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THE POTENTIAL OF THE FLUXGATE GRADIOMETER AS AN ARCHAEOLOGICAL RESEARCH TOOL IN NEW ZEALAND

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Introduction

In a recent paper in *Archaeology in New Zealand* Bickler and Low (2007) discuss the "uses and abuses" of remote sensing methods in New Zealand archaeology. They are especially concerned with the application of geophysical methods in the field of heritage management archaeology. While recognising the potential of remote sensing, they argue that current technical methods and field practices are not suitably tuned to the demands of the statutory planning and protection process. This paper reports the use of geophysical techniques – in this case the use of fluxgate gradiometer – in the framework of a research archaeology programme. The results of the work demonstrate the potential for the technology in a research context in New Zealand and confirm several of the points made by Bickler and Low, namely the need for a robust research design and the importance of ground truthing.

The Kawatiri site K29/8

The Kawatiri site, also known as the Buller River Mouth site (K29/8), is an early Maori site located near Carters Beach, Westport on the West Coast of the South Island (Figure 1). The site lies on low pasture land off Cape Road approximately one kilometre from the present shore line and on the true left bank of the Buller River and within 30 m of a lagoon and wetland associated with the Buller River system. The land on which the Kawatiri site lies has been recently acquired by the local council in the interests of site preservation.

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The site was discovered in the 1920s when the land was cleared for farming, turning up a number of artefacts which went into private collections. Some of these ended up in the Australian Museum in Sydney. In 1965 the site was entered into the New Zealand Archaeological Association Site Recording Scheme by Owen Wilkes. During Wilkes's examination of the site he noted artefacts he considered typical of Duff's (1950) "Moa-hunter" assemblage and described the site as a "midden/oven" (Jacomb et al 2004: 119).

In 1969-70 a small excavation was carried out by Wayne Orchiston which revealed material culture, ovens and a number of post holes. Although the results of the excavation were not published, Orchiston's Ph.D. thesis (1974) characterised the site as "Archaic" in nature.

Since 2004 three excavations have been carried out at Kawatiri by Chris Jacomb and Richard Walter in conjunction with the University of

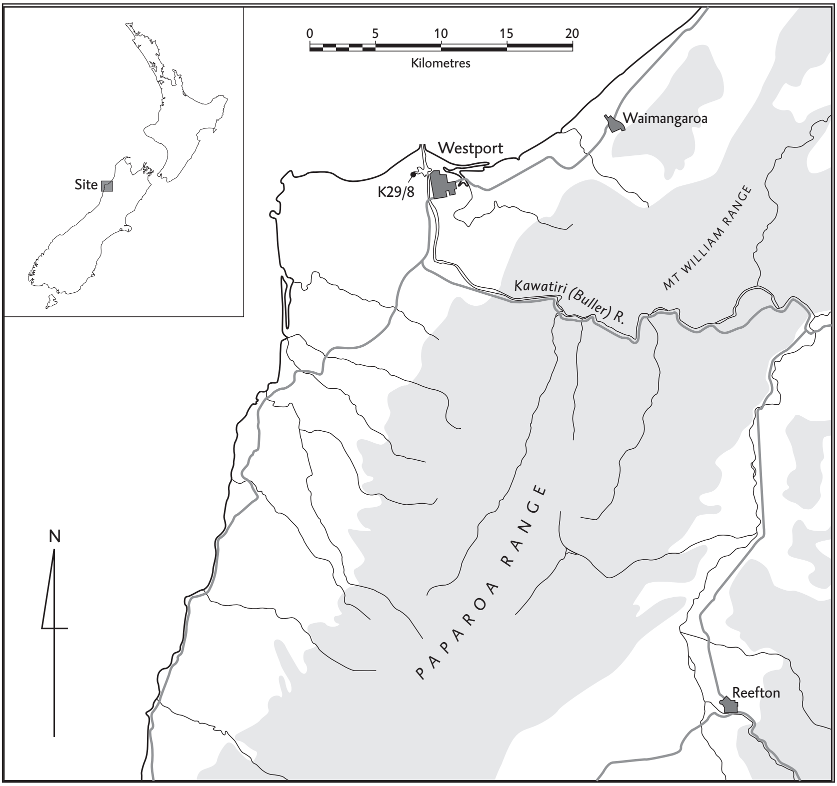

Figure 1. Location of Kawatiri Site (K29/8).

Otago Department of Anthropology archaeological field school (Figure 2). Radiocarbon dates on charcoal and shell provide an age estimate for occupation of about the early fourteenth century AD (Orchiston 1974; Jacomb and Walter 2004).

Summary of excavation results

The site is estimated to cover about one hectare. Today it lies on flat pasture land about 2 m above the high water of the lagoon, but when it was occupied it probably lay on a more active estuarine shoreline. The stratigraphy is relatively consistent and generally comprises three layers as follows:

Layer 1: The turf and the soil directly under it. Dark yellow-brown, fine grained and compact, this soil horizon is derived from river silts.

Layer 2: The cultural layer. Dark yellow-brown soil with concentrations of artefacts and charcoal. Layer 1 generally grades into Layer 2 without evidence of any major discontinuity. Layer 2 is primarily distinguished by an increased frequency of artefacts, charcoals and fire cracked rock.

Layer 3: The underlying base layer. Light yellow-grey silt. Features are commonly cut into Layer 3 from above. Some lensing occurs at the Layer 2 interface.

The results of the University of Otago research will be published in full over the next few years. The following summary points are relevant to the fluxgate gradiometer work we report on here.

Over three seasons an area of about 180 m^2 has been excavated by hand. In addition, a hydraulic excavator was used to expose a number of 2 m wide strips in the first field season. The machine excavation was carried out to determine whether or not a site of any size was present after test pits failed to reveal any significant archaeological evidence (Jacomb et al 2004). The excavations since then have concentrated on areal exposure of the Layer 2 cultural horizon using hand excavation methods. All radiocarbon dates indicate that this layer represents an occupation in the early fourteenth century AD (Jacomb et al 2004). Layer 2 contains a large number of cooking features as well as areas of post and stake holes and other features. It also contains a rich artefact assemblage that includes worked and unworked chert, flint and obsidian from several sources, adzes of argillite and nephrite, and stone "minnow lure" shanks. There is virtually no midden in the site except for some fragments of *Perna* sp. periostracum and sparse shell and bone deposits and we have not recovered any bone or shell artefacts. We attribute the rarity of bone and shell to the very low pH of the Buller soils.

Based on the quantity and range of artefacts, the site size and the layout of features, the Kawatiri site may be a small village or permanent settlement

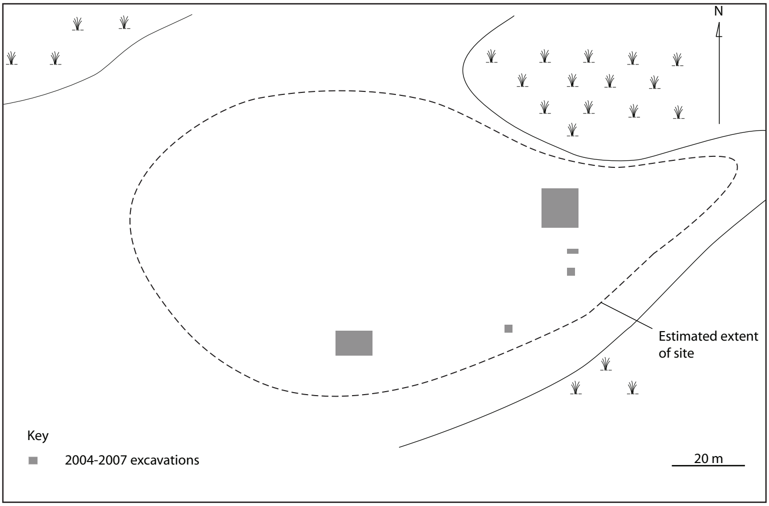

Figure 2. Plan showing estimated extent of site and areas excavated between 2004 and 2007.

rather than a seasonal (short term) or specialist camp site. On stratigraphic grounds it is unlikely that the site was occupied for long; certainly not more than a few decades at most and perhaps for only a few years.

The archaeological problem – spatial reconstruction

The Kawatiri site dates to the earliest known period of New Zealand prehistory and if we accept the "short chronology" model for New Zealand (as summarised in Walter and Jacomb 2007 for example) it is likely to have been occupied by individuals whose parents or grandparents (if not the people themselves) were born in tropical Polynesia. A number of sites of similar age to the Kawatiri site are known from both the North and South Islands, the best known, and perhaps the earliest, being Wairau Bar (Duff 1950). These sites were the target of extensive investigation in the early period of New Zealand archaeology. A number of regional museums have extensive collections of Archaic artefacts gathered from such sites during the first decades of the twentieth century.

Although archaeologists have learned much about the material culture and subsistence systems of this early period, very little is actually known about the social organisation of the people themselves (Anderson 1982: 107). The Kawatiri site offers a near-unique opportunity to pursue this type of research because of its size and its unusually well preserved record of the spatial distribution of features and material culture. An areal excavation approach aimed at identifying patterns in the use of community space should cast light on these issues and this is the approach we have adopted at Kawatiri.

The sampling problem

Unfortunately, using hand excavation methods to create wide areal exposures is an extremely time-consuming approach. Machine scraping can reduce time and costs, but in a shallow, artefact-rich, site like Kawatiri it has the potential to destroy fine-grained spatial information. Over three seasons at Kawatiri the roughly 180 m^2 that has been exposed by hand has revealed traces of a number of structures, activity areas and a rich material culture. But the context or representativeness of this exposure within the wider settlement space is still unclear and a "big picture" understanding of the site has yet to emerge. A sampling approach is required that will support a site-level interpretation of the layout and organisation of activities within the Kawatiri settlement.

There is a very wide range of potential sampling approaches available in archaeology (e.g., Orton 2000). In the absence of prior site information random sampling methods are often used, but a statistically valid sample sometimes requires a lot of excavation. In addition to the time and cost implications, there are ethical constraints about how much of a site it is reasonable to excavate. The ideal sampling approach at Kawatiri would be a stratified sampling method in which a sample sub-set is created based on some known or assumed dimension of variation within the site. Variation could exist in such areas as topography, hydrology, soil types, surface cultural exposures, etc. There is no such variation visible from the surface at Kawatiri. It is situated in a flat pasture with no visible patterning in its topography (except perhaps proximity to the estuary) and no surface features so there is little immediate information available on which to develop a stratified sampling design. Such information could be obtained by test pitting, although this approach would also require its own independent sampling design. In any case, test pitting has proven rather ineffective at identifying variation in the soils at Kawatiri (Jacomb et al 2004). In 2007 we decided to experiment with a fluxgate gradiometer to establish whether or not it could be used to inform a larger sampling design.

The fluxgate gradiometer survey

As Bickler and Low (2007) argue, remote sensing in archaeology should be carried out in relation to an explicit research strategy that details objectives, methodology and interpretation.

Objectives

The objective of the Kawatiri fluxgate survey was to generate a model of variation within the Layer 2 soils that would serve as the basis for constructing a stratified sampling design for planning a later areal excavation. This objective breaks down into two required outputs as follows:

1. A visual model of variation (or anomalies) in the Layer 2 soil in the form of a plan or map within the coordinate system used by the excavators.
2. Some qualitative information about what the different types of anomaly might equate to in archaeological terms.

Methods

The technical details of how a fluxgate gradiometer works are covered in a number of texts (e.g., Linford 2006), and Bickler and Low (2007) discuss various caveats and cautions to its use in New Zealand. Our research design recognises that the patterns resulting from a fluxgate survey will be influenced by local geophysical and other site conditions and that therefore, ground truthing is an essential prerequisite to interpretation. Thus we used a two-stage methodology in which the first stage involved using standard methods for carrying out a total survey of the Kawatiri site. The second involved a structured testing of the results using excavation-based ground truthing.

Stage 1 – the fluxgate gradiometer survey

A metric grid had been established over the entire site by the excavation team in the first season. For the fluxgate gradiometer survey a moving string line was set up across the site which facilitated sampling along parallel strips at 1 m intervals in alignment with this grid. The fluxgate gradiometer operator (Hans-Dieter Bader, of Geometria, an Auckland-based consultancy) walked transects along these string lines with the instrument (a Ferex 4.032 Fluxgate Gradiometer) set to take a point reading every 0.5 m. Before commencing the survey the instrument was calibrated to a local magnetic zero based on the local strength of the earth's magnetic field. The resulting data was normalised to eliminate any error from carrying the recording instrument over uneven ground during the survey and the final data was presented in the form of a greyscale map (± 25 nT). The resulting map is shown in Figure 3. Further technical details of the survey methods can be found in Bader (2007).

Stage 2 – the ground truthing

Based on the results of stage 1, specific areas were selected for ground truthing using hand excavation methods. A very simple two-stage sampling

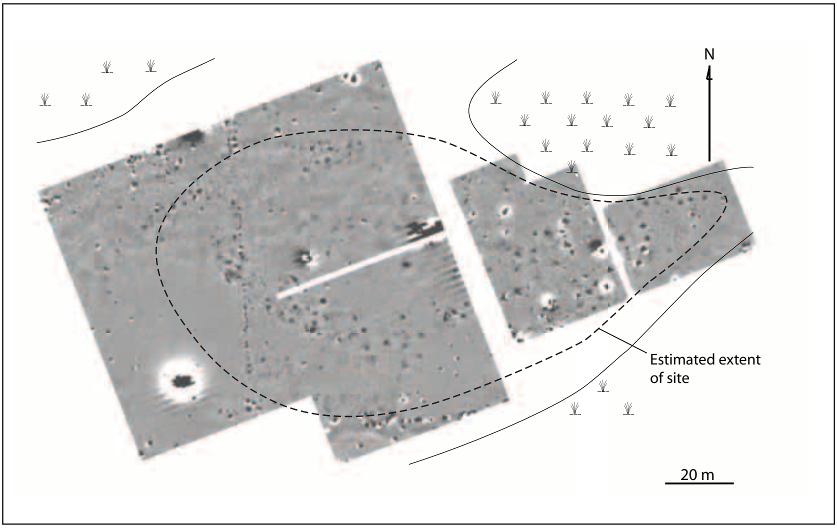

Figure 3. Results of the Kawatiri geophysical survey.

design was used. First, we defined four classes of disturbance based on the density and extent of the magnetic signature in the resulting plan (Figure 4). These were defined qualitatively (by eye), although it should be possible to use quantitative methods based on image (pixel) analysis (in Photoshop for example). These four disturbance classes are described as follows:

High contrast: Well defined black and white areas. These probably result from the bipolar remnant magnetism of buried iron (e.g., Johnson 2006). The large black and white signal near the southwest corner of the survey area, for example, is a farm rubbish hole. We also note that the alignment of high-contrast features running north-south and another running east-west coincide with old fence lines and the signals were caused by small fragments of wire and dropped staples. Given that we were interested in the prehistoric levels of Layer 2 we ignored the high contrast feature class in our interpretations and in Figure 4 (below).

High magnetic anomaly: Black shaded areas, usually well defined and frequently circular in shape.

Medium magnetic anomaly: Poorly confined or amorphous areas of mottled dark-grey and black pixels.

Low magnetic anomaly: Areas on the map of a light to mid grey shade with few or no darker pixels.

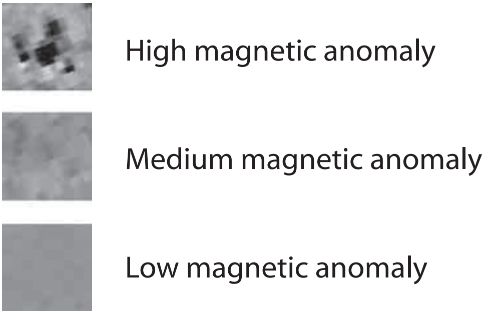

Figure 4. The three classes of anomaly defined from the fluxgate survey.

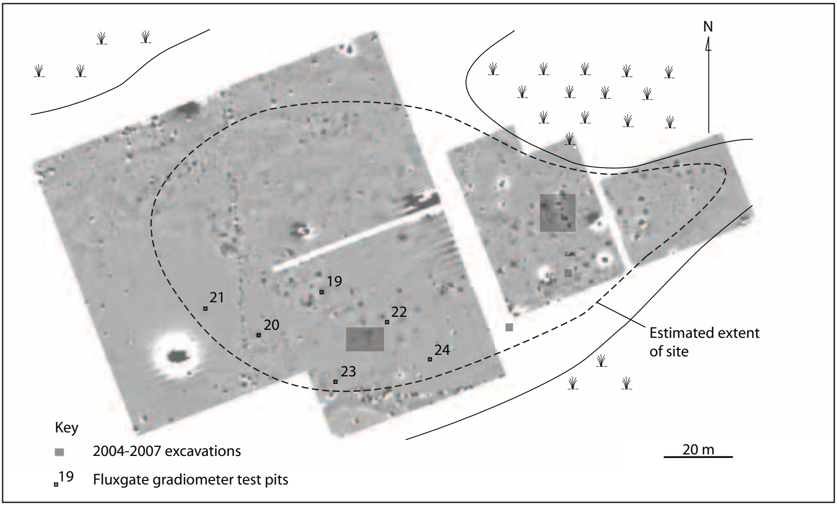

Figure 5. Locations of the test pits.

For each of the three classes of magnetic anomaly two 1 x 1 m test pits were selected for excavation so that, in total, six test pits were excavated (Table 1). These were not selected using any statistically meaningful strategy but according to convenience. The location of the test pits is shown in Figure 5.

Disturbance class	Test Pit Number
High magnetic anomaly	TP 19, TP 20
Medium magnetic anomaly	TP 22, TP 23
No magnetic anomaly	TP 21, TP 24

Table 1. Test pits selected for excavation

The test pits were hand excavated. Any material culture items were recorded to layer, and any features were recorded on plan drawings. Any features that cut into Layer 3 were half sectioned and then fully excavated to sterile silt so that the depth and size could be measured.

Results

The results of the Stage 1 work are shown in Figure 3 and discussed above. The results of the ground truthing exercise are discussed below.

High magnetic disturbance – Test Pits 19 & 20

Both these test pits contained well defined cooking features or ovens (Figures 6– 8). These features were completely outlined by fire-cracked rocks and contained high concentrations of charcoal that extended at least 25 cm below the surface of Layer 3 (Figures 6 and 7). There were only a few artefacts associated with these features. Each test pit contained a small number of argillite flakes. An adze and scattered adze flakes (flakes with polish) were found in TP 20.

Medium magnetic disturbance – Test Pits 22 & 23

The two test pits in this category both contained heavy concentrations of stone (Figures 9–11). In both cases this was a mix of large stones, many of which were fire cracked, as well as scatters of tool quality argillite and a local chert known as Pahutane flint. The soils were heavily charcoal stained through to the top of Layer 3. No distinct features were identified in TP 22 or 23 and there were no intrusions into Layer 3.

Low magnetic disturbance – Test Pits 21 & 24

The test pits excavated in areas of low magnetic disturbance contained very few stones and displayed only minor and localized charcoal-staining of the soils (Figures 12 and 13). A dark brown line ran SW-NE through the TP 21 unit but other than this, no features were present in either test pit. A small number of flakes were scattered through TP 24 and an adze was located in the NW corner of the unit (Figure 14).

Interpretation

The results generally follow a pattern suggesting three types of cultural phenomenon. There are small, discrete areas of high magnetic anomaly that appear to be associated with concentrations of fire-cracked rock and charcoal in earth ovens. Both of the test pits excavated to ground-truth this type of anomaly exposed circular oven features in-filled with fire cracked rock and

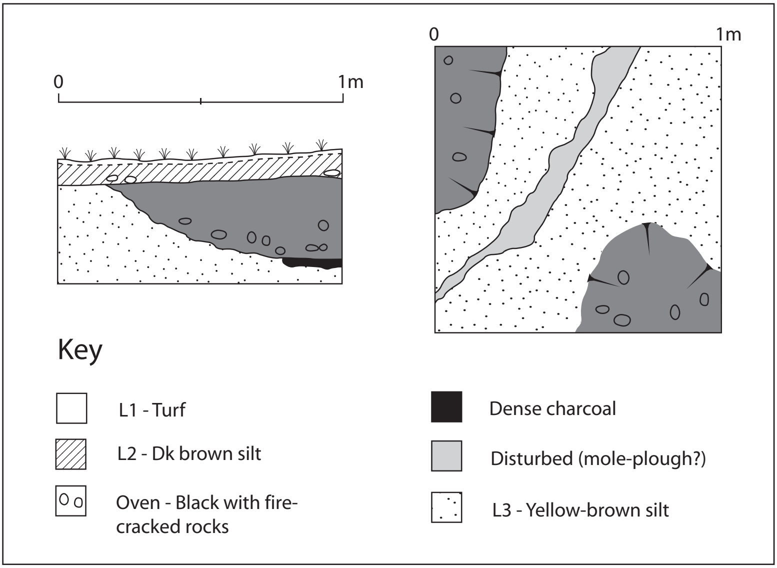

Figure 6. Drawings of section (north baulk) and plan view of Test Pit 19.

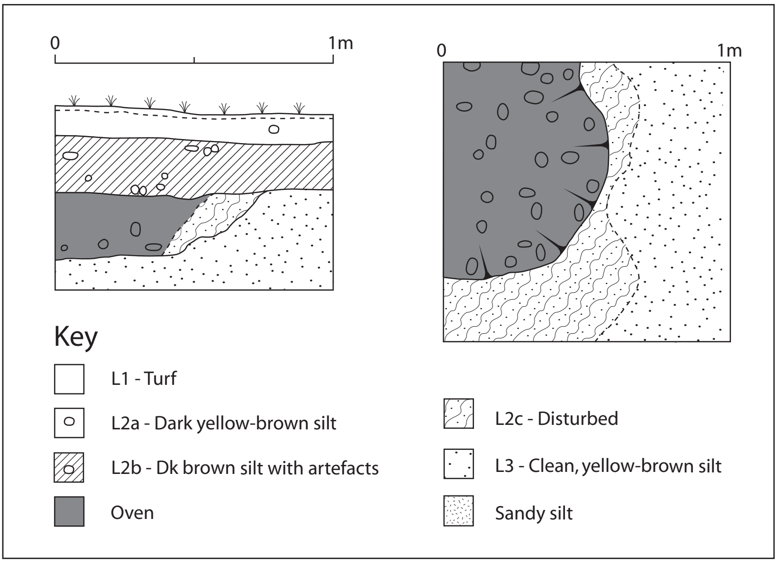

Figure 7. Drawings of section (north baulk) and plan view of Test Pit 20.

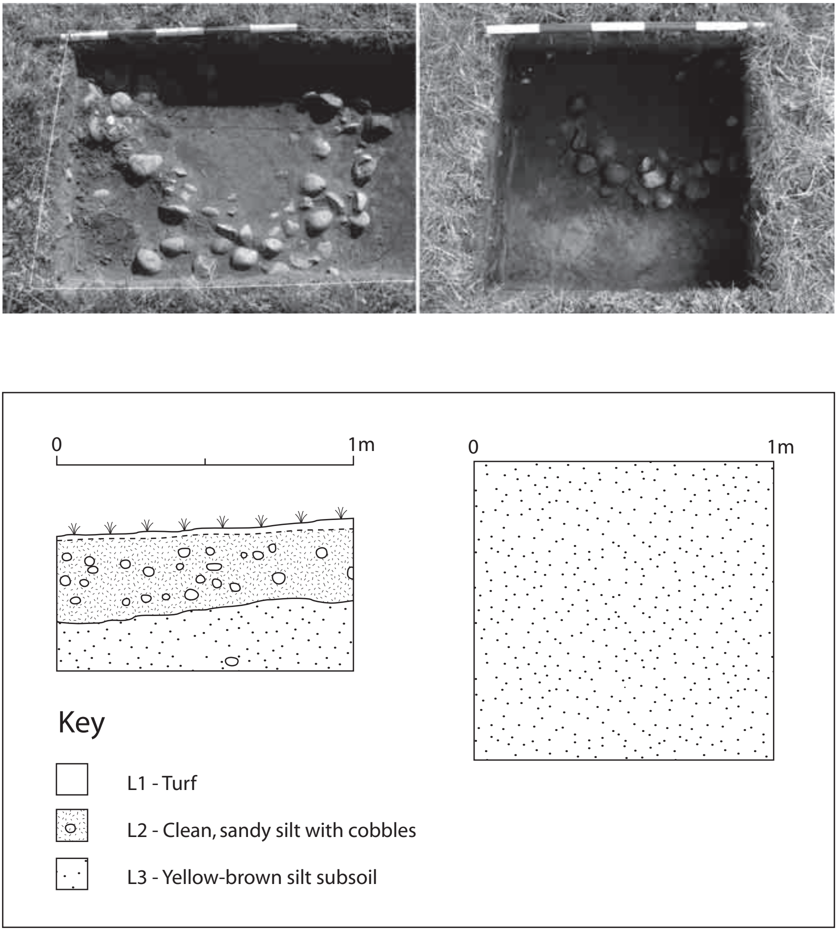

Figure 9. Drawings of section (north baulk) and plan view of Test Pit 22.

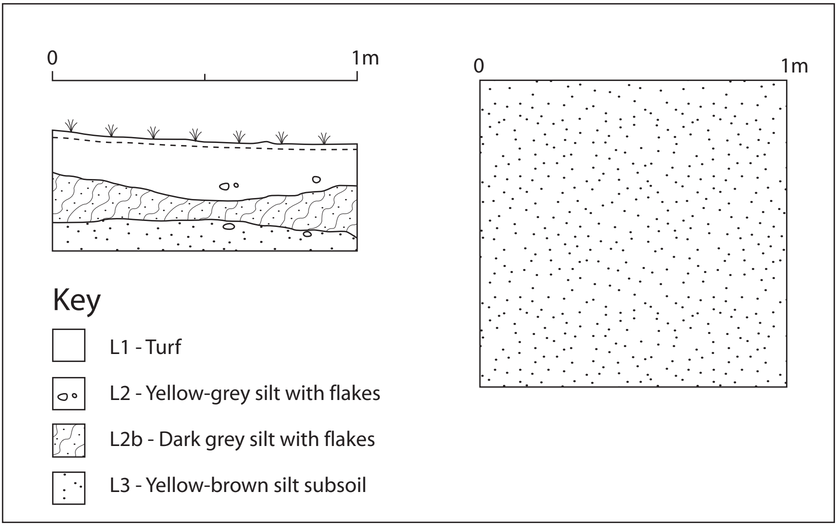

Figure 10. Drawings of section (north baulk) and plan view of Test Pit 23.

Figure 11. Test Pit 22. Note high concentrations of stone in Layer 2 (baulk).

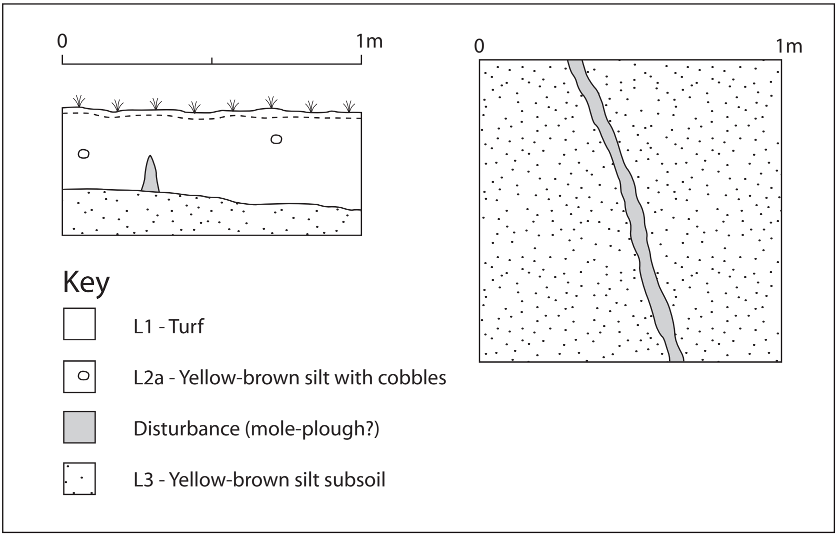

Figure 12. Drawings of section (north baulk) and plan view of Test Pit 21.

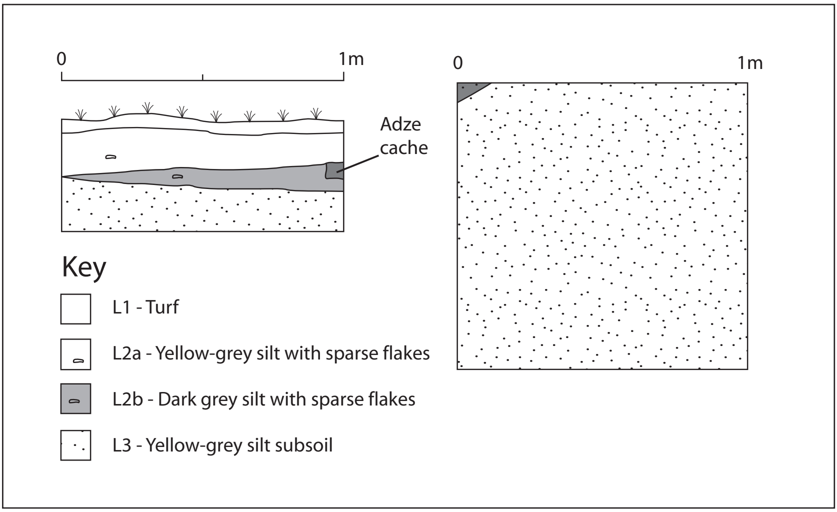

Figure 13. Drawings of section (west baulk) and plan view of Test Pit 24.

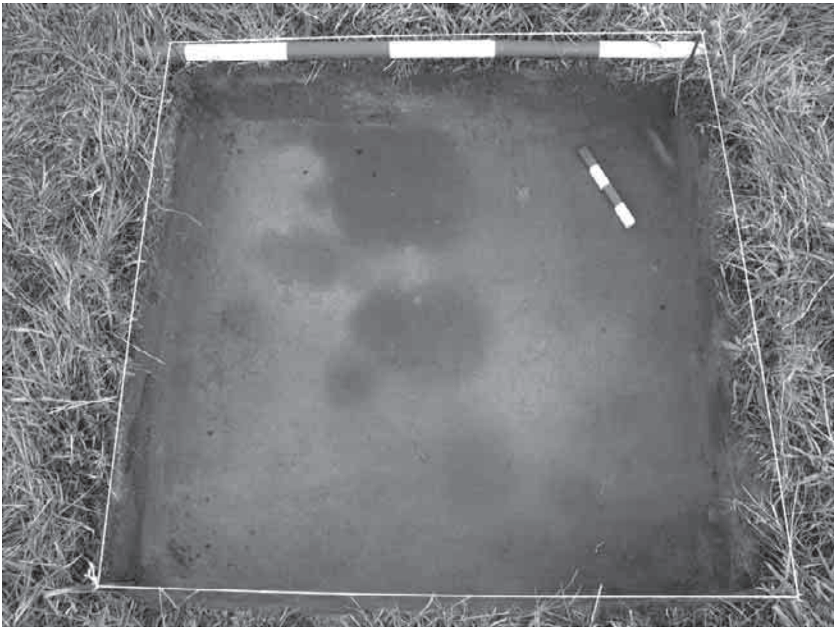

Figure 14. Test Pit 24 with adze in upper right hand corner. Note that the slight discolorations, upon excavation, were not identifiable as archaeological features.

charcoal-stained soil. In both test pits sparse flake scatters were also found, and this is consistent with findings elsewhere on the site that show stone working occurring at a low density close to many of the cooking features. The main cause of the discrete areas of high magnetic anomaly appears to be the presence of burnt stone and charcoal in an oven feature. Therefore, at Kawatiri, we would expect tightly circumscribed areas of high magnetic anomaly elsewhere in the site to represent ovens or perhaps hearths. Based on what we already know about spatial patterning on this site, we might also expect to find other activities, such as stone working, in relatively close proximity.

The areas of medium magnetic disturbance at Kawatiri were associated with charcoal stained soil, fire-cracked rocks and artefacts. The main cause of the magnetic anomalies in these parts of the site is likely to be soil disturbance that occurred during occupation, combined with scatters of fire-cracked rock, and these areas are best interpreted as zones of moderate to heavy human activity. Medium magnetic disturbance zones at Kawatiri are likely to contain artefacts and features, including post holes, but are very unlikely to include ovens.

Areas of low magnetic anomaly at Kawatiri are not as straightforward to interpret. Test Pits 21 and 24 were excavated in areas of very low discernable magnetic anomaly. Test Pit 21 was located near the western edge of the estimated extent of the site (Figure 5) at least 10 m beyond any of the high or medium magnetic anomalies identified with the fluxgate gradiometer. It was outside the boundary of the site as estimated by Orchiston (1974) and was also approximately 8 m west of the westernmost strip of topsoil that was removed in 2004 using a hydraulic excavator (Jacomb, Tucker and Walter 2004) and which appeared sterile at that time. When these points are considered together with the fact that there were no magnetic anomalies recorded to the west of TP 21 for a distance of at least 40 m – the limit of the fluxgate gradiometer survey – it is probably reasonable to conclude that TP 21 is outside the boundary of the site.

The area of low magnetic anomaly in which TP 24 was located, on the other hand, was within the known boundary of the site, based on previous excavation results (Orchiston 1974) and on the location of the southernmost hydraulic excavator trench (Jacomb et al 2004) and proximity to the 2004–2007 University of Otago excavations (Figure 5). In terms of features and presence of fire-cracked rock, TP 21 (Figure 12) was very similar to TP 24 (Figure 13) but TP 24 contained an adze in its NW corner (part of a cache) and a very sparse scatter of flakes, neither of which would be expected to show up as magnetic anomalies.

On this basis, areas of low magnetic anomaly do not necessarily imply a lack of human activity. They may be used to identify the approximate boundary of a site if there is prior information, as with TP 21, but they can also be interpreted as open spaces lying between structures and high-use areas as with TP 24. In these places there may have been low density human movement and small, special activity zones. In terms of the fluxgate gradiometer signal these areas are not distinguishable from areas outside the boundary of the site and therefore the absence of any magnetic anomaly on its own cannot be taken as a definite indication of absence of occupation.

Discussion

At Kawatiri the fluxgate gradiometer survey achieved the primary objective of providing a model of variation within the site that could support the development of a sampling programme for future areal excavation work. We note specifically that:

1. The three different classes of anomaly defined on the basis of the density and extent of the magnetic signature (as reflected in pixel shade and density) were shown to reflect real-world differences in the Layer 2 soils.
2. The ground truthing showed that it was possible to make some low-level assessments about what those different anomaly classes might mean in archaeological terms.

At this point the fluxgate survey at Kawatiri can be said to have been successful – it has provided all the information that was asked of it and it is now possible to develop a stratified sampling programme to guide the following season's excavation. Furthermore, even if those later excavation results are disappointing, this cannot in any way be attributed to a failure of the fluxgate survey. The fluxgate gradiometer has been shown capable of accurately identifying variation *in the Kawatiri soils* so we could no more blame the fluxgate work for poor excavation results than we could blame a topographic map if we had based our sampling programme on elevation. But this does raise the bigger issue, and one that is more immediately relevant to many archaeologists working with remote sensing in New Zealand – what have we actually learned of archaeological interest about the Kawatiri site as a result of carrying out a fluxgate gradiometer survey?

What have we learned about the site?

Areas of high magnetic disturbance are mainly contained within an area running approximately 120 m east–west and 80 m north–south (Figure 3). This provides us with definite information about the location of some types of cultural activities. But as Bickler and Low (2007: 206) argue, areas not classified as "anomalies" may also be of archaeological value. This was dramatically evident at Kawatiri in Test Pit 24. Test Pit 24 was excavated in an area of low magnetic anomaly and indeed it contained very little stone or charcoal, and no evidence of features. It did, however, contain a cache of two large quadrangular adzes made of Nelson region argillite (Figure 15). One of these was recovered in the edge of the test pit and the other was lying parallel and touching the first in the adjacent unit, but also within a similar area of low magnetic anomaly. Caches are extremely important in terms of understanding aspects of site use in sites like this but we would never expect to identify them using a fluxgate gradiometer.

The band of higher magnetic disturbance is clearly of archaeological interest, but further interpretation relies on the ground truthing exercise and on prior knowledge of the site. Drawing on that information it is likely that it represents areas of burnt stone and charcoal from cooking activities. But this still raises a very large range of possibilities: are these cooking features located within individual household clusters, do they represent communal cooking or processing events, are they isolated burning events on the outskirts of a village or successions of camp fires along an estuary or lagoon shoreline. These questions lie at the heart of understanding the social organisation of this early New Zealand community and their answer will require the application of standard archaeological excavation methods.

Finally, perhaps the greatest strength of the fluxgate gradiometer results is the clear indication given of the site's boundary. The site itself contained a largely indeterminate and apparently random distribution of anomalies, some of which have a reasonably high chance of being fire features, but there is a very clear difference between the area that we recognise as being the site and the area beyond, which shows as a uniformly light grey in Figure 4.

Some comments on remote sensing in research contexts

Bickler and Low (2007) raised the interesting point that there can be quite significant differences in expectation and method between the use of remote sensing in management versus academic research contexts in New Zealand archaeology. One major difference relates to archaeological expecta-

Figure 15. Adzes recovered from Test Pit 24 (low magnetic disturbance).

tion. In management archaeology there is an expectation that remote sensing, if properly applied, will support some quite major interpretations and decisions. As Bickler and Low argue (2007: 202) this derives from the nature of the statutory process whereby the archaeologist is required to balance competing demands on the land, and make decisions or recommendations that might "ultimately determine which archaeological features are preserved, damaged or destroyed." There are rarely such demands on the research archaeologist. Indeed, at Kawatiri no significant interpretations of the site were advanced on the basis of the fluxgate gradiometer survey and no decisions were made that would affect the preservation or future of the site. It is probably generally true that far fewer high level interpretations or "decisions" will be made based on remote sensing in academic research than in heritage management archaeology.

Furthermore, it is quite common in New Zealand heritage management for the archaeologist to be looking for something quite specific – the location of graves or blank spots in the landscape. This can be true in research archaeology too, such as in locating defensive features on a pa site. But more usually remote sensing is part of a more general research design, where the required outcomes of the actual survey are far less specific. The question of scale is also important. In a spatial survey in the field of heritage management the archaeologist is frequently looking at wide-area patterns, but at a very coarse scale. On the other hand, academic research questions in the area of spatial archaeology tend to require a much finer level of resolution. At Kawatiri, for example, we are interested in such issues as the patterns of flake distribution in relation to structures, or other artefact classes. Such resolution will probably never be achievable using remote sensing methods.

Conclusion

At Kawatiri the remote sensing work made an important contribution to the research programme. The fluxgate gradiometer demonstrated the ability to identify variations in Layer 2 composition, and inferences were able to be drawn about the nature of the anomalies based on their magnitude, size, shape and polarity. As expected, ground truthing was necessary before any magnetic anomaly detected by the fluxgate gradiometer could be identified with any certainty. But the ground truthing showed that certain types of anomaly could be associated, with reasonable confidence, with certain types of human activity. This provided us with an excellent basis for designing an excavation sampling strategy which we will implement in the next West Coast field season. However, it is important to note that the fluxgate gradiometer results were not expected to provide data that would allow the excavators to make any high level interpretations of the site. Indeed, it is unlikely that any of the research problems we are interested in at Kawatiri could be addressed using remote sensing, mainly because of the scale at which it works, and this is probably true of much academic research archaeology in New Zealand. As Bickler and Low argue, there are many problems to face in determining the most effective use of remote sensing in heritage management work given that big decisions are made based on the survey outcomes. But the demands of research work will often be more simple or modest and here remote sensing has already proved to be a very effective research tool.

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