Archaeologia Polona, vol. 53: 2015, pp. 467-471

High Royds: an integrated, analytical approach for mapping the unmarked burials of a pauper cemetery

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KEY-WORDS: graves, GIS, earth resistance, magnetometry, electromagnetic induction, ground penetrating radar

INTRODUCTION

Applying geophysical techniques to detect and map the physical extent of individual unmarked graves proves difficult in many cases. The success of individual geophysical techniques for mapping graves often depends on a site-by-site basis. The failure of geophysical techniques for detecting unmarked graves may be due to a poor understanding of the nature of the graves themselves, the context of which they lie in, and temporal changes to the burial state. Given the unpredictability of these variables, it is surprising that grave prospection is often undertaken using a single method only (Conyers 2006; Bigman 2012; Ruffell *et al.* 2009). This paper presents a multi-methodological survey strategy for detecting unmarked burials and utilises an analytical approach for visualising and evaluating the survey results.

SURVEY AREA AND STRATEGY

This case study presents High Royds Memorial Garden of Menston, West Yorkshire, England. The site contains the burial ground for 'unclaimed patients' from the High Royds Hospital, who died from 1890 to 1969. An archive plan of the cemetery shows 1,000 regularly aligned burial plots; yet the site is believed to contain the burials of 2,861 patients. The primary survey object was to verify the validity of the archival plan.

The cemetery is not an ideal site for geophysical prospection, with wet, clayey soils affected by intensive animal burrowing activity, which has created an undulating surface. As pauper burials, the individuals were likely buried in shrouds or rudimentary coffins, and may exhibit only weak contrast from background soils. Given the uncertainty of succeeding using a single geophysical technique, a multi-method approach was employed over a three year period (Table 1).

RESULTS

Earth resistance methods

Earth resistance surveys can identify the subtle variations of soil disturbance of ephemeral features ("grave cuts"). A standard twin-probe survey was complemented with less conventional non-linear

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Table 1. Geophysical survey techniques and methods of data acquisition

Technique	Hardware	Sample Interval x Traverse Spacing	Comment
fluxgate gradiometer	CartEasyN cart with Bartington 1000L sensors	10 Hz x 0.75 m	
earth resistance: twin-probe array	Geoscan Research RM15	0.5 m x 0.5 m	a=0.5 m probe separation
Earth Resistance: Square Array	Geoscan Research RM15	0.5 m x 0.5 m	alpha, beta, gamma, 0.75 m array size
earth resistance: trapezoid zrray	Geoscan Research RM85	0.5 m x 1.0 m	longitudinal, broad-side, theta, 0.75 m x 0.75 m x 1.25 m array size
ground penetrating radar	Mala Mini Mira	0.08 m x 0.08 m collected at 0.5 second intervals	400 MHz antennae
electromagnetic induction	GF Instruments CMD Mini Explorer	Collected at 5 Hz x 0.5 m, projected to 0.25 m x 0.5 m	conductivity and in-phase (HCP and VCP orientations)

arrays in square and trapezoid configurations. Non-linear arrays facilitate the simultaneous collection of several array permutations. For the square array, these are the "alpha," "beta," and "gamma" configurations, whose trapezoid array counterparts are referred to as the "longitudinal," "broadside," and "theta" configurations.

The earth resistance datasets (Fig. 1) show fewer discrete anomalies than the other techniques. In the north-east quadrant of the survey area, a number of rectilinear, high resistance anomalies are discretely resolved. These individual anomalies fit within the archival burial plots plan and likely correlate with grave or grave construction features. Considering the square gamma measurements, there is a directional bias of current flow in a southwest–northeast orientation, correlating with grave orientation. These responses produce a 'brick'-like pattern, likely a response to the grave cuts.

Magnetic and electromagnetic methods

Magnetic methods are seldom considered effective for detecting individual graves. They may be successful for detecting graves which contain magnetic material, grave goods, or coffin fixtures (David *et al.* 2008: 14–15). Given the economic status of the deceased in life, it is unlikely that such responses would be produced by their graves. Fortuitously, ferrous grave markers have been found on the site and it is assumed that each plot had an associated grave marker. These markers are associated with spatially

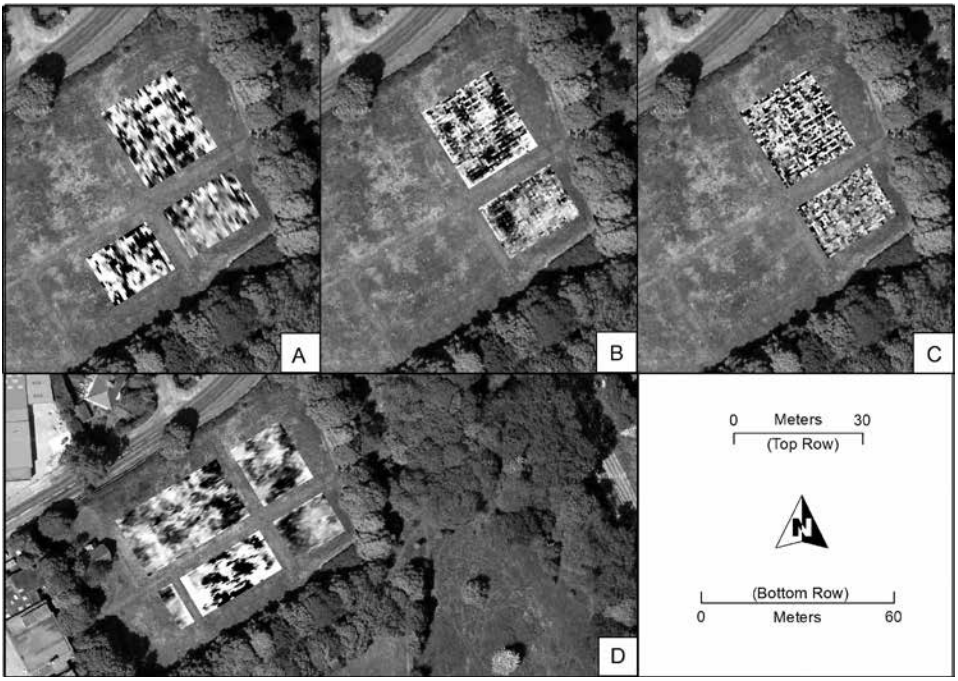

Fig. 1. Earth resistance survey results (plotted 1.5 SD, white [low] – black [high] ohms). Data were despiked, high-pass filtered, and interpolated. From top left: A – trapezoid array, theta configuration; B – square array, alpha configuration; C – square array, gamma configuration; D – twin-probe array

variable, highly magnetic, dipolar anomalies in the fluxgate gradiometer results (Fig. 2). Considering the electroma-gnetic results, a strong in-phase magnetic susceptibility response occurs at those graves containing the suspected subsurface ferrous grave markers. In this respect, the magnetic susceptibility component has a reasonable correlation with the gradiometer survey and these are interpreted as the position of the ferrous grave markers. The EMI conductivity response is strongly linked to the in-phase contribution; therefore, the graves containing the ferrous markers also have a correspondingly strong conductivity contrast (Fig. 2). Many of the grave marker responses appear to be regularly distributed. The random nature in some areas should not be seen as an area without burials or even originally without grave markers; no doubt many markers were removed by accident or intentionally. Those that are mapped give at least the impression of the grave locations and, where they are numerous and regularly spaced, an indication of grave locations and verification of cemetery planning.

Ground penetrating radar

The Mala Mini Mira system was selected for use over the survey area because of its near-surface detection range and high sampling density. Interpretation of the radar data is done with care, as extensive rodent burrowing activity over the survey area has produced anomalies that resemble responses from grave features. The highest number of grave responses have been delineated in the southwestern

Fig. 2. Magnetic and electromagnetic results (plotted white [low] – black [high]). From top left: A – fluxgate gradiometer (-10 to 10 nT); B – fluxgate gradiometer anomaly centres of mass; C – electromagnetic conductivity, HCP C1 (-3 to 8 mS/m); D – electromagnetic in-phase HCP I1 (-0.5 to 1 ppt)

end of the survey area, nearest to the chapel, oriented in parallel lines running NE–SW in direction, which correlate to archival mapping of grave orientation.

RESULTS AND CONCLUSIONS

Due to the differing results between the methods, a stand-alone method could not address the objectives of our project. For a holistic understanding of the results, we employed an integrated interpretation strategy that referenced associated grave responses with the archival burial plot. To resolve the complex responses from the magnetic and electromagnetic techniques, the analytical signal was calculated using open source software. These calculations migrated the broad anomaly responses back to a point source, which was determined by calculating the amplitude centre of mass (Fig. 2). These points were exported as shapefiles into ArcGIS, where a 0.5 m buffer was created around them. For the electromagnetic conductivity data, the association of these point sources with the burial plan were compared between all six datasets (three soil volumes for HCP and VCP orientations) and the associated greyscales. The ArcGIS Intersection tool was applied to compare where the different techniques show discrete anomalies associated with burial plots. The result of this integrated interpretation approach (Fig. 3) shows

Fig. 3. Summary interpretation based on different combinations of different techniques

that many of the graves have associated geophysical anomalies, but no graves were identified by all four techniques (earth resistance, fluxgate gradiometer, GPR, and electromagnetic conductivity). The magnetic and electromagnetic methods can be linked to the largest number of grave plots. However, most of the positive identifications relate to high amplitude grave markers, instead of detecting the grave cuts or coffins themselves.

Our results illustrate the complexity of characterising burials using ground-based remote-sensing techniques and substantiates the assertion that single techniques by themselves are unlikely to provide definitive statements on grave location. At High Royds Cemetery, applying an analytical integration strategy improved our understanding of the separate method results, both independently and in relation to one another. A more thorough understanding of the commonalities and differences between the disparate datasets, has led to a more holistic – and more confident – interpretation of the site.

RERENCES

Bigman, D.P. 2012. The Use of Electromagnetic Induction in Locating Graves and Mapping Cemeteries: an Example from Native North America. *Archaeological Prospection* 19: 31–39.

Conyers, L.B. 2006. Ground-Penetrating Radar Techniques to Discover and map Historic Graves. *Historical Archaeology* 40: 64-73.

David, A., Linford, N., Linford, P., Martin, L. and Payne, A. 2008. *Geophysical Survey in Archaeological Field Evaluation*. Swindon.

Ruffell, A., McCabe, A., Donnelly, C. and Sloan, B. 2009. Location and Assessment of an Historic (150-160 Years Old) Mass Grave Using Geographic and Ground Penetrating Radar Investigation, NW Ireland. *Journal of Forensic Sciences* 54: 382-394.