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IMAGE ENHANCEMENT OF PHOTOGRAMMETRIC MEASUREMENTS AT THE KAIAPOHIA PA SITE, CANTERBURY

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ABSTRACT

The photogrammetric technique was used at the Kaiapohia Pa site, Canterbury, New Zealand, to obtain a 11 657 point digital terrain model of position and elevation data. Contour plots of these data identified features of pa construction, such as the pa embankment walls, that are observed from the ground or from low angle aerial photographs. Computer generated false sun images of the digital terrain model have been used to identify internal features of the site that are not observed under natural light conditions and are possibly related to human occupation of Kaiapohia Pa.

INTRODUCTION

Geophysical and other remote sensing techniques allow non-destructive investigation of relics from human occupation at archaeological sites. White and Broadbent (1992, 1993) review the archaeological application of various geophysical techniques. They applied the geophysical techniques of magnetic and resistivity prospection to an area of the Kaiapohia Pa site, north of Christchurch (Fig. 1). Maps of magnetic gradient in a central area of the pa site identify lineations of magnetic anomalies. Features of the human occupation of the site seem to be identified by these lineations. Resistivity measurements, in an area (Fig. 1) within that of the magnetic investigation, also identify linear features some of which relate to those identified by the magnetic measurements. Some anomalies appear to form simple geometric shapes. White and Broadbent (1993) describe the history of the pa site.

'Qualitative' photogrammetry, where aerial photographs are interpreted in terms of observable ground features, has been applied before to archaeological problems in New Zealand. Brailsford (1981) and Keen (1990) interpreted aerial photographs for visual signs of walls, embankments, gardens and other evidence of human occupation. "Quantitative" photogrammetry is the measurement of ground elevation and position from aerial photographs. Ground elevation data can be processed using computer techniques of relief shading. An advantage of the relief-shading method in presentation of topographical

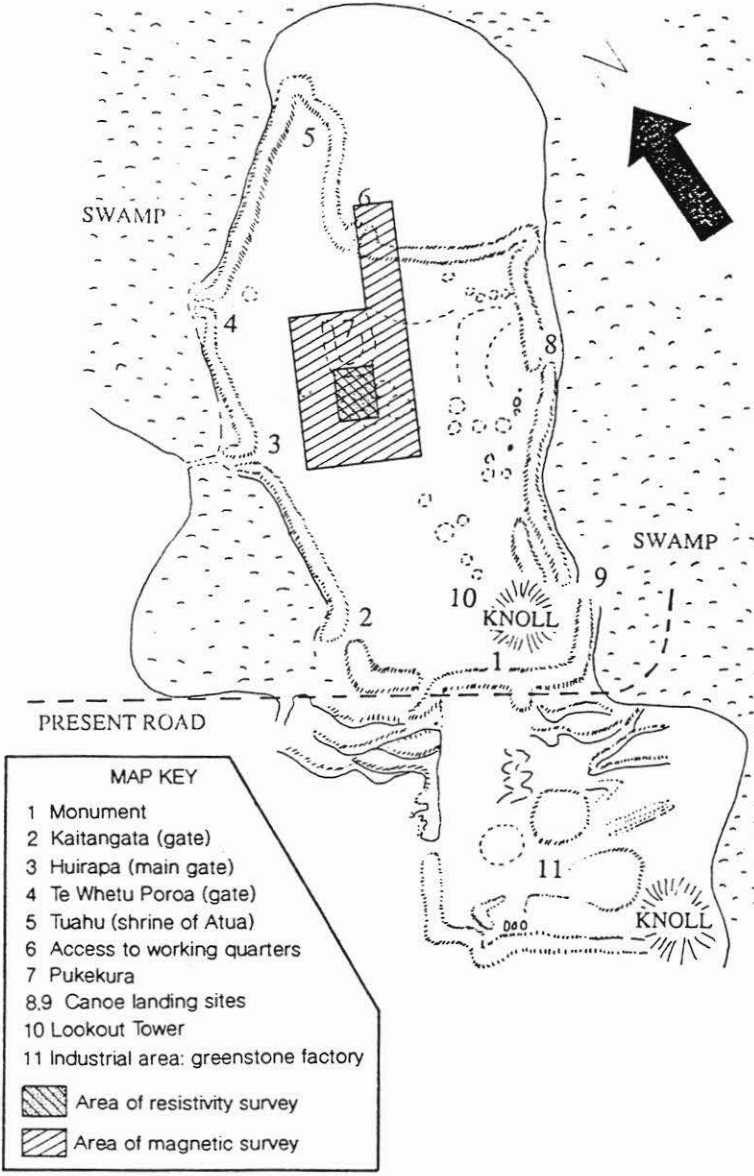

Figure 1. Map of the Kaiapohia Pa site (after England, 1989) showing magnetic and resistivity survey areas.

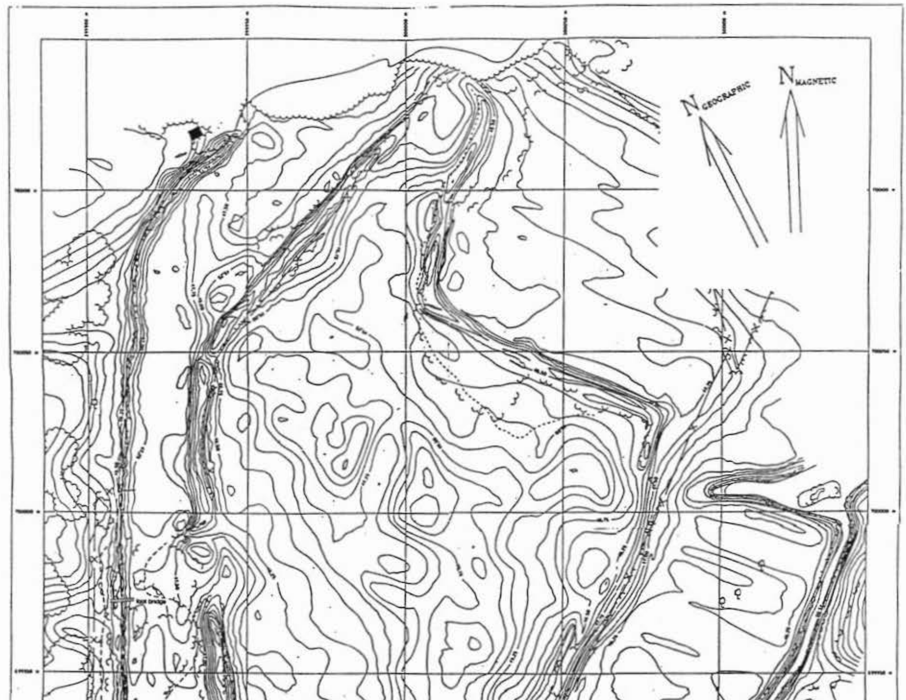

Figure 2. Contours of elevation from the digital terrain model at the Kaiapohia Pa site measured by photogrammetry. Contour interval 0.25 m.

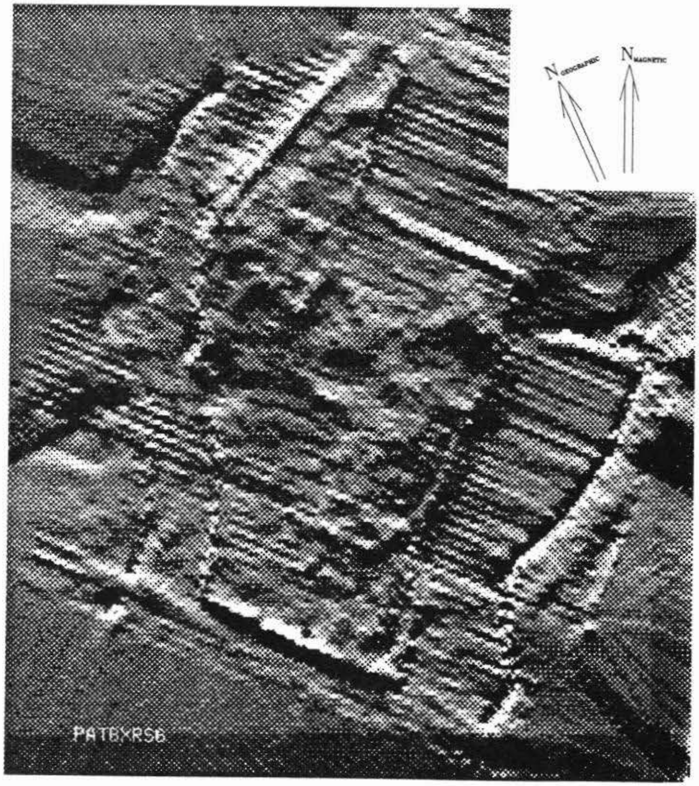

Figure 3. Relief-shaded image. Illumination azimuth 20°, illumination elevation angle 5°.

information is that the visual representation of subtle variations in elevation is clearer than on standard contour plots. The relief-shading method generates an image that looks like an aerial photograph. Aerial photography, particularly early or late in the day when the sun angle is low, is used traditionally in archaeological investigation and a number of such black and white and colour photographs of the Kaiapohia Pa site have been taken. Computer generated relief-shaded plots have great advantage over natural photography in that a "sun" may be simulated in any part of the sky, at any angle to the horizon, and an enhancement of natural topographic features can result.

This paper outlines the procedure for obtaining a digital terrain model from

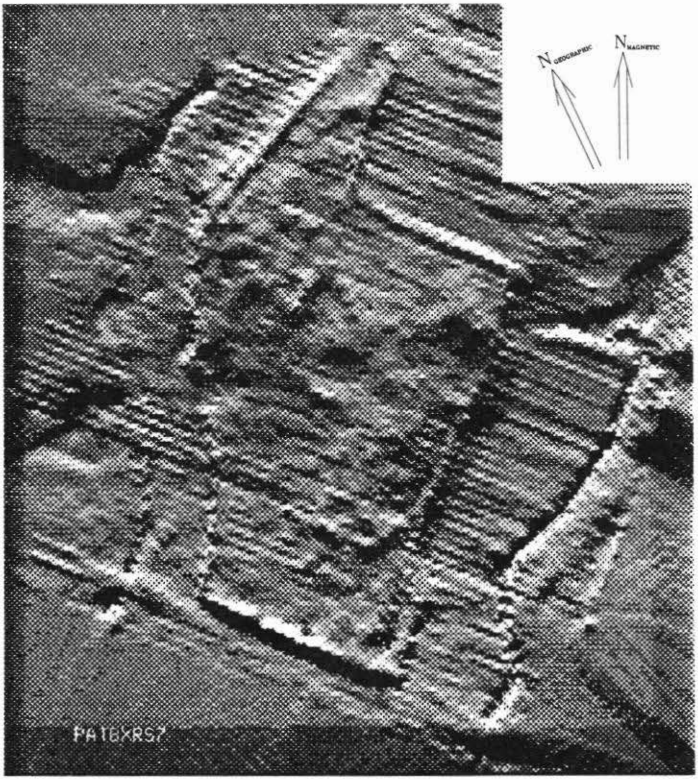

Figure 4. Relief-shaded image. Illumination azimuth 20°, illumination elevation angle 10°.

vertical aerial photographs using photogrammetry. The computer generation of relief-shaded images of the Kaiapohia Pa site is summarised, and various images presented. The relief-shaded images reveal features of the Kaiapohia Pa ground surface, many of which cannot be seen on the photographs under natural light conditions.

PHOTOGRAMMETRY MEASUREMENTS

Vertical aerial photographs were taken by the Institute of Geological and Nuclear Sciences. Ground control consisted of eight ground markers, spread evenly across the site, and surveyed to millimetre accuracy in elevation and plan. Each marker was made of four pieces of rectangular white card, each

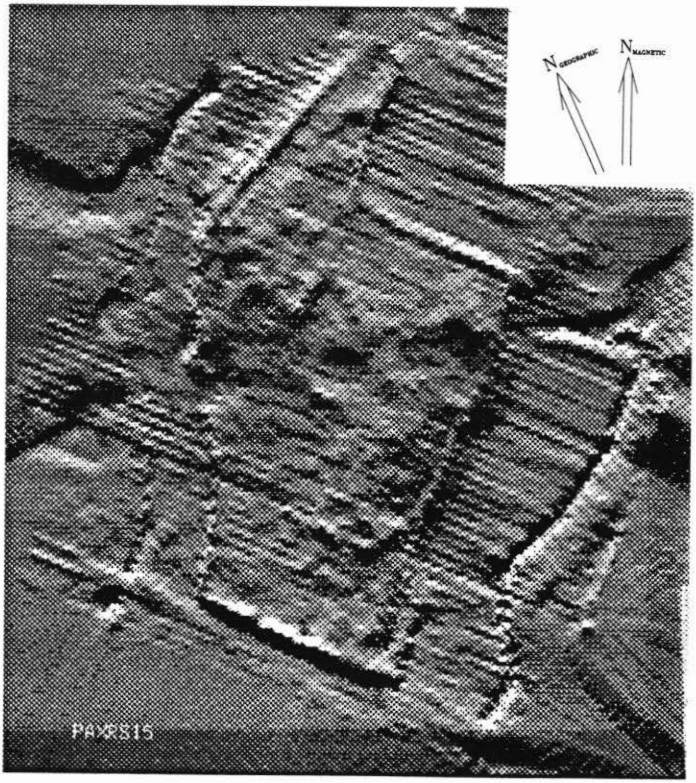

Figure 5. Relief-shaded image. Illumination azimuth 20°, illumination elevation angle 15°.

piece approximately 0.2 x 0.5 m, laid out in the form of a cross.

Three vertical aerial photographs were processed by the Department of Survey and Land Information. Large errors, of up to 1 metre in elevation, were discovered in the control values during the processing. Because of this two digital terrain models of separate parts of the pa site were created. There was an elevation difference of 0.3 m between the two models for points common to both models. This difference was corrected by adjusting the datum of each model. The two models were combined to produce a single digital terrain model on a 2.5 m grid of the whole site (Fig. 2). Relative accuracy is estimated as 90% within ±0.14 m for elevation and 90% within ±0.16 m for plan (Dykes, pers. comm.). The Department of Survey and Land Information produced the original of Figure 2 on a transparency of size 74 x 56 cm.

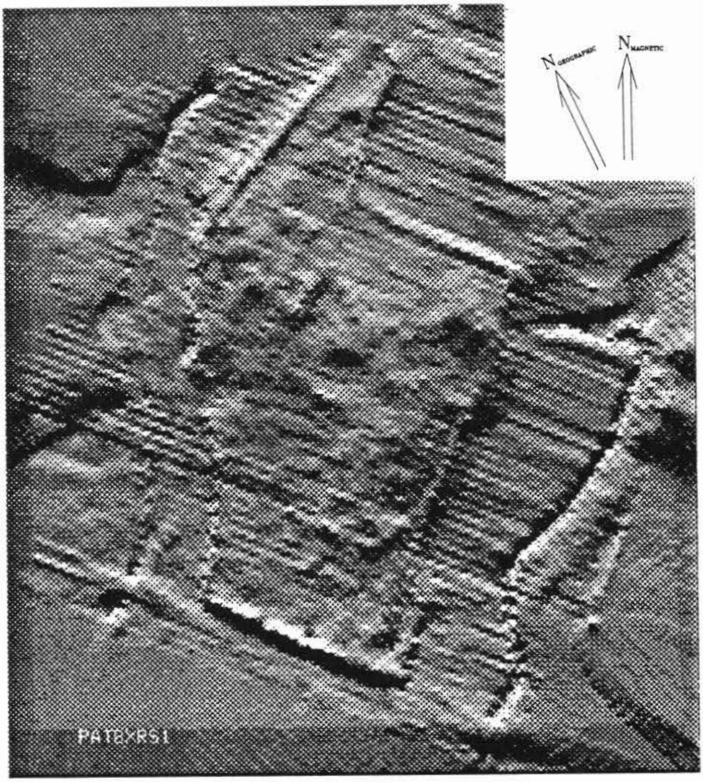

Figure 6. Relief-shaded image. Illumination azimuth 20°, illumination elevation angle 30°.

Contours at an interval of 0.25 m in Figure 2 clearly identify the two streams on the left and right of the pa site, and the embankment walls of the pa. Various surface features are marked on the map - the Kaiapohia Pa monument, Preeces Road, trees, two footbridges, and several buildings to the north of the site. Internal features of the pa are also identified by these contours. The "L" shaped depression in the ground around 700000N and 300000E can be observed, along with breaks in the contouring due to topographic disturbance in the vicinity of Huirapa gateway. Relatively flat ground is shown by the contours on the inside of the eastern embankment. The canoe landing sites are also observed on the contour map.

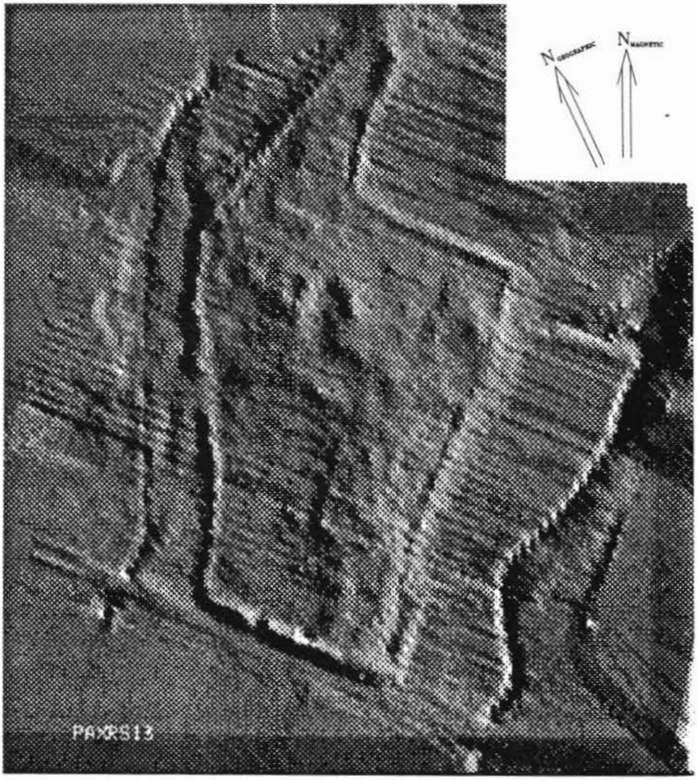

Figure 7. Relief-shaded image. Illumination azimuth 90°, illumination elevation angle 15°.

ENHANCEMENT OF IMAGES

Position and elevation data in the terrain model were provided by the Department of Survey and Land Information in digital form as 11 657 position and elevation points. The computer program PC-EPIC (Mongillo pers. comm.) was used to generate images of the pa site that are relief-shaded.

Figures 3, 4, 5 and 6 are relief-shaded images all having the same sun azimuth of 20° east of geographic north. The effects of varying sun elevation above horizontal from 5° (Fig. 3), through 10° (Fig. 4), 15° (Fig. 5), and 30° (Fig. 6), are seen as a decrease in the length of the digital shadow with increasing elevation. Images show some effects of errors in the data capture process as lineations with an orientation of 130° to geographic north. These errors are due

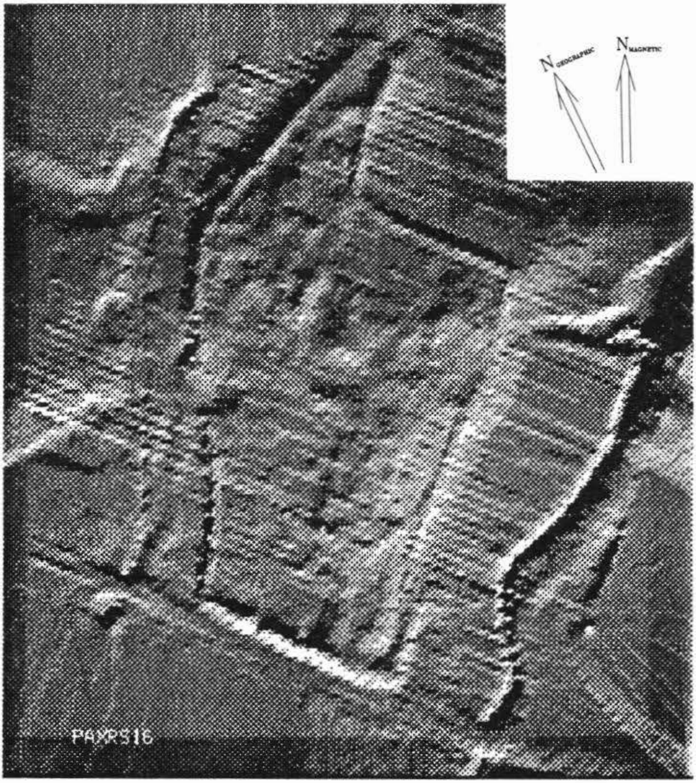

Figure 8. Relief-shaded image. Illumination azimuth 180°, illumination elevation angle 15°.

to the digitising process. It is possible that these erroneous lineations could influence visual interpretation of the images, particularly in Figure 3 which has the lowest sun elevation and enhances the lineations the most. However, a number of features of the pa construction are visible. The pa walls, and gaps in the walls, are obvious in these figures and in aerial photographs. Some details of internal pa construction, which are not observed on either low angle aerial photographs or contour plots, can be seen as lineations and/or rectangular depressions picked out by shadow or highlight. As the sun angle rises through Figures 4, 5 and 6, these features are still observed, although are less obvious. Figures 7, 8, 9, and 10, are relief-shaded images with the same sun elevation of 15° above the horizontal. The illumination direction varies from due east geographic (Fig. 7), due south (Fig. 8), due west (Fig. 9), and due north (Fig. 10). Some experimentation is required to find the best illumination

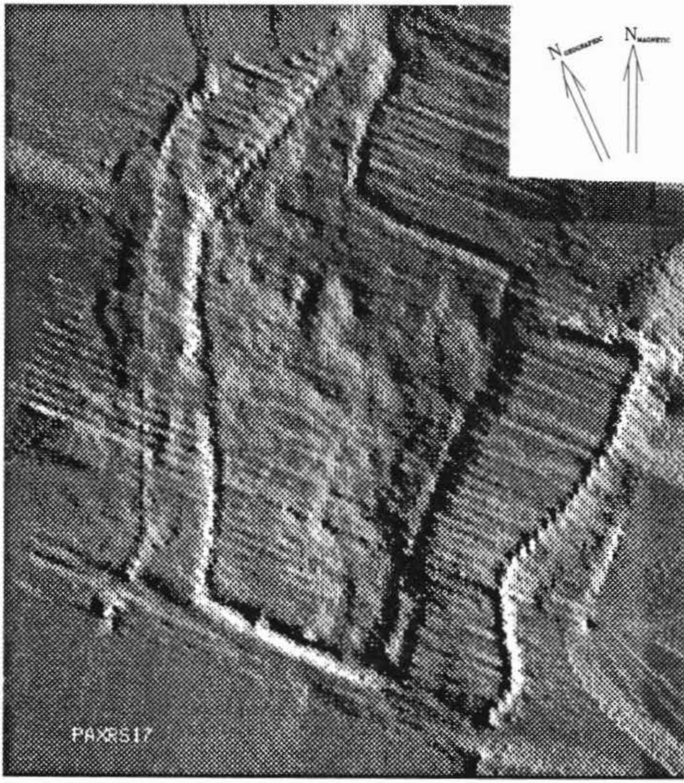

Figure 9. Relief-shaded image. Illumination azimuth 270°, illumination elevation angle 15°.

direction to enhance features within the digital terrain model. For example in the region near the northern canoe landing site, item 8 in Figure 1, there appears in Figure 7 a near-rectangular feature. The long axis of this depression is aligned approximately 10° west of north. Other relief-shaded images see this region as a depression, but not with the same clarity as in Figure 7.

Figure 11 is an interpretation which shows the features of pa construction that have been identified, or suggested by interpretation of low angle aerial photographs, by topographic maps and/or by relief-shaded images. The embankment wall is highlighted by the discontinuous line around the pa. Features A to K are tentatively identified as features of pa construction. Feature A, identified in shaded-relief images as having a relatively sharp north, west and south boundaries seems to be associated with a gap in the embankment wall.

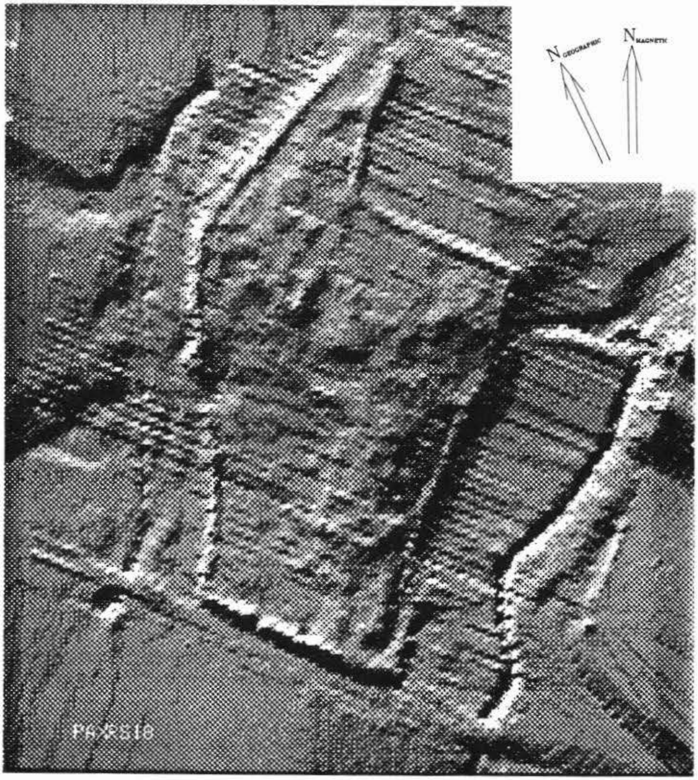

Figure 10. Relief-shaded image. Illumination azimuth 0°, illumination elevation angle 15°.

Note that item 6 in Figure 1 places a gateway immediately to the south of Feature A. It seems likely that the gateway in Figure 1 is misplaced, and should be at A further to the north. Features B, C, E and H are based on "right angled" features in the relief-shaded maps. A saw-tooth pattern has been drawn on one edge of these features because an enclosed geometric feature is not identified. It is possible feature B could be rectangular, centred near the "B" in Figure 11.

The most obvious feature within the pa is feature D, which is visible, in part or in total, on all the relief-shaded images as well as in aerial photographs and on the ground. Although ground contours (Fig. 2) show the northern and eastern lobes of the feature, relief-shading shows closure of the shape in the southwestern corner. Feature F is shown by relief-shading as near the eastern

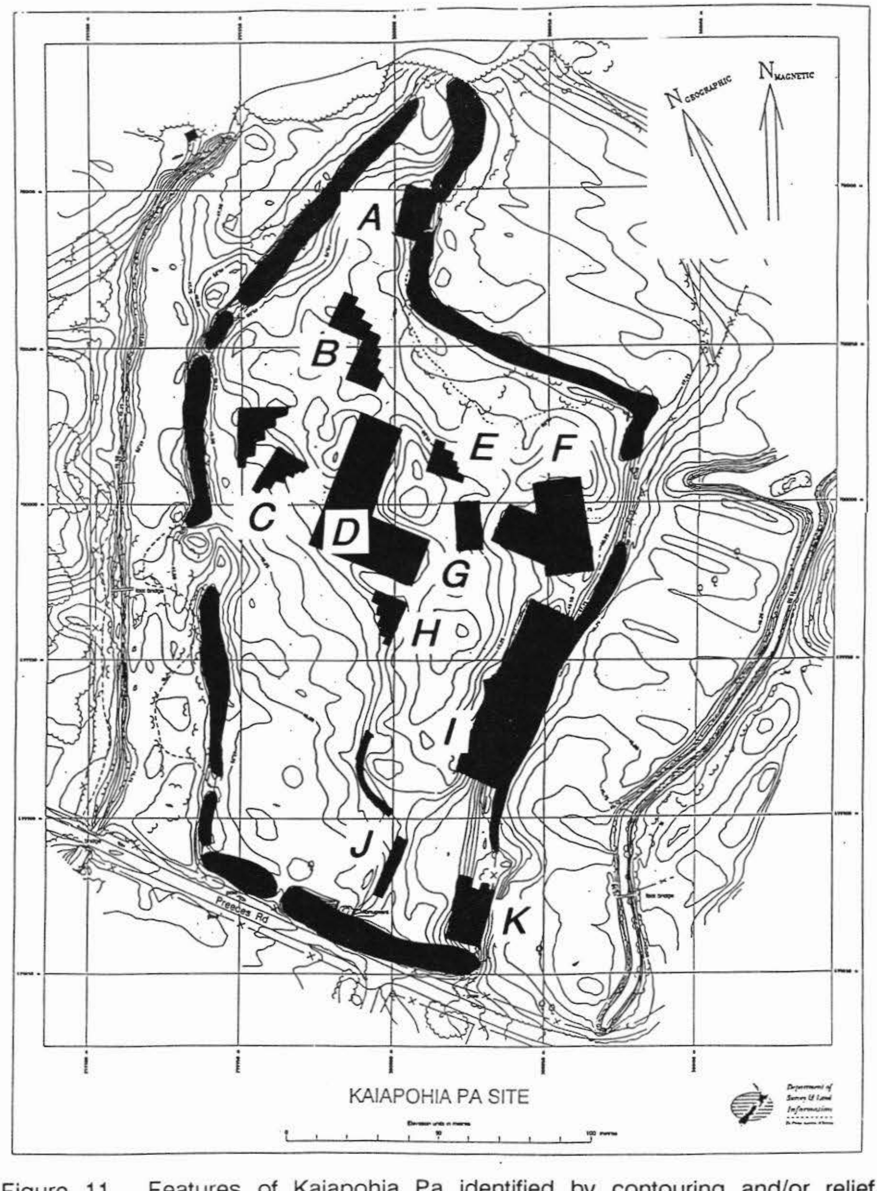

Figure 11. Features of Kaiapohia Pa identified by contouring and/or relief shading of the digital terrain model. These features may be related to the human occupation of the site.

embankment wall. Ground contours seem to identify a northwestern lobe to the rectangular depression, which is also seen on some of the relief-shaded plots, but F is not observed in aerial photographs. Feature G is a small rectangular depression observed, for example, in Figure 10. Feature J appears to be two regular lineations, while features I and K appear to be flat rectangular depressions closely associated with the eastern embankment wall. It may be that feature K has something to do with the southern canoe landing site.

SUMMARY

The photogrammetric technique was used at the Kaiapohia Pa site to obtain a digital terrain model from vertical aerial photographs. Position and elevation information was measured for 11 657 points at a 2.5 m grid spacing over the pa site. Contour plots generated by this process clearly showed some of the more obvious topographic features like nearby streams, embankment walls and some internal construction of the pa. Contour maps also showed some systematic error that is related to the data capture process. Relief-shaded images of the digital terrain model were generated by computer for a variety of illumination azimuth and elevation angles. This process resulted in a number of regular features being identified within the pa embankment walls that were not observed in the aerial photographs. The shapes of some of these features suggests that they are probably related to the human occupation of the site.

ACKNOWLEDGEMENTS

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