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SHORT REPORT

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Integration of GPR and magnetics to study the interior features and history of earth mounds, Mapoon, Queensland, Australia

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Abstract

The nature of earth mounds and their function over time in northern Australia is of ongoing academic debate. Here we present how the integration of ground-penetrating radar (GPR) and magnetic data, after being adjusted for surface elevation changes, was used to analyse the interior features and objects within six earth mounds in Mapoon, western Cape York, Australia. These geophysical techniques were merged and interpreted jointly to produce images of the stratigraphic units and objects within the mounds to determine their extent and composition. It was found that some mounds were built over burned areas that contain large objects on the original ground surface. Those modified areas were then converted into substantial earth mounds, which reach a maximum height of about 4 m. Other mounds nearby show no evidence of pre-construction burning. In one mound cluster the western three mounds contain human burials that were visualized using GPR profile interpretation. The nearby eastern three mounds were devoid of human burials, but contained many of the pre-mound burned features seen in those just a few hundred metres to the west. The close proximity of these six mounds, with very different associated features and internal objects suggests that they are related in some way, but differed in their function. It is also possible that they were constructed at different times by different people. The data analysis techniques presented in this article assists with further opportunities to undertake non-destructive investigations of these earth mounds that are culturally appropriate to living Aboriginal people. They will also help to resolve the function and possible importance of these constructed features over time.

KEYWORDS

Australia, earth mounds, GPR, human burials, magnetics, Queensland

1 | INTRODUCTION

For many decades archaeologists have studied and puzzled over the earth mounds in northern Australia (Allen, 1996; Allen & Barton, 1989; Bourke, 2005; Brockwell, 1996a, 1996b, 2001, 2005, 2006; Brockwell & Webb, 1993; Burns, 1999; Cribb, 1986, 1996; Cribb, Walmbeng, Wolmby, & Tasman, 1988; Kamminga & Allen, 1973; Meehan, 1988, 1991; Meehan, Brockwell, Allen, & Jones, 1985; Peterson, 1973). These prominent constructed features on an otherwise very flat landscape vary in shape, size, and presumed functions. Their prehistoric and possibly historic use has been suggested as foundations for shelters (Peterson, 1973) transient and seasonal base camps of hunter-gatherers (Brockwell, 2005; Burns, 1999; Cribb, 1986; Meehan, 1988, 1991 ; Peterson, 1973), areas where ovens were constructed (Meehan, 1988, 1991; Peterson, 1973), food preparation and consumption areas (Ó Foghlú, Wesley, Brockwell, & Cooke, 2016), territorial markers and burial sites. Others have suggested that they are not anthropogenic at all, but were areas where shells were concentrated, or are the nests of large birds (Stone, 1991, 1993). A recent synthesis suggests that some of these mounds from northern

Australia were multi-functional (Brockwell, 2006). In all these studies, an analysis of the internal components of these prominent features was determined by excavations or coring. To date there have been no published analyses of earth mounds using near-surface geophysical techniques. Here we report findings of ground-penetrating radar (GPR) and magnetic gradiometric surveying conducted at a cluster of mounds in the Mapoon area of northern Queensland on the Cape York Peninsula (Figure 1). More than 20 mounds have been identified through a survey north of the town of Mapoon along the Cullen Point Road [although light detection and ranging (LiDAR) mapping indicates there are at least another 250 similar features in a stretch of country from Cullen Point to the Pennefather River to the south of the study area that were not studied]. Eleven mounds in the Mapoon area have been surveyed geophysically and results from six of them are presented here.

The initial goal of this work was to search for burials within these earthen features. Our initial efforts at two earth mounds along the Cullen Point Road in 2016 were chosen for study as they were places remembered by the Mapoon Elders as burial places of family members and contained at least two unmarked graves. On the surface of these mounds were found coral pieces, traditionally used as grave markers, and historic items such as spear heads and the presence of planted flowering trees such as frangipani and other flowering native flora, all of which are indicative of a burial area. The initial GPR work identified a number of burials within the mounds. They were recognized by detailed GPR mapping of reflection hyperbolas, found at an appropriate depth for human burials, and which could be identified within at least three parallel GPR profiles spaced 50 cm apart to provide size and orientation. Models for what human burials would look like in this ground using GPR reflection profiles were obtained by previous analysis in 2013 of a formal cemetery at the Mapoon Mission Cemetery (Figure 1), just to the north of the study area (Sutton & Conyers, 2013). In all cases only hyperbolas visible at the appropriate depth and which were correlative to similar hyperbolas along three adjoining lines, oriented as a human burial were mapped as human internments. While there are other features in the ground that could be mistaken for burials, such as roots and animal burrows, those could be discounted as they form sinuous patterns in the ground distinct from an elongated human body.

When more mounds were discovered and mapped, additional GPR surveys were conducted on them, and magnetometry data were also gathered over some of these prominent features. As data processing, analysis and method integration proceeded, it was discovered that these mounds contain a number of unexpected features, which could be identified and analysed geophysically in three-dimensions. Those features notably include modified and burned surfaces constructed on the original ground surface prior to mound construction. Only after the mounds had been constructed (at least partially if not wholly) were some of them used for human interment. It was also revealed that there was variation of the placement, geometry and composition of sub-mound features and that some mounds contained none of these pre-mound features whatever. Even more puzzling was

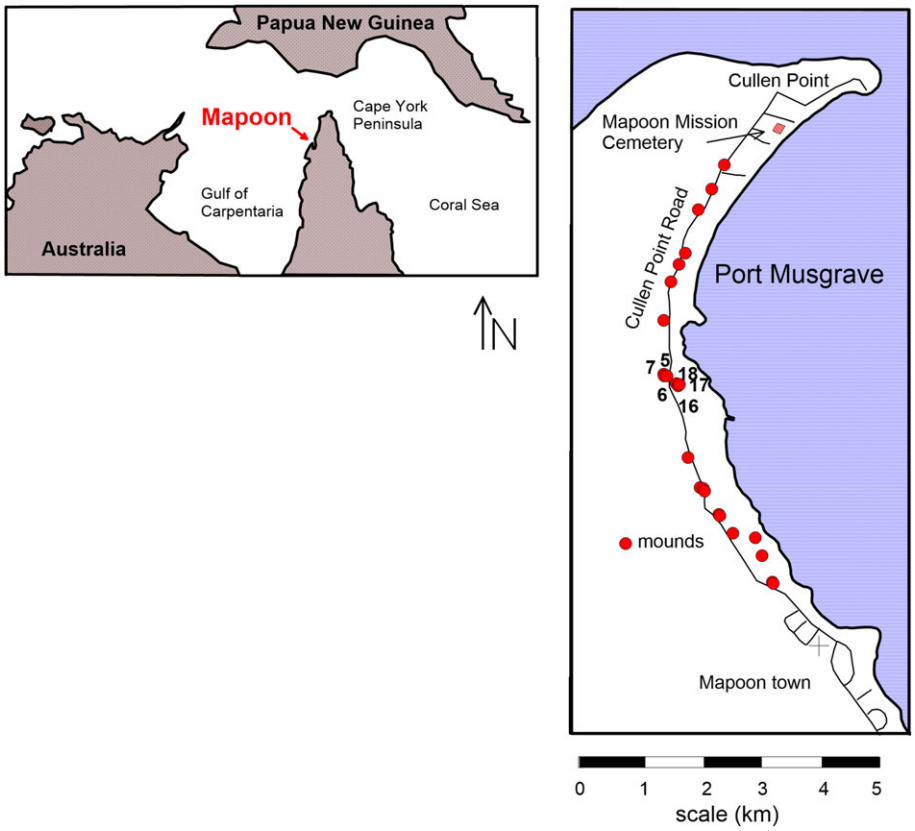

FIGURE 1 Base map showing Mapoon on Australia's Cape York peninsula, with the earth mounds mapped north of the town of Mapoon [Colour figure can be viewed at wileyonlinelibrary.com]

FIGURE 2 Mounds 6 and 7 after vegetation clearing [Colour figure can be viewed at wileyonlinelibrary.com]

the realization that while some mounds contain many human burials (most of which are on the northern flanks of the mounds), others appear to be totally barren of interments.

The variability of internal mound features and the presence or absence of 'whole human burials' that which can be identified geophysically, has raised a number of questions about the antiquity of these features and possibly changes in burial practices and usage of these areas over time. A variety of hypotheses have been developed based on this new geophysically-derived knowledge about the earth mounds, which is not possible without this technology for non-invasively looking into the features and mapping the ground surface prior to mound construction. In addition, the integration of GPR and magnetics presented here provides a novel analysis method for understanding a variety of the three-dimensional aspects of these complex packages of sediment (Conyers, 2018).

In general, the Mapoon earth mounds are between 15 and 25 m in diameter and average 2 to 3 m in height, with some reaching 4 m (Figure 2). A few are much less pronounced and reach only between 50 cm and 1 m in height. They are generally circular, with a few that are somewhat oblong in shape. Geomorphological assessment indicates that they are built on and within sand dunes and barrier ridges that are no older than mid to late Holocene in age (Burne & Graham, 1995; Chivas et al., 2001). Those sediments rest on very ancient bedrock composed of highly-weathered bauxite-rich sedimentary rocks. The mounds were first identified in the Mapoon area during the time that Moravian Christian missions were active (1891–1963) and considered to be either shell mounds or scrub fowl nests (Stone, 1991, 1993).

Mapoon is located on the western side of Cape York Peninsula (Figure 1) bordered by the Gulf of Carpentaria to the west and a shallow embayment known as Port Musgrave to the east. The elevated ground consists of two coastal barrier systems with sand dunes surrounded by salt water lagoons and a large interior area of mangrove swamp, reed beds, and salt pans (Burne & Graham, 1995; Chivas et al., 2001). The presence of both freshwater wetland and ocean environments surrounding the raised ground along Cullen Point where the mounds are located, likely provided rich plant and animal resources for the people living there in the past.

2 | THE MOUND CLUSTER (5, 6, 7, 16, 17, 18) STUDY AREA: FIELD PROCEDURES, DATA PROCESSING AND ANALYSIS

Within only 200 m six mounds are clustered together, bisected by the Cullen Point Road (Figure 3). It is not known if other mounds may have existed at one time in this vicinity and were destroyed by road building.

Prior to conducting geophysical surveys the low vegetation on top and around the mounds was cleared (Figure 2), grids were established over multiple mounds when possible, and the ground surface was surveyed with real-time kinematic global positioning system (RTK GPS). Topographic data points were collected over each grid so that all geophysical data could be corrected for elevation differences and the results of data analysis accurately placed within space. The GPR data were collected with a GSSI SIR-3000 system using 400 MHz antennas. Reflections were recorded in a 55 ns time window filtered between 200 and 800 MHz, with 40 reflections traces collected per metre. Reflection profiles were spaced at 50 cm.

The magnetic data were collected with a Bartington dual gradiometer placed on a cart with collected data points placed into space using RTK GPS real-time integration. The magnetic and GPR grids were then integrated and placed within the same coordinate system so that the two could be analysed together both in maps and profiles (Conyers, 2018).

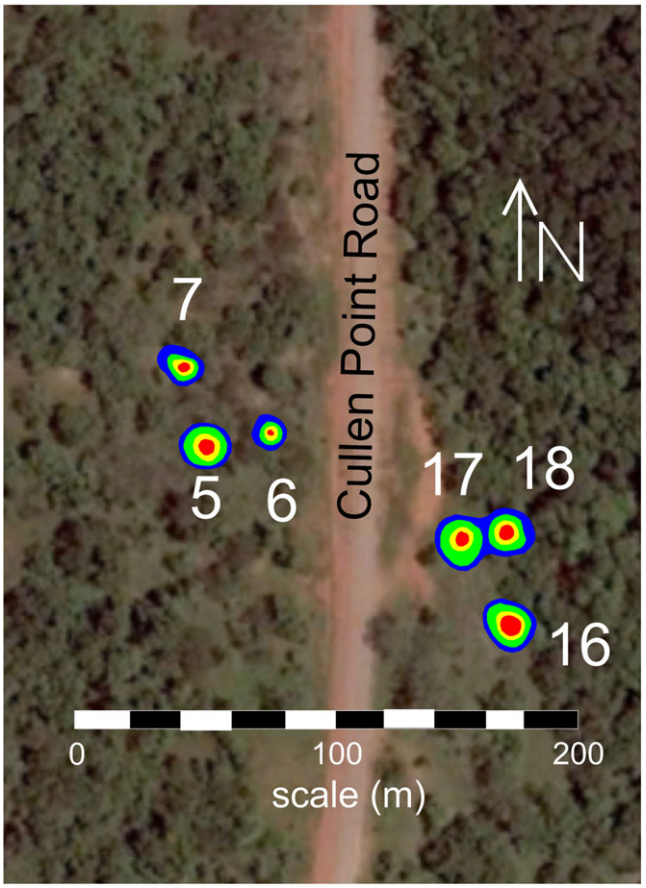

FIGURE 3 The six mound clusters bisected by the Cullen point road placed on an aerial photograph of the area [Colour figure can be viewed at wileyonlinelibrary.com]

All grids of GPR reflections were sliced into 50 cm thick horizontal slices through the mounds, and along the pre-mound ground surface. The slice corresponding to the buried ground surface prior to mound construction is displayed for Mounds 5 and 6, overlain by the contours of the present mound surface (Figure 4). That surface generated radar wave reflections with high amplitudes below the mound fill sediment, which are concentrated directly under the mound sediment. The fill of Mound 5 was then built on that very reflective GPR-defined layer. Mound 6 to the east has only limited reflective materials (perhaps a few rocks) under its sediment fill. A GPR reflection profile across both mounds, corrected for topography, display the pre-mound ground surface, which consists of many large objects [greater than 20 cm or so in diameter, which is the maximum size resolvable using the 400 MHz antennas (Conyers, 2013)] on a compacted and possibly burned surface. Those objects reflect radar energy in typical 'point-source hyperbolas', with splayed axes (Figure 5) due to the low relative dielectric permittivity (RDP = 3) of the sediment (Conyers, 2013). These objects are preserved on a distinct compacted or burned (or both) ground surface visible as a high amplitude planar reflection.

Within the mound sediment of both features are many human burials, identified using GPR profile analysis (Figure 4). Cultural sensitivity of the Aboriginal inhabitants of this area, who are the traditional owners, precluded their excavation for confirmation, and the methods described earlier to identify burials with GPR, were used in all the results presented here. These burials are mostly found on the north edges of the mounds, with a few discovered in the ground surrounding the mounds. No burials were presumably placed on the mound crests. Figure 5 (lower expanded section) shows one of the typical hyperbolic reflection features common to burials in the Mapoon area. Burials were identified with GPR (Figure 5) using the same interpretation techniques developed at the Mapoon Mission Cemetery (Figure 1) just to the north (Sutton & Conyers, 2013).

The mound cluster to the east of the Cullen Point Road (Figure 3) contains many of the interesting sub-mound features that have been seen in most other Mapoon area mounds. What is most interesting about these mounds is that detailed GPR analysis of profiles displays no typical human burial-generated hyperbolas, which are so prevalent in other mounds in the area. They display other sub-mound features, which may indicate that there were different activities associated with these mounds both before the mounds were built, and also afterward (Mounds 16, 17 and 18 shown in Figure 6).

Magnetic mapping, accompanied by an analysis of the sediment packages within and surrounding the mounds using GPR was used as a way to show a general history of human use and modification of these important landscape features. In the Mapoon area there are only a very few sediment and rock types within 3–4 m of the ground surface. Bedrock throughout the area is highly weathered bauxite-rich rock that is non-magnetic. The overlying sediment is composed of primarily aeolian-deposited quartz and carbonate sand, with only small additions of organic matter, which has very weak remnant magnetism.

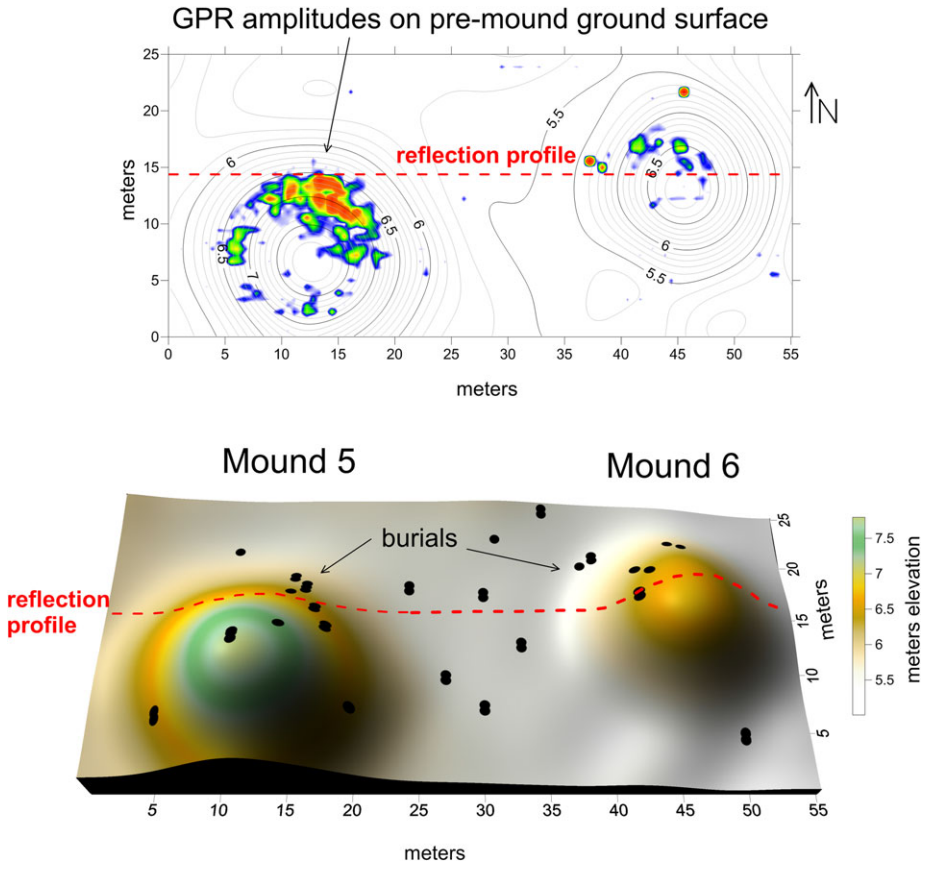

FIGURE 4 Three-dimensional representation of mounds 5 and 6, with the locations of burials discovered using GPR (bottom image). The upper image is a contour map of the surface of the mounds with the amplitudes of the GPR reflections along the pre-mound surface displayed. The location of the reflection profile in Figure 5 is shown in both images [Colour figure can be viewed at wileyonlinelibrary.com]

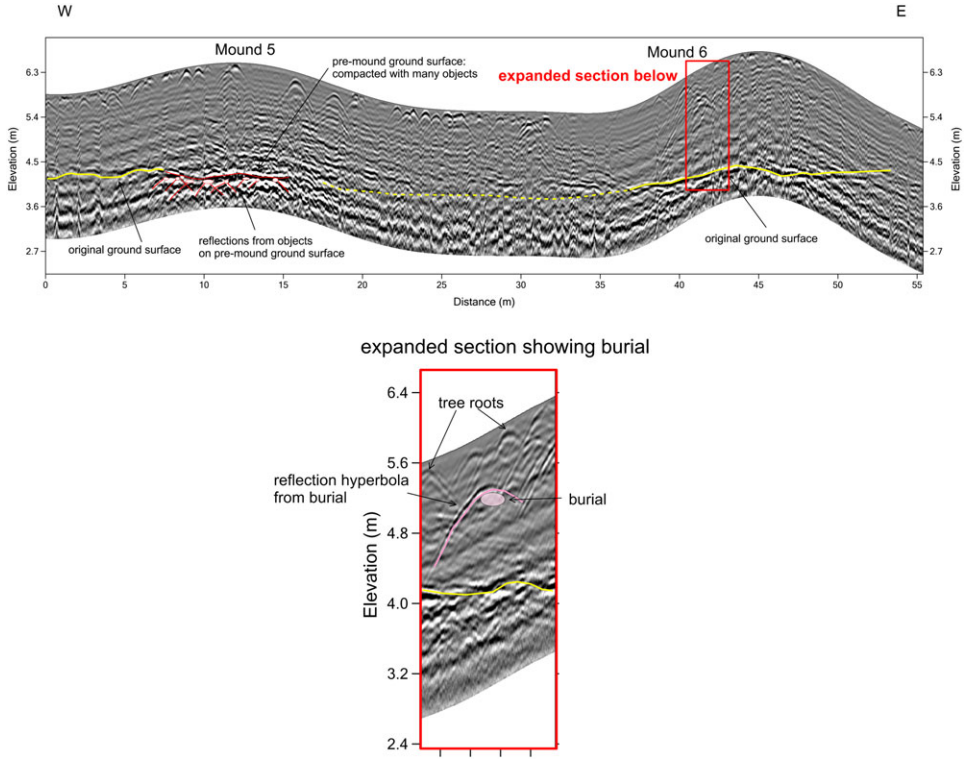

FIGURE 5 GPR reflection profile crossing mounds 5 and 6 showing the pre-mound surface under the mound 5 fill. An expanded portion of the profile displaying a burial within mound 6 exhibits a high amplitude hyperbolic shaped reflection [Colour figure can be viewed at wileyonlinelibrary.com]

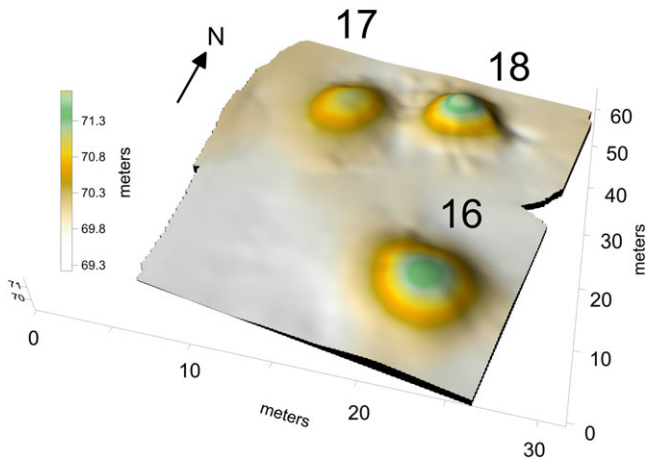

FIGURE 6 Relief map of the ground surface of the eastern cluster of mounds 16, 17 and 18 [Colour figure can be viewed at wileyonlinelibrary.com]

Surface soils are weak A horizons with a somewhat higher percentage of organic matter than the underlying aeolian sand. In this high-rainfall area organic matter quickly decomposes, and is leached from the system. There are no volcanic rocks or other types of sediment or bedrock types that would produce anomalous magnetic readings and no evidence in soil or sediment outcrops for the presence of sedimentary units deposited in standing water that may have concentrated organics to produce detrital or depositional remnant magnetism. An area of the world with less remnant magnetism from natural processes would be hard to find. Therefore, any variations from the background (whether positive or negative) are therefore of interest in this study.

For this project the magnetometer was 'nulled' in an area away from the mounds where the ground was undisturbed by mound digging or burial activity. The zero values of magnetic readings are therefore indicating undisturbed surface soil (and the non-magnetic sediments and bedrock below), or materials of a similar composition. All magnetic readings either above or below the zero value are therefore indicating different buried material from this 'background' (Fassbinder, 2015). The "zero value" area for magnetometer nulling was used as the nulling location for all magnetic surveys conducted over a number of days. While some geophysicists null their magnetometers some distance in the air to remove the 'arbitrary effect' of the ground, this was not done here. Instead it was deemed important to collect magnetometer values that varied from the weakly magnetic ground as those areas would indicate disturbance by digging and mound building (values lower than the nulled zero value) or burned areas (values higher than the zero value). In this way the spatial location of positive and negative magnetic readings were showing areas of likely anthropogenic activity (digging, mounding and burning), while the areas of zero (or close to zero) magnetic readings were identifying areas of undisturbed ground.

The hypothesis employed for this project is that magnetic values collected over the mounds are either higher (positive) or lower (negative) than the zeroed value used for magnetometer nulling from the off-mound location where there was no human disturbance (Conyers, 2018). When the very slightly magnetic near-surface sediments and soils were removed and placed on the mound during the building activity, whatever weak magnetic orientations may have been present 'in place' were effectively jumbled, cancelling each other out and producing material that is slightly lower than the undisturbed ground (Fassbinder, 2015).

In this way the magnetic grains that were oriented in common as either depositional remnant magnetism or bacterial-induced magnetic susceptibility are cancelled out and produce material that is lower in magnetic readings than the surrounding undisturbed ground. It is also likely that the mound fill contains a volume of less magnetically susceptible material containing some soil and much aeolian sand, and therefore registers lower magnetic readings than the surrounding ground. When mapped spatially these areas produce negative magnetic regions when viewed in the map (Figure 7), which is coloured blue at Mound 16. Mound fill materials, when not underlain by ground that has been altered in some way, are almost uniformly negatively-magnetic in all the mounds surveyed in this area. At Mound 16, the western side displays a distinct positive magnetic feature (Figure 7) indicating the presence of something that is relatively more magnetic than the surrounding soil in this area. This

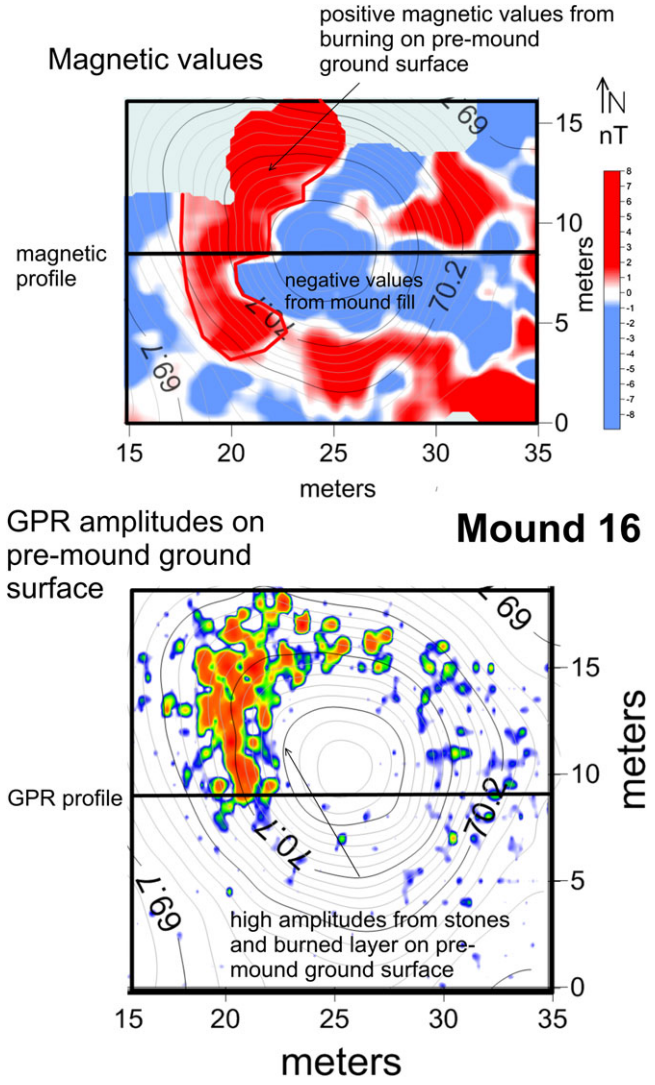

FIGURE 7 Magnetic map overlain on the ground surface topographic map on top displaying positive magnetic readings in red with negative in blue over mound 16. The mound fill displays negative relative magnetism. The stones and burned material on the pre-mound ground surface display high amplitudes, in the lower map. Those high amplitudes are derived from stones and the burned materials on that pre-mound surface, which correspond to the area of high positive magnetism in the upper map. The location of the GPR reflection profile with corresponding magnetic readings in Figure 8 is noted on both maps [Colour figure can be viewed at wileyonlinelibrary.com]

region corresponds in space almost perfectly to the high amplitude GPR reflections generated from materials preserved on the pre-mound ground surface (lower map in Figure 7). Those high amplitude objects are very similar in origin to those visible on the pre-mound ground surface on Mound 5 to the west (Figures 4 and 5).

A GPR reflection profile displayed with the corresponding magnetic readings at Mound 16 illustrate that the mound sediment contains almost no large objects, other than some tree roots at the surface (Figure 8). The mound fill is almost completely negative magnetically, except on its western edge where the distinct positive values correlate to the area along the pre-mound ground surface that contains a number of reflection hyperbolas generated from stones or large coral fragments (Figure 8). The positive magnetic readings associated with that area indicates that this surface was probably burned, or contains some burned materials. The magnetic values of this positive magnetic anomaly are still low (2–4 nT or so), but significantly different from the rest of the mound area that is either negatively magnetic or neutral.

Similar GPR and magnetic features are visible under Mound 17 to the north (Figure 6). Under this mound an area of high amplitude GPR reflections is concentrated in two areas on the east and west sides of the mound (Figure 9). When comparing the GPR and magnetic maps, the highest positive amplitude magnetic anomalies correspond to that same western portion of the mound with the GPR-defined features. There is also a more amorphous positive magnetic anomaly zone corresponding to the GPR feature on the east side of the mound, but those high positive magnetic readings are not concentrated, and are generally lower in value. No magnetic data were collected over Mound 18 just to the east of Mound 17 because of the thick vegetation and large trees that could not be cleared. That mound also has no distinctive high amplitude GPR features on the pre-mound ground surface.

A GPR profile crossing Mound 17 shows the distinctive planar reflection generated from the pre-mound ground surface, but here there are no objects on it to produce hyperbolic point-source reflections (Figure 10). There is a 20–30 cm layer of magnetic material on the original ground surface along the western edge of the mound, which generates relatively high positive magnetic values. That layer resting on the original ground surface is likely responsible for these higher magnetic values, averaging between 4 and 8 nT. These nanotesla values are indicative of burning, as there are no other materials in this area of Mapoon that could conceivably produce these high positive magnetic values. The usual ground in the Mapoon area is neutral or very slightly positive magnetically, and the coral and quartz sand without soil development is very slightly negative or neutral. It is possible that the bedrock here, which is bauxite, could be contributing a small amount of magnetism from the trace amounts of iron found in this geological unit. However, those layers are more than 2 ms below the mound top, at a distance from the surface sensors that would make that potential component of the magnetic readings almost non-existent (Conyers, 2018).

At Mound 17 the pre-mound ground surface was burned on the west side of the grid under what would become Mound 17 (Figure 9). Here it is appears that some of those burned materials were swept or moved in some other fashion to the east. More intensive burning on the west and sweeping the remains of that fire to the east would have produced the two positive magnetic features visible in the magnetic map (Figure 10).

An analysis of the very subtle stratigraphic layers within the mound fill shows some eastward sloping laminae, indicative of wind-

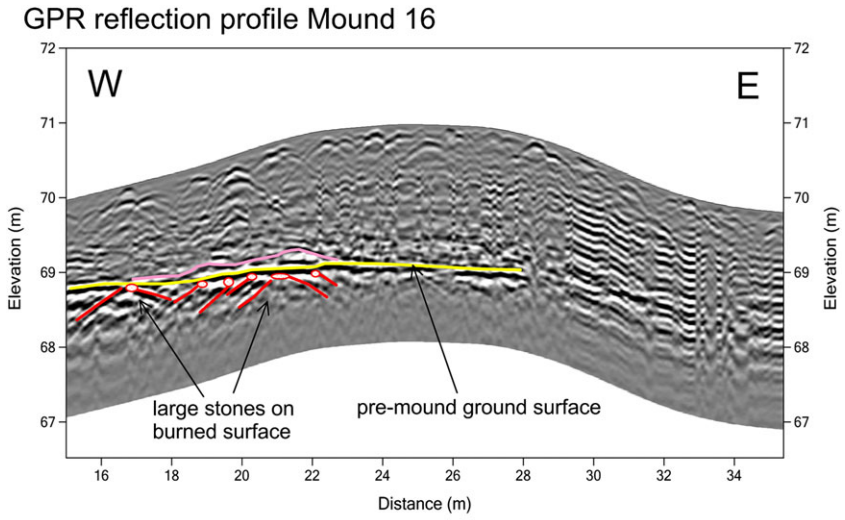

FIGURE 8 GPR reflection profile (location shown in Figure 7) showing the high amplitude pre-mound ground layer with many stones that produce reflection hyperbolas. The area of many stones is magnetically positive, suggesting that area of the ground had been burned. The remaining portion of the mound fill is negatively magnetic and contains few if any large objects [Colour figure can be viewed at wileyonlinelibrary.com]

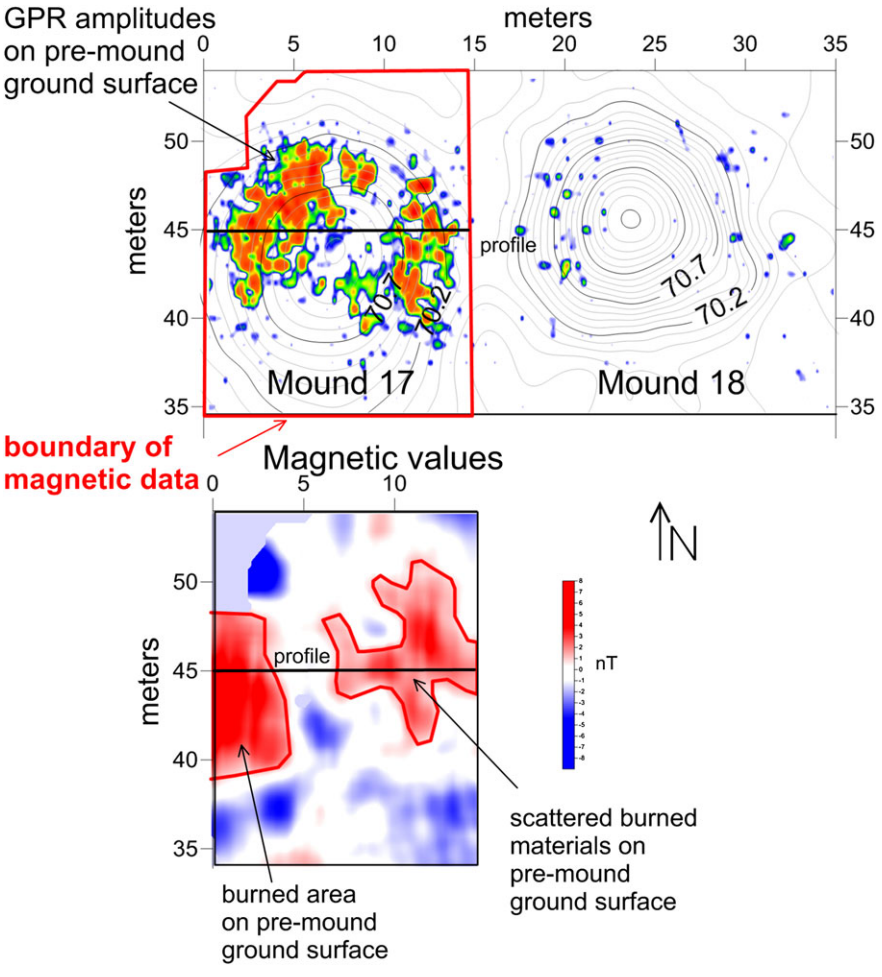

FIGURE 9 GPR high amplitude reflections from a burned and stone-rich layer under the mound fill in the upper map, which occur only under mound 17. The location of the GPR and magnetic profile in Figure 10 is shown. The stone-rich layer shows a distinctive positive magnetic reading over a well-defined area on the west. On the east, the positive magnetic readings are lower in value and more amorphous in shape, suggesting an area of scattered burned materials on the pre-mound ground surface. There is no distinctive surface that can be defined with GPR on the pre-mound surface below Mound 18. No magnetic data were collected over Mound 18 [Colour figure can be viewed at wileyonlinelibrary.com]

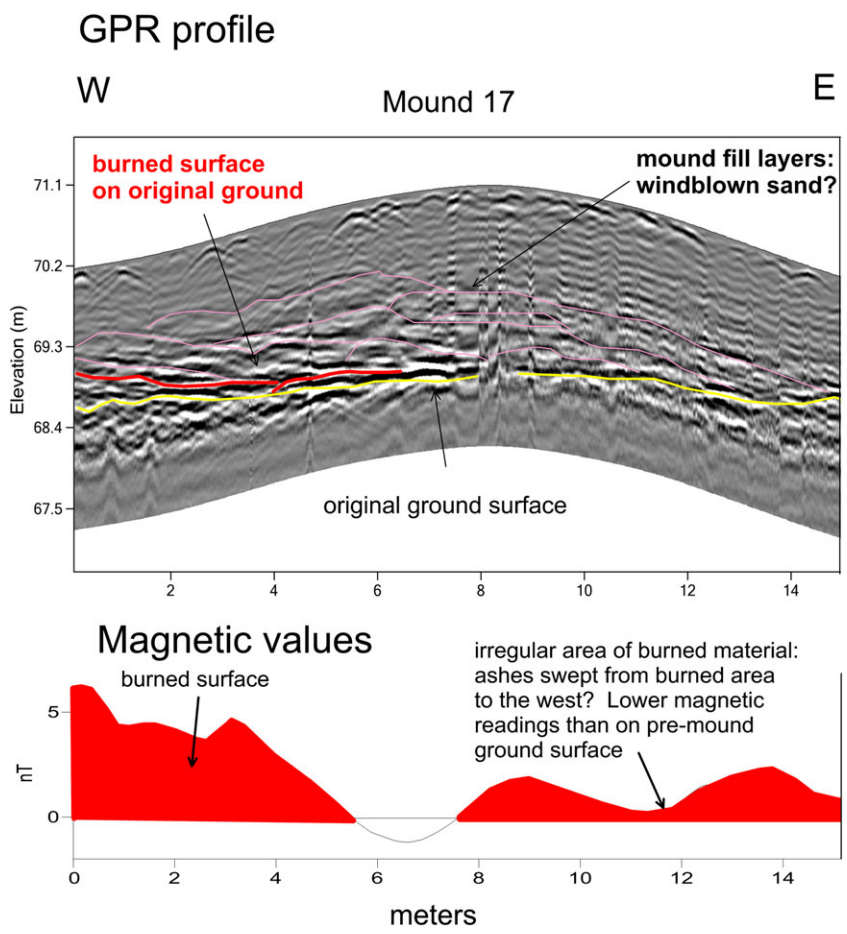

FIGURE 10 GPR reflection profile and corresponding magnetic readings for a profile crossing Mound 17. Location of the profile is shown in Figure 9 [Colour figure can be viewed at wileyonlinelibrary.com]

blown deposits (Conyers, 2016). That mound fill may therefore be partially aeolian in origin, which could indicate that the underlying burned surface was first covered by sand dune deposits, and only later converted into the constructed mound we see today. This is very speculative, but an interesting hypothesis, as it could show that considerable amount of time may have elapsed between when the ground was burned and this area was converted into a mound.

It is also significant that the eastern three mounds in this cluster contain no burials, unlike the three on the west. While it is possible that human remains were interred within mounds 15, 16 and 17, they could have been cremated first, and only those burned remains then placed in the mound. They would therefore not present a large enough buried feature to reflect 400 MHz radar waves, and be effectively invisible with the GPR system used. Cremated remains would also remain invisible with magnetometry, as incinerated human bodies contain no iron whatever, which is necessary for magnetometry analysis. Or it is possible that the three eastern mounds had some other function in Aboriginal society, which was different from those to the west. Cremation mounds of this sort have been identified south of Mapoon, near the former mission of Aurukun (Peter Sutton, personal communication 2017 to Mary-Jean Sutton).

3 | CONCLUSIONS

The geophysical results from mounds surveyed in the Mapoon area indicate that these mounds are much more complicated than previously thought. The GPR and magnetic results show that some mounds contain whole human burials, but some do not. Some mounds were built over features on an original ground surface that had been burned, with large stones moved into the area for some reason. How long ago that burning and modification of the ground surface took place cannot be determined until excavations are conducted. It is hypothesized that some of these burning events could have been cremation rituals and the use of funeral pyres, or ritual smoke-purification of the deceased (McConnel, 1936; Virtus Heritage, 2015). It is also possible that these areas were locations of cooking and feasting, perhaps associated also with funerary rituals. Oral histories obtained by the Elders in the Mapoon area attest to some of these types of rituals that took place in these mound areas within living memory (Virtus Heritage, 2015). There are some memories within the Mapoon community of large stones being buried in a mound with a person during the mission time (Elder A, 2017 interview with Aunty Zoe De Jersey and Mary-Jean Sutton). It is also not unusual for Aboriginal people to be buried with various grave goods, such as grinding stones, dishes, stone axes and other objects made of stone (Roth, 1907). The discovery of burned surfaces under the mounds, and the burials within the mounds after construction both suggest that these areas had continued ritual activities over a long period of time, right up through the period where living people still remember the importance of these locations for ceremonies.

It is important to take into consideration when generating hypotheses about human behaviour that many of these burned and modified areas on the original ground surface were later transformed into

'monumental architecture' by the construction of the earth mounds. The geophysical interpretation indicates that mounds were sometimes built directly on the previously burned areas, but other times offset a few metres. Also, it may be important that some mounds were not constructed over burned features on the original ground surface at all, which may show that they had some other function or perhaps were built by different people at a different time.

There are also some very preliminary results that indicate there may have been a good deal of elapsed time between when the burning episodes occurred on the original ground surface and when these areas were transformed into burial mounds. That evidence comes from the orientation and geometry of the layers in the mound fill from one mound, suggesting wind-blown sand sedimentary units that are visible in GPR profiles. That preliminary evidence is indicative of a period of time of non-use of the area when sand dunes covered over the burned ground surface and only later were they transformed into mounds used for burial.

The Elders of Mapoon have memories from their childhood that some of the mound areas were used as family burial grounds, supporting the GPR results showing a continuation of traditional mortuary practices well into the late nineteenth and twentieth centuries (GHD & Virtus Heritage, 2017; Roth, 1907; Virtus Heritage, 2015). Ethno-history related to these mounds has shown that in mission time (late eighteenth and early twentieth centuries) homes were built on traditional family camping areas and that these mounds were possibly interconnected with specific families long before those missions were established.

It is also possible the function of some of the mounds was unrelated to mortuary activities and many may have had multiple functions over time. Or perhaps the burials in these mounds visible with GPR are only fairly recent phenomena and these areas were used for some other very different purpose in the more distant past. The positioning of many mounds on the prepared and burned surfaces, however, indicates that there must have been a memory of these important locations on the landscape. The diversity of the pre-mound ground surfaces seen in these six clustered mounds indicates that there were likely very different behaviours that led to these differences. Some areas show prepared burned surfaces and some do not. Perhaps certain mounds and/or pre-mound surfaces were reserved for certain activities? Or perhaps certain locations were reserved for particular clans or families, which performed different activities here? These are interesting ideas that can be potentially tested with excavations in the future.

It can be said with some surety that the construction of mounds in this area of Mapoon was monumental and likely has a long history. Burial mounds elsewhere in the world are indicative of complex societies, where influential people were capable of motivating people to perform these building activities (Childe, 1949; Clark & Martinsson-Wallin, 2007; Peebles & Kus, 1977; Trigger, 1990). Elsewhere in the world the burial of specific people within mounds was reserved for the more elite members of society (Earle, 1997). Whether this was the case at Mapoon can only be speculated at this time. All these hypotheses presented for the pre-mound and mound functions at Mapoon are preliminary at this time, but the geophysical information discussed here indicates a very interesting and possibly complex history of peoples' use and changing uses of important areas on the landscape. This information provides new input into the current debates in northern Australia on the nature and use of earth mounds that is not possible by any other archaeological methods.

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