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Title: Geophysical investigations of the Tabernacle (Yilki) Cemetery, Encounter Bay, South Australia

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Geophysical investigations were undertaken using ground penetrating radar (GPR) and electromagnetic induction (EMI) at the Congregational Tabernacle (Yilke) Cemetery, Encounter Bay. These yielded 25 probable and 16 possible grave locations, identified due to the presence of adjacent stratigraphic breaks in the soil profile on multiple GPR lines. Two larger areas of disturbance were identified in the GPR survey and an additional area by the EMI survey which may represent possible locations of the former Congregational Church, founded by Reverend Ridgeway Newland in 1846. While the results show no direct evidence of coffins and approximately half of the site was inaccessible to GPR survey, the results show that the currently accepted number of burials for this site (29) is probably too low.

Introduction

A geophysical survey of the Tabernacle (Yilke) Cemetery site in Encounter Bay was undertaken at the request of the Newland Uniting Church Council. The site, which formerly contained a church as well as the cemetery, was superseded when the congregation moved to its current location in Victor Harbor. As a result of this move the cemetery fell into disuse leading to many of the former headstones becoming lost. To remedy this loss, the Newland Uniting Church Council were interested to determine the number and location of possible burials on the site using geophysical techniques to aid in its future management.

Background to the Study Area

The Tabernacle (Yilki) Cemetery is a site of approximately 80m x 50m located on the western side of Tabernacle Road in Encounter Bay, South Australia. The cemetery is approximately 500m from the coast, and is well-defined by fences on all sides. The site formerly contained a church building and a cemetery, however the church was removed and as noted above the cemetery has fallen into disuse, with only a small number of intact headstones remaining today.

Site History

The Tabernacle Cemetery and its church were built and used by the English settlers who arrived in the area in 1839 under the leadership of Rev. Ridgway Newland. Newland set sail with his family and fellow settlers from England in December 1838 bound for Holdfast Bay (*The Advertiser* 1910:4). Upon arrival in Adelaide in June of 1839, under the advice of the then Governor Colonel Gawler, Newland led his party to Encounter Bay (*The Register* 1918:4).

The Tabernacle (Yilki) site initially contained only a cemetery, with the first interment being John Jagger in 1840 (Zilm 1987). The Tabernacle church was not built until 1846, before which services were undertaken initially in a “bough shed” and later at Newland’s home (*The Register* 1918:4). The cemetery continued to be used officially until 1860 when it was decided that no more plots could be sold due to the opening of the Victor Harbor Cemetery in 1855 (*The Mail* 1926:17). Occasional burials took place after this date in lots sold previous to the 1860 decision, with the last recorded interment occurring in 1941 (Zilm 1987). Twenty-nine burials are recorded from this site in total.

The Tabernacle Church (Figure 1) is reported to have been located in the southwest corner of the site, been built from limestone and having dimensions of approximately 8.5 x 5.8 metres (*South Australian Register* 1864:2U3). Following his death in 1864, Newland was buried beneath the pulpit of this building before being re-interred at the Victor Harbour Cemetery (*The Mail* 1926:17). Rev. Charles Hodge replaced Newland in 1868 and continued to preach at Tabernacle Church for a number of years (*The Register* 1925:11). Finally the church itself was closed and the congregation moved to the Newland Memorial Church in Victor Harbor. Today a memorial erected by descendants of Rev. Newland stands within the vicinity of the Tabernacle Church.

Figure 1 The Tabernacle Church c.1880. Image B3187, State Library of South Australia).

Local Physiography

The site is located on a flat sandy coastal plain, probably emplaced by coastal activity and fluvial sediment from the Inman River. No bedrock is visible, however, it is probably underlain by Permian glacial and fluvio-glacial deposits or Cambrian metamorphics of the Kanmantoo group (Thomson and Horwitz 1962). Several individual hewn sandstone blocks found on the site are interpreted to be remanent of grave accoutrements rather than representing local bedrock. The site is heavily vegetated, principally with mature sugar gum and stringy bark trees.

Detecting Burials with Geophysical Techniques

Geophysical techniques such as magnetometry, electromagnetic induction, ground penetrating radar and direct current resistivity have become an increasingly common component of surveys for unmarked graves (e.g., Bevan 1991; Conyers 2006; Nobes 1999; Nobes 2000; Powell 2004). The non-invasive nature of these techniques make them ideal for use in burial sites, due to the strong cultural disinclination concerning the disturbance of human remains (e.g., Wallis

et al. 2008) and the generally ineffective nature of alternative non-destructive methods (e.g., Killam 1990).

While the potential of the above methods is great, no Geophysical method can reliably directly detect skeletal material in individual burials under field conditions, probably due to its small volume and low contrast with the surrounding regolith. As a result, most studies focus on imaging anthropogenic stratigraphic disturbance related to the digging of an interment pit, although other approaches such as locating coffins or metallic burial goods are also valid (Conyers 2006). In addition to the location of graves, another potentially fruitful application of these methods is to delineate areas without burials to facilitate repatriation (Wallis *et al.* 2008), contribute to knowledge about community history (Bladon *et al.* 2011) or to guide site redevelopment.

Ground penetrating radar (GPR), as summarised by Conyers (2004), works by transmitting a pulse of electromagnetic energy into the ground, where it reflects off boundaries between materials with different physical or chemical properties (Van Dam and Schlager 2000). The time taken for these reflections to return to the antenna provides, when considered with an appropriate velocity for the ground material, an indication of the depth of these features (Conyers 2004). Individual measurements are combined along survey transects into radar profiles or can be combined into data cubes in three dimensions.

Electromagnetic induction (EMI) (sometimes known as Frequency Domain EM) works by actively inducing a magnetic field between two coils a fixed distance apart (Reynolds 1997). Both an in-phase (IP) and quadrature (Q) measurement of the signal is undertaken, allowing the investigation of features with varying conductivity and the calculation of other indices such as magnetic susceptibility (MS) from the quadrature response or electrical conductivity (EC) from the in-phase response (Witten 2006). With some instruments, multiple frequencies can be measured allowing the measurement of a range of different depths (Won *et al.* 1996). The advantage of EMI is that large areas can be surveyed, processed and interpreted quickly and a wider range of material can be detected than the ferrous material found through magnetometry. Unfortunately, the interpretation of EMI data can be complex, particularly when the site contains varies from ideal conditions (as summarised by Reynolds 1997:597U603), making it preferable to augment this method with others to ensure robust interpretations.

Methods

The GPR survey was undertaken using a Mala X3M ground penetrating radar with a shielded 250MHz antenna mounted in a survey cart. Survey settings included a measurement frequency of 5646 MHz, a time window of 60 ns, a trace increment of 0.02m and 337 samples per trace. A calibration of the survey wheel and a search for time zero were under taken at the start of each survey day. Lines were collected parallel with an alternately SSE and NNW orientation

with a spacing of one metre, beginning at the S end of the site. Lines were not emplaced where significant impediments to survey existed, including mature trees and extant head stones and burials, which unfortunately led to the exclusion of more than half of the cemetery from the survey. During the survey any features which could interfere with the GPR results, such as tree roots or topographic irregularities, were noted with reference to their position along the survey line.

GPR data was processed and picked using Mala Ground Vision software. DC removal, automatic gain control, running average, band pass, time varying gain and subtract mean trace filters were applied to all lines to accentuate features of interest. Features of interest in the GPR profiles were classified as stratigraphic breaks, hyperbola, ringing hyperbola, discrete non-hyperbola features or conjoined stratigraphic breaks and their positions along the survey line recorded. All features were plotted with reference to the site plan to identify their spatial form and extent. The electromagnetic induction data were collected using a Geophex Gem-2 at frequencies of 4075, 9875, 18075, 24975 and 41375 Hz, with the higher frequencies representing a shallow depth of survey. The survey grid was orientated approximately SSEUNNW and had a line and station spacing of one metre. The data were combined with positioning information based on a local grid and points outside of one standard deviation of the mean value for each parameter were removed in an attempt to reduce the effect of metallic surface features on the data. In-phase, quadrature, EC and magnetic susceptibility data were gridded using Magpick software using a spline interpolation and the results were displayed with reference to the site plan.

Results

All geophysical features of interest are summarised in Figure 2.

The GPR survey identified 988 points of interest, with approximately one third of these features being hyperbola or single point source anomalies. These features are particularly common in the middle section of the site. Stratigraphic breaks, represented in the GPR data as a sudden change in the soil/sediment structure (see Bladon *et al.* 2011 for further discussion of this phenomenon) were very common, being represented by more than 500 features. Con-joined stratigraphic breaks are relatively uncommon, being represented by 41 features. Probable and possible graves were identified by 3 and 2, respectively, adjacent con-joined stratigraphic breaks of an appropriate spatial extent to represent an interment.

GPR investigations revealed 25 probable graves within the site and an additional 16 possible gravesites. These features are distributed relatively homogenously throughout the areas accessed by GPR in this survey. Excellent correlation was achieved between visible headstones and GPR anomalies identified as possible or probable graves suggesting that the headstones are in-situ and that the methodology for grave identification is robust.

A number of the identified graves are associated with topographic irregularities, such as discrete mounds or hummocks, which provide additional evidence of ground disturbance. The apparent discontinuous distribution of graves throughout the cemetery (Figure2) is an artefact of the survey methodology, which excluded several large sections of the site due to the presence of trees. The IP, Q and EC results from the EMI survey revealed a large conductive feature of about 40m x 25m in the central area of the site which is present in all frequencies of EC, although significantly decreases in size at depth, as shown in the frequency 4075Hz. The spatial distribution of this feature shows some significant heterogeneity, particularly around its eastern extent. An additional region of approximately 15m x 7m containing a number of discrete conductive features is present in the southern corner of the site. Some additional small discrete conductive features with a diameter of approximately 2m are present in the southern portion of the site.

Geophysical Anomaly Map of the Tabernacle (Yilke) Cemetery, Encounter Bay

Figure 2 Compilation plot of geophysical anomalies of interest from the Tabernacle (Yilke) Cemetery, Encounter Bay.

Perhaps unsurprising given the abundance of surface metal on the site the magnetic susceptibility data were dominated by anomalies corresponding to known surface features, particularly graves. Unusually, these were much clearer in the lower frequencies, particularly 4075Hz.

Discussion

Clearly, a survey which uses a methodology of identifying stratigraphic discontinuities can only provide an indirect indicator of the location of burials on this site and therefore some of the identified features are almost certainly due to ground disturbance from non-burial related activity. No direct evidence of burials, such as a GPR anomaly interpreted to represent a coffin (i.e., Conyers 2006:67), was observed in this survey. The absence of these features is probably due to a combination of the highwater table, as suggested by the GPR data, and the relative antiquity of the burials. Additionally, approximately 50% of the site was excluded due to inaccessibility and these areas almost certainly contain additional burials. Overall, the discovery, using GPR, of 41 possible or probable burials in approximately 50% of the cemetery area suggests that the listing of 29 burials in the historical record is too low.

The ground penetrating radar point source anomalies, both with and without hyperbola, are interpreted to principally represent buried tree roots. This interpretation is suggested by the abundant trees on the site. In areas where roots or trees were visible on the surface during the survey these features are locally ubiquitous, lending additional weight to this interpretation. Of particular interest in this survey is that the ability of the GPR data to resolve stratigraphic breaks at depth is unimpeded by tree roots, in contrast to some other GPR burial surveys (e.g., Nobes 2000). This may reflect the choice of a lower frequency (250Mhz) antenna than some other surveys, which some authors (e.g., Moffat *et al.* 2010; Nobes 1999) provides clearer evidence of anthropogenic soil disturbance due to many small point source diffractions being below antenna resolution.

The two large stratigraphic anomalies, a 5m x 7m feature located mid-way along the northern boundary (Figure 3) and a 3m x 15m feature in the northeast corner of the site, are interpreted to represent disturbance of the subsurface of the site by a large feature, such as the foundations of building. The feature on the northern side of the site (as shown in Figure 3) contains deep stratigraphic cuts approximately 5m apart. There is also a feature in this area of the site which is caused by a piece of buried metal. Neither of these features corresponds to the expected location of the church building in the southwest corner of the site, so may represent another instance of disturbance on this site.

Figure 3 GPR profile from the large stratigraphic anomaly on the northern boundary of the site.

There is a poor correlation between the location of conductive anomalies on the EMI data and grave locations identified by either intact headstones or GPR. This is unsurprising as while EMI may be able to identify graves (e.g., Bigman 2012) due to Changes in the hydrological properties of the soil resulting from the digging of the grave, or due to changes in the bulk conductivity as a result of the mixing of the soil layers, a sample spacing of 1m is probably too coarse to easily define grave features.

The cause of the large conductive feature in the central portion of the site is difficult to interpret based on the evidence available. The heterogeneities on the eastern part of these features are probably not due to subsurface material, but rather the presence of a park bench and memorial tablet in this area. The ubiquitous presence of this feature at all surveyed depths suggests it might be a geological rather than archaeological feature. This could represent a variation in the porosity of the sand in the area, perhaps due to a variation in the environment of deposition such as a palaeochannel or a former shoreline.

Conclusions

The use of geophysical techniques at the Tabernacle (Yilke) cemetery in Encounter Bay, South Australia, has provided significant new information about the subsurface of the site without requiring any soil disturbance. 25 probable and 16 possible grave locations were identified using GPR, which is significantly more than the historical record suggests are present.

A number of large stratigraphic features could represent the foundations of the former Congregational Church on the site, although the location does not correlate with that shown in the historical record. The EMI survey was not able to define any grave on this site, however it revealed the presence of a large conductive feature which may suggest a variation in the underlying regolith.

While a definitive audit of the burial locations of the graves and the former location of the church at the Tabernacle (Yilke) Cemetery would require direct investigation through excavation, this approach would be destructive, expensive and disrespectful to the cemetery inhabitants and their families. In contrast, the geophysical survey has contributed significantly to the knowledge available for this significant site in a non-invasive fashion.

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