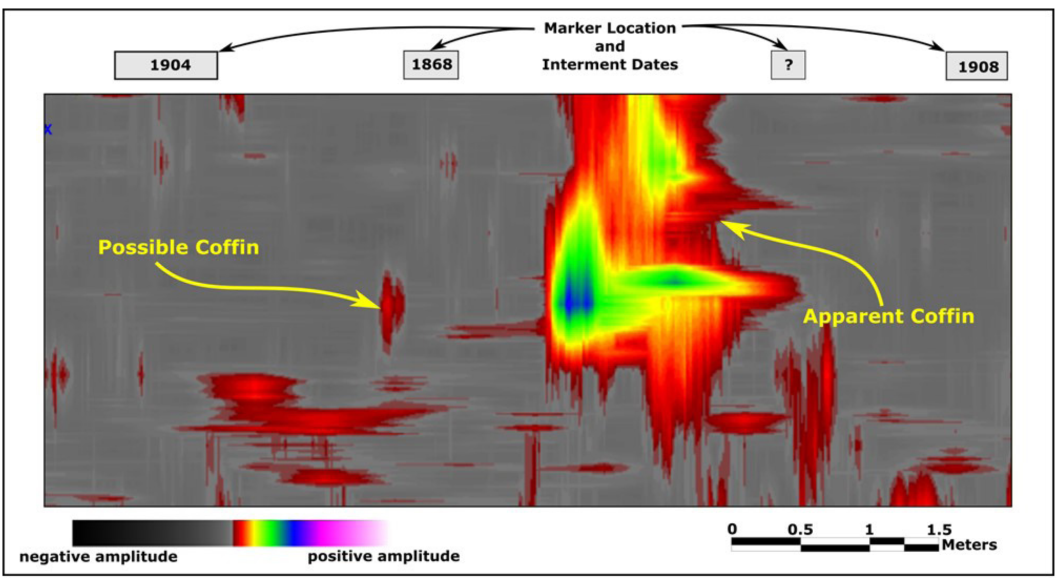

Figure 7. Murphysboro City Cemetery Block 3 amplitude time slice at 95 cm below the ground surface.

produced no reliable signal regardless of date of interment, including the most recent interment from 1962.

Conclusions

In the absence of data concerning the material used for coffins, it is difficult to determine why GPR was unable to detect burials in many of the marked plots. The strong signals and distinct patterns associated with the 1939 burial marker in Figure 4 and the unmarked location in Figure 7 likely represent coffins constructed of more substantial materials than those in the surrounding interments. They may be metal coffins or even concrete vaults. Without excavation, the exact materials will remain a mystery. The remaining interments, including those that produced little or no radar reflection, likely represent wooden coffins in various states of decay. In local contexts, results suggest that the absence of a signal is not sufficient evidence to exclude the possibility of an interment in areas where burials are suspected.

The results presented here attest to the challenges posed to researchers interested in noninvasive burial detection. In the case of southern Illinois, the practicality of GPR for burial detection revealed anomalies in at least 14 of the 21 expected burials, maintaining a rate of positive identification at 66.7 percent. This frequency is far lower than that found in some previously reported studies (e.g., Fiedler et al. 2009) and could be due to a combination of variables, such as soil type, moisture content of soil, and interment date. Thus, this study stresses the importance of establishing methodological baselines using local known burial plots prior to using GPR in other contexts, such as in the search for clandestine graves. Although this study found no reliable information to distinguish the success rate among burials diachronically, future studies in the region might benefit from sampling larger blocks within each soil type with controls focusing on a specific time period. Such controls would permit adequate statistical comparisons among success rates for each soil type; however, researchers must also consider variations in burial practice (vault presence, coffin type, preservation). Other studies have proposed using a 250 MHz antenna in similar conditions (Aziz et al. 2016) to achieve higher success rates. Such instrument modifications should be the subject of future investigation in southern Illinois.

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