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Title: Ground penetrating radar investigations at the Lake Condah Mission Cemetery: Locating unmarked graves in areas with extensive subsurface disturbance

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Ground penetrating radar (GPR) was used to non-invasively map the location of unmarked graves within the Lake Condah Mission Cemetery in western Victoria as a means of siting future interments. This cemetery was associated with the former Lake Condah Mission (established in 1869) and continues to be an important site for local Indigenous people. It is anecdotally thought to contain more than 100 graves however only 26 are currently marked. The GPR survey identified an additional 14 probable unmarked graves as well as 49 other areas that may contain one or more unmarked burials. The extensive subsurface disturbance present at the site and the presence of many extant tree roots made the effective interpretation of the GPR data difficult. Despite this, it was still possible to delineate areas where no unmarked graves are present. This is an important outcome for managing the cultural heritage of the cemetery because it identifies areas where new graves can be emplaced in a culturally appropriate fashion. This demonstrates the utility of GPR as a means of effectively managing heritage sites containing unmarked graves, even when substantial subsurface disturbance is present.

Introduction

Ground penetrating radar (summarised for archaeological application by Conyers 2013) is a geophysical technique that uses high frequency electromagnetic (EM) waves to image the subsurface. A transmitter generates a short pulse of EM energy that is radiated into the ground before being reflected back to the receiving antenna from interfaces between materials with a sufficient contrast in dielectric permittivity, making it ideal for mapping changes in lithology or soil structure. GPR is an attractive method for locating graves as it is non-invasive, data collection is relatively rapid, and it is inexpensive compared to large-scale excavation (Moffat 2015). Many Australian Indigenous communities are often anxious not to disturb graves and consequently GPR has frequently been employed as part of burial investigations involving these groups (Bladon et al. 2011, Everdeen and Conyers 2013, Lowe et al. 2014, Moffat et al. 2010, Wallis et al. 2008).

The detection of burials with GPR for forensic and archaeological investigations has accumulated a voluminous literature, which is summarised by Moffat (2015), Conyers (2006) and Ruffell and McKinley (2005). Most authors now agree that the reliable direct detection of skeletal material under field conditions is challenging and that the most appropriate means of locating graves is by mapping the disturbance to the soil created when digging and re-filling

the burial shaft (Moffat 2015). Subsurface disturbance without context is obviously not diagnostic of a grave, so this approach relies on defining the spatial dimensions of each potential feature on multiple GPR lines to determine if these can credibly be a burial. The disadvantage of this approach is that any sharp stratigraphic discontinuities with the appropriate dimensions may be interpreted as graves, regardless of how they were created. While the balance of probabilities favours these features being burials when found in a cemetery, a degree of caution must be retained. The most important requirements for the effective detection of graves with GPR are a close line spacing (no greater than 0.5m) and centimetre accurate positioning (which is usually provided by differential GPS or total station measurements) so that all anomalies can be accurately positioned in space so their spatial distribution can be determined. Furthermore, locating burials in this way usually relies on minimal post interment disturbance to the grave fill and surrounding stratigraphy by human, animal or plant action (Conyers 2006:67), although this was not the case at the Lake Condah Mission Cemetery.

History of the Lake Condah Mission

The area of the former Lake Condah Mission Station, located near Heywood in south-west Victoria (see Figure 3), was originally inhabited by the Gunditjmara (sometimes spelt Gournditch-jmara) people (McVicker et al. 2007:41). The Gunditjmara built stone houses and utilised the local water sources by constructing stone and woven fish traps (Couatts et al. 1977, Lourandos 1987, McNiven et al. 2012, 2015). Following European settlement in the area in the early 1830s the Gunditjmara way of life was disrupted when conflict, starvation and disease led to a dramatic decrease in the Aboriginal population (Gould and Bickford 1984:10, McVicker et al. 2007:42). As a result, the Victorian Government conducted a Royal Commission into the protection of the Gunditjmara people in 1858, and in 1860 the Anglican Church was appointed to establish a Mission (Gould and Bickford 1984:11, McVicker et al. 2007:42). This occurred in 1867 with 2043 acres designated for Indigenous use and five acres for the Mission Station (Gould and Bickford 1984:11, McVicker et al. 2007:42).

The Lake Condah Mission Station initially prospered with an extensive building program and expansion in agriculture, however in 1886 Aboriginal Protection laws forced those who were over 33 years old and of “mixed blood” to leave the Mission and seek employment elsewhere (McVicker et al. 2007). This deprived the Mission of much of its work force and income, leading to a decline that led to the Building and Planning Authority eventually taking over the management of the Mission in 1913. As a result, many residents were removed (although a number of Aboriginal people remained living on site as “permitted trespassers” (Gould and Bickford 1984:17) and the land was leased to graziers before being ultimately used for the Soldier Settlement Scheme after World War II (McVicker et al. 2007:43). Despite the removal of people from the Mission, the church continued to be used for special occasions until 1957, at which point it was deemed to be collapsing and was demolished (McVicker et al. 2007:43). The area of the Mission and cemetery are now owned by Gunditj Mirring following an out of court settlement related to the *Onus vs Alcoa* case (1984) (Weir 2009:13).

There is very little historical reference to the cemetery, which was established as part of the Mission. The oldest extant marked grave in the cemetery is of Robert Sutton, buried in 1877. There are currently 26 marked graves visible on the site, which remains an important location for Gunditjmara people who continue to use it for burials to the present day. The site is anecdotally thought to contain approximately 100 burials. The GPR survey undertaken for

this study aimed to facilitate future burials taking place on the site without disturbing any unmarked graves.

Figure 1: GPR unit and RTK-GPS equipment used for the Lake Condah Mission Cemetery survey. Photo Shows the Western Boundary of the Lake Condah Mission Cemetery Site Looking North. Photo by I Moffat 2012.

Survey Methodology

The survey comprised 102 parallel GPR lines collected in two grids trending approximately N-S with a spacing of 0.5m between lines, within the survey area shown in Figure 3. Lines were stopped where obstacles (such as headstones or trees) were encountered and a new line (with a subsidiary line number) started on the other side. In areas with significant survey impediments, such as thick vegetation, GPR lines were discontinued or omitted in order to expedite the survey.

The survey was conducted using a Malå X3M GPR with a shielded 250 MHz antenna (shown in Figure 1). Data was acquired using the Ramac Groundvision program running on a Toshiba computer. Data was collected using a sample frequency of 5791 MHz, a time window of 83ns, 480 samples, trace increment of 2 cm and 4 stacks. These settings provided an appropriate level of detail to detect graves while not impeding survey speed. The co-ordinates of the start and finish of the survey lines were collected using a Topcon GP3 differential GPS rover. A base station was established on a known position at survey mark 24200210 (Mark name: Condah PM 6) located to the south east of the corner of Condah Estate Road to provide differential correction via UHF to the GPS rover. Distance along GPR lines was measured using the measuring wheel attached to the survey cart which was calibrated against a tape measure at the beginning of each day's survey. The heavy tree cover surrounding the site (shown in Figure 3) significantly impeded RTK-GPS signal cover, particularly on the eastern side of the survey area. Where this prevented the collection of positioning data, locations were extrapolated using survey tapes or the survey wheel of the GPR cart.

All GPR data was processed and interpreted using the ReflexW program. Data was imported with positioning information and then processed using a sequence involving a dewow, a bandpass butterworth, a time cut, an energy decay, a Stolt fk migration and a move start time filter. These filters were chosen to enhance the interpretability of the data by accentuating

features of interest (as shown in the processed GPR profile in Figure 2). Data interpretation was undertaken in ReflexW using the pick menu. Features were identified based on the presence of apparent breaks in the soil stratigraphy or the appearance of discrete hyperbola. Features were identified using three “pick” codes; 1 for individual hyperbola, 2 for individual stratigraphic breaks and 3 for paired stratigraphic breaks (shown in Figure 2). Stratigraphic breaks were interpreted based on the noncontinuation of sub-surface reflectors or significant amplitude variations. Of these features, paired stratigraphic breaks are considered most likely to represent burials. The co-ordinates and characteristics (including depth, amplitude and pick code) of these features were saved as ascii files and then plotted on the site plan using ArcGIS software.

The spatial characteristics of these features in combination with the nature of the GPR response was used in ArcGIS to classify areas with identified subsurface features into three categories in terms of their likelihood of containing unmarked graves. These mapped areas were classified as probably, possibly or being unlikely to contain unmarked graves. Areas identified as probably containing unmarked graves have 3 or more adjacent stratigraphic discontinuities (pick code 3 features) arranged spatially in a way that may represent a human burial. Areas identified as possibly containing unmarked graves contain 3 or more adjacent stratigraphic discontinuities (pick code 3 features) which are spatially larger or smaller than a human burial and may have an irregular shape. Areas identified as being unlikely to contain unmarked graves have 3 or more adjacent stratigraphic discontinuities (pick code 3 features) which are spatially larger or smaller than human burials, may have an irregular shape and are in areas which are not believed to contain graves.

Results

A total of 8908 individual subsurface features were identified in the GPR data including 3911 hyperbola, 2804 single and 2193 paired stratigraphic breaks. These results were interpreted to represent 14 individual unmarked graves and 42 areas of extensive subsurface disturbance which may contain one or more unmarked graves. Unfortunately the mapping of discrete unmarked graves was largely impossible due to the complexity of the subsurface of this site. As an alternative, larger areas that contain subsurface disturbance and are considered possible or unlikely to contain one or more graves were mapped and are shown in Figure 3.

Figure 2: 20m of GPR Line Six showing examples of Pick Code 1, 2 and 3 features. Note the high density of subsurface features on the line (particularly individual hyperbola) and the resulting difficulty in observing stratigraphic breaks (see the Discussion for further details). As discussed in Survey Methodology the Pick Code 3 feature are interpreted to be unmarked graves where a number of these features occur on adjacent lines. Figure by I Moffat 2018.

Figure 3: (page 11) Map showing the results of the GPR survey at Lake Condah Mission Cemetery. Areas of probable, possible and unlikely unmarked graves located with GPR are indicated. The methodology for identifying the probable, possible and unlikely unmarked graves is discussed in Survey Methodology. The implications of the large areas identified as possible and unlikely unmarked graves is considered in the Discussion. Surface features including the fence and marked graves are also identified, as is the total GPR survey area. Map by I Moffat 2018 including map data from Google, CNES/Airbus 2018.

Discussion

The 14 individual probable unmarked graves identified by this survey (shown in Figure 3) all show soil disturbance on multiple adjacent lines which is of an appropriate size (approximately 2m x 1m in plan view) to represent a burial. This soil disturbance is most often visible as a reduction in the amplitude of the GPR signal and a discontinuation of horizontal reflectors in the shallow subsurface, as shown in the feature from approximately 2-4m in the GPR line shown in Figure 2. These features are considered with a very high degree of confidence to be individual graves. Many of the hyperbolas (pick code 1 features) mapped during this survey are interpreted to be tree roots or buried metal objects rather than graves based on their high amplitude, shallow depth and (often) linear distribution (Barton and Montagu 2004, Butnor et al. 2001). This differs from the approach used in some other burial investigations (Damiata et al. 2013, Pringle et al. 2012, Schultz et al. 2008) in which hyperbola are interpreted as resulting from a coffin or a body. As summarised by Moffat (2015:47), the direct detection of graves by hyperbola is largely only appropriate where a strong contrast between the dielectric properties of the burial and the surrounding strata exist, such as where a metal coffin, grave goods or a crypt are present. Nonetheless, the abundant hyperbola at the Lake Condah Mission Cemetery due to tree roots and/or metal objects makes the definitive identification of stratigraphic breaks problematic. Even after the hyperbola are removed using migration, they overprint the stratigraphy such that assessing the level of stratigraphic disturbance can be difficult (as shown from ~14-16m on the GPR line in Figure 2).

Furthermore, the disturbed nature of the subsurface away from extant tree roots made the definitive interpretation of individual graves in many areas extremely challenging. This unusual level of subsurface disturbance (as shown from ~18.5-19.5m on the GPR line in Figure 2) is attributed to floraturbation (soil bioturbation by plants, for example, tree roots) (Schaetzl et al. 1989), which has been shown to cause soil mixing and destroy original horization (Schaetzl et al. 1990) and is present in most forested environments (Stephens 1956). Floraturbation can be caused by tree throw, soil displacement by roots and the infilling of stump holes (Philips and Marion 2006). The mounds and pits formed by these processes can have a significant density in plan view (Lyford and MacLean 1966). While the surveyed areas of the site are largely free of trees today the disturbance caused by floraturbation may persist for more than 1000 years (Schaetzl et al. 1990). Therefore we consider it credible that these features may derive from former vegetation and, in particular, tree throw related to the clearing of the site (ie. MacPhail et al. 1990).

On the basis of the extensive soil disturbance and masking of the stratigraphy from multiple hyperbola it was impossible to further subdivide the broad areas identified as being possible or unlikely to contain graves into individual burials. The only means of discrimination was to arbitrarily consider that paired stratigraphic breaks found in the northern parts of the survey area were more likely to represent unmarked graves than those in southern parts. This hypothesis was based on the increased concentration of extant graves in this region and the presence of complicated (possibly anthropogenic) fill in this area. The large number of anomalies and our inability to discriminate between them clearly leads to an overestimation of the area of the site that might contain burials in Figure 3. This would be inappropriate for investigations, such as for forensic cases (ie. Nobes 2000), where definitively locating targets (usually for direct investigation) is the priority. In the case of the Lake Condah Mission

Cemetery, in contrast, the focus of the investigation was to manage the cultural heritage values of the site by preventing the disturbance of in-situ burials. In these circumstances, this conservative approach of focusing on locating areas that are clear of burials (also used by Wallis et al. 2008) is an appropriate methodology.

The direct investigation of some of these features could provide more discrimination of the grave locations however this approach would be expensive, destructive and unnecessarily risks disturbing in-situ burials. The ample space within the cemetery with no anomalies identified by this GPR survey provides the opportunity for the Guditj Mirring Traditional Owners Corporation to place additional burials in the future with a greatly reduced risk of disturbing in-situ graves. This demonstrates the utility of GPR as a non-invasive and culturally appropriate tool for the cultural heritage management of cemetery sites, even where sub-surface conditions are challenging.

Conclusions

A GPR survey of Lake Condah Mission Cemetery identified 14 probable individual unmarked graves as well as 30 areas that possibly contain unmarked graves and a further 19 areas that may, but are unlikely, to contain unmarked graves. This compares well to anecdotal reports that the cemetery may contain ~100 graves in total, given that there are an additional 26 marked graves on the site. The site was particularly challenging for the location of burials with GPR due to the presence of extensive tree roots in the subsurface, which meant that it was appropriate to identify areas that may contain graves rather than individual graves in many cases. Despite these issues, GPR fulfilled the project aims by providing a useful and non-invasive tool to assist the Guditj Mirring Traditional Owners Corporation in planning future burials within this cemetery by identifying large areas which are free of graves.

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