Introduction

Near-surface geophysical detection methods have begun to become accepted as effective forensic search tools [1-2]. There is still a real need to scientifically ascertain optimum search technique(s) and configuration(s) for a variety of different buried targets in different scenarios and burial environments. However, little control study research has been published in which buried forensic objects are detected using a variety of geophysical methods, other than to confirm metal detection team results (e.g. 3-4) and for human remains (e.g. [3, 5-9]). [10] conducted a control study with buried weapons and found that electro-magnetic equipment could detect metallic objects buried in a grid distribution in a rural environment. The [11] control study found that magnetic techniques had difficulty in differentiating between target buried weapons and background materials. [11] also found that Ground Penetrating Radar (GPR) methods could locate buried forensic targets but were difficult to locate in certain orientations, so GPR is an obvious technique to trial, especially as it is relatively easy to collect and view data in real time, and can be used to detect buried objects below tarmac/concrete etc. GPR is becoming increasingly popular to use when trying to locate a cadaver in a clandestine burial [12-13]. GPR has been used since the late 1980s by police services to locate graves of buried victims in a range of different environments [12-13]. Research into better forensic techniques with GPR has been continually undertaken in recent years with the use of simulated burial and pig cadavers as these are similar in the way they decompose to humans (see, e.g. [6,8,9]).

There is also no published research into the locating of a victim under a domestic patio. [14] used GPR to try and locate victims under concrete, positive results were obtained; however upon excavation nothing was found [14]. Multi-frequency GPR will be used here to monitor the grave, as research in other environments such as urban [14], beach [15] and soils [6,9] have shown this importance to be documented. This will allow the subsequent datasets to be analyzed for optimum GPR frequencies and for any temporal changes to be quantified.

Methodology

Initially a 5 m by 5 m grid was set out on Keele University campus in a semi-urban (i.e. made-ground) area, with a variety of metallic objects typically encountered by forensic search teams buried in a non-ordered distribution (see Fig. 1). Metal detectors (swept), magnetic susceptibility surveys ($0.25m^2$), fluxgate gradiometry surveys ($0.25m^2$), potassium-vapour gradiometry surveys (0.2m x 0.02m), ground penetrating radar (100-900 MHz) surveys and finally fixed-offset resistivity surveys ($0.25m^2$) were then all collected and the respective datasets processed (see [16] for details). The domestic patio was then laid on top and the surveys repeated (except for the resistivity surveys, as the probes could not gain a good contact with the concrete patio slabs).

A second investigation then used a pig cadaver to simulated a murder victim buried under the patio. Repeat multi-frequency (110, 225, 450 and 900 MHz) GPR surveys (every 3 months) were then undertaken over a two year period to image any temporal changes. Profiles were 0.25 m spaced for all four frequencies utilised and also collected in both xy and yx directions.

Results

The initial forensic object trial had quite different target detection success rates using the trialled equipment, especially once the patio had been laid (Fig. 2). Comparison of all techniques and with other studies showed success rates are dependent upon the technique utilised, local burial environment and ground covering. The metal detector surveys was successful, although only 63% success over the patio (Fig. 2). Magnetic susceptibility (MS) surveys were also surprisingly good and out-performed the metal detector with anomalies clearly indicating all targets (Fig. 1). MS surveys are also very easy to collect. 900 MHz frequency antennae were deemed optimal with simple interpretation of 2D profiles deemed more useful than horizontal time-slice generation in this environment.

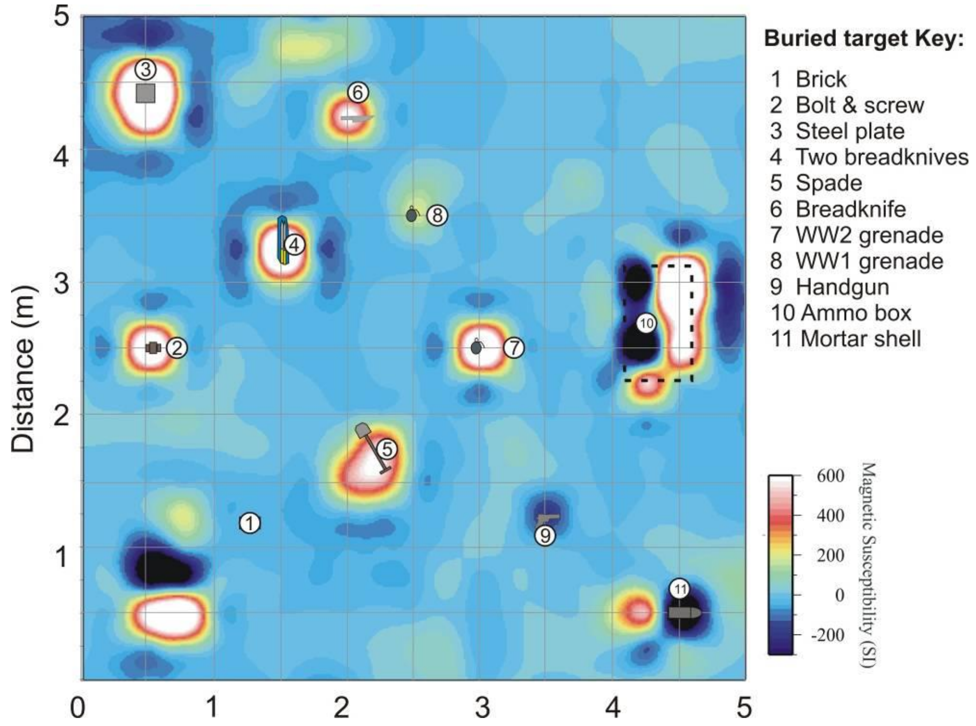


Fig. 1. *Magnetic susceptibility results over the forensic search objects (see key).*

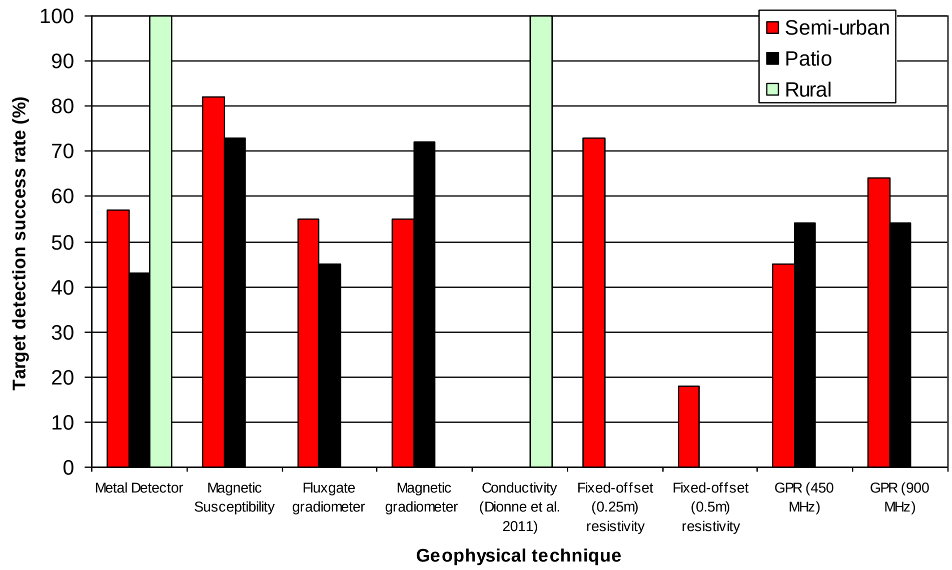
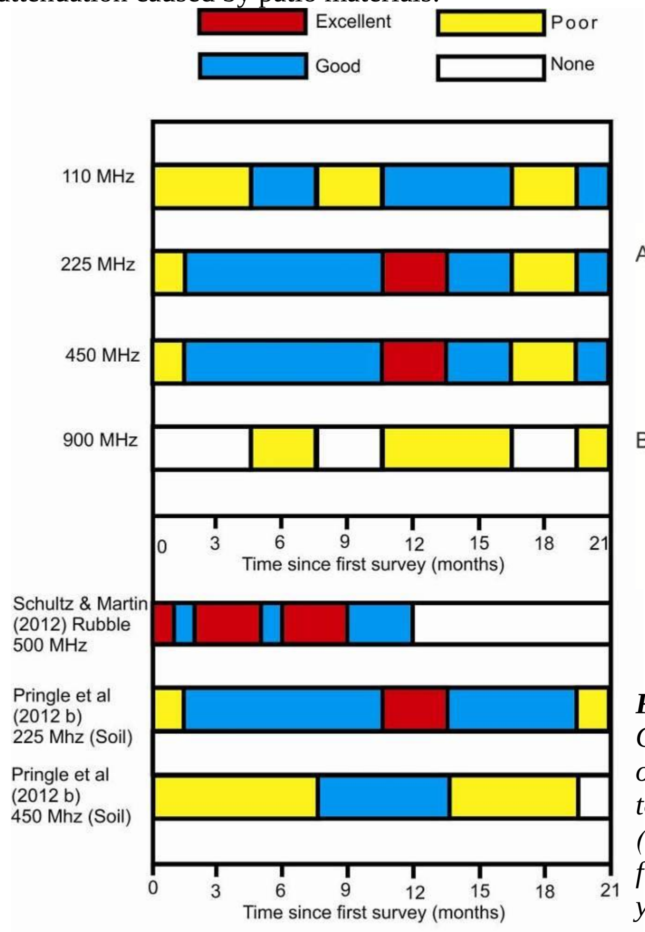


Fig. 2. *Comparison of forensic geophysical technique target success rates and compared to other published studies. Adapted from [16].*

The subsequent project over the simulated clandestine burial of a murder victim also showed a variety of success, depending upon the GPR antennae frequency utilised and the time since burial (Fig. 3). The optimal time window survey post-burial was judged to be 1 year in this environment. From this study, it is also suggested that a relatively low frequency GPR survey be undertaken first to identify areas of interest before revisiting with a higher frequency GPR survey. Although there is an obvious trade off between resolution and penetration, i.e. you will only resolve small objects with high frequency antennae, which will not penetrate very far into the subsurface, there is also the issue that high frequency surveys will take more time to collect than low frequency surveys as more traces need to be collected to avoid spatial aliasing. Clearly decomposition of the target is also a major factor in such searches, with decomposition state determining optimum detection techniques. However, there are differences observed when these project results are compared to other burial studies which are not under a patio (*cf*. Fig. 3); the higher frequencies are especially poorer with burials below patios, presumably due to the significant radar attenuation caused by patio materials.



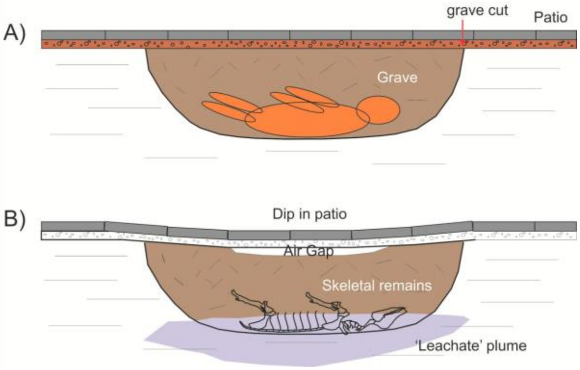


Fig. 3. *Graphical display of (left) temporal GPR location imaging (from excellent – none) over the two year survey period and compared to other (non-patio) published studies and (right) variations of 'grave' seen over time from (A) just buried to (B) end project at 2 years post-burial .*

Conclusions

Clearly there are a variety of forensic search techniques that could be utilised to detect near-surface buried material of interest to forensic search teams. Research shown here indicates that resistivity, magnetic susceptibility and medium-frequency GPR systems are optimal in these depositional environments to successfully detect the buried targets utlised in this project. Searching for human remains will additionally be significantly affected by time since burial which needs careful consideration before a search is initiated.

Acknowledgements

Keele University is thanked for providing test sites and financial support to undertake this research.

References

[1] M. Harrison and L.J. Donnelly, Locating concealed homicide victims: developing the role of geoforensics, in *Criminal & Environmental Soil Forensics (eds Ritz, K., Dawson, L. & Miller, D.)* pp. 197–219, Springer, The Netherlands, 2009.
[2] D.O. Larson, A.A. Vass and M. Wise, Advanced scientific methods and procedures in the forensic investigation of clandestine graves, J. Cont. Crim. Jus. Vol. 27, pp. 149–182, 2011.
[3] G.C. Davenport, Remote sensing applications in forensic investigations. Hist. Arch., vol. 35, pp. 87–100, 2001.

[4] M.M. Rezos, J.J. Schultz, R.A. II Murdock and S.A. Smith, Controlled research utilizing a basic all-metal detector in the search for buried firearms and miscellaneous weapons, For. Sci. Int. vol. 195, pp. 121–127, 2010.
[5] P.S. Miller, Disturbance in the soil: finding buried bodies and other evidence using GPR, J. For. Sci. vol. 41, pp. 648–652, 1996.
[6] J. Schultz, M. Collins and A. Falsetti, Sequential monitoring of burials containing large pig cadavers using GPR, J. For. Sci. vol. 51, no. 3, pp. 607-616, 2006.
[7] J.K. Pringle, J. Jervis, J.P. Cassella and N.J. Cassidy, Time-lapse geophysical investigations over a simulated urban clandestine grave, J. For. Sci. vol. 53, No. 6, pp. 1405-1417, 2008.
[8] J.K. Pringle, J.R. Jervis, J.D. Hansen, N.J. Cassidy, G.M. Jones, *et al.* Geophysical monitoring of simulated clandestine graves using electrical and GPR methods: 0-3 years, J. For. Sci. vol. 57, pp. 1467-1486, 2012.
[9] J. Schultz, Sequential monitoring of burials containing small pig cadavers using GPR, J. For. Sci. vol. 53, No. 2, pp.279-287, 2008.
[10] C.A. Dionne, J.J. Schultz, R.A. II Murdock and S.A. Smith, Detecting buried metallic weapons in a controlled setting using a conductivity meter, For. Sci. Int. vol. 208, pp. 18–24, 2011.
[11] J. Murphy and P. Cheetham, A comparative study into the effectiveness of geophysical techniques for the location of buried handguns. Abstract presented at the Geoscientific Equipment & Techniques at Crime Scenes, Forensic Geoscience Group Conference, 17 December, Geological Society, London, 2008.
[12] J. Schultz, Using Ground-Penetrating Radar to Locate Clandestine Graves of Homicide Victims. Homicide Studies, Vol. 11, No. 1, pp. 15-29, 2007.
[13] M. Solla, B. Riveiro, M.X. Alvarez and P. Arias, P. Experimental forensic scenes for the characterization of gpr wave response. For. Sci. Int.. vol. 220, No. 1-3, pp. 50-58, 2012.
[14] M. Billinger, Utilizing GPR for the location of a potential human burial under concrete, For. Sci. J., vol. 42 No. 3, pp. 200-209, 2009.
[15] J.K. Pringle, C. Holland, K. Szkornik and M. Harrison, Establishing forensic search methodologies and geophysical surveying for the detection of clandestine graves in coastal beach environments, For. Sci. Int., vol. 219, e29-e36, 2012.
[16] J.D. Hansen and J.K. Pringle, Comparison of magnetic, electrical and GPR surveys to detect buried forensic objects in semi-urban and domestic patio environments. In: D. Pirrie, A. Ruffell and L.A. Dawson (eds), Environmental and Criminal Geoforensics, Geological Society of London Special Publication, vol. 384, http://dx.doi.org/10.1144/SP384.13, in press.