



Archaeology in Oceania, Vol. •• (2014): ••–•• DOI: 10.1002/arco.5039

Ground-penetrating radar and burial practices in western Arnhem Land, Australia

KELSEY M. LOWE, LYNLEY A. WALLIS, COLIN PARDOE, BEN MARWICK, CHRIS CLARKSON, TIINA MANNE, MIKE A. SMITH and RICHARD FULLAGAR

KML, LAW, CC, TM: The University of Queensland; LAW: Flinders University; LAW: Wallis Heritage Consulting; CP: The Australian National University; BM: University of Washington; MAS: National Museum of Australia; RF: University of Wollongong

ABSTRACT

A GPR survey was carried out in advance of archaeological excavations at Madjedbebe (formerly known as Malakunanja II), a sandstone rock shelter in western Arnhem Land (Australia) containing numerous Aboriginal burials. GPR revealed subsurface patterning of rocks in the shelter deposits and archaeological excavation demonstrated that these were related to burials. Post-excavation, GIS and statistical analysis further elucidated the relationship between the rocks and human burials. This integration of detailed mapping, GPR and excavation afforded the opportunity to test a way to identify unmarked burials using GPR in sandstone rock shelters and to document a marker for burial identification in this region. Application of the methodology developed through this case study provides a useful management tool for Indigenous communities and other heritage practitioners.

Keywords: ground-penetrating radar, GIS, burial practices, Indigenous communities, Arnhem Land.

Correspondence: Kelsey M. Lowe, School of Geography, Planning & Environmental Management, The University of Queensland, Brisbane, QLD 4072, Australia. Email: k.lowe4@uq.edu.au

INTRODUCTION

In Australia, where the density of burials tends to correlate strongly with population densities, and where burials may be found within residential spaces, developing methods for the detection of burials is an area of keen research and management interest. Geophysical techniques provide a non-invasive way to investigate subsurface features (Gaffney & Gater 2003; Johnson 2006; Witten 2006), and for these reasons these techniques, particularly ground-penetrating radar (GPR), have become very popular in projects where burials are anticipated.

GPR works by transmitting electromagnetic energy in the form of radar waves into the ground (Bevan 1998; Conyers 2012). When the wave encounters a contrasting material in the soil (such as air voids, stone or moisture content), a reflection occurs, sending part of the wave back to the surface, where it is received and recorded. The remainder of the wave continues downward until it too is reflected back to the surface by deeper objects, or dissipated through absorption by subsurface materials. The depth of radar wave penetration and velocity is highly dependent on soil type and moisture conditions, or the dielectric properties (the ability of a radar wave to hold and transmit an electric charge).

Conyers (2006: 66) suggests that the physical features frequently associated with burials that can be identified by

GPR include: (1) "undisturbed" sediment below and surrounding the grave shaft; (2) a buried coffin or human body and associated artefacts; (3) "disturbed" sediment used to fill the grave shaft; and (4) any surface sediments that have accumulated above the shaft and surroundings after internment (Conyers 2006: 66). The identification of areas of soil compaction and void spaces is also of particular relevance, especially in Indigenous burials. As Lowe (2012) has discussed, it is for these reasons, coupled with the ease of access to GPR equipment, that this has become the most routinely used geophysical instrument for identifying burials in Australia (cf. Bladon *et al.* 2011; Brown *et al.* 2002; L'Oste-Brown *et al.* 1995; Moffat *et al.* 2010; Powell 2004, 2010; Randolph *et al.* 1994; von Strokirch 1999; Yelf & Burnett 1995).

Yet GPR does not offer foolproof detection of all graves, sometimes producing false positives due to other sources of disturbance or, in cases where graves are indistinguishable from the surrounding strata, false negatives or no results (Bevan 1991; Dalan *et al.* 2010; Davenport 2001; Nobes 1999). Unmarked burials, which are common in Australian historical archaeology and almost exclusively the case in Australian Indigenous archaeology, present specific challenges. The particular form of these burials (e.g. bundle, cremation, limited grave goods, shallow depth, no coffin etc.; see Meehan 1971) and the nature of the geologically ancient sediments into which interment occurs, often impedes their identification with GPR. Further, in areas where the sedimentary matrix consists of gravelly, shelly or cobble-rich sediments, there can be significant "distortions" in the data for both the disturbed area of the grave shaft and undisturbed areas adjacent to the grave, adding to the complexity of interpretation (Conyers 2006). The limited case studies with which to compare and contrast results in Australia also mean that interpretation is often speculative, with excavation rarely carried out to confirm the specific nature of GPR-identified anomalies.

In this paper, we detail how GPR was combined with archaeological excavation data using a geographic information systems (GIS) approach to test and identify numerous unmarked burials in a rock shelter context. The results were also tested with statistical analysis to confirm that the documented association was deliberate rather than random. Burial methods across Arnhem Land are known ethnographically to include secondary rock shelter burials, excarnation, tree burial and hollow-log coffins (Meehan 1971), though there is little evidence of why certain individuals might receive particular treatment, or whether this changed through time. While several accounts have been documented in our study region, none have been reported for our study site.

In addition, changing legal codes over the past 30 years defining Indigenous peoples as the primary holder of rights regarding decision-making in respect to their heritage have done much to improve the relationship between archaeologists and Traditional Owners, though they have also resulted in fewer burial site investigations being carried out in Australia. When our research partners, the Gundjeihmi Aboriginal Corporation (GAC) – representing the Traditional Owners of the study area, the Mirarr – granted permission to study the Madjedbebe rock shelter in northern Australia as part of broader heritage initiatives, it afforded a rare opportunity to perform a detailed geophysical survey prior to archaeological ground disturbance.

THE MADJEDBEBE SITE

Madjedbebe (formerly known as Malakunanja II) is a Pleistocene-aged rock shelter located in Arnhem Land, Australia (Figure 1). The shelter is a narrow, north-west-facing sandstone overhang at the base of the Arnhem Land Plateau escarpment, located approximately 40 km west of the East Alligator River. The shelter wall contains a gallery of pigment art, and the shelter floor is generally flat, sandy and mostly vegetation free. The archaeological deposits at Madjedbebe comprise a ~70 cm thick Holocene-aged shell midden unit, underlain by a further ~3 m of late Pleistocene-aged cultural deposits (Kamminga & Allen 1973). This subsoil parent material is a mix of sand and silt weathered from the adjoining quartzose sandstone escarpment of the Middle Proterozoic Kombolgie Formation (East 1996: 40). For this study, it is only the shell midden unit with which we are concerned.

Figure 1. The study area location in western Arnhem Land. Areas shaded in grey indicate the East and South Alligator River catchments (Geoscience Australia 2004).



Archaeology in Oceania

Madjedbebe has been the focus of several archaeological investigations, being first excavated in 1972 (Kamminga & Allen 1973) and again in 1989 (Roberts *et al.* 1990); the latter investigation yielded luminescence dates of 50000–60000 years BP. While these investigations involved only small test-pits, they did reveal that burials were present within the midden unit, though they were assumed to be few in number and primarily secondary bundle burials (Smith 1989). This prior identification of burials caused concern when the site was to be reinvestigated, and thus a geophysical survey was conducted prior to re-excavation to allow researchers to be better informed about what they might encounter.

METHODS

In late 2011, a geophysical survey grid measuring 8×18 m was established adjacent to the Madjedbebe shelter wall (Figure 2). This grid was used to conduct two surveys: one with transects spaced by 0.25 m, running parallel to the shelter wall, and the other with transects spaced by 0.50 m, running perpendicular to the shelter wall. This methodology provided the necessary high spatial resolution for discerning small, discrete features. GPR data were collected with a Geophysical Survey Systems, Inc. (GSSI) SIR-3000, 400 MHz antenna and a model 620 survey wheel. Sixteen-bit data were collected with an 80 ns time window, 512 samples per scan and with 25 scans per metre. Data were processed and converted into slice-maps using GPR-SLICE v7.0. Time slices were made using the hyperbola fitting function to

estimate the relative dielectric permittivity, which is calculated from the two-way travel time to depth (Goodman & Piro 2013). These depth estimates generated in the software were then verified in the excavations.

Archaeological excavations and detailed mapping using a Nikon Total Station with Trimble Survey Pro software were carried out in mid-2012. Nine adjoining 1×1 m (Squares C2, C3, C4, D2, D3, D4, E2, E3 and E4), and two smaller (B2 and B3) test-pits were established within the overhang and geophysical survey grid, adjacent to the previous investigations. These test-pits were excavated in 5 cm spits in the upper midden deposit and in 2 cm spits in the lower sands. Excavation was discontinued in Squares E3, E4 and D4 at a depth of 1.2 m to create a step down into Squares C2, C3, C4, D2, D3 and E2, which were excavated to a depth of ~3 m. Squares B2 and B3 were excavated to a total depth of ~3.5 m.

All excavated material, with the exception of the human remains, was dry-sieved through 3 and 7 mm sieves and sorted in the field. A complete 1×1 m bulk sample for flotation analysis was retained from every spit of C2, as well as from all hearth features. Analysis of collected material from the investigations, including radiocarbon and optically stimulated luminescence dating, are ongoing and therefore are not included as part of this study.

A comprehensive mapping regime was designed and implemented to allow the creation of a high-precision map of the site as a means by which to digitally archive the spatial excavation data. This form of total station archaeology is highly effective at enabling rapid data

Figure 2. A topographic map showing the location of the 1972, 1989 and 2012 excavation areas and that of the 2011 geophysical survey at Madjedbebe.



integration and for understanding site formation processes (cf. Marean *et al.* 2007; McPherron 2005), as well as for managing and analysing field data (McCoy & Ladefoged 2009; Tripcevich & Wernke 2010). A dictionary of all collected data was established and used to build a database/attribute file and vector data for analysis in ESRI ArcGIS 10.2. These data were used to examine the spatial relationships between rock deposits and human burials within the sedimentary sequence.

The output of the collected GIS data was also used to look at the statistical relationships between particular archaeological features. While one could visually observe and develop a "sense of" some of these patterns during excavation, they were rigorously verified post-excavation statistically. In this case, resampling methods and geometric morphometry were used to investigate the relationship between human burials and rocks by determining if the rocks were randomly or deliberately (anthropogenically) positioned as part of the burial practice. Statistical measurements were computed in R3.0.1 and RStudio 0.97.336, using the GIS vector data of both rock and burial features.

RESULTS

The GPR data revealed the complex nature of the shelter deposits. The local sandstone geology was a critical factor, with large rocks in the deposit causing very strong reflections and slight contrasts in the data (Figure 3a). These were interpreted as dense roof-fall, since the reflections occurred directly below and beyond the shelter's drip-line. A subset of the GPR data/dataset adjacent to the shelter wall and within the drip-line was selected for additional post-processing to investigate the area within the drip-line that appeared to have no roof-fall and where human activity would probably have been more regular.

The original GPR reflections became much clearer after the selected subset of the original dataset was processed. The subset revealed a number of strong reflections within

Figure 3. (a) Amplitude slice-maps of Madjedbebe (49–61 cm). Areas with higher reflections are denoted by yellow and red. (b) A resampled amplitude subset. Squares E2, D2, C2 and B2 were located under the shelter wall and were not surveyed.



Figure 4. A resampled selected amplitude slice-map of subsets (left) showing selected (A–E) high-amplitude features/ concentrations in two selected reflection profiles (right). Areas outside the black rectangle are unexcavated.



the drip-line and adjacent to the shelter wall (Figure 3b). These were apparent in both the amplitude slices and reflection profiles, and defined easily even amongst the shell midden (Figure 4). Excavation revealed that these reflections were from medium (15–50 cm diameter) sized rocks. While other hyperbolic reflections were apparent in the reflection profiles resembling those defined as rocks (see Figure 4), these were not excavated and therefore their cause is unknown.

The 2012 Madjedbebe excavations unearthed 17 individuals (coded as skeletal remains, hereafter SR) in various states of completeness (Figure 5). These comprised predominantly primary interments (n = 13) dug into, or just through, the shell midden unit into the uppermost level of the underlying sand unit. All of the burials contained minimal amounts of grave goods and occurred in both flexed and extended positions.

Although narrow GPR survey transects (i.e. 0.25 m) were used at Madjedbebe, the identification of human bones, burial shafts or void spaces within the shell midden unit in the collected GPR data was not possible. However, at least nine of the burials were associated with rocks, a tradition similar to that documented by Schrire (1982) at the nearby site of Nawamoyn. At Madjedbebe, most rocks were placed on the individual's head and, in two instances, rocks were placed on both the head and feet (SR1 and SR5), while one burial had a rock placed only on the feet (SR4). With the exception of two burials in a single grave

(SR3 and SR14), the rocks associated with each burial were similar in size, averaging 20 cm in diameter – a size small enough to be moved by an individual, but unlikely to be displaced by animal activity or bioturbation as indicated by the relatively intact and articulated nature of the burials. Plotting of the rocks during excavation revealed that they coincided with the burials (Figure 6) and when compared with the GPR data, it became clear that the high-amplitude reflections in the GPR data corresponded with these rocks and, in turn, with the primary interments (Figure 7).

Considering that naturally deposited sandstone rocks were also present on the surface and in the deposits at the site, statistical analysis was used to determine if the association of the rocks with the burials was random or deliberate (anthropogenic). To test this, the GIS vector data of all rocks and skeletal remains in the excavated deposits were used to compute the probability that the observed amount of overlap was due to random process. One thousand random arrangements of the rock polygons were simulated in the excavation area and the area of overlap with the skeleton polygons (whose locations were kept constant) was computed for each random arrangement. The mean area of overlap in the random permutations was 0.34 ± 0.09 m², compared to the observed area of overlap of 0.53 m². Only 2.5% of the random permutations have an overlap area equal to or greater than the observed area, indicating that the observed area of overlap of rocks and skeletons is significantly

Figure 5. The locations of burials identified in the nine 1×1 m test-pits (Squares C2, C3, C4, D2, D3, D4, E2, E3 and E4) and two smaller test-pits (B2 and B3). Note that there is no SR12.



Figure 6. A plan view map showing the location of rocks on the skeletal remains.



Figure 7. Both an amplitude slice-map and a subset showing the cause of the high reflections; the cluster of rocks identified in the 2012 excavation (grey circles). Burials are noted as circles.





non-random (Figure 8) (for supplementary information, see http://dx.doi.org/10.5281/zenodo.10616).

DISCUSSION

It was expected that burials would be present at Madjedbebe, which were thought to have caused alterations in the subsurface material. However, as the burials were initially anticipated to be small secondary bundle burials, the initial geophysical survey was designed with the primary goal of mapping more distinctive and larger features such as bedrock and roof-fall. Even when a subset of the GPR data was selected for detailed post-data processing, Conyers' (2006: 66) list of four physical features used for geophysical burial identification was largely inapplicable, since no changes in natural soil or surrounding material were apparent, coffins were not used and vertical shafts were impossible to distinguish in the shell-rich deposits. The GPR survey thus did not identify grave cuts or fill; it was the combination of ethnographic and archaeological evidence with detailed GIS plots that demonstrated the mortuary practice involving placement of rocks over the burials.

Much research in Australian archaeology has explored regional variations in material culture (e.g. tula adzes and cylcons), burials, rock art and biology, and attempts have been made to utilise the results to extrapolate past territorial organisation (e.g. David 1991; David & Chant 1995; David & Cole 1990; Franklin 2004; McDonald 2008; Pardoe 1988, 1994, 1995; Wade *et al.* 2011). With respect to mortuary practices, any regional patterning present may be strongly dependent on external – rather than cultural – factors, such as the presence of trees suitable for burial or excarnation (flesh removal), a soft substrate into which to dig a grave or rock shelters for placement of bundles.



80 Observed value = 0.53 60-Frequency (p = 0.021)20 0-0.2 0.4 03 01 0.5 0.6 Area of intersection of rocks and skeletons (m²)

The ethnographic and archaeological documentation of burial practices amongst groups in the Arnhem Land region has demonstrated that variations exist. The Gagadju (Kakadu) were reported to have taken the body into the bush, covered it with grass and leaves, then earth and finally stones to discourage dogs from digging the bodies up (Berndt & Berndt 1992: 463; Spencer 1914: 240-9). At the Nawamoyn rock shelter site, not far from Madjedbebe, archaeological evidence for both an intact flexed and an extended burial has been observed (Schrire 1982). It was noted that the body was placed on the surface of the midden and large rocks put on top, one of 36 kg on the ribs and two, of 23 kg and 12 kg, on the pelvis. Smaller rocks were placed on the legs just above the knees, potentially to protect the body from predators or as markers of its position (Schrire 1982: 126). Among the Murngin of north-east Arnhem Land, a similar style of burial was practiced, but with the body placed face downward and not flexed (Warner 1969 [1937]: 422).

Secondary burial is also common in Arnhem Land, with the body first being either excarnated on a platform built in a tree, or buried for a season, before disinterring and wrapping in paperbark to be placed elsewhere, perhaps on a rock ledge and into rock shelters (White 1967: 431). At the rock shelter sites of Paribari and Malangangerr, also close to Madjedbebe, Schrire (1982: 56) found abundant evidence of secondary burials in the form of bones that had been "burnt, broken and stuffed into the [rock shelter] niche packed around with grass, bark and other debris". While this anthropogenic process does not require subsurface burial, when placed into rock shelters the remains can become buried by the natural accumulation of sediment through time; prior to the 2012 excavations, it was thought that these would be the primary form of burial at Madjedbebe.

Our engagement with the Mirarr custodians who were involved in overseeing the excavations also provided insight into local burial practices. Although it was unknown explicitly why rocks were used as part of their mortuary practice, one possible reason may have been to protect the remains of the deceased from disturbance by scavenging animals such as dingoes (or Tasmanian tigers), as noted by Baldwin Spencer during his 1912 visit to this region (Batty *et al.* 2005: 161). However, protecting the living from the spirits of the deceased may also have been another consideration (Mark Djandjomerr, July 2012).

Graves were dug into the shell midden deposit and rocks were placed on the individuals before they were covered. These rocks were the source of the strong reflections in the GPR data, and detailed archaeological mapping and excavation verified their location. Statistical analysis of the rock subsurface distributions using resampling and geometric morphometry over the burials confirmed that the rock placement was unlikely to have resulted from random processes, and indicates deliberate placement of rocks and not natural roof-fall deposition. While these are not considered as grave goods in the usual sense, the inclusion of the rocks placed on an individual's head and/or feet was a cultural aspect of the burials, and introduced a substantially different physical element to the subsurface deposit that was detectable using geophysical techniques.

By integrating GPR with archaeological excavations, GIS and statistics, we have provided a powerful way to identify human burials in this part of Arnhem Land. Despite rock shelters being common, and one of the most regularly excavated site types in Australia, there has been minimal work on geophysical investigations of Australian rock shelters (Conyers 2012), though internationally this is not the case (Convers 2011: 19; Horle et al. 2007; Porsani et al. 2010). In combination with GIS mapping and archaeological excavation, we have demonstrated the successful application of GPR in an Australian sandstone rock shelter environment. The GPR results provided, first, information on subsurface material associated with geological features such as bedrock and roof-fall and, second, cultural material, in the form of deliberately positioned rocks associated with human burials.

The success of this study has important implications for future investigations and/or management of other sites in Mirarr country and elsewhere. While in this instance the presence of a thick shell midden unit in the Madjedbebe

Archaeology in Oceania

site provided conditions conducive to bone preservation, sandstone environments are typically acidic and rarely preserve bone. In addition, water table fluctuation, soil fauna (e.g. ants and termites), soil acidity and mineralogy are also all known to strongly influence bone preservation. For deposits lacking suitable conditions for bone preservation, such as the Pleistocene levels of the Madjedbebe site, GPR identification of subsurface rocks could provide a tentative indication of burials, which might be further supported by subsequent excavations, GIS and statistical study. GPR identification of rock patterns in midden deposits at other sites in Arnhem Land might also alert researchers and managers to the possibility of burials being present, thereby allowing communities to be more informed prior to considering permission to excavate or in other cases, choose avoidance. Further, GPR can be used to investigate the spatial layout of these rock shelter sites, by defining subsurface geological features such as buried bedrock or areas affected by natural processes such as roof-fall concentrations.

CONCLUDING REMARKS

This research has highlighted the importance of detailed data recording and integration when attempting to investigate and map complex archaeological sites. Although GPR surveys are extremely rare in Australian rock shelter studies, the study described herein demonstrates their potential value. The integration of GPR and excavation results through GIS proved to be very beneficial in understanding burial practices at Madjedbebe because of the specific way in which individuals were interred at this particular site. The initial GPR study identified the presence of numerous subsurface rocks of unknown origin; subsequent excavation identified they were associated with 17 burials, and statistical analysis indicated that the association was deliberate, rather than random. Studies such as this indicate the potential of GPR to shed light on intra- (individual burial and cemetery practices) and inter-site (regional variation and territorial organisation) variability, particularly where information about cultural history is lacking.

The partnership with the Mirarr community and the formal approval process adopted to facilitate its development and continuance were critical aspects of this project. While research at Madjedbebe is ongoing, this partnership could potentially lead to future research collaborations, offering additional opportunities to explore further applications of archaeological geophysics in Mirarr Country.

ACKNOWLEDGEMENTS

The authors are grateful to the custodians of Madjedbebe, the Mirarr Senior Traditional Owners, Yvonne Margarula and May Nango, and to our research partners, the Gundjeihmi Aboriginal Corporation, for granting permission to carry out this research and publish this paper - thank you for trusting us with your Old People. To David Vadiveloo and Justin O'Brien, your support, advice and guidance, especially during the field season, is graciously acknowledged. We also acknowledge the work of Jo Kamminga, Bert Roberts and the late Rhys Jones during earlier excavations at Madjedbebe. To the other members of the field crew and research team, thank you for all your efforts during the long field season, especially Billy Griffith for all the fabulous meals you prepared that kept us on our feet, and Jessica Thompson for providing the information and protocols for the GIS mapping. This research was carried out as part of ARC Discovery Project DP110102864.

REFERENCES

- Batty, P., Allen, L. and Morton, J. 2005. *The Photographs of Baldwin Spencer*. Miegunyah Press, Melbourne.
- Berndt, R.M. and Berndt, C.H. 1992. *The World of the First Australians. Aboriginal Traditional Life: Past and Present.* Aboriginal Studies Press, Canberra.
- Bevan, B.W. 1991. The search for graves. *Geophysics* 56: 1310–1319.
- Bevan, B.W. 1998. *Geophysical Exploration for Archaeology: An Introduction to Geophysical Exploration*. National Park Service, Midwest Archaeological Center, Lincoln, NE.
- Bladon, P., Moffat, I., Guilfoyle, D., Beale, A. and Milani, J. 2011. Mapping anthropogenic fill with GPR for unmarked grave detection: A case study from a possible location of Mokare's grave, Albany, Western Australia. *Exploration Geophysics* 42: 249–257.
- Brown, S., Avery, S. and Goulding, M. 2002. Recent investigations at the Ebenezer Mission cemetery. In R. Harrison and C. Williamson (eds), *After Captain Cook: The Archaeology of the Recent Indigenous Past in Australia*, pp. 147–170. Altamira Press, Lanham, MD.
- Conyers, L.B. 2006. Ground-penetrating radar techniques to discover and map historic graves. *Historical Archaeology* 40: 64–73.
- Conyers, L.B. 2011. Discovery, mapping and interpretation of buried cultural resources non-invasively with ground-penetrating radar. *Journal of Geophysics and Engineering* 8: S13–S22.
- Conyers, L.B. 2012. Interpreting Ground-Penetrating Radar for Archaeology. Left Coast Press, Walnut Creek, CA.
- Dalan, R.A., DeVore, S.L. and Clay, R.B. 2010. Geophysical identification of unmarked historic graves. *Geoarchaeology* 25: 572–601.
- Davenport, G.C. 2001. Remote sensing applications in forensic investigations. *Historical Archaeology* 35: 87–100.
- David, B. 1991. Fern Cave, rock art and social formations: Rock art regionalisation and demographic models in southeastern Cape York Peninsula. Archaeology in Oceania 26: 41–57.
- David, B. and Chant, D. 1995. *Rock Art and Regionalisation in North Queensland Prehistory*. Queensland Museum, Brisbane.
- David, B. and Cole, N. 1990. Rock art and regionalisation in north Queensland prehistory. *Antiquity* 64: 788–806.
- East, T.J. 1996. Landform evolution. In C.M. Finlayson and I. Von Oertzen (eds), *Landscape and Vegetation Ecology of the Kakadu Region, Northern Australia*, pp. 37–55. Kluwer Academic, London.
- Franklin, N.R. 2004. Explorations of Variability in Australian Prehistoric Rock Engravings. British Archaeological Reports International Series 1318. John and Erica Hedges, Oxford.

GPR and burials in Arnhem Land, Australia

- Gaffney, C. and Gater, J. 2003. Revealing the Buried Past: Geophysics for Archaeologists. Tempus Publishing, Stroud, Gloucestershire.
- Geoscience Australia. 2004. *GEODATA COAST 100K 2004: Product User Guide*. National Mapping Division, Australian Government, Canberra.
- Goodman, D. and Piro, S. 2013. *GPR Remote Sensing in Archaeology*. Springer, New York.
- Horle, S., Huneau, F., Salomon, A. and Denis, A. 2007. Using the ground-penetrating radar to assess the conservation condition of rock-art sites. *Comptes Rendus Geosciences* 339: 536–544.
- Johnson, J.K. (ed.). 2006. Remote Sensing in Archaeology: An Explicitly North American Perspective. University of Alabama Press, Tuscaloosa, AL.
- Kamminga, J. and Allen, H. 1973. *Report of the Archaeological Survey: Alligator Rivers Environmental Fact-Finding Study*. Government Printer, Darwin.
- Lowe, K.M. 2012. Review of geophysical applications in Australian archaeology. Australian Archaeology 74: 71–84.
- L'Oste-Brown, S.L., Godwin, L., Henry, G., Mitchell, T. and Tyson, V. 1995. "Living Under the Act": Taroom Aboriginal Reserve 1911–1927. Cultural Heritage Monograph Series, Vol. 1. Queensland Department of Environment and Heritage, Brisbane.
- Marean, C.W., Bar-Matthews, M., Bernatchez, J., Fisher, E., Goldberg, P., Herries, A.I.R., Jacobs, Z., Jerardino, A., Karkanas, P., Minichillo, T., Nilssen, P.J., Thompson, E., Watts, I. and Williams, H.M. 2007. Early human use of marine resources and pigment in South Africa during the Middle Pleistocene. *Nature* 449: 905–908.
- McCoy, M.D. and Ladefoged, T.N. 2009. New developments in the use of spatial technology in archaeology. *Journal of Archaeological Research* 17: 263–295.
- McDonald, J.J. 2008. Dreamtime Superhighway: An Analysis of Sydney Basin Rock Art and Prehistoric Information Exchange. Terra Australis 27. Australian National University E-Press, Canberra.
- McPherron, S.J.P. 2005. Artifact orientations and site formation processes from total station proveniences. *Journal of Archaeological Science* 32: 1003–1014.
- Meehan, B. 1971. The Form, Distribution and Antiquity of Australian Aboriginal Mortuary Practices. Unpublished MA thesis, University of Sydney, Sydney.
- Moffat, I., Wallis, L.A., Hounslow, M.W., Niland, K., Domett, K. and Trevorrow, G. 2010. Geophysical prospection for late Holocene burials in coastal environments: Possibilities and problems from a pilot study in South Australia. *Geoarchaeology* 25: 645–665.
- Nobes, D.C. 1999. Geophysical surveys of burial sites; a case study of the Oaro urupa. *Geophysics* 64: 357–367.
- Pardoe, C. 1988. The cemetery as symbol: The distribution of prehistoric Aboriginal burial grounds in southeast Australia. *Archaeology in Oceania* 23: 1–16.

- Pardoe, C. 1994. Bioscapes: The evolutionary landscape of Australia. Archaeology in Oceania 29: 182–190.
- Pardoe, C. 1995. Riverine, biological and cultural evolution in southeastern Australia. *Antiquity* 69: 696–713.
- Porsani, J.L., de Matos Jangelme, G. and Kipnis, R. 2010. GPR survey at Lapa do Santo archaeological site, Lagoa Santa karstic region, Minas Gerais state, Brazil. *Journal of Archaeological Science* 37: 1141–1148.
- Powell, K. 2004. Detecting buried human remains using near-surface geophysical instruments. *Exploration Geophysics* 35: 88–92.
- Powell, K. 2010. Grave Concerns: Locating and Unearthing Human Bodies. Australian Academic Press, Bowen Hills, Queensland.
- Randolph, P., Wilson, V., Frampton, C. and Merritt, G. 1994.
 Rottnest Island Aboriginal Prisoners Cemetery: Delineation of extent using ground-penetrating radar evolution. In M.
 Sullivan, S. Brockwell and A. Webb (eds), Archaeology in the North: Proceedings of the 1993 Australian Archaeological Association Conference, pp. 394–415. North Australia Research Unit, Australian National University, Darwin.
- Roberts, R.G., Jones, R. and Smith, M.A. 1990. Thermoluminescence dating of a 50,000-year old human occupation site in northern Australia. *Nature* 345: 153–156.
- Schrire, C. 1982. The Alligator Rivers: Prehistory and Ecology in Western Arnhem Land. Terra Australis 7. Department of Prehistory, Research School of Pacific Studies, Australian National University, Canberra.
- Smith, M.A. 1989. Field notes. Archaeological excavations at Malakunanja II, July–August 1989. Unpublished field notes on file AIATSIS, Canberra.
- Spencer, B. 1914. Native Tribes of the Northern Territory of Australia. Macmillan, London.
- Tripcevich, N. and Wernke, S.A. 2010. On-site recording of excavation data using mobile GIS. *Journal of Field Archaeology* 35 (4): 380–397.
- von Strokirch, T. 1999. A Report on a Ground Magnetic Survey over the Ebenezer Mission Cemetery and Surrounds. Aboriginal Affairs Victoria, Melbourne.
- Wade, V., Wallis, L.A. and WVA Corporation. 2011. Style, space and social interaction: An archaeological investigation of rock art in inland north Queensland, Australia. *Australian Archaeology* 72: 23–34.
- Warner, W.L. 1969 [1937]. A Black Civilization: A Social Study of an Australian Tribe. P. Smith, Gloucester, MA.
- White, C. 1967. The prehistory of the Kakadu people. *Mankind* 6: 426–431.
- Witten, A.J. 2006. *Handbook of Geophyics and Archaeology*. Equinox Publishing, London.
- Yelf, R. and Burnett, A. 1995. Ground-Penetrating Radar Survey of Unmarked Cemeteries at Taroom Aboriginal Reserve, Bundulla, Queensland. Department of Environment and Heritage, Rockhampton.