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A ground penetrating radar survey near the excavated burial site of Kiacatoo Man

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ABSTRACT

Ground penetrating radar technology has advanced in the last decade to the point where it is possible to identify objects as small as a grave quickly and with great precision. This study investigates its potential for identifying possible human burials alongside the grave site of Kiacatoo Man in central New South Wales. In 2011, the weathered remains of this individual were discovered in a levee of an ancient course of the Lachlan River, and measurements taken from the reconstructed femur suggest an individual of exceptional size and rugosity. Preliminary OSL analyses of fine sandy sediment underlying the grave floor provide a maximum age for the skeleton of around 17,000 years. A GPR survey over a 200 m x 40 m grid of the levee revealed five disturbances that are consistent with the geophysical and morphological expression of grave excavations. The technique appears to be an effective tool for mapping of unmarked graves, and may be particularly useful for systematic archaeological exploration of the source-bordering dunes and levees of the Riverine Plain. These landforms may hold the key to understanding burial patterning, the distribution of people, and land-use during the late Pleistocene in Australia.

INTRODUCTION

This paper forms part of a larger project that explores the ancient river systems of inland SW Australia and how people lived along them in the past. It builds on a long tradition of collaboration in Australia between earth sciences and archaeological sciences. Geomorphological research in the Lachlan's riverine plains has identified a system of surface palaeochannels that records the evolution of the river and its highland catchment through the last glacial cycle. In February 2011, a burial unearthed at Kiacatoo on the bank of one of these ancient channels, along with other archaeological finds, presented a new opportunity for linking our two disciplines to provide a richer understanding of Australia's past. This paper reports on a Ground Penetrating Radar (GPR) survey near the initial Kiacatoo burial to investigate the nature of the levee as well as potential archaeological contents, including further burials. An overview of geomorphological research conducted in the region provides context to the survey. This is followed by a summary description of the original burial, its excavation and location, to situate Kiacatoo Man in his chronological, spatial and archaeological context. The methods and results of the GPR survey are followed by a discussion that shows its value for research in fluvial sedimentology, archaeology and land management.

GEOMORPHOLOGICAL EVOLUTION OF THE LACHLAN PLAINS AT KIACATOO

Geomorphological research using optically stimulated luminescence (OSL) dating on the middle Lachlan River has provided an environmental context for the time from when people first occupied the area, ~50,000 years ago until the present day (Bowler *et al.*, 2003). To date, there is no archaeological evidence for occupation of the SE highlands until 9,800 years ago (Aplin *et al.*, 2010), but the rugged slopes of the upper Abercrombie and the exposed tablelands of the upper Lachlan near Lake George produced runoff sufficient to sustain large sinuous channels, lagoons and lakes on the plains downstream that would have supported resources of fish, shellfish, waterfowl, large and small fauna, as well as tubers and yams (Kemp and Rhodes, 2010; Pardoe, 1995). Decreasing temperatures 34,000 years ago produced larger, actively meandering channels and greater seasonality of water resources. Flows may have declined in magnitude at the Last Glacial Maximum (LGM), but snowmelt floods were more predictable and larger than present.

The floodplain downstream from Kiacatoo features palaeochannel systems similar to those described near Condobolin and Forbes, 10 to 200 km upstream (Kemp and Spooner, 2007; Kemp and Rhodes, 2010). Older channel traces ascribed to the Gulgo Palaeochannel System are preserved, largely infilled, in the plain between the modern Lachlan River and Borapine Creek (Fig. 1A). In the vicinity of the Kiacatoo burial, these channels have been cut by sinuous channels with large meander wavelengths and scrolled, fine sandy floodplains of the Ulgutherie Palaeochannel System, dated from 20,000–35,000 years near Forbes. In this location, Ulgutherie channels are followed by the present Borapine Creek, which flows at moderate to high stages from the Lachlan River. Smaller wavelength channels south of the burial site may represent reducing flows within the Ulgutherie stage or diversion by local anabranching. The burial site of Kiacatoo Man was found in a natural levee lying north of this inset channel belt that follows its northern edge for 3 km. Locally the levee is elevated ~1.5 m above the plain with ~1.6 m of strong brown silty fine sand of fluvial origin overlying 2.4 m of brown fine sandy silt grading downwards into silty fine sands of the former floodplain. Six OSL samples extracted from the grave fill and from the underlying levee sediment are presently being analysed at Griffith University (Fig. 2A). The modern Lachlan trench lies 1 km north of the burial site and was formed by avulsion away from the Ulgutherie channel belt around the time that the modern flow regime was established.

KIACATOO MAN, HIS EXCAVATION, LOCATION, AND ARCHAEOLOGICAL CONTEXT

Kiacatoo is the Wiradjuri name for this region of the Lachlan Valley and survives as the name of a station property north of the river and a small settlement nearby. *Kiacatoo* is also the name of a poem by local Wiradjuri writer, Kevin Gilbert, (Gilbert, 1988: 189–90) that describes a massacre on the banks of the Lachlan in this area. Burials in such a context need to be approached with consideration and local community support (Pardoe, 2013a).

The burial at Kiacatoo was exposed by erosion from stock and an old vehicle track. Once identified as being of some antiquity (based on mineralisation, carbonate encrustation and preservation), there was considerable community interest leading to a decision to remove the remains, carry out some investigations and then rebury them near the original grave (Fig 2B).

The excavation was carried out in May 2011, when the soil was moist and suitable for such work. Summer conditions generally preclude excavation of skeletal remains as the soil is hard with soil carbonates cementing the sun-baked sediment. Members of the local Wiradjuri Aboriginal community authorised and participated in the excavation along with other interested volunteers (Fig. 2C). Only fragments of the cranium remained along with the right mandibular body (Fig. 2D). The post-cranial skeleton was complete, but fragmented with poor preservation of articular surfaces and other elements with thinner cortical bone. Very little cancellous, or spongy, bone was preserved. Preservation is a relevant, but imprecise indicator of antiquity. The bone was evenly mineralised, but with slightly darker colouration on the external surfaces. No chemical examination of the mineralisation was possible. Manganese staining was not evident.

A carbonate wash was present over exposed surfaces and appeared to be of an even thickness on upper and lower surfaces of bone in resting position. The carbonate had infiltrated the bone, assisting the destruction of cancellous bone and exacerbating or causing expansion of micro-fractures so that, while complete in situ, the bones reduced to hundreds of fragments following excavation. Limited reconstruction was possible during the time the remains were in the laboratory. Given the greater amount of carbonate on external surfaces compared to broken edges, it may be that vehicular traffic was responsible for a considerable part of the fracturing.

The preservation, with such a degree of mineralisation and carbonate encrustation, is typical of remains that are at least several thousand years old. Carbonate deposition, both type and amount, is dependent on its solution in the

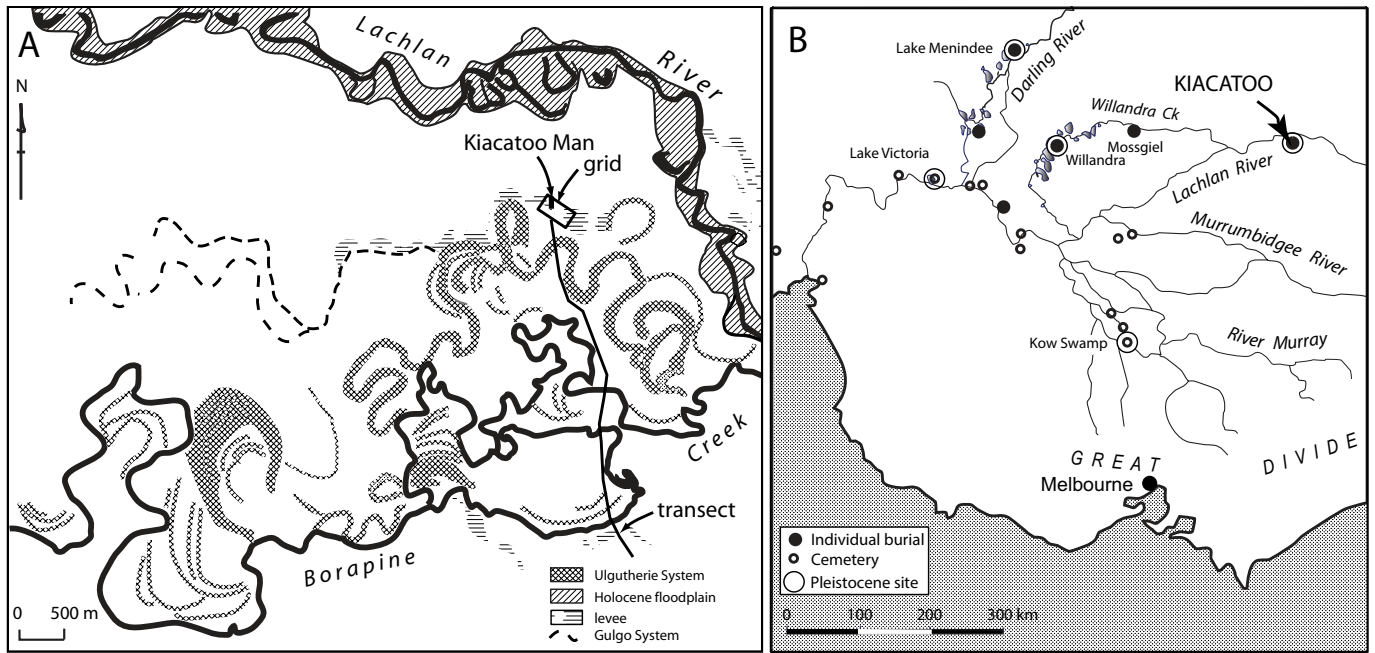


Figure 1: A. Geomorphic map of the Lachlan River at Kiacatoo. B. Distribution of individual burial sites and cemeteries in the riverine plains. Modified from Pardoe (1995).



Figure 2: Photographs from the 2011 excavation of Kiacatoo Man. A. The trench excavated adjacent to the grave revealed a clear boundary between the grave sediments and the underlying fill at 20-22 cm depth. The original depth when dug may have been around 60 cm, implying that 40 cm of the levee surface has been lost through erosion. B. Remains were returned to the gravesite in 2012 for reburial. C. Tim Pietsch explains the principles of OSL dating to community participants. D. The post-cranial skeleton of Kiacatoo Man was well preserved. The large, heavily-built legs have the shins folded back against the thigh in a manner only possible some time after death and rigor mortis. Although most of the cranium was fragmented, morphological features of limb bones, skull vault and face indicate an individual of great size and strength. Analysis suggests that Kiacatoo Man would have stood around six feet tall when alive, making him the largest Pleistocene individual yet discovered in Australia.

water table, degree of evapo-transpiration, depth of burial, amount of carbonate in the soil, type of soil, and no doubt many other factors. The degree of preservation, indicating great antiquity, is supported by the location of the burial in the levee of an ancient palaeochannel. Preliminary OSL analyses of one OSL sample on sediment from beneath the grave floor carried out by Griffith University has suggested a maximum age for the burial of ~17,000 years. A similar age was obtained for sediment comprising the grave fill, but an experimental study on OSL signatures in grave excavations suggests that grave fill may be indistinguishable from the age of the underlying, undisturbed sediment using OSL techniques (Kemp *et al.*, in press). Uranium-series ages on a number of teeth are currently being investigated by Rainer Grün at the Australian National University.

A more detailed description is in preparation, but in summary the remains are those of a large man, possibly the biggest individual documented in Australia. For example, the cranial fragment is as thick as any of the Willandra series, excepting the enigmatic WL 50. From in situ estimation, long bone lengths are at the upper end of the range, exceeded by no more than 2% of an Australian sampling that includes those from mid to early Holocene Rufus River as well as Kow Swamp further upstream in the Murray River corridor. This individual has the largest absolute femoral and tibial diameters of any recorded. Measurements taken from the femur, both length and circumference, place him in the top five percent of Aboriginal measurements along with exceptional rugosity. Although not necessarily the tallest of men, he would have been among the most heavily built, pushing back the contemporary Wiradjuri affinity with Rugby League by millennia. The term 'rugosity' is used instead of 'robusticity' in order to avoid the confusion this term has occasioned, particularly in related disciplines outside of biological anthropology. The former term refers to morphology related to muscle markings, including insertion of tendons, ligaments and fascia, which is itself determined by sex, body build and daily activity through life. A fuller discussion will be made in a following paper concerned mainly with the biology of Kiacatoo Man.

Their most ancient ancestor links Wiradjuri people to those further downstream, at a time when the Lachlan River had yet to jump its course west of Lake Cargelligo, and still flowed along what is now Willandra Creek, feeding the lakes and people of Willandra. During the last millennia of the Pleistocene, people would have been linked up and down the Lachlan River, preferentially marrying their neighbours in a manner required by the nature of the country (Pardoe, 2006). The size, shape and details of skeletal anatomy provide indications of the

biological links between groups, and adaptation to the particular environment of rivers crossing the Riverine Plain when this was part of the Arid Zone.

Virtually all of the ancient (greater than 7,000 years) human remains in Australia have come from the Riverine Plain of the Murray-Darling Basin. People have lived throughout the region since earliest times, burying their dead close to and within residential places that are typically close to rivers, ephemeral lakes and wetlands. Most burials are considered to be in sandy deposits such as lake-edge lunettes, source bordering dunes, and other sand bodies. While burials have been noted in levees, these have tended to be associated with the large palaeochannel traces that meander across the Riverine Plain [Littleton, 1997, 1998; Pardoe and Martin, 2001].

In the Lachlan-Willandra system, source-bordering dunes and levees may hold the key to understanding the distribution of people during the coldest phase of the LGM: whether they were able to range widely or retreated to the river systems as the lakes dried. So far, apart from Kiacatoo Man, there is no direct evidence of a human presence on any of the riverine corridors upstream of Willandra Lakes before 15,000 years (Pardoe, 1995), but an extensive search has not been undertaken. The oldest and best preserved human burial sites are found in lunettes around now-dry lake systems, where high population density relative to the surrounding desert is combined with ease of excavation, high preservation potential, and in eroding sites, ease of discovery (Fig. 1B). But the subtle sandy rises on Pleistocene channels, such as that containing Kiacatoo Man, are likely to have similar favourable features. This implies that many preserved burials along ancient river corridors have yet to be recorded and this is where GPR proves useful.

METHODS

Over the past decade, improvements in GPR technology have facilitated the subsurface identification of small-scale sedimentary structures, disturbances and archaeological objects (Neal, 2004). GPR is an effective tool to identify graves because it provides a clear geological association of the skeleton with the underlying landform as well as the stratigraphic relationship between channel-floodplain-bar-levee systems. This also reduces the opportunity for uncertainty with dating methods associated with stratigraphic variations (Gontz *et al.*, 2011; Damiata *et al.*, 2013; Zhao *et al.*, 2013).

Exploratory GPR surveys were conducted using a MALA GeoScience Pro-Ex GPR system with a 500 MHz antenna to image the subsurface in a grid on both sides of the grave site. The grid was 200 m along the levee by 40 m wide, and survey lines were 0.5 m apart. A survey line

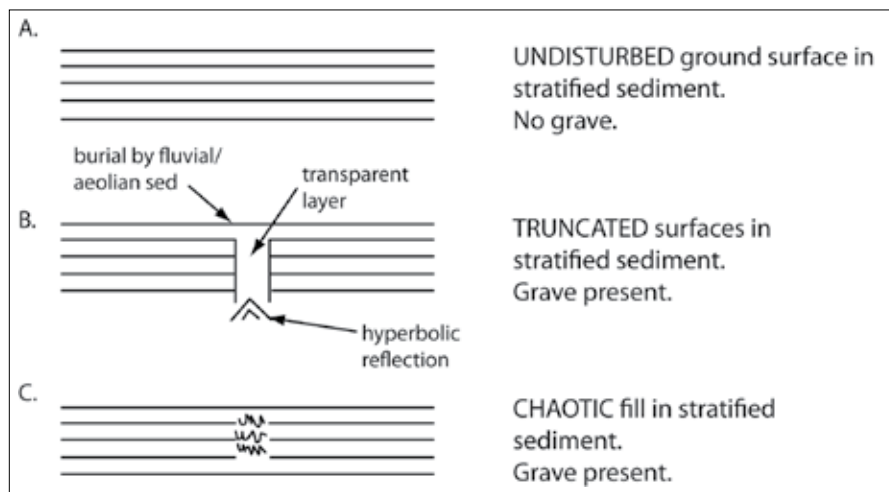


Figure 3: Typical grave signatures in stratified sediment, modified after Gontz *et al.*, 2011; Schultz and Martin 2011.

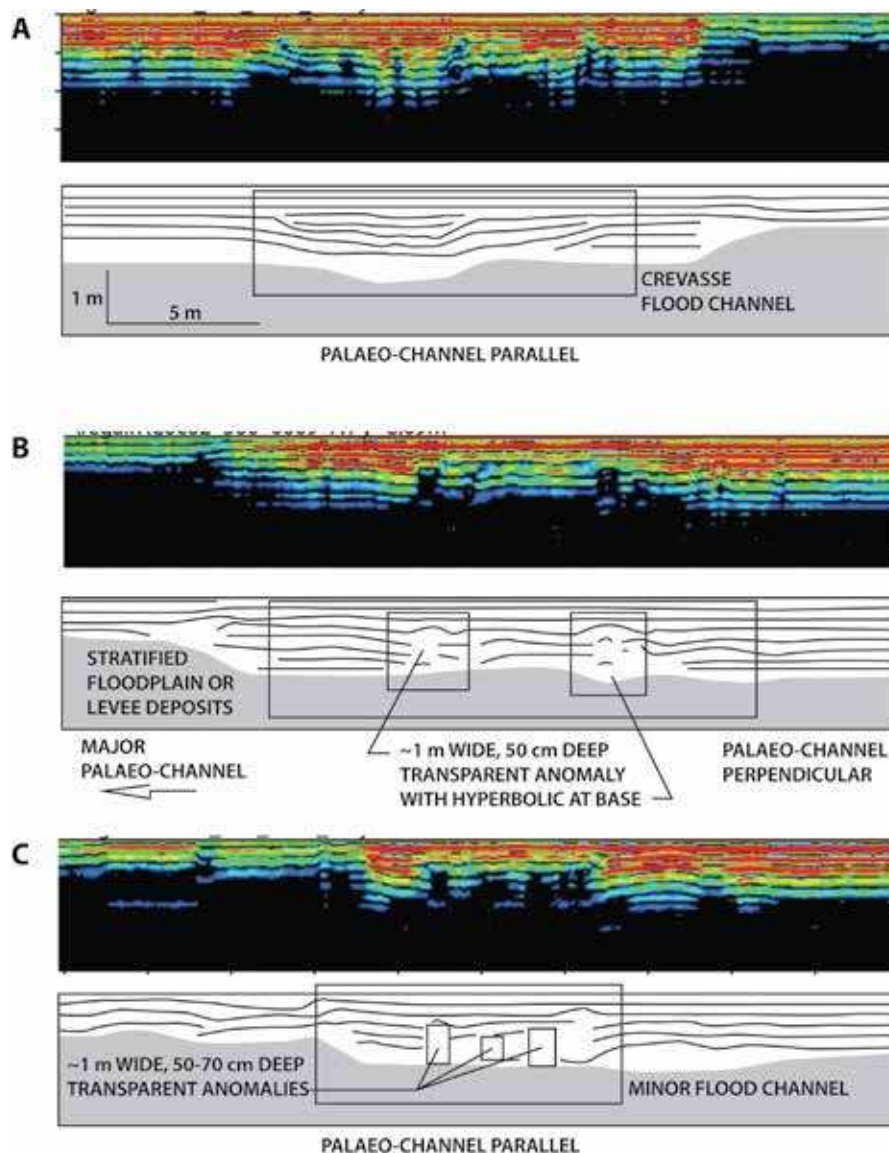


Figure 4: Ground penetrating radar lines collected and subsurface features interpreted at the site. All GPR sections are presented at the scale indicated on Panel A. Only anomalies interpreted as potential grave sites are highlighted. Other anomalies occur and could be the result of subsidence, biological processes or interference from surficial topography and/or materials.

Panel A: This line runs parallel to the major palaeochannel approximately 15 m to the south of the burial site. The radar stratigraphy indicates a small flood channel cut through the stratified sediments of the levee and floodplain deposits.

Panel B: This line was acquired approximately 5 m west of the burial site and runs perpendicular to the major palaeochannel. The radar stratigraphy shows primarily stratified sediments of the floodplain and levee system. In the centre portion of the image, three transparent anomalies are highlighted. These are consistent with the manifestation of small-scale excavations and the size (~ 1 m wide x 50/70 cm deep) is consistent with burials.

Panel C: This line is parallel to the major palaeochannel and is 5 m south of the burial site. The radar stratigraphy shows a small flood channel cut with transparent anomalies in the channel fill. The anomalies have a similar scale to those imaged in Panel B. These anomalies have a hyperbolic reflection at the base, suggesting a change in the character of the sediments above and below buried objects.

was also run from north to south for 3.5 km across levees, channels, and scroll plains of the Ulgutherie channel belt (Fig. 1A). The GPR system was coupled to a Hemisphere VS100/R100 real-time kinematic global positioning system (RTKGPS) to provide subdecimeter geospatial information, which was digitally integrated into the record at time of acquisition. A Windows XP laptop running MALA Geosciences GroundVision2 1.26 was used to log data and view real-time data during acquisition. Real-time visualization coupled with integrated RTKGPS allowed for modification of survey lines during acquisition to avoid obstructions or follow subsurface features of interest. Survey lines were acquired by dragging the antenna array along the ground towed by a survey team member or a slow-moving vehicle with radar pulses emitted at 10 Hz. Post-processing was accomplished using GPRslice v7 developed by Geophysical Archaeometry Laboratory and consisted of DEWOW, bandpass filtering, background removal, application of user-defined gains, topographic correction, and conversion from time to depth sections. The processing increased the record quality through selectively removing noise associated with the broad-spectrum frequency emitted by the antenna, interference and signal backscattering. The resultant data has a horizontal resolution of 0.05 m and a vertical resolution of 0.075 m.

Typical GPR signatures of excavated graves are depicted in Fig. 3 (Gontz *et al.*, 2011; Novo *et al.*, 2011; Schultz and Martin, 2011; Hansen *et al.*, 2014). In stratified sediment, which includes most fluvial and aeolian sediment, undisturbed ground appears as parallel lines that depict reactivation or depositional surfaces. Dug ground usually appears in one of two ways: either as strata truncated by a transparent layer and underlain by a hyperbolic reflection caused by a side wall reflection at the base and the underlying sediment; or alternatively, as an assemblage of disturbed sediments (termed 'chaotic fill') between stratified deposits. Occasionally, depending on the frequency of the GPR antenna, the age of the burial, the orientation of the survey lines with respect to the burial and the soil type, hyperbolic reflections are observed that relate to either the chest cavity and/or the leg bones (Novo *et al.*, 2011; Schultz and Martin, 2011). The planform geometry of individual and multiples graves can be important and the scale of the disturbance is necessary to discriminate between graves and other stratigraphic disturbances. These could include crevasses and buried channels, blowouts (in the case of dunes), other anthropogenic disturbances, and tree throw (Ferguson and Brierley, 1999; Skelly, 2003; Neal, 2004; Okazaki *et al.*, 2013).

RESULTS

The GPR penetration in this landscape was virtually zero in the black soil clays of the regularly inundated palaeochannels south of the burial site, owing to the deposition of highly conductive clay minerals during overbank events (Neal, 2004; Gomez-Ortiz *et al.*, 2010). In the sand and silty sand of levee and deposits, penetration increased to over a metre at the site and in excess of 5 m where thicker channel sand deposits were present. Line 8 (Fig. 4A) reveals ~20 cm deep strata dipping inwards towards a shallow depression 30 m wide that may represent a buried crevasse in the levee (van Overmeeren, 1998; Skelly *et al.*, 2003). The same feature produced a consistent geophysical signature over successive survey lines. Line 9 (Fig. 4B) shows evidence of a stratigraphic disturbance as a ~0.5 m wide interruption in the strata containing chaotic fill with a hyperbolic reflection at ~0.6 m depth. A transparent layer of similar dimensions within a stratigraphic interruption is apparent 20 m to the left. Line 16 (Fig. 4C) exhibits an area of disturbed stratigraphy consistent with burials, excavations or tree-throw disturbance. Five stratigraphic anomalies are revealed in an area 20 m wide. The anomalies are ~0.6 m deep by 0.5 m wide, and are preserved 0.2 m below the present levee surface. While the cause of these anomalies will not be known unless they are excavated, we can say that they are consistent with the geophysical signature and morphological expression of grave diggings. Other anomalies are visible on each of the GPR sections. These have been eliminated as potential grave sites owing to their scale; their occurrence on a single survey line; and/or their stratigraphic relationship with overlying and underlying units.

DISCUSSION

A high-resolution survey grid is ideal for exploration of cemeteries or individual burials. Survey lines in a 0.1 m grid will cross a small grave of 0.8 x 0.5 m (the size of the Kiacatoo burial) at least 11 times and will provide a detailed delineation of the excavation. A 50 cm grid should cross a grave site at least three times, but the grave may be difficult to distinguish from tree throws of similar dimensions. Additional improvement to survey design could include the use of a higher frequency antenna. The 800 MHz antenna for the ProEx system is capable of a vertical resolution of 0.03 m, but sacrifices penetration and is generally limited to imaging to <2 m. Ideally, one would combine numerous techniques to separate anomalies. This would include a nested survey approach based on scale of investigation; for example, a large-scale geomorphic analysis using aerial photographs, followed by a geomorphic field-based study to delineate areas of interest. Once areas of interest are identified, lower resolution, deeper penetrating GPR would be employed

to locate subsurface anomalies followed by higher resolution GPR to reduce the number of anomalies based on geophysical signatures. The last survey would consist of archaeological investigation to excavate individual anomalies. Through a reiterative process of geomorphic, geophysical and archaeological investigation, a team can hone interpretations and reduce effort expended during each survey phase. The work conducted during this survey exemplifies only a portion of the complete and integrated approach required for the confident identification of human burials.

Burials reveal important information about regional cultures, while the remains themselves inform our understanding of biological variation and change. The study of biological patterning and environmental adaptation requires remains from a variety of environments and from different time periods. These conditions are met in the riverine landscapes of south eastern Australia, but we need to make a more systematic search than previously attempted. Burials in levees along abandoned channels may be more common than previously thought. Although chance discoveries of skeletons have been made in palaeochannel levees, such as Mossgiel Man south of Willandra Creek (Macintosh, 1967) and Barham near the Murray River (Daly, 1986), it may be that lack of erosion has obscured our observations. Of burials recorded on the eastern Riverine Plain, 12% (19/164) have been in levees, of which there were small groups of 7, 4, 3 and 2 as well as 2 individual inhumations (Littleton, 1997, 1998). These do not occur further west, mainly because the palaeochannels become fewer.

In 2011, 20 burials were identified during major construction work in Koondrook-Perricoota State Forest near Barham on the Murray River (Pardoe, 2012, 2013b). Of these, most were in small levees associated with small channels that form a capillary bed throughout the forest. These levees are typically 5 m wide and less than 1 m high. They consist of dark grey clay with a high organic content, partly the result of organic debris and fine sediment deposition from overbank flooding, and partly from human occupation where cooking activities were common, being distributed along the levees as well as vertically over time. These levees are important as locally high ground when the forest is flooded, but also as roads because they are generally grass-covered and offer a pathway through the riparian forest. From LiDAR (Light Detection And Ranging) mapping of the forest, it was possible to calculate the length of levees cut by construction. Just over 1,000 m of channel levee was cut by the earthworks, resulting in the discovery of 20 burials at an average of two burials per 100 m of levee, measured along the channel. The Kiacatoo GPR survey has revealed a cluster of five potential burials, in addition to the

original burial, within a 200 m length of levee, giving an average of three burials per 100 m.

Linear features have advantages over point sources in these changeable landscapes, because they functioned as pathways, are easily identified and tend to be more extensive. The search for new sites may be facilitated by new-generation geophysical techniques, including Electromagnetic Induction (EMI) and Earth Resistivity Survey (ERS) in fine-textured sediments (Bersezio *et al.*, 2007; Zhao *et al.*, 2013; Hansen *et al.*, 2014) as well as new GPR technologies (c.f. <http://www.malags.com/products/mala-easy-locator-hdr>).

CONCLUSIONS

Ground penetrating radar technology has advanced in the last decade to the point where it is possible to identify objects as small as a grave much more quickly and with greater precision than previously. Our GPR reconnaissance survey has mapped several buried grave-like disturbances in a sandy landscape unit on the riverine plains. While fine-grained, clay-rich sediments present a potential challenge for GPR, the 500 MHz frequency range, capable of penetrating <5 m with high-resolution, is adequate for geoarchaeological surveys. While GPR surveys to identify potential burial sites are somewhat time-intensive, they are still more rapid than traditional archaeological and forensic techniques (Fielder *et al.*, 2009). The application of GPR, coupled with fluvial geomorphology and archaeology, provides the opportunity to develop palaeoenvironmental models and relate former landscapes to human settlement and land use patterns. This approach is integral to our ongoing project. In addition to the research value, it will also contribute to the development of clear and predictable assessment processes for industry, Aboriginal organisations, and local government authorities that will lead to improved results for heritage and land management.

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