Geophysical monitoring of simulated clandestine graves using electrical and GPR methods: 0-3 years after burial

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Summary

This study provides forensic search teams with systematic geophysical monitoring data over simulated clandestine graves for comparison to active cases. Simulated 'wrapped' and 'naked' burials were created. Multi-geophysical surveys were collected over a three-year monitoring period. Bulk ground resistivity, Electrical Resistivity Imaging, multi-frequency Ground Penetrating Radar and grave 'soil water' conductivity data were collected. Resistivity surveys revealed the naked burial had consistently low-resistivity anomalies, whereas the wrapped burial which had small, varying high-resistivity anomalies. GPR 110-900 MHz frequency surveys showed the wrapped burial could be detected throughout, with the 'naked' burial difficult to resolve after 18 months. 225 MHz frequency data was optimal. 'Soil water' analyses showed rapidly increasing (year one), slowly increasing (year two) and decreasing (year three) conductivity values. Results suggest resistivity and GPR surveys should be collected if target 'wrapping' is unknown, with winter to spring surveys optimal. Resistivity surveys should be collected in clay-rich soils.

Main Objectives:

1. Systematically monitor the geophysical responses of clandestine graves over a three-year burial interval. The selected geophysical monitoring methods were electrical (both fixed-offset surveys and electrical resistivity imaging 2D profiles) and multi-frequency GPR surveys.

2. To determine, of the geophysical techniques and configurations investigated, which would be optimal to detect buried human remains in the different burial styles (naked and wrapped) and if this changed over time.

3. To determine which dominant frequency GPR antennae would be optimal for forensic search teams to utilize for the detection of similar clandestine burials.

4. To measure changes in the conductivity of soil-water within a grave, in order to better understand the geophysical survey data collected over the graves.

5. To generate and calibrate 2D resistivity models of the survey site at yearly intervals to explain the changing resistivity responses.

6. Simultaneously collect appropriate site data (rainfall and temperature) to allow comparisons with other research studies and criminal search investigations.

New Aspects Covered:

This study is the first to simultaneously collect multi-frequency GPR, fixed off-set and 2D ERI electrical surveys, grave 'leachate' conductivity measurements and site-specific factors (local climate, moisture content, porosity) etc over a three-year monitoring period. Results show surprising variations both temporally and seasonally, with winter surveys consistently better for electrical surveys, which has important implications for other areas of research. The results will provide crucial comparison data for forensic search investigators to compare their active case data to.

Topics

1. Environmental Geoforensics
2. Archeogeophysics
3. Monitoring and characterisation

Introduction

Forensic investigators are increasingly using geoscientific methods to aid them in civil or criminal forensic investigations, predominantly to assist search teams or for trace evidence purposes (Ruffell and McKinley 2008). One key and high-profile 'target' for forensic search teams to detect and locate are human remains buried within clandestine graves (Harrison and Donnelly 2009). Geophysical surveys have been used to locate clandestine graves in a number of reported criminal search investigations (Ruffell 2005; Pringle and Jervis 2010). Geophysical surveys collected over simulated burials have been undertaken in order to collect control data. These studies have shown that the resulting geophysical responses could be reasonably well predicted, although responses seem to vary both temporally after burial and between different study sites. A few studies have also collected repeat geophysical surveys over controlled experiments (e.g. Schultz 2008; Pringle et al. 2008), which have documented temporal changes in geophysical responses over their study periods. However, uncertainties still remain over what, and how long, temporal variations occur in geophysical surveys after burial, with sites needing to be fully quantified to allow comparisons with other studies or indeed for active forensic cases.

This study was conducted to systematically assess the changing geophysical response of simulated clandestine graves during the three years after burial. The simulated clandestine burial depths of 0.5 m below present ground level (bgl) were based on the average depths of discovered burials (see Pringle et al. 2010), with it being deemed important to simulate both *naked* and *wrapped* burials as statistics from discovered clandestine burials showed these to be evenly divided (Hunter and Cox 2005). There are many potential near-surface geophysical search techniques for these scenarios (see Pringle et al. 2008). Electrical resistivity methods were selected as they have been shown to detect clandestine graves in different ground conditions (Jervis et al. 2009). Ground Penetrating Radar (GPR) is also the most frequently-used geophysical search technique (Ruffell 2005), thus datasets at the commonly-acquired (100-900 MHz) frequencies were also collected for comparison purposes.

Method

The study was undertaken within a controlled test site on Keele University campus in the UK (Figure 1). The site is underlain by the Triassic Keele Sandstone Formation which lies ~4 m below ground level (bgl), based on nearby borehole records. The overlying, predominantly sandy loam soil is partly made ground, due to demolished greenhouse shallow foundations. The survey area contained three graves (Figure 1), one being empty to determine whether the geophysical results were influenced by the disturbed ground. The other two graves contained 80 kg pig cadavers; one naked and one wrapped in a tarpaulin sheet. The nearby Keele meteorological weather station supplied total rainfall and 0.5m bgl soil temperature information over the study period.

Bulk ground resistivity surveys were collected at monthly intervals post-burial. 2D Campus TIGRE™ Electrical Resistivity Imaging (ERI) profiles and PulseEKKO™ 1000 110, 225, 450 and 900 MHz dominant frequency data were collected quarterly. Every 0.5m 2D GPR profiles were collected, with trace spacings for the different frequencies at 0.20m, 0.1m, 0.05m and 0.025m respectively. Standard GPR processing steps were undertaken (Pringle et al., 2008), as well as more advanced steps of migration and time-slice generation.

Results

Conductivity measurements from the 'grave' fluids showed a high degree of temporal variability when compared to background values, with peak values occurring 1 to 2 years post-burial (Figure 2). Both fixed-offset resistivity and 2D ERI profiles show a consistent low anomaly over the 'naked pig' and a temporally variable but mostly small high anomaly over the 'wrapped pig', with respect to background values, graphically summarised in Figure 3. GPR results showed the wrapped burial could be consistently imaged throughout with the naked burial hard to define after 18 months of burial. Low frequency were optimal as fewer non-target anomalies were identified.

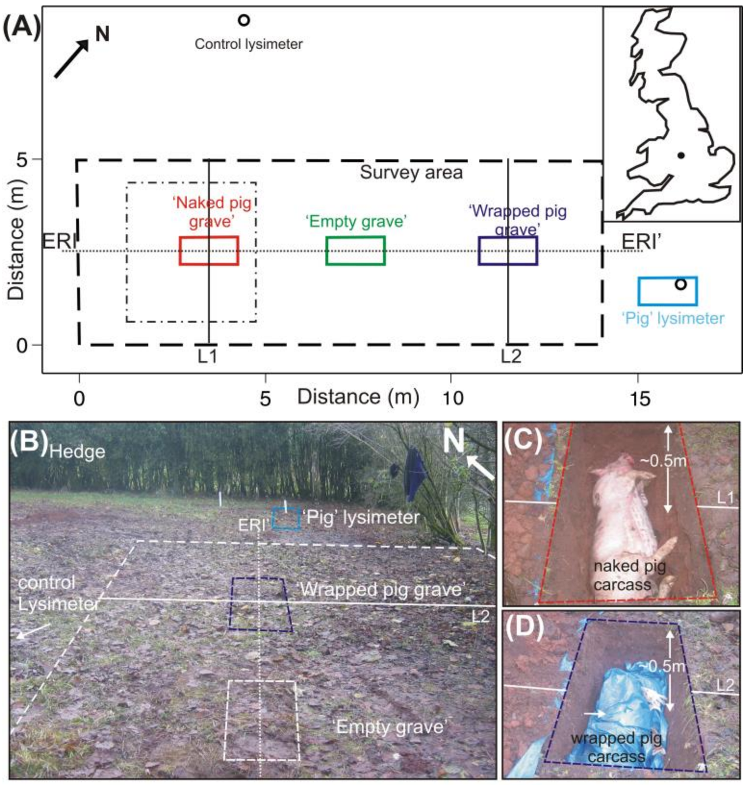

Figure 1. *(A) Map of survey area (dashed rectangle) with graves, ERI profile line, lysimeter positions and UK location map (inset). (B) Study site, (C) 'naked pig grave' and (D) 'wrapped pig grave' respective photographs. Modified from Jervis et al. (2009a).*

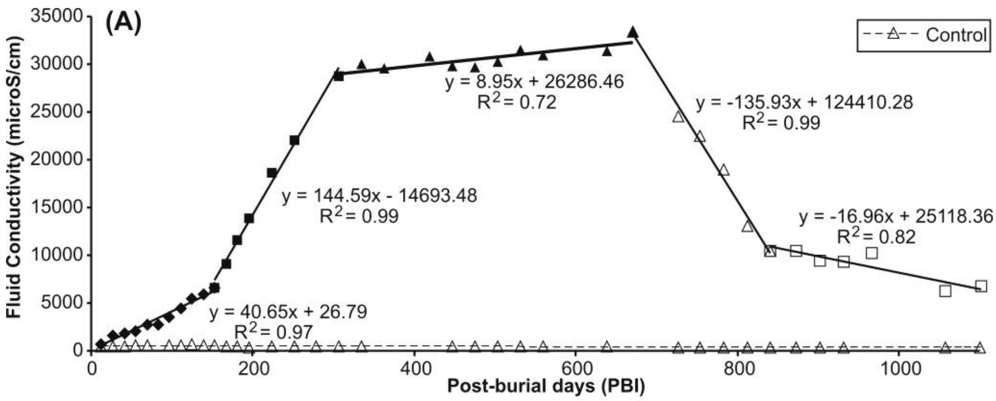

Figure 2. *(A) Measured pig leachate (solid line) and background (dashed line) soilwater fluid conductivity values over the three year survey period.*

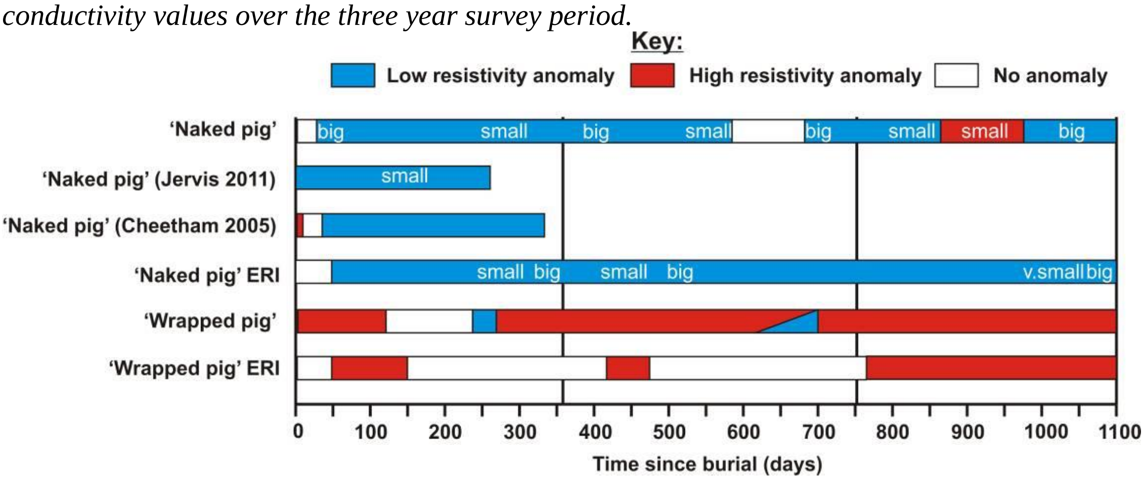

Figure 3. Graphical timeline (vertical lines indicate time in years) showing resistivity changes over simulated graves. Relative anomaly sizes are also noted. Two other named studies are shown for comparison. All graves were buried at 0.5 m bgl.

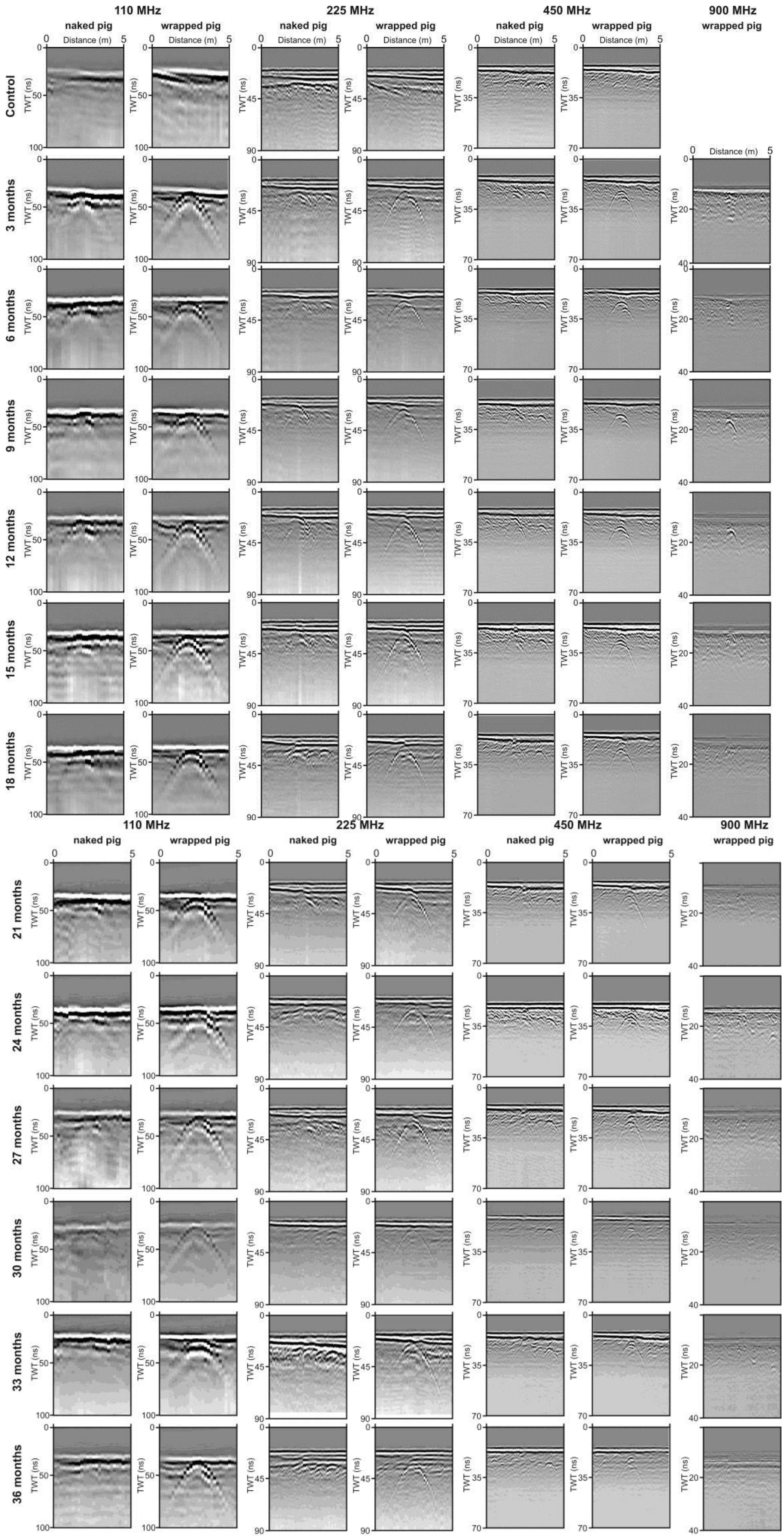

Figure 4. *Key sequential processed 110, 225, 450 and 900 MHz dominant frequency GPR profiles that bisect the naked and wrapped pig 'graves' respectively (Fig. 1A for location).*

Conclusions

'Naked' buried victims should be able to be imaged by electrical resistivity surveys, with an optimal time period of one year to two years post-burial when the conductivity values of the decomposition fluids are high. Wrapped victims will be imaged by GPR, with the 225 MHz frequency antennae deemed optimal from this study. It is important that detrending processing of the raw electrical data is undertaken to give clear anomalies, whereas any processing is of less importance to raw GPR data. It is recommended that a phased geophysical investigation approach is undertaken with GPR/ERI profiles being collected over suspected burial sites. From these results, electrical surveys should be performed in winter as the data shows less variability during these periods with less false anomalies being imaged. As shown by other studies, GPR works better in sandy soils whereas resistivity is more effective in clay-rich soil types. Finally it is recommended that geophysical surveys should be conducted prior to other, more invasive investigations; otherwise any soil disturbances may be picked up rather than the targets.

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