

An Analysis of the Structure and Function of Prehistoric Maori Pa Sites

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Abstract

Maori pa sites are fortified settlements built in the prehistoric period in New Zealand, usually situated on an elevated position. A sample of sites has been mapped using a total station theodolite in order to provide data for the 3D modelling of these sites. GIS analysis in ARC/INFO of the 3D models of pa is used to answer questions about the structure of these sites, their relationship with the landscape and aspects of their function within prehistoric society. The relationship between the internal organisation of these sites and the landform on which they are situated is particularly important. The use of GIS allows several types of analysis of these features, such as slope and aspect, area and arrangement of features, line of sight between parts of the site and immediate surroundings and movement of sunshine across different parts of the site at different times of the year. These types of analysis can add to our understanding of how and why pa sites were built where they were.

Geographic Information Systems have become well-established tools in archaeological research, as well as fields such as Cultural Resource Management. The ability of GIS to enhance our abilities to analyse information, as well as manage databases and produce maps, is well recognised. GIS applications in archaeology have been the subject of at least two recent books, many more papers and even a few conferences and colloquia (there is significant input from people using GIS in the UISPP Commission IV and the World Archaeology Congress Special Interest Group in Information Technology Communication in Archaeology). There is even an annotated bibliography concerning GIS and archaeology (Petrie, Johnson, Cullen and Kvamme 1995). More powerful GIS software and more accurate data have enabled archaeologists to explore new analytical techniques. One of the more recent techniques involving GIS is 3 dimensional modelling. This technique can be used to allow one to analyse sites or artefacts as they occur in space. In the case of sites, 3 D modelling allows one to analyse the relationship between the site and the landform on which it is situated, as well as the relationship between the site and its component parts and elements of the surrounding landscape.

This paper reports on the application of GIS and 3 D modelling to spatial and other excavation data from Maori pa sites in New Zealand. Pa are defended sites, often situated on raised, easily defensible landforms where the natural defences provided by the landscape were enhanced by the addition of artificial earthwork defences. The relationship between the sites and their immediate physical environment is therefore

important in order to understand the sites. Pa sites were constructed primarily during the period from about 1500 AD to the early 1800s (Schmidt 1996). In the early 1800s the European colonisation of New Zealand and the increasing availability of firearms led to a change in site form and by the start of the 20th century, pa sites were no longer constructed.

Pa sites have been excavated in New Zealand since the 1940s and there is now a wealth of information concerning the sites. As part of a PhD project at the University of Auckland, New Zealand, this information has been gathered into a database. The maps of the sites have been digitised and linked to the database. A sample of sites was re-surveyed in order to provide digital data so that 3 D models could be constructed. The database of information from the sites has been linked to the database of maps of the sites held in ARC/INFO. The surface maps of the sites can be analysed in comparison to the information from excavations in order to examine the relationship between surface and subsurface features at these sites. The data from these sites is currently being analysed in an attempt to understand the factors involved in the construction and layout of these sites, particularly with respect to choice of landform, defensive device and internal organisation of features and structures. The role that the sites played in the society that built them is also being addressed from the perspective of the factors mentioned.

Critical dimensions in the analysis are the relationship between the site and the immediate landscape and the relationship between features within the site. The aim of the project is to gain some

understanding of the internal structure and layout of these sites and the influence of the landform chosen for the site's location, on the layout of that site. The use of a GIS allows for the incorporation of additional information from databases and coverages into the models created. For example, the relationship between a coastal site and the coastline can be examined, by incorporating the coastline into the 3 D model created in ARC/INFO. Thus, the connection between the site and the landscape is maintained.

The 3 D modelling facility in ARC/INFO allows one to view 3 dimensional models of the sites, reconstruct contour lines at different intervals, analyse intervisibility between different parts of the site and the site and the surrounding landscape and change the illumination angle to determine how the sun would have tracked across the site. Other forms of analysis can also be performed, but those listed here are being used to analyse pa sites. Once the digital survey data has been entered into the computer a TIN or Triangulated Irregular Network is created in ARC/INFO. The TIN provides the basis for most of the subsequent analysis and display. All other points on the surface of the sites can be interpolated from the TIN.

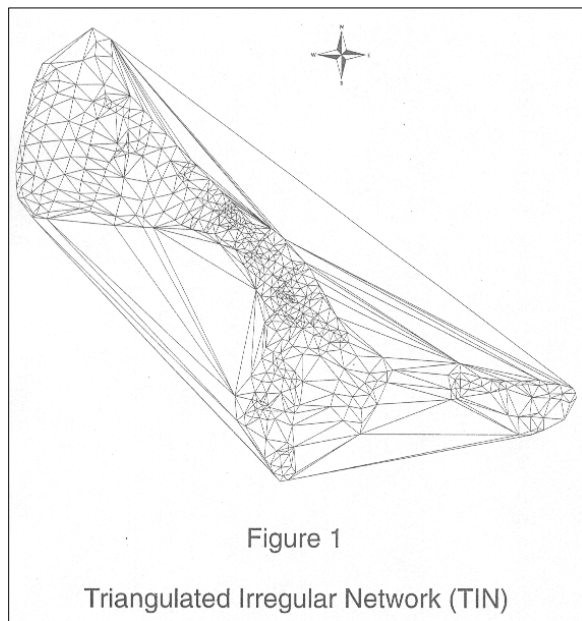


Figure 1.

Figure 1 shows the basic TIN derived from the data from the survey of a pa site. The triangles created by the TIN join all the points originally surveyed. The edges of the site must be determined in order to increase the accuracy of the model. If edges are not defined then the calculations performed with respect

to the sides of the model do not reflect the true surface. The TIN is then used to produce other representations of the sites. Figure 2 shows a contour diagram with contour lines at an interval of 0.3m produced from the TIN shown in Figure 1. The importance of the surveyed edges can be seen in the reduction of scope between Figures 1 and 2. Contour lines outside the edges defined in Figure 2 would not represent the true landform if generated automatically.

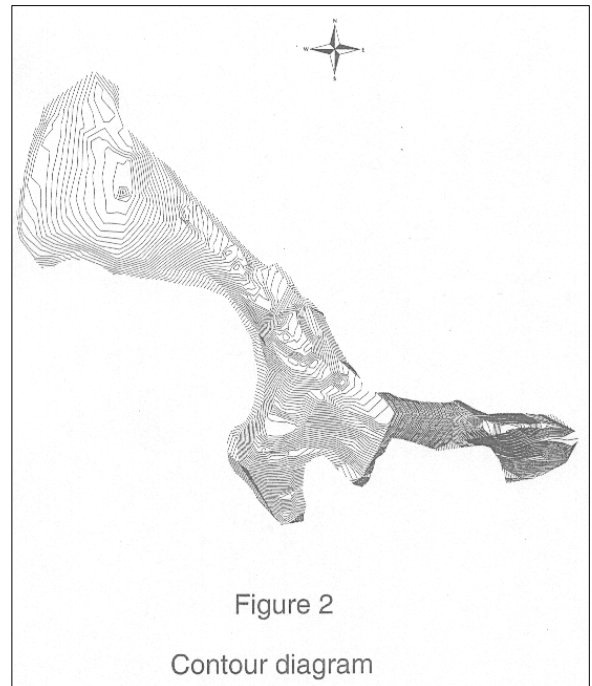


Figure 2.

The contour diagram is easier to interpret than the TIN, as it is a more familiar representation of the landscape of the site. Contour diagrams are useful for analysis as well as display. The relative heights of different component parts of the sites can be determined, which helps one to understand the internal dynamics of the site. Fine resolution contour lines also help one to understand the modifications of the original landform that have occurred. The fine resolution contours illustrated in Figure 2 show small-scale changes that have been made to the terrain, giving details of features such as pits and terraces. The resolution is restricted by the resolution of the original survey, for example contour intervals of 0.3m produced from survey points 2m or more apart would not be very meaningful. The contour interval of 0.3m used here reflects survey points of approximately the same resolution (i.e. 0.3m) over the more detailed parts of the site.

Pa sites contain many features that represent modifications of the original landform. One of the most important functions of the sites seems to have been defence. Pa were generally situated on easily defensible landforms and often the natural defences were enhanced by the addition of constructed defences. These defences took the form of earthwork defences such as ditches and banks, as well as fences and palisades. The latter do not often survive in the archaeological record and so the archaeological definition of pa has concentrated on the presence of earthwork defences. The issue of how well this represents the way that these sites were perceived by the people who built and used them, even at the time of contact with Europeans, will not be addressed here. Nevertheless, the way in which the earthwork defences represent modifications of the landform on which the site was situated is an important aspect of the analysis. The relationship between the type of defences constructed and the topography of the site has been examined during the course of this study.

No direct deterministic relationship between topography and defensive system could be demonstrated quantitatively. In other words, topographic type cannot be used directly to predict the number or nature of defences on pa sites. This is not a surprising result since human behaviours are seldom, if ever, so simplistic that they respond in a deterministic way to single environmental factors. However, some topographic types reveal a trend towards more complex defensive systems than other types. The choice of defences was also directly influenced by the nature of the topography of the individual site and constructed defences were employed in places where natural defences were weak or lacking. However, the choice of defensive system, such as ditch or bank or combinations of these, was not solely dependant on topography and other explanations can be sought to broaden our understanding of the employment of these features. The articulation of the defences with the landform is very evident from the 3 D modelling. For instance, ditches can be shown to have been placed at the most strategic places for cutting off access to certain parts of the sites, which supports their definition as defensive features, rather than as access routes or other non-defensive features.

The dynamics of the interaction between site form and topography can be analysed through the use of 3 D modelling more easily than from traditional 2 dimensional maps. The 2 dimensional maps produced of pa sites that accompany most of the literature do not reveal details of slope and aspect. Although the

location of the archaeological features is noted, one cannot easily determine the relationship between these features and the terrain. There are obvious differences between terraces on the slopes of a hill and terraces which are merely slightly flatter areas of an already flat landform. These differences are more easily quantified and assessed from a 3 dimensional model.

Terraces were constructed along the slopes in order to maximise flat areas for habitation and other activities and also in order to steepen the slopes approaching the flat areas. The terraces show up as flattened areas within the 3 D model. The relationship between the terraces and the landform can be examined and the internal arrangement of terraces assessed. The degree of preservation of the terraces is also evident to some degree in the clarity with which these features are defined, although of course the resolution of the survey data is an important influence. The sharpness of all the features in the site can be assessed as long as there is some control over survey resolution. Terraces are shown clearly in Figure 3.

Modelling of the sites in three dimensions can also help to determine how the terrain was modified in order for the terrace to be constructed. There are two main ways in which terraces might have been constructed. They were either cut back into the slope and the soil removed was discarded or reused elsewhere, or they were cut partway into the slope and the soil removed was used to steepen the front edge of the terrace. The latter type was partly cut back into the slope and partly built out from the slope. These two types of terrace construction are illustrated in Figure 4. Increasing the steepness of the front edge of the terrace has defensive advantages. It is possible that one method was used for some terraces on a site, and the other method was used for other terraces on the same site. It may be possible to suggest which method of manufacture was used for terraces from the 3 D models produced in the computer.

For example, the large, relatively flat terrace shown in southwest of Figure 3 indicated by the arrow, seems to have been cut back into the slope, as indicated by the contour lines to the north of it. These contours are closer together than the contours across the rest of the slope. The slope below the terrace does not seem to have been significantly steepened, and so it might be suggested that provision of a flat area was the primary role of this terrace. There is no evidence to suggest that steepening the slope below the terrace was a primary concern, although one cannot discount

the possible effects of weathering on the angles of the slopes. Defence would almost certainly have been one component of the terrace's function, but the relative importance of different terrace functions can help to determine the dynamics of the site as a whole.

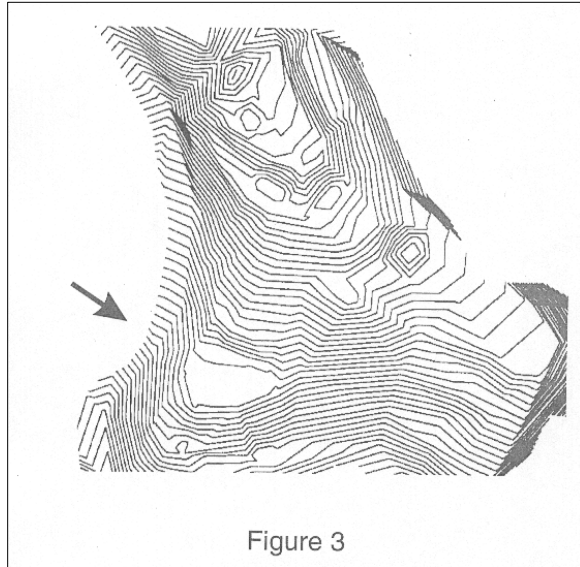


Figure 3.

Pits are also features often found on pa sites. They often can be seen on the surface and more pits are usually uncovered during excavation as pits were infilled during the prehistoric as well as the modern period. Pits were often deliberately infilled once they were no longer of use. Most rectangular holes, which are termed 'pits', on pa are assumed to be the archaeological remains of semi-subterranean storehouses. The average size is 2m wide and 4m long, and the average depth is 0.8m (from a sample of 229 pits from excavated pa sites). Many of these storehouses were used for storing kumara, the New Zealand sweet potato *Ipomoea batatas*, although others were used for weapons, equipment and special objects. There is some evidence that the storehouses occasionally became undesirable due to being infected with vermin or moulds and were occasionally burnt and/or infilled. In the more recent past many pits on what became farmland were filled in as a result of farming practices. The surface evidence of pits is an important part of the analysis of the relationship between surface and subsurface features.

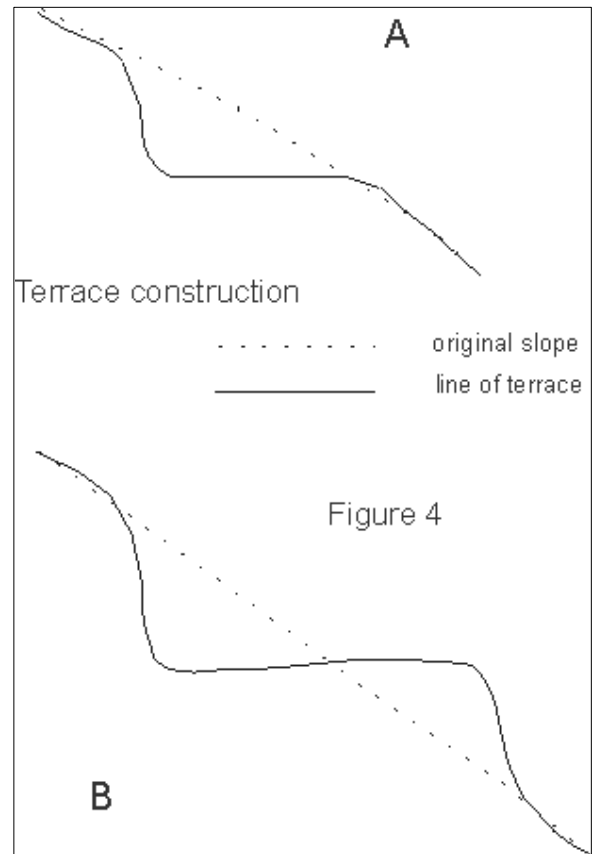


Figure 4.

The storage of kumara, a subtropical plant by origin, was a critical component of agriculture in New Zealand's temperate climate. Root crops were stored over the cooler winter months in order to be planted during the following growing season. A fairly restricted temperature and humidity range was crucial to ensure the viability of the root stock. Roofed semi-subterranean storage huts helped to maintain this temperature and humidity. Many pits occur along ridges and it has been argued that they were so positioned in order to maximise sunlight. The use of 3 D models to investigate the path of sunlight across these features can help to investigate the relationship between the positioning of pits within pa sites and the path of the sun. The influence of different sun angles on the shadows cast on a site can be seen in Figures 5 and 6

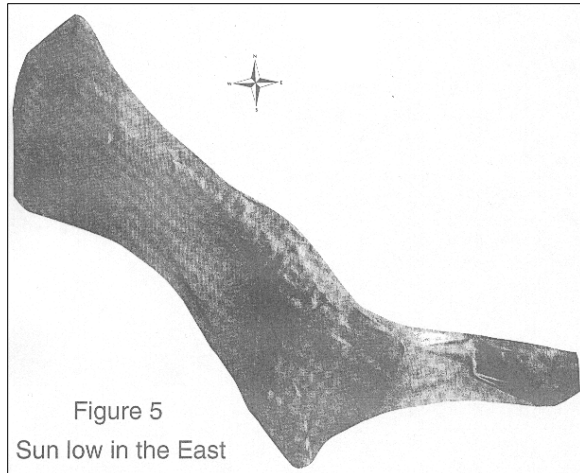


Figure 5.

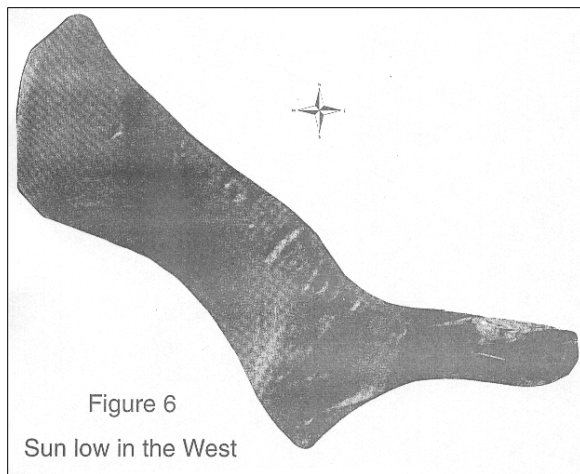


Figure 6.

An alternative perspective is that storehouses, since they contained valuable resources whether food or weapons and special objects, were situated where they could be easily defended. Many undefended sites containing pits have been found, so this argument is not meant to encompass all pits found on sites in New Zealand. However, within the context of defended sites such as pā, it is possible that the storehouses were meant to be defended (Barber 1996). There is evidence in the historical literature that storehouses occupied prime positions within some pā sites. In fact there are conflicting accounts stating that the chief's house and/or the main storehouse were situated on the highest part of the site (Nicholas 1817, Cruise 1824, Mascarin 1985). Although there was undoubtedly some confusion in the early literature concerning storehouses and dwellings as they both looked very similar when viewed externally, some of the accounts do refer specifically to storehouses, listing their contents, and

situating them within well-defended parts of the sites. Using GIS it is possible to examine the relationship between pits and defensive features in their archaeological context.

The arrangement of features within the sites is the result of the interplay of many complex factors. These factors include the constraints of the landform chosen for the site, the requirements of the people for whom the site was constructed in terms of living space at those sites where habitation occurred, storage space and space for other activities, domestic or defensive. Sunlight may have been an influence on the arrangement of features, perhaps in the case of pits, but other influences can be examined as well.

Defence seems to have been an important aspect of these sites' function. Archaeologists have analysed the types of earthwork defences employed at pā sites (see for example Groube 1964, 1970, Fox 1976, Davidson 1984). Analysis of the intervisibility between different parts of the site provides a new perspective on the defensive nature of these sites. Visibility between the sites and the surrounding landscape is also important. In particular, line of sight to the coastline - a potential route of access for people arriving by canoe, can be determined and the orientation of features within the site can be determined with respect to the views of the coastline. The reverse perspective - that of the view of the site exhibited to those people arriving by canoe, through the positioning of features within the site, must not be forgotten. The impression made by the site on people approaching was probably also of significant importance. Alternatively features may be orientated in order to provide a view of landward approaches to the site, or a view from the pā to the gardens where people would have been involved in cultivation of their crops. The relationship between features and the views of the surrounding landscape may have been an important defensive factor in the placing and layout of these sites.

Visibility studies provide another avenue for examining the site within the context of its immediately surrounding landscape. The land around a pā would have been as well known to the people who built the pā as our hometowns are to ourselves. The influence of the landform on which the site was situated was recognised very early in the study of pā. Best (1927) used it as the basis for his classification system. Analysis of the excavation reports and maps of pā has shown that the relationship with topography was important but not simplistic. Topography cannot be seen as a determinant of site form per se, although

it does have an obvious influence on the layout of the site. Recent studies of pa have demonstrated the importance of soil type and water availability with respect to pa (Irwin 1985, Jackson 1997). The use of GIS has demonstrated these relationships very clearly (Jackson 1997). Investigating lines of sight between the pa sites and the surrounding landscape provides an additional perspective on the way that these sites were used.

Lines of sight may be particularly important with respect to small sites where it is unlikely that habitation was of primary importance. Some defended sites are tiny and would not have provided much space for living activities. At these sites defence probably played a primary role and the situation of the site and its component features within the surrounding environment is more likely to have been as a result of mainly defensive reasons. It has been argued that such sites may have been used in a similar way to lookouts (Phillips 1987), from which lines of sight are, of necessity, crucial.

The use of a GIS capable of constructing 3 D models, therefore allows one to place the site in the context of its surrounding landscape. The immediate physical environment, including the landform on which the site is located, can be modelled and analysed according to factors such as slope and aspect which have an important influence on the way the sites were constructed and used. There is a fairly large amount of information available in New Zealand from excavation reports of pa, detailing what has been found below ground. This information, when used in combination with the surface information of archaeological features, can give an insight into how these sites were constructed and their history of use.

The first attempt at an overall synthesis of pa sites was the monograph on the subject was produced by Best in 1927. Pa typology formed the basis of the early archaeological work (Golson 1957, Groube 1964, 1970). Some more general descriptions and discussions of site function can be found in the literature, most notably Fox (1976) and Davidson (1984). There have also been some regional studies of pa sites (Irwin 1985). The use of modern technology has enabled the collation of a large amount of information from excavation reports as well as from the surveying of sites. GIS allows a new perspective on this information and increases our knowledge about certain aspects of pa site

manufacture and use. The use of GIS also provides the basis for additional forms of computer analysis, such as fuzzy logic and neural networks, which allow one to examine the dynamics of sites in greater detail.

The collection of accurate survey data in order to be able to construct 3 D models of the site is very important. The influences of the resolution of this data have already been mentioned. Data that is too coarse or inaccurate cannot be used for modelling. However, once accurate, detailed data has been collected, the benefits are many, both in terms of analysis and display. The GIS software can produce images of the sites that are almost photographic in quality (cf Figures 5 and 6). These images can be used to show people what the sites look like, from all angles, when actual access to the site may be restricted. These images can be used to satisfy the curiosity of visitors, whilst limiting the number of people actually walking across the site. Some pa are regarded as *tapu* by many Maori and 3 D models are occasionally accepted as acceptable alternative ways to show people the sites. The images can reveal the nature of densely vegetated sites, where vegetation obscures the view of the site, but does not restrict the collection of survey data. The 3 D models have enormous potential for education, especially using the World Wide Web. They can enable people to visit the sites in a 'virtual tour' and be used for explanation of aspects of New Zealand archaeology.

The results of research into pa using GIS can therefore easily be used to inform the wider public about these sites. The use of computer technology and GIS makes this easier than ever before and we should certainly take advantage of it. As our knowledge about these sites increases, so they become more interesting to other people as well. Furthermore, the use of computer technology allows us to generate information about these sites in a way that is more accessible to people, both in terms of ease of use as well as ease of interpretation.

In terms of the research itself, many new perspectives into pa sites are being revealed through the use of GIS and related technologies. A greater understanding of the interaction between site and landscape is being achieved, as well as between features, both surface and subsurface, on the sites themselves. This understanding can be used as the basis for further research and highlights other interesting research questions concerning pa.

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