EFFECT OF SOIL GRAIN SIZE ON THE GEOPHYSICAL RESPONSE OF GRAVES: CLAY VS SILT VS SAND

D.C. Nobes

Department of Geological Sciences, University of Canterbury, Private Bag 4800, Christchurch 8020, New Zealand
david.nobes@canterbury.ac.nz

Keywords: geoforensics, geophysics, indigenous burials, grain size, non-invasive imaging.

Abstract

Non-invasive geophysical imaging of Maori ancestral burial sites (*urupa*) have allowed us to test when and where geophysical surveys are most likely to succeed. Results from five sites, with both marked and unmarked graves, in three coastal settings along the east coast of the South Island of New Zealand show that burials in *clay* and *silt* (loess) can be readily identified using geophysical techniques, but burials in *sand* frequently have ***no*** anomalous responses. The differences in responses are likely due to the depositional setting. Clay and loess are usually deposited as layers or massive beds so any disturbance due to burial is relatively clear. In contrast, near-shore, fluvial and dune sands contain sedimentary structures that can be difficult to distinguish from burials, and can mask the geophysical responses of the graves

1 Introduction

Many researchers have tested non-invasive geophysical methods for the detection of unmarked graves (e.g. [2], [3], [4], [5], [6] and references therein). In the search for unmarked graves, we eliminate methods that lack the resolution (the detail) to "see" the target graves. Gravity and seismic methods, for example, fall into this category. Infrared scanning can be used to detect the thermal anomaly of a burial, but the exponential decay of the thermal signal allows only younger graves to be detected. Electrical methods can work, but practical limitations may preclude their use, specifically the need to physically put electrodes into the soil. We have the greatest likelihood for detecting burials using magnetic field, electromagnetic (EM) and ground penetrating radar (GPR) methods. The response will depend on the contrast between the graves and the soil within which the graves are placed.

Surveys of Maori ancestral burial sites (*urupa*), with both marked and unmarked graves, have allowed us to test the nature of the geophysical response in different soil types. Results from five sites in three settings along the east coast of the South Island of New Zealand show that burials in *clay* [4] and *silt* (loess) [1, 6] can be identified using geophysical techniques, but burials in *sand* frequently yield ***no*** anomalous responses [5, 6]. More work is needed to test how general this conclusion is; nonetheless, these results are strongly indicative.

2 Site descriptions and methods

The surveyed *urupa* are along the east coast of the South Island of New Zealand (Table 1), and represent a range of soil types and environments, from clay to sand and from humid to semi-arid. Oaro and Mangamaunu are near Kaikoura, a major tourist destination on the northeast coast of the South Island of New Zealand. Mason Bay is on the west coast of Stewart Island, in the far south of New Zealand. The other two sites, Koukourarata and Wairewa, are on Banks Peninsula, south of Christchurch.

Site	Soil Type	Latitude & Longitude	References
Oaro	Clay	42.52 S, 173.50 E	[5]
Wairewa	Silt (loess)	43.78 S, 172.80 E	[1], [7]
Koukourarata	Silt (loess)	43.65 S, 172.84 E	[1], [7]
Mangamaunu	Coastal sands	42.31 S, 173.75 E	[7]
Mason Bay	Dune sands	46.97 S, 167.69 E	

Table 1. Burial Site Locations and Soil Types.

The Oaro site, dating from the mid-19th C, is in clay soil over limestone bedrock. The Wairewa and Koukourarata urupas are in loess soils overlying basalt. Koukourarata has two sites: one is an early historic site, abandoned in 1875 and recently surveyed and delineated [1]; the other has been used since 1870. The Mangamaunu urupa has also been used since the mid-19th C, and is located in a mix of dune, beach and fluvial sands. The Mason Bay site is in dune sands, and may be as much as 600 years old, predating any historical European contact with indigenous Maori.

Oaro, Koukourarata, Mangamaunu and Wairewa were surveyed using a total field magnetometer/gradiometer, and all sites were investigated using:

- horizontal loop EM ground conductivity meter; and
- ground penetrating radar (GPR) system with 200 MHz bistatic antennas.

The details are contained in the references cited in Table 1.

3 Results and discussion

3.1 Oaro

The Oaro results are discussed in detail elsewhere [5] and are not presented here. The EM and magnetic responses from the graves were clear and unequivocal. The GPR responses were largely masked by banded "ringing" commonly associated with high clay content. When the profile average was subtracted, the residual response clearly showed ground disturbance due to graves. The results were collated into an "availability map", which is still used today to determine space available for new graves.

3.2 Wairewa and Koukourarata

Wairewa and Koukourarata are treated together, because the results are similar. Both sites are in loess soils overlying basaltic bedrock. The EM and magnetic responses from the loess-hosted graves are less distinct than for the Oaro clay-hosted responses, but the GPR anomalies are obvious and distinct (Figure 1). A similar effect has been observed in European-style graves from the Victorian period [3].

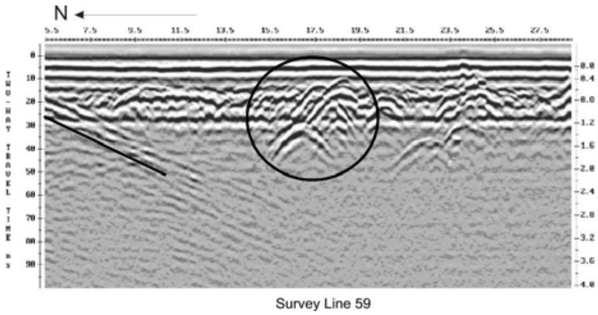

Figure 1. Sample GPR profile from Wairewa, showing clear diffractions from graves (circled). Reflections from the boundary fence are also marked, but the fence response did not mask the unequivocal grave responses.

3.3 Mangamaunu and Mason Bay

Mangamaunu and Mason Bay, though quite different in age, are similar in setting, i.e. near-shore sands. The EM response for both was subdued to non-existent, even for marked graves. The magnetic response at Mangamaunu was similarly subdued, with the exception of graves with concrete covers, which had clearly anomalous responses. The GPR response is dominated by sedimentary structures, to the extent that the graves are virtually indistinguishable from depositional features (Figure 2). A similar result was obtained for a forensic investigation [6], where the EM response was anomalous, but the GPR response was dominated by sedimentary structures. Unmarked graves in sand can thus be difficult to identify.

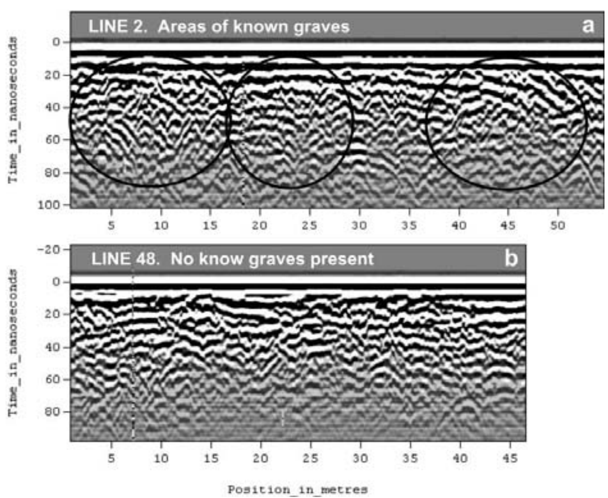

Figure 2. A Mangamaunu GPR profile for a line with known graves (a), shows that some graves have no GPR response (middle circle). In contrast, some sedimentary structures along a line with no known graves (b) have grave-like diffractions.

4 Conclusions

Results from sites in three types of soils representing three depositional settings (clay, loess/silt and sand) indicate that graves can be clearly delineated when located in clay or silt, but that the responses from graves in sand are often not clear, even from marked graves.

A possible explanation for the differences in the responses is related to the process of deposition. Clay and loess are usually deposited as layers or massive beds so any disturbance due to burial is relatively clear. In contrast, near-shore, fluvial and dune sands contain sedimentary structures that can be difficult to distinguish from burials, and can mask the geophysical responses of the graves.

Acknowledgements

Many people have supported this work over the years, not least the local people who asked that their burial sites be investigated. A number of students, particularly Leah Bateman, and colleagues, especially Harry Jol of the University of Wisconsin – Eau Claire, have participated at various stages.

References

[1] Bateman, L. Applications of near-surface geophysics in the search for graves in Maori urupa. Unpublished B.Sc. (Honours) project in Engineering Geology, Department of Geological Sciences, University of Canterbury, 69 pp, (2003).

[2] Bevan, B.W. The search for graves. Geophysics, **56**, pp. 1310-1319, (1990).

[3] Field, G., Leonard, G. and Nobes, D. C. Where is Percy Rutherford's grave? *In* Jones, M. and Sheppard, P. (Eds.), *Australasian Connections and New Directions: Proceedings of the 7th Australasian Archæometry Conference*. Research in Anthropology and Linguistics, 5, 123-140. University of Auckland, Auckland, New Zealand, (2001).

[4] Freeland, R.S., Miller, M.L., Yoder, R.E. and Koppenjam, S.K. Forensic application of FM-CW and pulse radar. *Journal of Environmental and Engineering Geophysics*, **8**, pp. 97-103, (2003).

[5] Nobes, D.C. Geophysical surveys of burial sites: a case study of the Oaro urupa, *Geophysics*, **64**, pp. 357-367, (1999).

[6] Nobes, D.C.. The search for "Yvonne": A case example of the delineation of a grave using near-surface geophysical methods, *Journal of Forensic Sciences*, **45**, pp. 715-721, (2000).

[7] Nobes, D.C., Bateman, L., Butland, C., Flintoft, M., Gaiger, F., Lea, J., Wilkinson, S., Jol, H.M. and Geer, M.A. From Kaikoura To Kaitorete: Non-Invasive geophysical mapping of Maori burial sites. Presented at the Workshop on Criminal and Environmental Soil Forensics, 18th International Symposium on the Forensic Sciences, Perth, Western Australia, (2006).

Biography

David Nobes obtained his BSc (Physics), MSc and PhD (Geophysics) from the University of Toronto. After a post-doctoral fellowship with the Geological Survey of Canada, he took up academic posts, first at the University of Waterloo, Canada, then at the University of Canterbury, New Zealand, where he is Senior Lecturer in Geophysics. His main research interests are in the development and application of non-invasive imaging in sensitive environments. He has carried out research from the Andes to Antarctica, and from New Zealand glaciers to Maori burial sites.