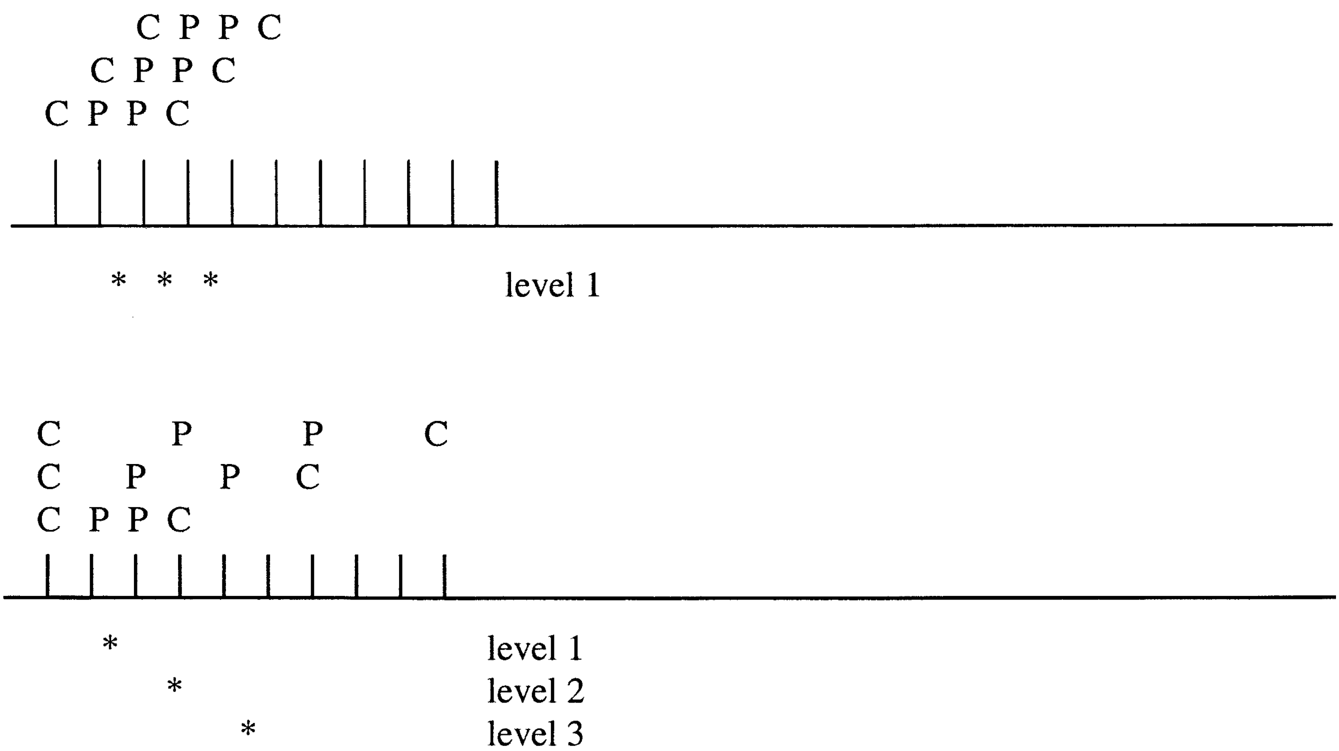
5 **Geophysical survey** *by Lindsey Collier, Bruce Hobbs, Tim Neighbour and Richard Strachan*

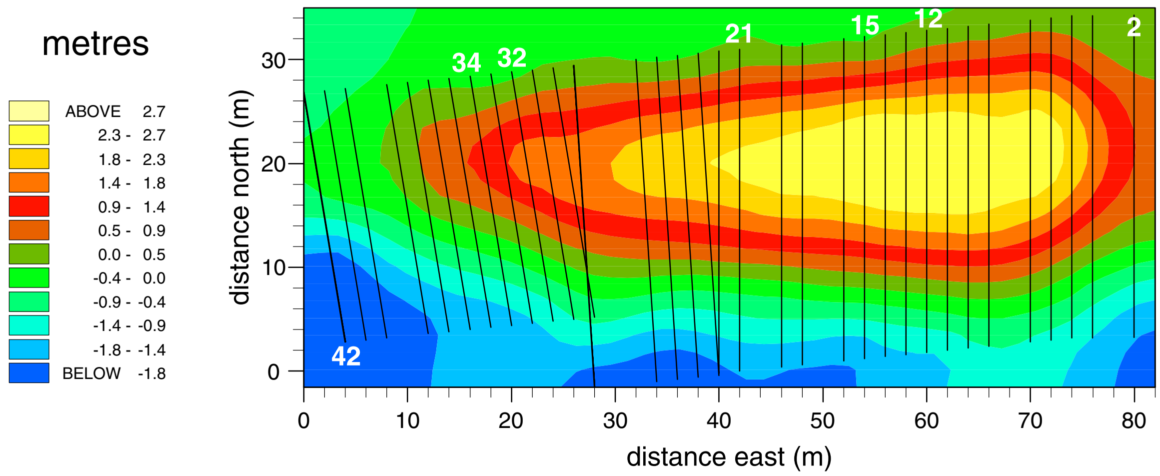
Various geophysical prospection techniques are applicable to specific archaeological problems (Clark 1996). Whilst area resistivity and gradiometry surveys have been used with some success to record ploughed-out long barrows (Marshall 1998), these techniques would have been logistically difficult in the terrain at Capo. Furthermore, as the main aim of the project was to attempt to reveal internal structure, a technique that would provide depth information was required. Capo Long Barrow is covered with tree stumps and bracken and was considered to be inaccessible for a ground-penetrating radar survey. However, the success of resistivity imaging conducted on the banks and ditches at the Mull of Galloway (Neighbour *et al* 2001) suggested that resistivity profiling would also prove useful at Capo Long Barrow. The survey was undertaken with the particular goals of testing the hypothesis that the internal structure of the barrow was similar to that at the nearby, excavated long barrow at Dalladies (Piggott 1974) and attempting to assessing the level of damage that had been caused to the barrow by rabbit burrowing and tree roots. The data at Capo was collected by Lindsey Collier over twenty days in September 1999.

5.1 The Resistivity imaging technique

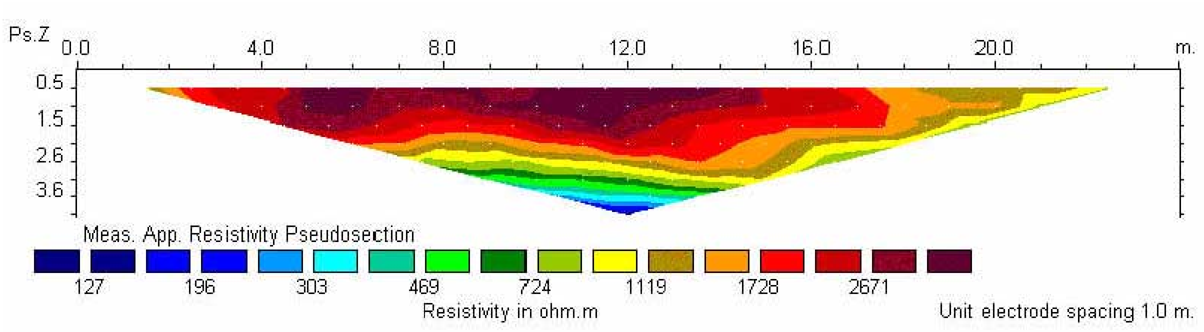
In the resistivity imaging technique (e.g. Loke and Barker 1995), a number of electrodes (in our case 25 or 32) are equi-spaced along a profile and connected via a multi-core cable to a resistivity meter and a laptop computer. The selection of electrodes (generally two current electrodes and two potential electrodes) and the subsequent resistivity measurement is made under software control. For the Capo survey the Wenner electrode array was used throughout, whereby four equi-spaced electrodes are selected (Illus 5a). Current is passed through the outer two and the potential difference measured between the inner two, enabling apparent resistivity to be determined for the given spacing and electrode array position along the profile. A pseudo-section may be generated by assigning the value of the measured apparent resistivity to a location corresponding to the centre point of the 4-electrode array at a nominal depth of half the electrode spacing. Using a multicore cable with electrodes equally spaced a distance a apart along a line, the software selects all the Wenner configurations with electrode spacing a,



Illus 5 Capo Barrow: (a, above) use of electrode sequences to obtain measurements at different lateral positions; (b, below) use of electrode sequences to obtain measurements at different depths.



Illus 6 Capo Barrow: positions of resistivity profiles taken across the long barrow and the topography used in modelling the profiles



Illus 7 Capo Barrow: Profile 34, apparent resistivities (no topographical correction); north at left side of plot

then all those with electrode spacing 2a (providing deeper information) and continues to a spacing of 8a for a 25-electrode system. This yields a triangular vertical cross-section of apparent resistivity beneath the profile (Illus 5b). By moving some electrodes along the profile, a trapezoidal region can be obtained. Electrode spacings for the Capo survey varied between 1m and 8m, yielding resistivity information to a depth of approximately 4m.

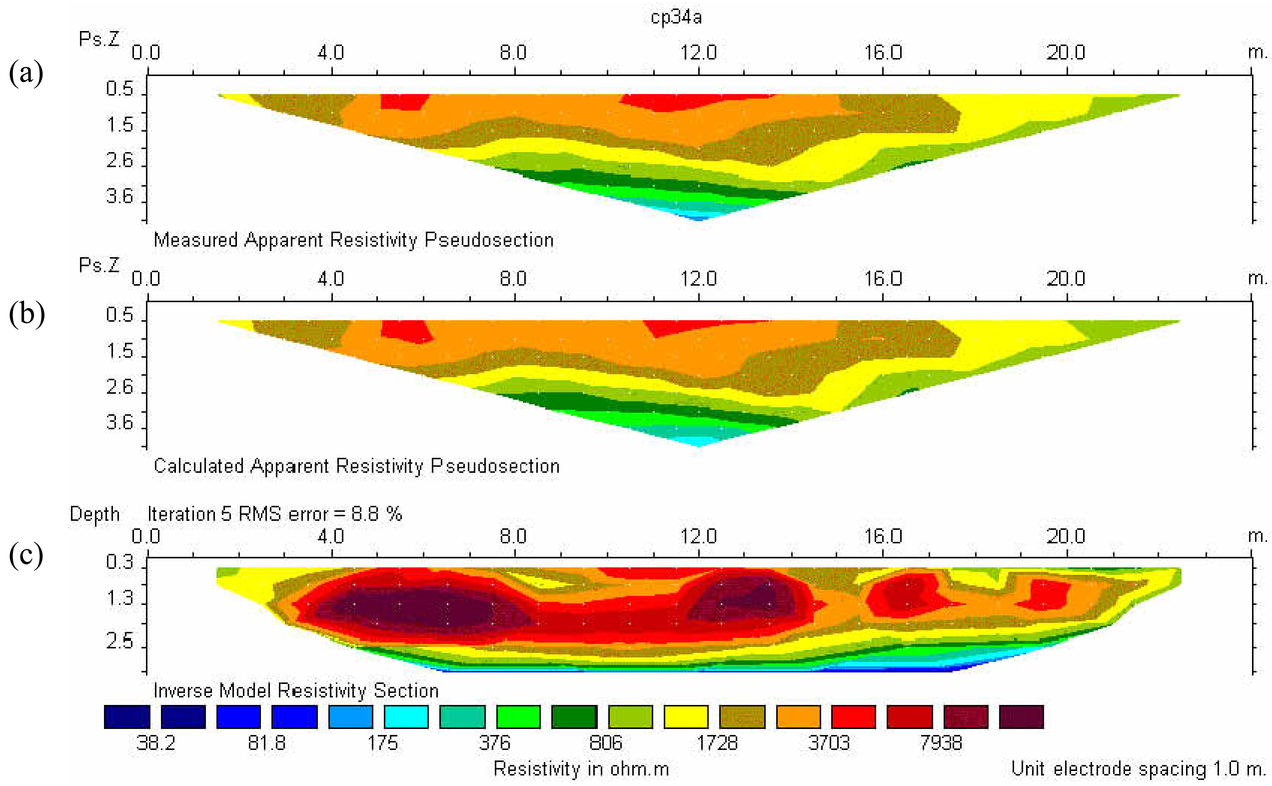
Measured apparent resistivities have then to be inverted to determine a model of the resistivity structure beneath the profile. Where a profile is not along a flat surface, the topographic relationships between the electrodes have to be taken into account. The two-dimensional inversion package 'RES2DINV', which includes the effects of topography, was used throughout.

5.2 Resistivity images

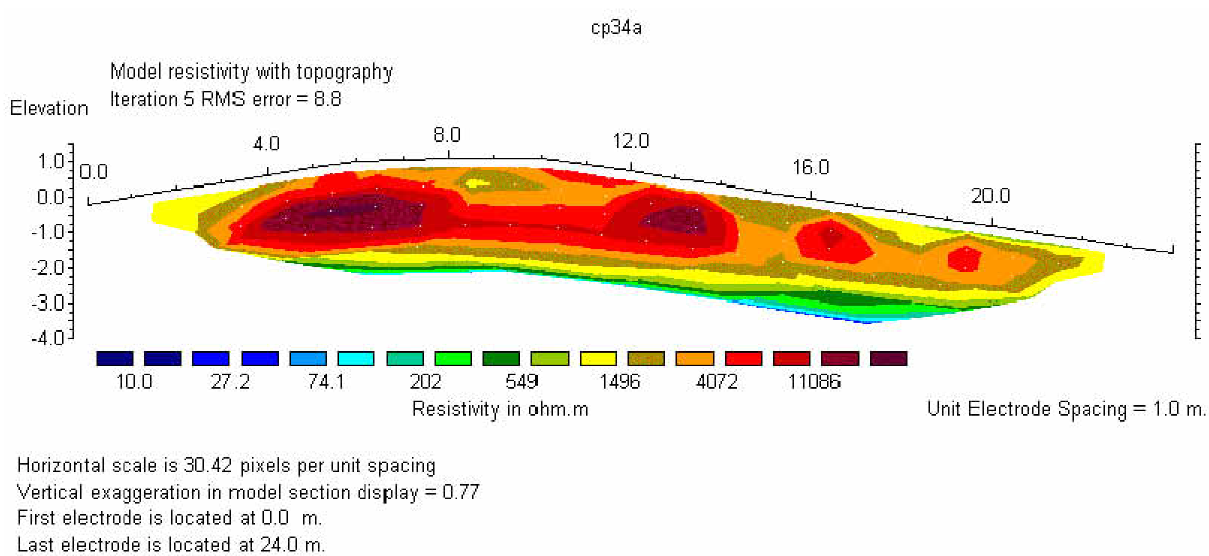
Forty-eight profiles were surveyed across the barrow and the small mound to its east. Illus 6 shows the positions of the 35 resistivity profiles taken across Capo Long Barrow, together with the topography used in modelling the images. The electrode separation was 1m and the profiles were generally spaced 2m apart, although this was not always possible, due to having to place the line so that it avoided tree stumps. Measuring tapes were used to locate the profiles and individual electrodes. Profiles are labelled to indicate their position along the barrow. The positions of those profiles on which 'bad data' were recorded are not shown.

Selected images from positions 34, 32, 21, 15 and 12 (Illus 7–13) have been used to illustrate some of the main features seen in the vertical cross-sections and then an alternative way of viewing the data has been presented.

Illus 7 shows the apparent resistivity measured along profile 34 at the narrower, western end. The profile length is 24m and the depth scale is pseudo-depth (i.e. resistivities are plotted at half the electrode spacing). High resistivity regions can be seen at about 5m and 12m along the profile and the deeper regions are more conducting. These apparent resistivities have to be inverted to obtain modelled resistivities with a true depth scale. Inversion is achieved using 'RES2DINV' and account is taken of the topographic positions of the electrodes. RES2DINV accepts electrode positions as measured along the surface and these are estimated to be

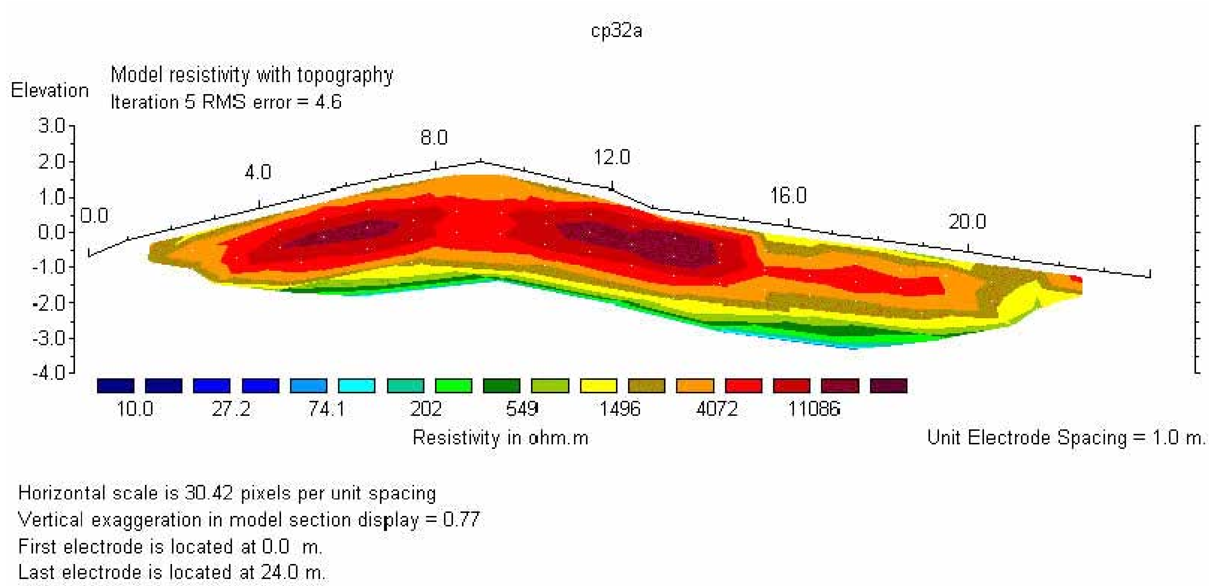


Illus 8 Capo Barrow: (a) Profile 34, measured apparent resistivities and topography used in modelling the profiles (scale altered to accommodate larger variations seen in the model [8c]); (b) Profile 34, apparent resistivities calculated from the model; (c) Profile 34, modelled resistivity cross-section with true depth scale. North at left side of plots

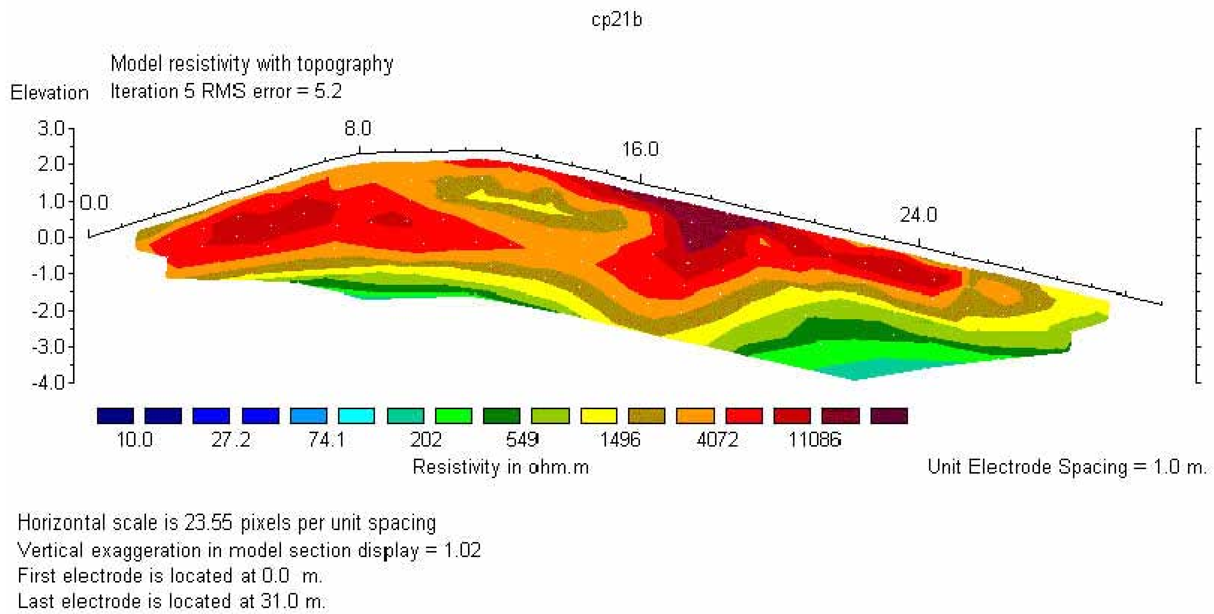


Illus 9 Capo Barrow: Profile 34: modelled resistivity cross-section, topographically corrected. North at left side of plot

accurate to 20mm within an individual Wenner array. This yields an uncertainty of at most 2% (for near surface apparent resistivities), which is comparable to the instrument measurement error demanded on acquisition and is negligible in comparison to the two orders of magnitude variation in the range of resistivities encountered. Illus 8(a) shows the original measured apparent resistivities, but with a resistivity scale change to accommodate the larger variations seen in the model; Illus 8(b) shows the apparent resistivities calculated from this model; and Illus 8(c) shows the resulting modelled resistivity cross-section with true depth scale. The calculated apparent resistivities compare reasonably well with



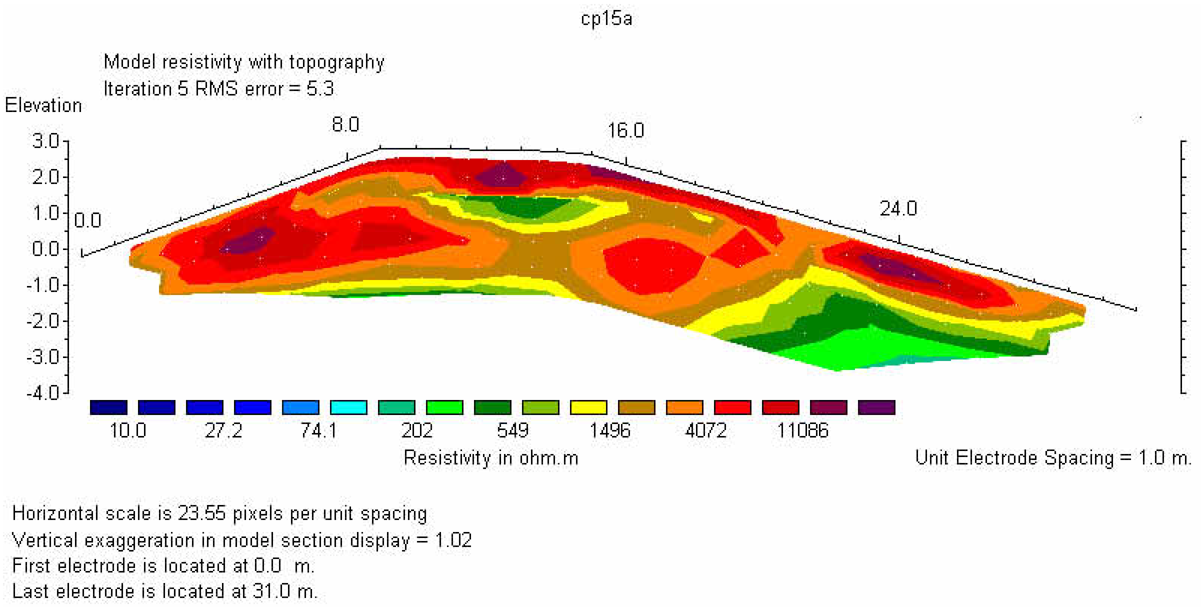
Illus 10 Capo Barrow: Profile 32: modelled resistivity cross-section, topographically corrected. North at left side of plot



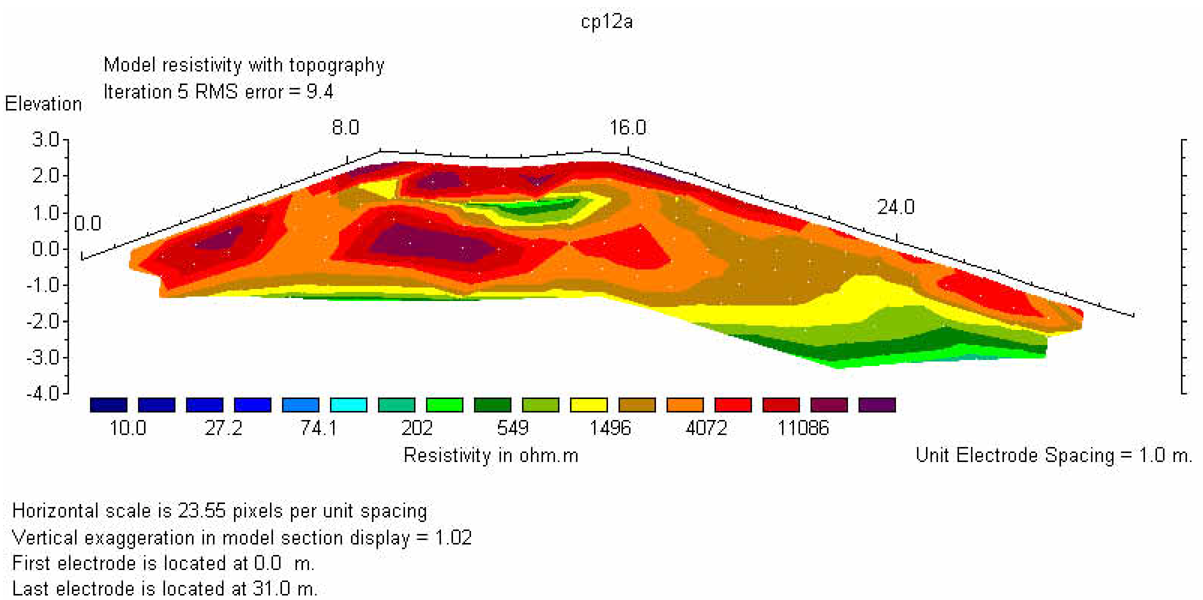
Illus 11 Capo Barrow: Profile 21: modelled resistivity cross-section, topographically corrected. North at left side of plot

the measured apparent resistivities, the root mean square (rms) difference being 8.8%. Topography has been used in this calculation and the final model with the topography included is shown in Illus 9. Two high resistivity features dominate the cross-section and are interpreted as the revetments defining the edges of the barrow at 5.5m and 13m along the profile.

Nearby, profile 32 shows similar features (Illus 10); the revetments are well delineated at 6m and 13.5m. The inversion result for profile 21, midway along the barrow, is shown in Illus 11. The revetments can be seen at 5m and 18m, and in between there is a region with distinctly lower resistivity. Further to the east, profile 15 (Illus 12) shows the revetments lying at 5m and 24m, and in between them a conducting region surrounded by high resistivity. The surrounding high resistivity is suggestive of stones that may have formed part of a stone-defined mortuary structure. Profile 12 (Illus 13) is a further example with a distinct high resistivity block surrounding an area of low resistivity. Similar structure is seen on neighbouring profiles between profile 23 and profile 11. Either this represents a continuous inner chamber



Illus 12 : Cappo Barrow: Profile 15: modelled resistivity cross-section, topographically corrected. North at left side of plot



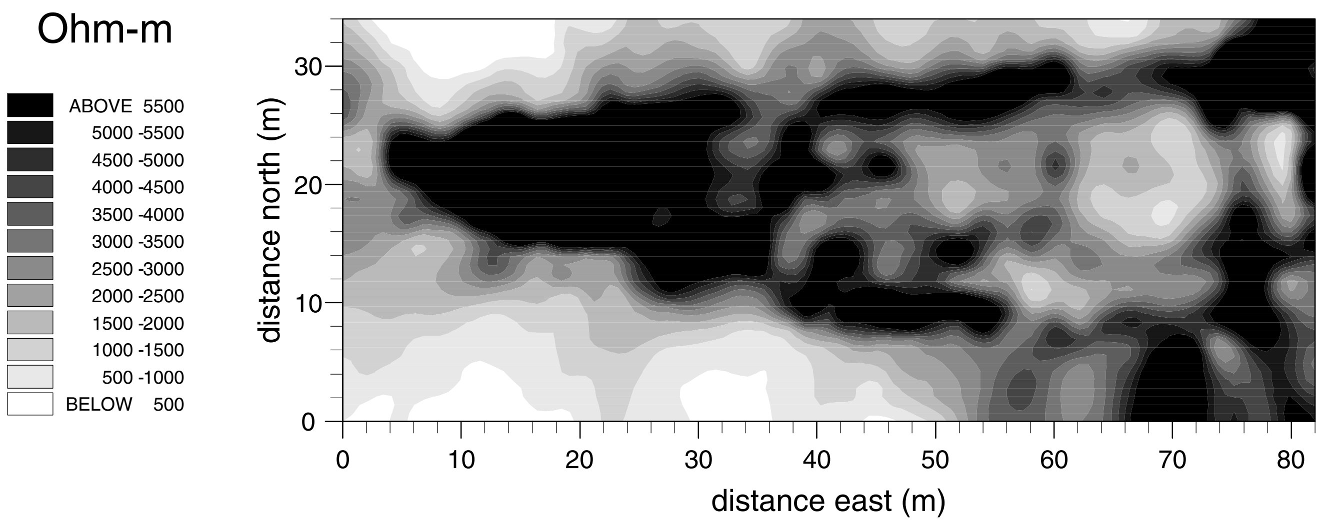
Illus 13 Capo Barrow: Profile 12: modelled resistivity cross-section, topographically corrected. North at left side of plot

24m long by 8m wide, or individual blocks may be associated with distinct burials.

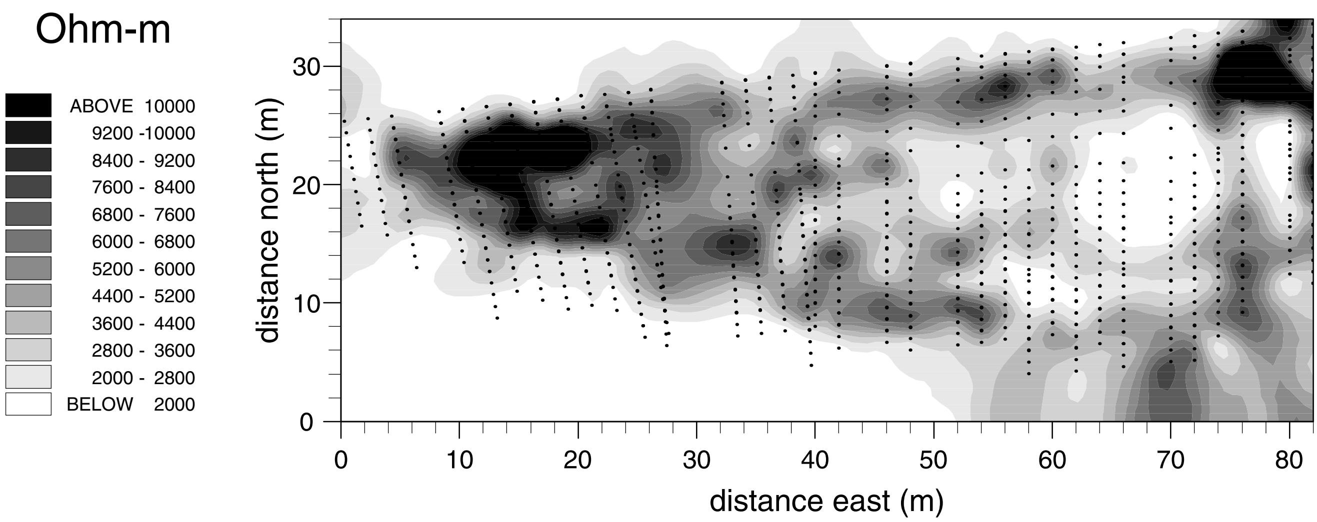
5.3 Plan views of resistivity

An alternative method of presentation, often used when image data has been collected beneath several neighbouring profiles, is to collate all the modelled images and to view horizontal slices of resistivity variations at particular depths (Illus 14–17). The depths are related to an arbitrary datum of 0m (Illus 6). The positions of all the profiles surveyed are shown on Illus 6 and the data points (resistivity blocks in the inverted models) that contribute to the horizontal slices at –0.5m are shown on Illus 17: these can be used to judge a high level of confidence in the features described below. Those parts of the plots of the horizontal slices (Illus 14–17) that lie beyond the ends of the profiles, as shown on Illus 6, are data-processing artefacts and should be ignored.

Coordinates in parenthesis in the following text relate to the axes on Illus 14–17. Eastings precede



Illus 14 Capo Barrow: Horizontal depth slice through collated modelled images at a datum level of –0.5m (Scale 500Ωm – 5500Ωm). Presented by UNIMAP

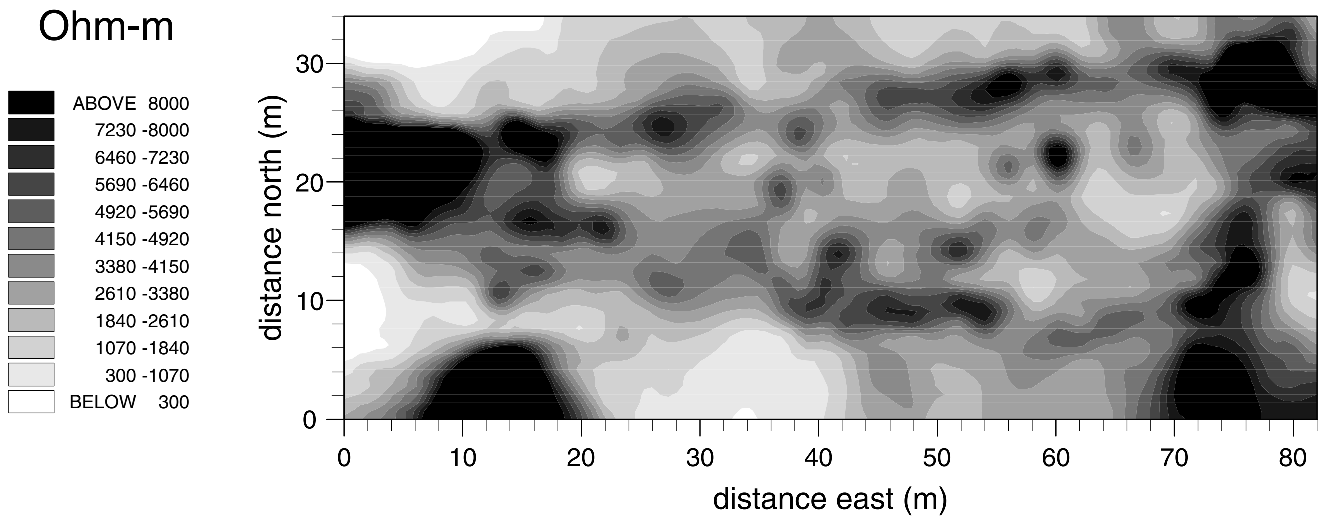


Illus 15 Capo Barrow: Horizontal depth slice through collated modelled images at a datum level of –0.5m (Scale 2000Ωm – 10,000Ωm). Presented by UNIMAP

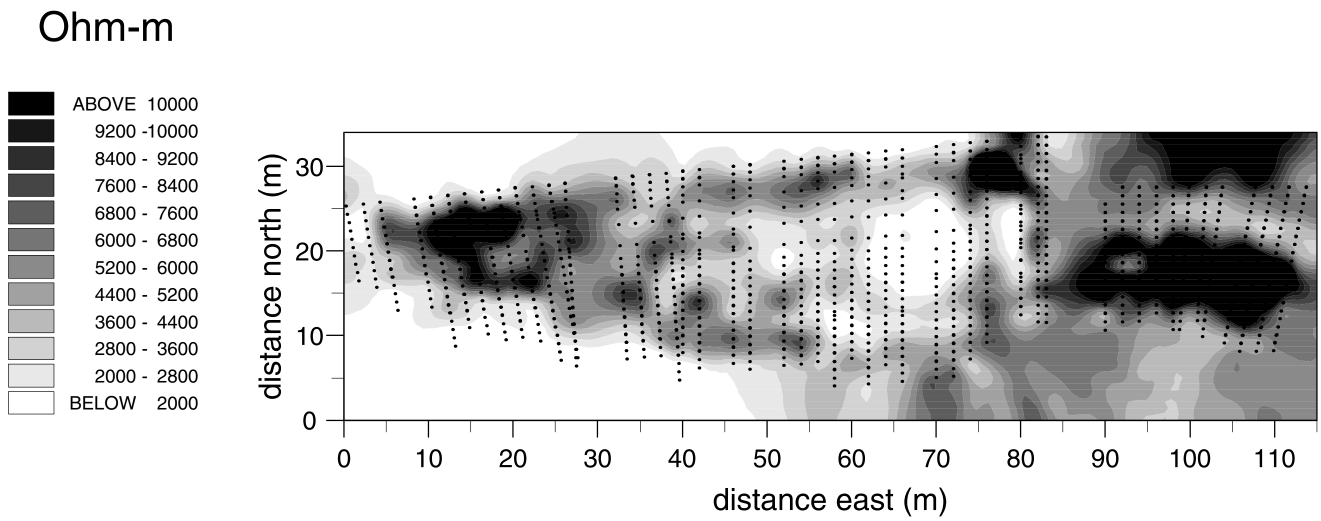
northings and the units of measurement used are metres.

Illus 14 shows such a horizontal slice through the barrow at 0.5m below the datum level. The plan position of the revetments is revealed together with a number of other features. At the wider and taller eastern end of the barrow the side revetments are well-defined narrow regions of high resistivity and the frontal façade is very straight. Gaps in the revetments at (64,28), (56,8) and (36,26) and the façade at (74,24) may be entrances to the barrow, some or all of which could lead to mortuary structures. One of the possible side entrances on the northern side of the barrow, near location (36,26), leads into a low resistance region measuring *c*8m by 4m, which is particularly readily interpreted as a mortuary structure.

Resistivities above 5000Ωm collectively appear black and thus the western end of the barrow appears featureless at the scale used in Illus 14. Detail within this region is provided by a change of scale and Illus 15 shows the same horizontal slice with resistivities ranging from 2000Ωm to 10,000Ωm. At the lower and narrower western end of the barrow a rectangular section with lower resistivity than its surroundings appears at location (20,20). Whilst it is possible that this anomaly may be a mortuary structure, it is equally possible that



Illus 16 Capo Barrow: Horizontal depth slice through collated modelled images at a datum level of –1.5m (Scale 300Ωm – 8000Ωm). Presented by UNIMAP



Illus 17 Capo Barrow: horizontal depth slice through collated modelled images, including the small mound to the east of the barrow, at a datum level of –0.5m (Scale 2000Ωm – 10,000Ωm). Presented by UNIMAP

the surrounding areas of high resistivity are the response from the revetments at the western end of the barrow.

Examination of all the vertical cross-sections of modelled resistivities shows the revetments to lie approximately 1.5m below datum level to the west, rising to about 0m to the east. This suggests an inclined plane as the ground surface prior to the construction of the barrow. A slice through the resistivity data at 1.5m below datum level is shown in Illus 16. At this depth, the side revetments at the lower, western end of the barrow can be seen clearly as well defined areas of high resistivity. A similar area of low resistivity to that on Illus 15 can be seen at around (20,20), but is less readily interpreted as a mortuary structure at this depth.

5.4 The mound to the east of the barrow

Following the main survey, a further 13 resistivity profiles were taken to the east of the barrow, in front of the presumed entrance and over the low mound. Collating all 48 profiles and selecting a horizontal slice at 0.5m below datum results in Illus 17. A distinct high resistivity region is seen extending from the barrow entrance. Note the change of resistivity scale in comparison with Illus 14 to accommodate the higher resistivities seen outside the barrow. The results of the resistivity survey over the low mound to the immediate east of the barrow cannot be used to argue either for or against an anthropogenic origin for this feature.