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EXPERIMENTAL GEOPHYSICAL SURVEY ON MOTUTAPU ISLAND 1994-96

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From 1994-1996 experiments in remote geophysical prospecting were carried out at seven archaeological sites on Motutapu Island of which six were also test excavated. By the end of this programme we had learned how to interpret the geophysical data with reasonable success in the context of local conditions. Future application of the method is feasible but this experience suggests it is labour-intensive and imprecise without associated sub-surface investigation.

In initial discussions with officers of the Department of Conservation and representatives of Ngai Tai Ki Tamaki Trust and The Huakina Trust, it was agreed that the Department of Anthropology would investigate the applicability of geophysical survey on Motutapu Island. The project was related to a contract (No.1813) with the Science and Research Directorate of DOC to assist in the Motutapu Restoration Plan administered by DOC, Auckland Conservancy. This particular objective was to devise a methodology for the non-destructive investigation of archaeological sites on Motutapu. It was clear that in the context of a programme to re-establish forest over parts of the island it would be necessary to establish the perimeters of Maori archaeological sites to avoid damaging them. A programme of geophysical survey and test excavation was conducted on the island to establish the level of correspondence between remotely sensed data and surface and sub-surface archaeological phenomena.

Research in geophysical prospecting has a relatively long history and during the last few years there have been significant innovations in developing more accurate and efficient methods for detecting different subsurface sediment properties associated with archaeological features (Clark 1990).

Improvements have been made in instruments and data logging devices to record field measurements. In addition, research has gone into improving the analysis and visual presentation of geophysical data. However, our developing experience shows it still requires sufficient archaeological understanding of the field situation to adequately interpret any such patterns in the data.

Geophysical data have been analysed by a variety of mapping techniques, such as grid-point or level maps, variable density contour maps, the standard line contour map, isometric trace lines, and dot-density maps (Weymouth 1986:328; Clark 1990:141-146). The most common method is the standard line contour map (Scollar 1990:495). These maps have limitations in terms of ease of data manipulation and visual interpretation. One difficulty is that only one data set can be analysed at a time, and another is that values are difficult to manipulate in order to enhance contrasts. Recent innovations in image processing have helped alleviate these problems. Grey scale images, the use of false colour and the development of image enhancement and classification techniques have increased the ability to interpret archaeological geophysical data (Cheetham *et al* 1991; Allsop 1992; Ladefoged *et al* 1996).

In New Zealand, geophysical surveying has taken place in a number of areas (McFadgen 1977; White and Broadbent 1992; Young 1993; Ross *et al* 1994; Ladefoged *et al* 1996). On Motutapu, the geophysical fieldwork was carried out between 1994 and 1996. Sites investigated included R10/22, R10/39, R10/47, R10/410, R10/496, R10/497 and R11/1277. Of these seven sites, six were also test excavated.

Ground conductivity, resistivity and magnetic susceptibility were employed on Motutapu. Ground conductivity and resistivity meters essentially measure the passage of an electric current through the ground. The identification of archaeological features is based on the measurement of a contrast between the physical properties of the feature in relation to the surrounding uniform matrix (Scollar 1990:9; Tabbagh 1984:159). Conductivity, and its inverse, resistivity, are affected by sediment size, structure, porosity, moisture, and generally by the degree of compaction, loosening and organic enrichment of sediment. The conductivity data on Motutapu was collected with a Geonics EM38 meter. When measuring ground conductivity the EM38 instrument can either maximize measurement sensitivity at the ground surface with a gradual decrease to a depth of over 1 m, or the sensitivity of the meter can peak at a depth of 0.4 m below the surface with a gradual decrease to a depth of over

1 m. In either case, the conductivity data was stored in a DC720 Data Logger in the field and downloaded later to a laptop computer. The resistivity data were collected using a Mann-Clark resistivity meter in a Wenner array at a 1 m interval. Contour maps of the geophysical data were generated using Rockworks software. We also transformed the data for analysis by the raster based GIS software Idrisi which enhanced patterns by supervised and unsupervised classification, image-processing, and the generation of useful colour output.

Magnetic susceptibility was the third type of geophysical data collected. It can be influenced by the enhancement of the organic content of sediments especially in features such as rubbish pits, middens and ditches filled with topsoil (Weymouth 1986:343). Features that have been thermally altered such as hearths produce enhanced magnetic susceptibility, as do intrusive structures such as walls and foundations which differ from the surrounding sediment matrix (Clark 1990:100-101; Challands 1992:34; Weymouth 1986:343). The Geonics EM38 was used to measure the extent to which time-varying magnetism was induced in materials where the response was expressed in terms of apparent magnetic susceptibility.

Data collection and analysis

In 1994, geophysical data were collected at Site R10/410 (Ross 1994). The site consists of a number of features on a broad ridge that runs above an old stream bed. Shell midden is exposed on the upper slopes with transverse terraces running across the ridge further down. On one of these terraces are two pits. A large and extensive midden is exposed on the steep slope on the western side of the ridge. Throughout the area there has been considerable surface disturbance from grazing stock.

A 3460 m^2 grid was laid out over the broad flat ridge of R10/410. This area was surveyed with a ground conductivity meter at two depths of prospection, and image enhancement techniques were used to analyse the data. Figure 1 displays the raw conductivity data at a sensitivity peak of 0.4 m below ground surface, and Figure 2 displays the same data with a linear stretch with 2% saturation applied to it. Stretching algorithms are designed to accentuate the contrast between features for better visual display (Lillesand and Kiefer 1994:546). A linear stretch uniformly scales the range of input image values to fit the total range of output values, in the case of Idrisi, 256 greyscales. In a linear stretch, the program allocates as many display levels to the infrequently occurring input image values as it does to the frequently

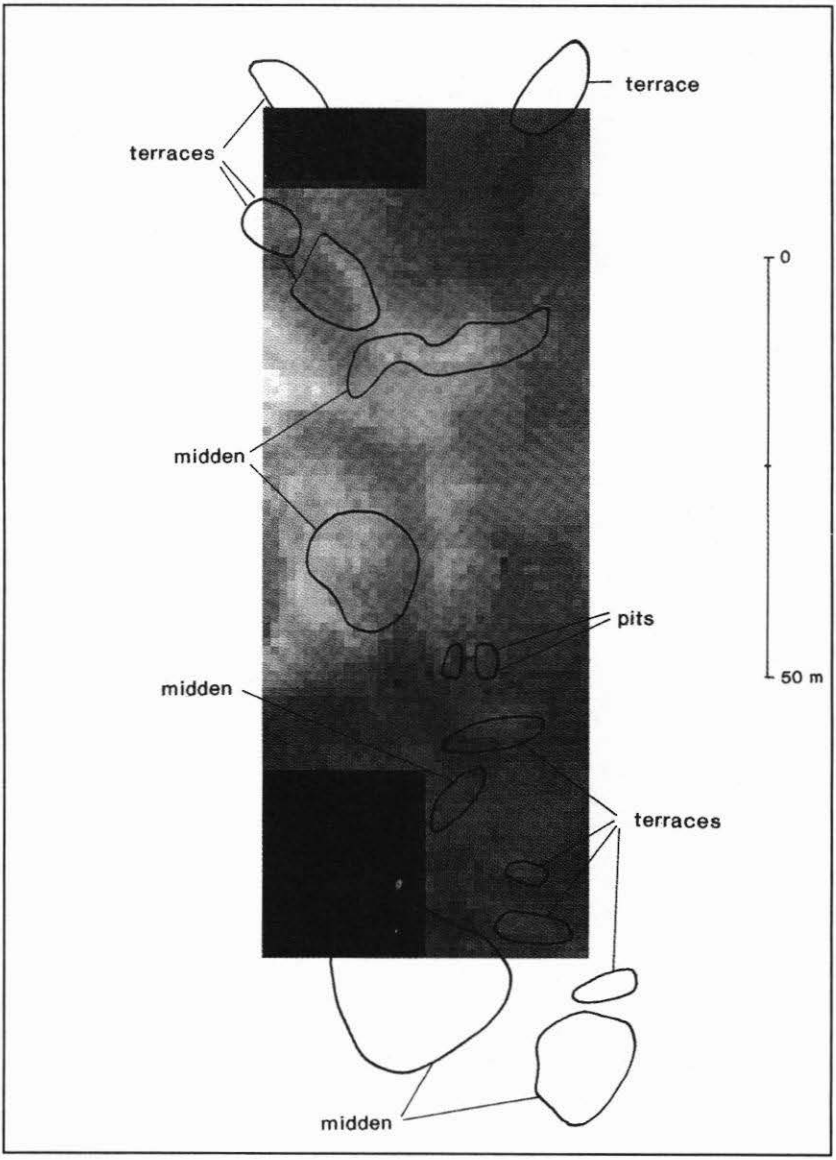

Figure 1. Ground conductivity data ranging between values of 13.2 and 71.3 mS/m

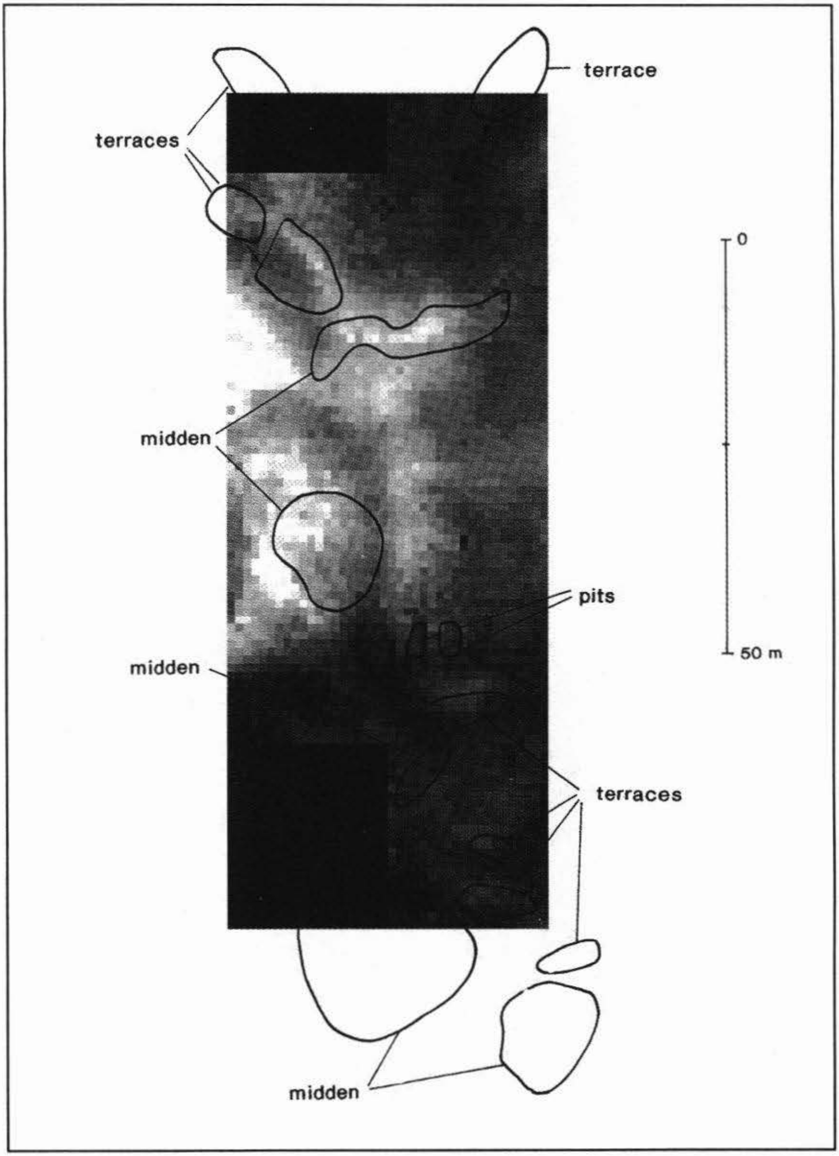

Figure 2. Ground conductivity data with a linear stretch of 2% saturation.

occurring values. To alleviate this, a linear stretch with saturation forces a specific percentage (in this case 2%) of image pixels with extreme values at either end of the range to single output classes. The remaining input values can then be redistributed over a wider range of output values. The linear stretch with saturation of the Site R10/410 data clearly defines areas of moderate conductivity associated with the terraces on the surface of the site. In the original interpretation of the data (Ross 1994), the pattern of conductivity values associated with terraces being offset from their surface manifestation was not recognized. We discuss this phenomena below in detail with respect to Site R10/497.

An 860 m^2 subset of the larger grid was defined in which data from resistivity and magnetic susceptibility surveys were also gathered. This was done to obtain multiple geophysical data sets which could be combined and analysed through image classification procedures. Both supervised and unsupervised classification procedures were applied (Ross 1994:23-27), with the unsupervised procedures being the most successful. The unsupervised procedure grouped the pixels into categories, or classes, based on the inherent spectral signatures of the conductivity, resistivity, and magnetic susceptibility data. Four classes were defined, which were interpreted as being associated with 1) shell midden, 2) pits and background values, 3) terraces, and 4) scarps. Again, the spatial offset of the geophysical responses and the location of surface terraces was not originally identified (Ross 1994), but surface features and areas of potential subsurface features are identifiable.

During the field seasons of 1995 and 1996 ground conductivity alone was measured and test excavation of sites followed. Initially the degree of specific correlation between archaeological features and conductivity patterns continued to be problematical. However, there were some very conspicuous subsurface features which gave no problems. For example, conductivity clearly revealed the presence of miscellaneous metal in a disturbed part of Site R10/22. Similarly, a very striking pattern shown was found running across Site R10/496 which lies on a ridge rising above Administration Bay and which we excavated at two locations. Initially we suspected this was a World War II cable linking the military camp at Administration Bay to the major gun emplacements on the hill to the northeast; or possibly a more modern telephone cable. Eventually we discovered that this signal was produced by intermittent lengths of No.8 wire and metal staples which were the remains of a fence now buried in the topsoil.

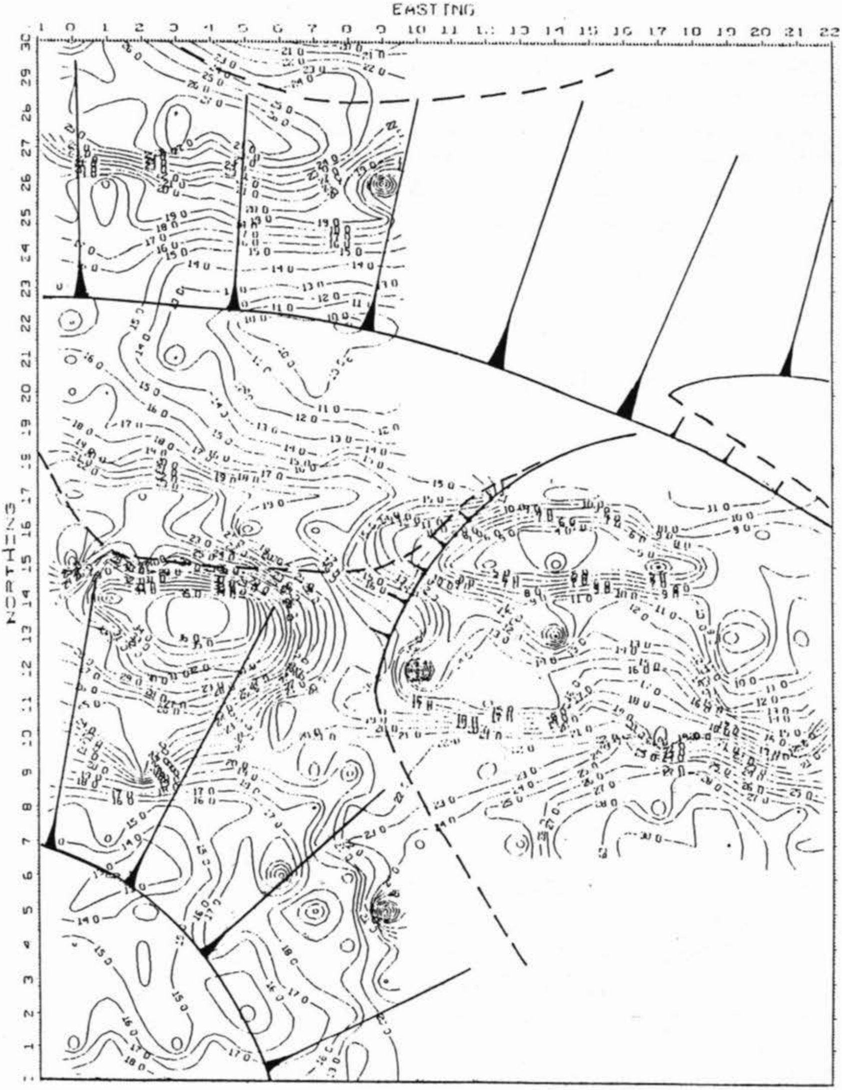

Figure 3. Individual terraces at R10/497 were found to have a transverse conductivity gradient with high values at the back and low values at the front.

Our major efforts were concentrated on Site R10/497 where excavation was supervised by Rod Wallace and Marianne Turner. During 1995 and 1996 we excavated a substantial area of this small and apparently typical Motutapu pit and terrace site. It revealed a house located at the back of a terrace with drains and successive walls at the uphill side. There were two associated concentrations of flaked stone including much obsidian, front and back. Close to the house on a slightly higher extension of the same terrace were several intercutting kumara storage pits. Downslope from these was an area of concentrated shell midden. There was also an extensive scatter of cookstones and worked local greywacke over parts of the site. Prior to the first excavation in 1995 the ground conductivity meter was run over much of the site on a 1.0 m grid and calibrated to measure electrical conductivity at a depth of c.0.4 m. Figure 3 shows the resulting values plotted as a contour map together with a plan of the scarps and terraces making up part of the site. Figure 3 indicates that individual terraces have a transverse conductivity gradient with high values at the back and low values at the front.

In fact, as shown in Figure 4, the conductivity signal has its peaks and troughs systematically out of phase with the archaeological features. At the time of its pre-European construction, this flight of terraces and scarps had been originally cut through topsoil and then some 0.6 m of volcanic ash to expose the natural clay basement at the foot of each scarp and the back of each terrace. The fronts of terraces were built up with some of the derived material. This constructional fill was fragile and the disturbed soil and ash on the hillside was very unstable. After the time of Maori occupation, especially, this situation resulted in a considerable downslope movement of sediments to produce the disposition of overburden shown in Figure 4. At the back of terraces, deep overburden of loose texture and poor drainage lay above a structure which produced a relatively lower ground surface to volume ratio than at the front of terraces where the overburden was thinner and more freely draining. Thus a single artificial terrace did not give a uniform conductivity signal but produced a gradient of values.

Subsequently, our most successful effort in detecting sub-surface features was made in 1996 as work continued at Site R10/497. For this run, values were collected on a 0.5 m grid (a fourfold increase in data). Runs were made in both horizontal and vertical dipole modes to investigate different depths. In addition, cutting the grass and weeds very short improved the strength of the archaeological signal. The area of storage pits was relatively less affected by systematic distortion than the scarps and terraces and Figure 5 is a contour map of conductivity values shown superimposed on a plan of excavated archaeological features. There is a level of correspondence between the two.

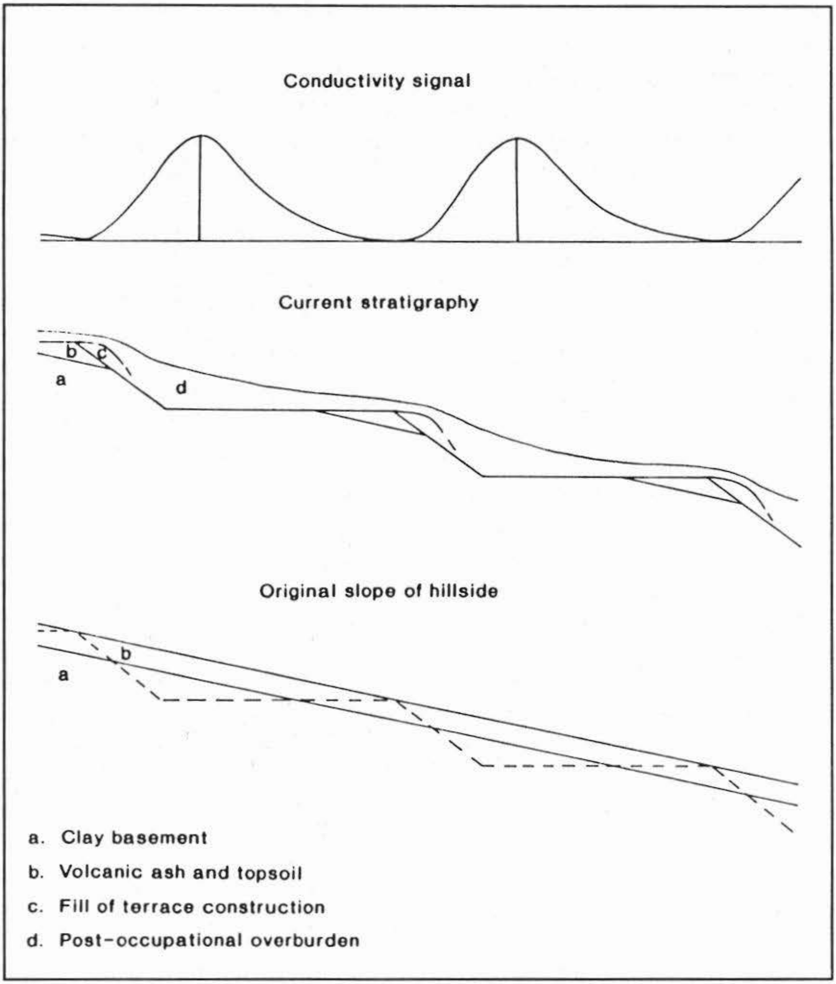

Figure 4. A schematic section of terraces and scarps of R10/497 showing the conductivity signal has peaks and troughs that are systematically out of phase with the archaeological features.

We believe it should be possible in the future to ameliorate the effects of any systematic background signal confounding such an archaeological survey. This may be accomplished by observing that systematic background signals are continuous and operate over a larger scale than the discrete archaeological phenomena we typically wish to detect. By fitting a smooth polynomial trend surface to the geophysical data we can extract the residuals with the expectation that these will reflect the archaeological signal, if any, isolated from the distortion of the background (Jones and Irwin n.d.).

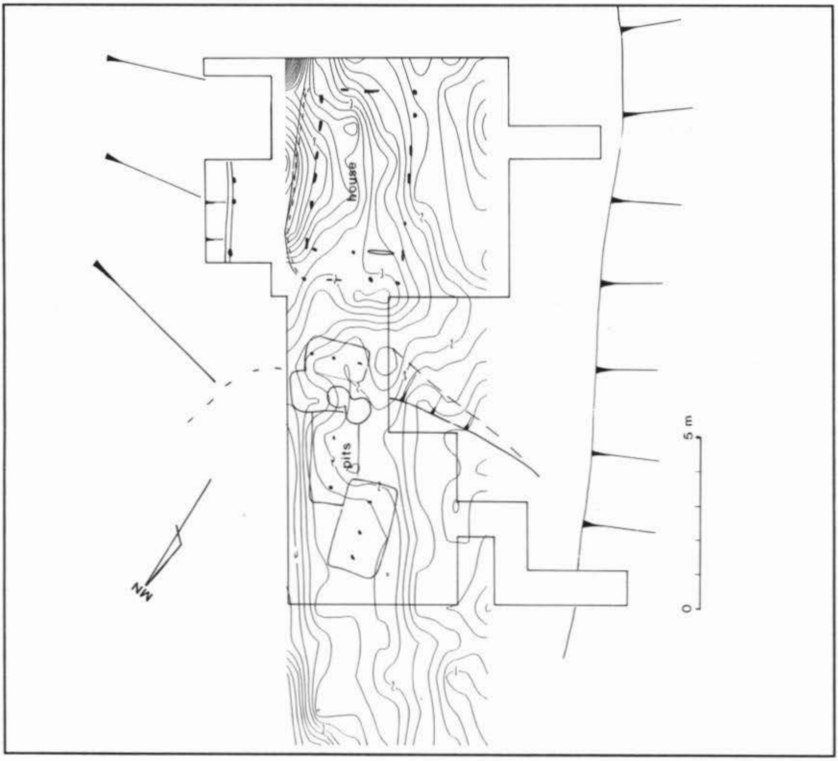

Figure 5. A contour map of conductivity values superimposed on a plan of excavated pits.

The situation as interpreted at Site R10/497 applies generally to parts of sites R10/47 and R11/1277 which were both measured for conductivity and test excavated under the field supervision of Caroline Phillips and Simon Best respectively. As seen on the surface, Site R10/47 was a line of four possible artificial terraces running down a small spur at the northern end of Sandy Bay in the northwestern part of the island. We were concerned to ascertain their cultural or natural status. Test excavations were carried out along a 50 m baseline aligned to the long axis of the site and these revealed a storage pit, some midden and haangi stones while parts of the slope were found to be unmodified. In such cases it is necessary to understand post-occupational sediment processes influencing conductivity to distinguish, even in a vague way, the location of modified sub-surface features.

In conclusion, the application of geophysical prospecting on a number of sites on Motutapu proved to be a two-stage process. The first involved measuring geophysical values on sites and subsequently producing computer-generated patterns of data. The second stage involved interpretation of these patterns and images in the archaeological and geological field context. The first stage, without the second, while technically proficient, could be naive. Eventually we achieved a level of confidence in our ability to measure, process and interpret these remotely-sensed data. However, we do not believe that geophysical measurement alone could be relied upon in the future to define archaeological sites without associated sub-surface testing and appropriate archaeological interpretation on Motutapu, or elsewhere.

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