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Introduction

The ground-penetrating radar (GPR) method has a unique ability to record reflections of electromagnetic waves in the near-surface within 3-D volumes of ground Conyers 2013). All GPR processing software now commonly allows for large-scale grids of data to be analyzed and many recent practitioners have streamlined their processing and interpretation procedures to move rapidly from field-collected data to slice-map images. This data processing and analysis approach is extremely popular, especially with many younger geophysicists, as it is much like what I think of as the "smart phone app" approach, where icons can be chosen and the internal workings of software then produce the desired result. The reasoning behind each of the processing steps is often not necessarily understood by the users, and the internal software algorithms that generate the final product are either absent or difficult to access. This "immediate gratification" method of GPR data visualization is often neglects other important analyses such as understanding individual reflection traces, reflection profile analysis, and changing sampling and gridding procedures for specific site parameters (Conyers 2012).

The site and GPR data processing and analysis

Here I analyze GPR data collected on two mounds in northern Australia (Figure 1), which were interpreted using a variety of interpretation methods in non-standard ways in order to visualize certain internal mound features (Conyers et al. 2019). The mounds were found to contain a number of burials, recognized by reflection hyperbolas visible in profiles, which were visible 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 the size and orientation of human remains (Conyers et al. 2018). The two mounds reported on here, and many hundreds of similar mounds nearby are between 15–25 m in diameter and average 2–3 m in height, with some reaching 4 m.

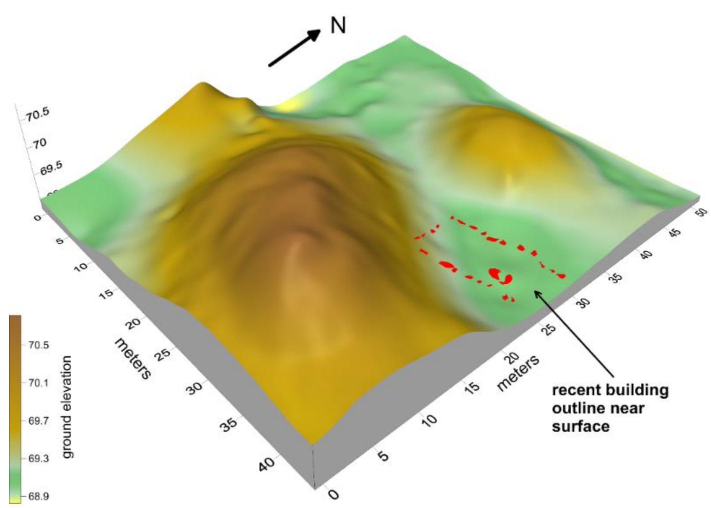

Figure 1. Surface image of the mounds showing the location of the recent structure between the north and south mounds, which was discovered by standard amplitude slice-mapping.

The GPR data were collected with a GSSI SIR-3000 system using 400 MHz antennas and a survey wheel for distance calibration. The reflection profiles were first sliced into 6 ns slices (each about 44 cm thick), constructed parallel to the ground surface. A first-pass reflection amplitude slice-map created parallel to the ground surface shows the outline of a rectangular structure in the top 44 cm of the ground (Figure 1). There is no surface evidence for this structure, and it is hypothesized to be a temporary enclosure used for ritual purposes.

When each of the reflection profiles were viewed and interpreted individually, a number of reflection hyperbolas are visible, which are distinct from those produced from shallow tree roots and were generated from burials as they are visible in three or more parallel profiles spaced 50 cm apart and in no more than four profiles, they are the length and width of an adult human body (Figure 2).

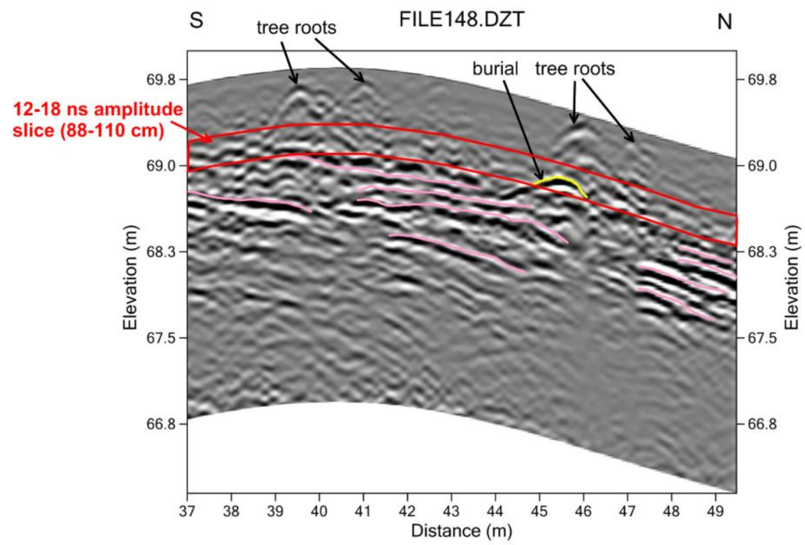

Figure 2. Reflection profile corrected for topography, showing the reflection hyperbola produced by a human burial below the tree-root reflection. Mound fill units are shown in pink.

Standard amplitude slice-mapping gives no indication of the burials and they were only visible in detailed profile analysis after being corrected for topography. Once their presence was known, the reflection profiles were re-sampled in a smaller grid resampling the amplitudes from the depth where the burial was identified in the profiles. Every reflection within the depth slice was sampled and given its own unique location in space, with a 1.2 m search radius used in interpolation during the gridding procedure. The kriging gridding method was also used, which mathematically biases the interpolation values closer to the center of the search radius, producing a more detailed map of the burial feature. The burials were only visible after topographic adjustment of each reflection profile where the hyperbolic reflections were visible at the correct depth for human remains (below the depth of the tree roots). Once their location was approximately known from reflection profile analysis, the reflections within the profiles could be resampled and re-gridded and mapped, showing the correct spatial location of a burial. Fourteen other burials of this sort were visible in these mounds using the same methods.

In deeper slices within the mounds, four concentrations of high amplitude reflections were visible (Figure 3), constructed after topography was adjusted so that slices were parallel to the pre-mound surface. These reflection features are located at or just above the original ground surface prior to mound construction. The amplitude map is interesting as it indicates something important at this depth under the mounds, but little else. The reflection profiles show that the high amplitudes were caused by layers of sediment that appear to have been piled up in layers (Figure 3).

In order to obtain a more detailed view of the pre-mound ground surface and the initial layers of material constructed on it, a standard topographically-adjusted profile was frequency filtered so that only the 400–600 MHz reflections were used to display the smaller reflection features (Figure 3). In this display of reflections the small objects (stones or coral pieces) generate distinct hyperbolic reflections consistent with standard point-source reflections. The pre-mound surface reflection is visible just below these point-source generating objects. The upper surfaces of three distinct piles of material that were placed on the pre-mound surface, covering the objects on it that can be seen, are consistent with piling sediment to create some kind of a living surface or at least elevated area of some sort. Only after frequency filtering the raw radar waves and then producing a detailed profile of only the stratigraphy of interest can the origins of the pre-mound units be determined. It is apparent that objects of some sort were first placed on the ground surface, and covered by intentionally mounded units to create elevated areas for some reason. Perhaps they were areas for people to keep dry during the rainy season or had some other function that cannot be determined without excavations. Later, this area was transformed into a mound, the remains of which we see today, which was used for the burial of human remains.

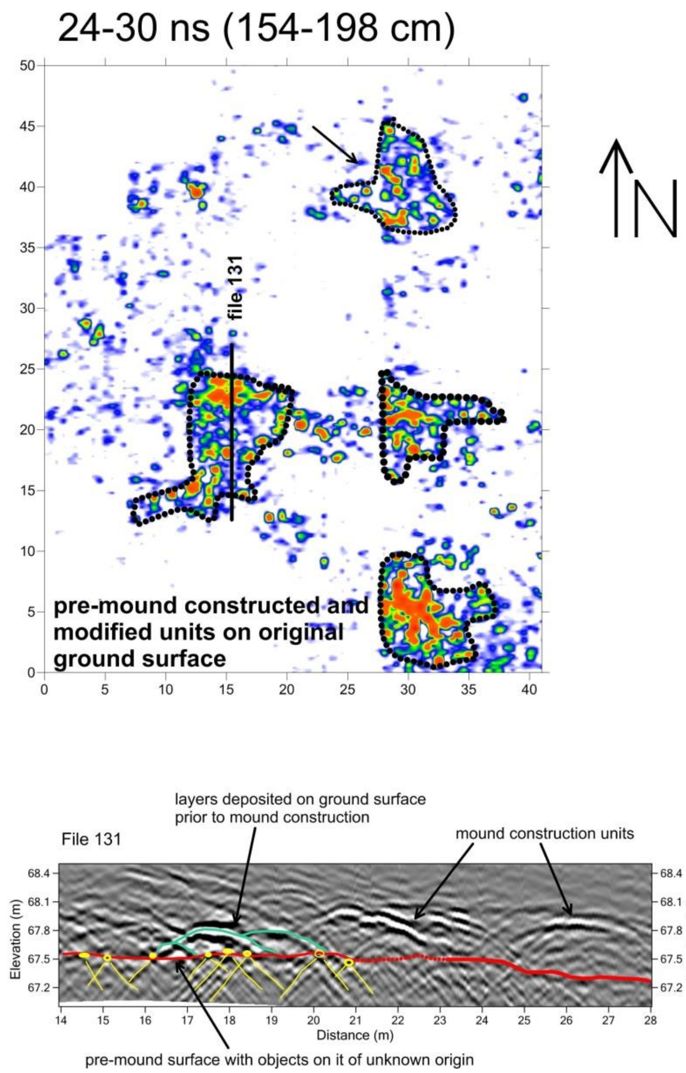

Figure 3. Amplitude slice map of the deepest slice showing the concentrations of high amplitude reflections on the pre-mound surface that are concentrations of stones. A reflection profile produced after the reflections were frequency filtered to include only those between 400 and 600 MHz shows the point-source reflection hyperbolas (axes of which are shown in yellow) from the stones on the original ground surface.

Conclusions

At these two mounds any one method of GPR analysis would have yielded only a partial interpretation of the cultural features below and within the mounds. Amplitude slice-mapping would have discovered the shallow rectangular enclosure and the general outline of the pre-mound construction layers but little else The pre-mound layering units were only visible once profiles were adjusted for elevation and then re-sliced, and the profile used to interpret the specific origin of the pre-mound materials needed elevation adjustments and frequency filtering in order to see the individual stones.

Smaller features within the mound, such as the numerous human were only visible after individual reflection profile analysis. These burials were effectively invisible using standard amplitude slice-mapping, but a re-sampling and gridding of a small area around one discovered burial showed its exact orientation and size.

Any one data display technique using the 3-D GPR datasets will only produce a limited picture of the ground from which to make interpretations about buried materials. Both amplitude slice-mapping and reflection profile analysis, used in unison and in an iterative way, can provide a more detailed view. Standard GPR displays must be modified and later reconstructed once something is known about the size and geometry of the features discovered.

Most important for this project is that the GPR analyses indicate these mounds were an important place on the landscape of northern Australia. It is apparent that people were using this area in an intensive way perhaps for feasting, ritual, and everyday activities. Those locations were later transformed into constructed mounds, which necessitated a good deal of coordinated labor, suggesting some authority and motivation by individuals within the societies. After the mounds were constructed, they were used for burials of some, but likely not all, members of society, also indicating social complexity and perhaps incipient social stratification. The mounds continued to be used for burials until recent times, and are remembered by elders as both burial and ritual locations. The shallow rectangular feature is likely the remains of a structure built in the last few centuries, related in some way to a continued ritual use of this important place on the landscape.

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