IRISH-DUTCH PEATLAND STUDY

GEOHYDROLOGY AND ECOLOGY

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AGP 92/2

Geophysical Mapping Techniques to Investigate the Geological Structure of two Raised Bogs, Clara and Raheenmore, Co. Offaly.

by

Mary Smyth

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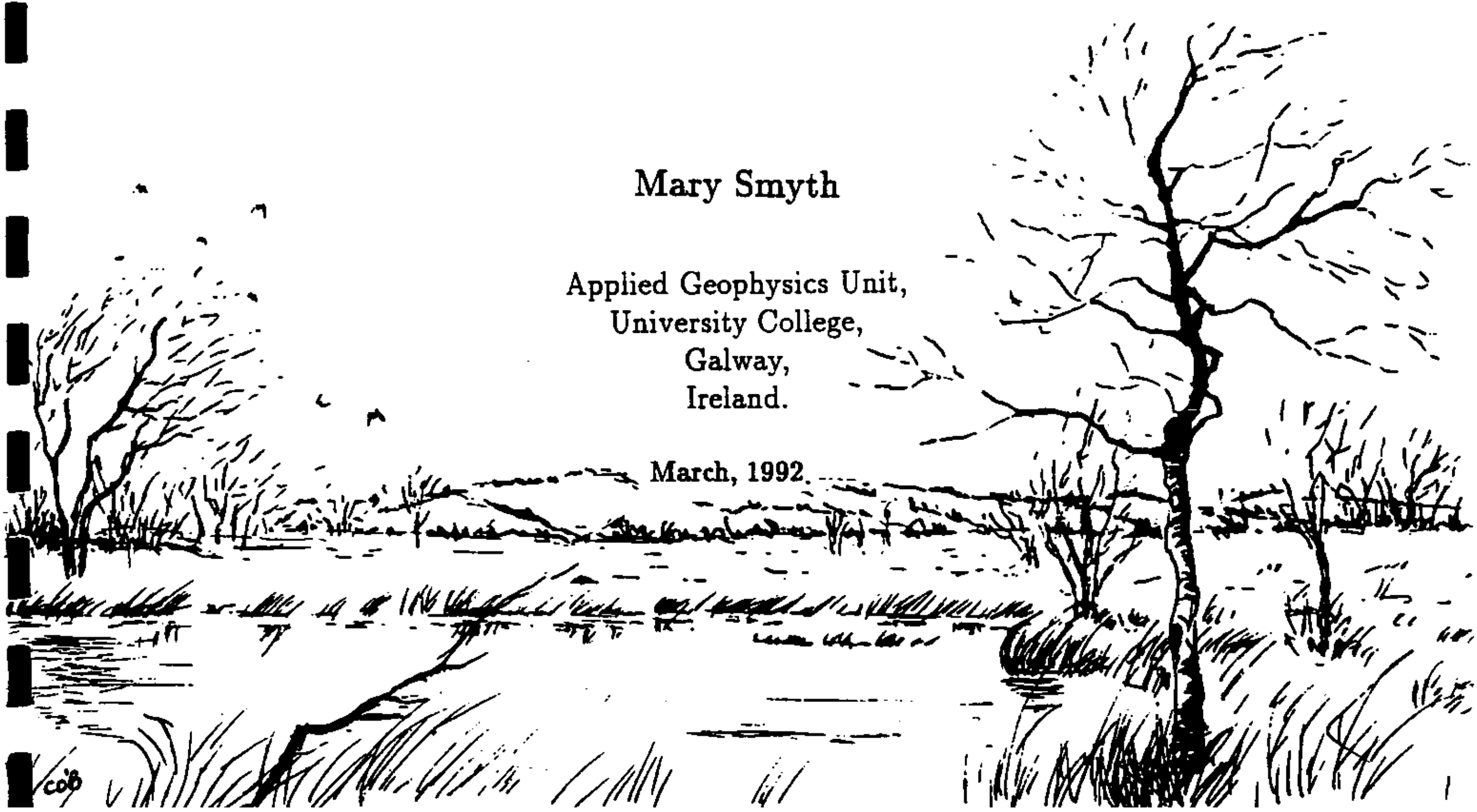
Ireland.

March, 1992.



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Project Report Series

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Chapter 1

Introduction

1.1 Scope of this Report

Geophysical surveys carried out under the supervision of the Applied Geophysics Unit, U.C.G. in the areas of Clara and Raheenmore bogs, in Co. Offaly, are discussed in this report. Details of the surveys carried out are discussed in the departmental reports of Smyth et al (1990), Madden (1990) and Smyth (1991), and in the departmental M.Sc. theses of Dowling (1991), Keohane (1991) and Naughton (1991). Non-departmental reports include Flynn (1990), Farenhorst et al (1991) and Rijsdijk et al (1991).

1.2 Summary of Work Completed

A geophysical Resistivity Vertical Electrical Sounding (VES) survey was carried out on both bogs using the Schlumberger and Offset-Wenner arrays. Sounding coverage on both bogs was quite extensive, with a total of 18 Schlumberger soundings and 68 Offset-Wenner soundings being carried out in the area of Clara bog. A total of 36 Schlumberger soundings were carried out on Raheenmore bog. In this report all soundings are reinterpreted, in light of more detailed knowledge about the geology of the respective areas.

Resistivity Electrical Profiling transects, using the co-linear Dipole-Dipole array were conducted along survey lines in the two areas. Resistivity pseudosections were constructed by contouring the apparent resistivities along the traverses, yielding qualitative information about the subsurface geology. However it has yet to be assessed quantitatively.

EM - VLF-R (Electromagnetic - Very Low Frequency-Resistivity) surveys carried out in the two areas proved to be a very useful quick reconnaissance mapping technique for the subsurface geology. It proved to be a good indicator of variation in bedrock depths, and thus important information for determining the position of resistivity soundings.

Geophysical data sets obtained from the various surveys are assessed in this report. The interpreted results of the respective surveys will be compared and discussed in relation to the geological information presently available, and in relation to each other. An impression of the subsurface geology is formed from the interpreted results of the geophysics, which are constrained by the geological information available. This will form the basis of a preliminary 3-dimensional spaceform model of the bogs.

All the maps presented in this report are produced using the "GEOSOFT" mapping package at the Applied Geophysics Unit, U.C.G. Processing techniques used in the production of maps, such as gridding, smoothing, etc. are discussed in the various internal theses and reports (see Section 1.1), and will not be discussed here. However, the map label indicates the processing involved in the production of the respective maps.

Other geophysical data sets for the study regions include the EM34-3 electromagnetic survey (Farenhorst, 1990), a seismic survey to the north of Clara bog and regional gravity and magnetic data sets for the Midlands (Keohane, 1991). These data sets are not included in this report due to time constraints, but will be interpreted fully in the final thesis.

Chapter 2

Clara Bog

2.1 Geological Drilling Information

2.1.1 Peat Drilling

In 1981 an extensive survey was carried out by Bord Na Mona to obtain information about the thickness of the peat. A Hiller borer was used to take peat samples at various depth intervals. Figure 2.1 shows the grid system which was established by Bord Na Mona to obtain a widespread coverage over the bog. Grid lines were orientated parallel to the road, with lines spaced 100yds (1yd=0.9144m) apart. Station spacings along the lines were at a maximum interval of 100yds, with occasional stations being placed in between at minimum intervals of 10 yds. At each station the surface height (O.D.) of the peat was recorded. By subtracting the peat thickness from the surface height, contour maps of the peat subsurface were produced. All Bord na Mona data were recorded in imperial units, however the data were converted to metric units using the "Geosoft" mapping package at the Applied Geophysics Unit, U.C.G. Peat surface, peat thickness and peat subsurface contour maps were produced in metric units. These latter maps (Smyth, 1991) are incorrect, as an inaccurate grid co-ordinate was used in the initial data conversion process. This has been corrected in the updated maps.

In Figure 2.2 peat surface contours show the central area of Clara West, and that of Clara East to be greater than 59m O.D. This high surface elevation would be expected to spread uniformly across the entire centre of the bog (in the case of a raised bog) but is distorted due to drainage along the road. Surface elevation of the peat descends rapidly in the south central area of the bog, due to the effects of peat cutting, in addition to drainage.

Peat thickness contours for Clara bog are shown in Figure 2.3. Peat is thickest in the centre of Clara East and West, where it displays a thickness in excess of 8m. A thinning out of the peat gradually, towards the margins in the south and north occurs. Effects of drainage on the peat along the road,

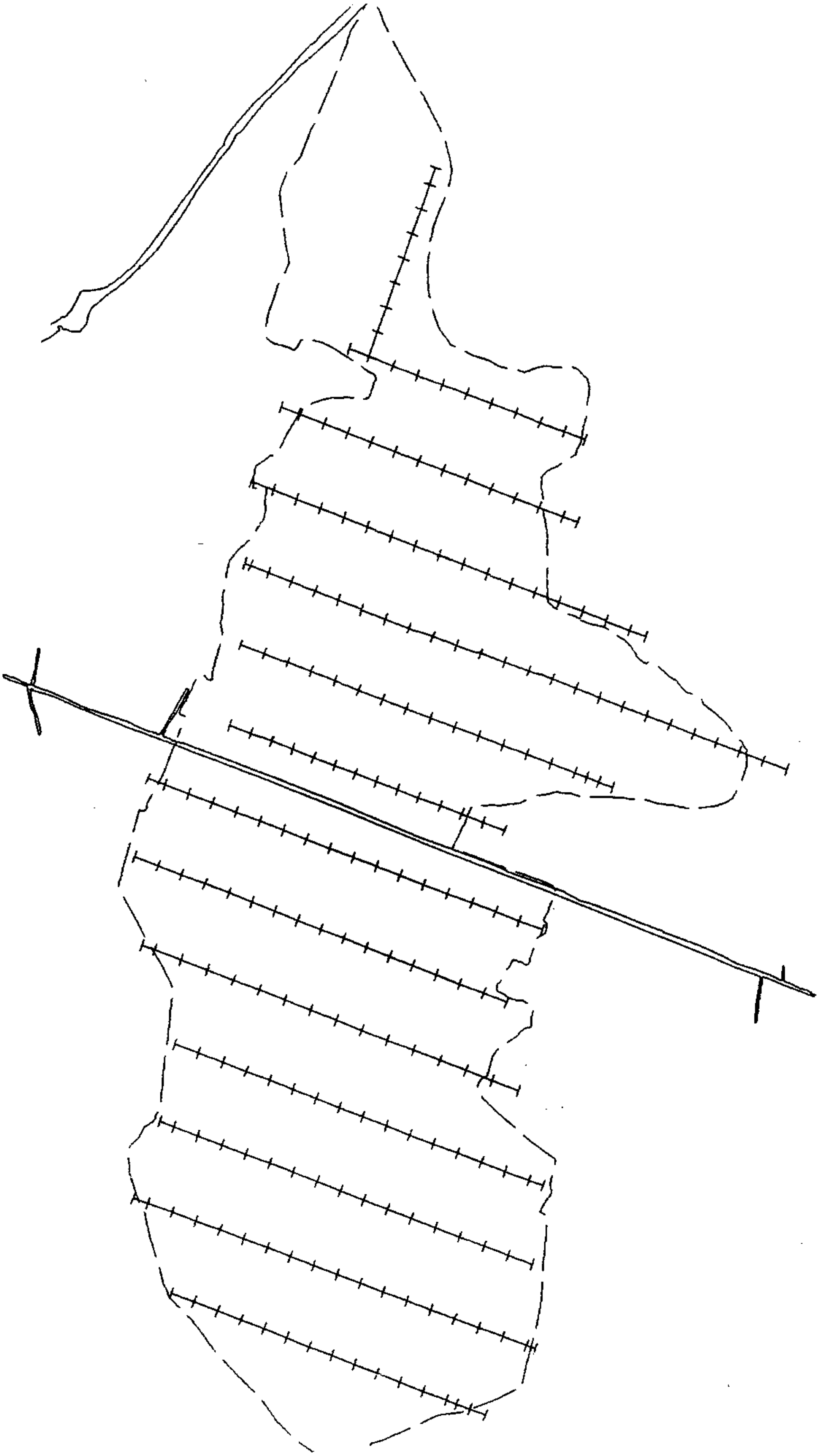

Figure 2.1: Bord Na Mona Grid on Clara Bog

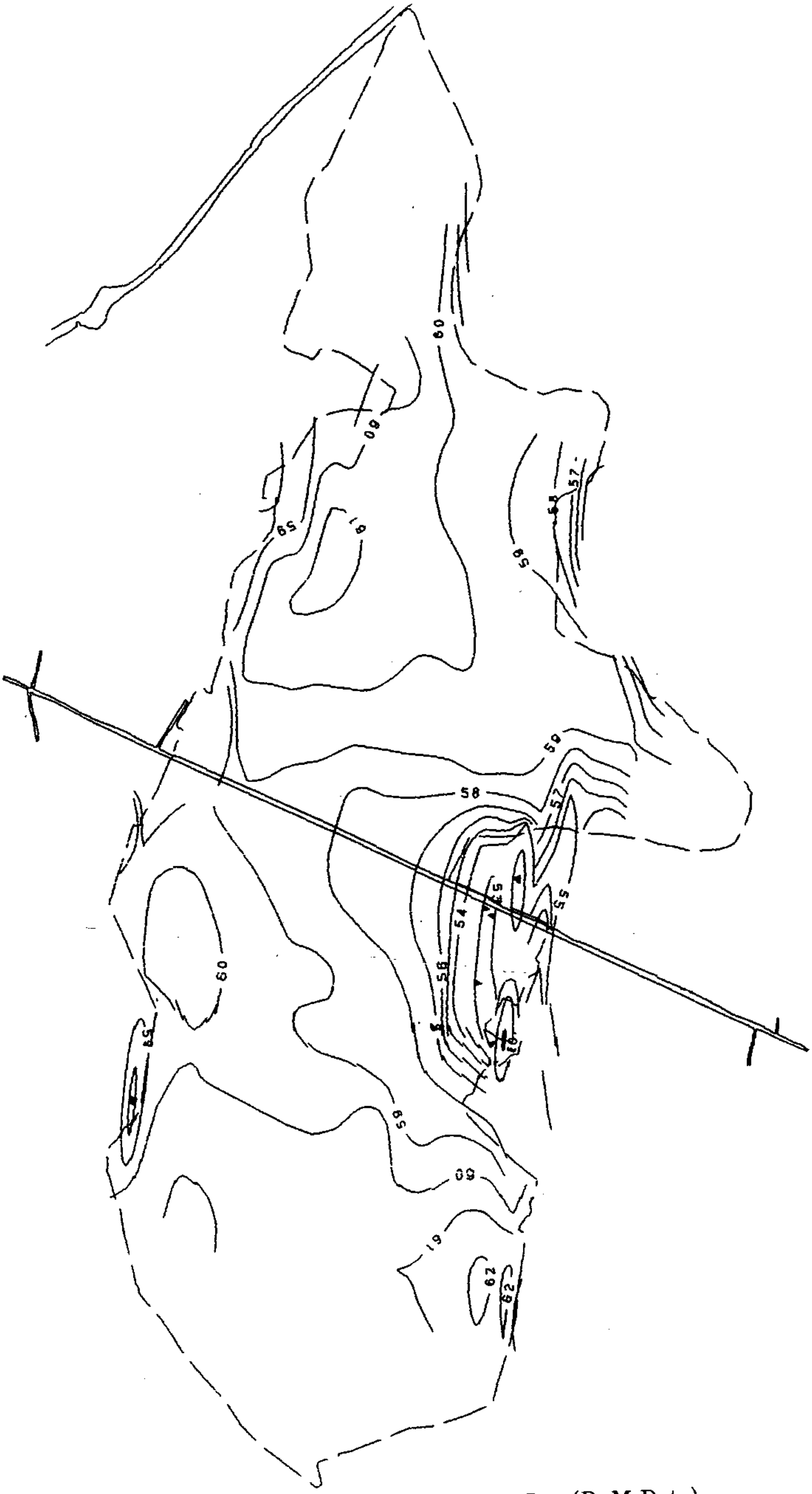

Figure 2.2: Peat Surface Contours of Clara Bog (BnM Data)

are not represented fully in this map.

Contoured elevations of the peat base surface (M.O.D.) are shown in Figure 2.4. Lowest elevations for this surface are in the south central area, which lies below 50m O.D. The entire centre of the bog lies below 52m O.D. forming a broad depression, which extends into narrower channels to the west and the south east. High surface elevations, greater than 52m O.D., are present in the north west, north east and south west. A till mound in the peat base, greater than 54.5m O.D. is shown in the central area to the south west. This corresponds to a conical shaped mound of dry peat on the surface of the bog.

2.1.2 Bedrock Drilling

Borehole logs provide essential information on the subsurface geology. The importance of such geological information as a control in the processing of geophysical data sets, and in the interpretation of the results, will become apparent when discussing the various geophysical techniques.

A drilling programme was conducted by the Geological Survey of Ireland (G.S.I.) on Clara bog, during the summers of 1990 and 1991. Samples of the various unconsolidated lithologies were acquired, and the bedrock was cored for 5m. Borehole locations are shown in Figure 2.5, numbered in the 300 series (301,302,etc.). Borehole nos. 301, 302, and 303 were drilled in 1990. Details of the 1990 drilling programme are discussed in Henderson (1991), and Smyth (1991). Borehole nos. 304 to 307 were drilled in 1991, using the shell and augering technique described in the drilling report (Smyth, 1991). Figure 2.6 shows the drilling logs of the respective boreholes. The respective lithologies are displayed on the map in Figure 2.7.

Borehole 301 is situated on the east side of the road in the centre of the bog. Peat thickness at this location is 6.5m. A lacustrine clay 4m thick underlies the peat. At a depth of 10.5m gravels are encountered, with a thickness of 5.5m these gravels rest on the limestone bedrock, at a depth of 16m. Due to a problem with drilling equipment, the sampling for this borehole is not precise.

On the northern margin of the bog, 200m east of the road, borehole 302 is located. A peaty topsoil of 0.5m overlies a lacustrine clay layer of 1m thickness. Underneath this a boulder clay lithology extends to a depth of 4.25m. A gravelly sand lithology encountered at 4.25m progresses into a pebbly sand layer at 6m. This latter lithology has a thickness of 2.5m, and rests on the limestone bedrock at a depth of 8.5m

Borehole 303 is situated on the esker ridge 180m to the north of borehole 302, and at a surface elevation of almost 6m above that of borehole 302. Underneath the 0.5m of topsoil, lies a sand layer of similar thickness. A gravel lithology extends from a depth of 1m to rest on bedrock, which is at

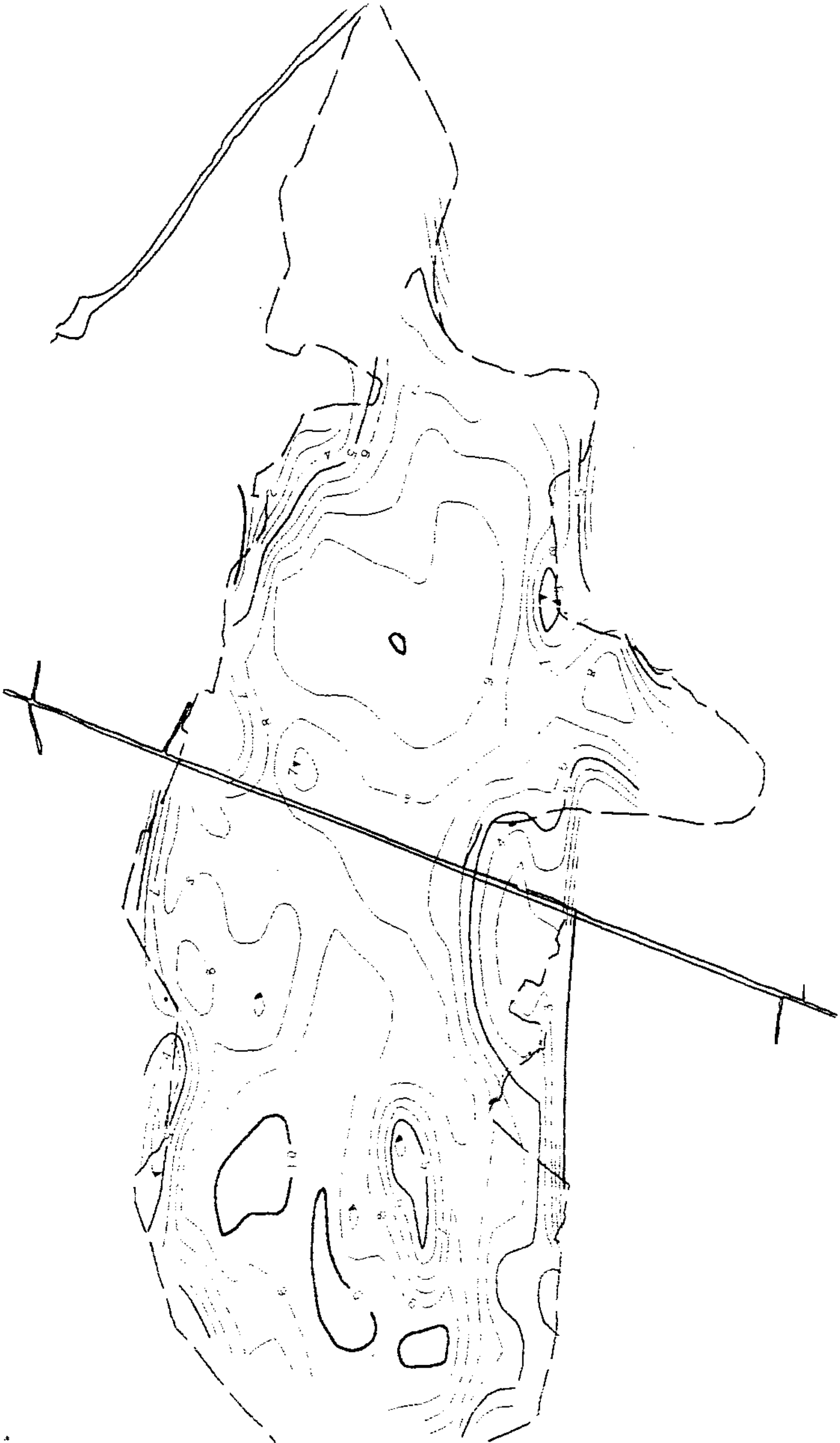

Figure 2.3: Peat Thickness Contours of Clara Bog (BnM Data)

Figure 2.4: Peat Base Contours of Clara Bog (BnM Data)

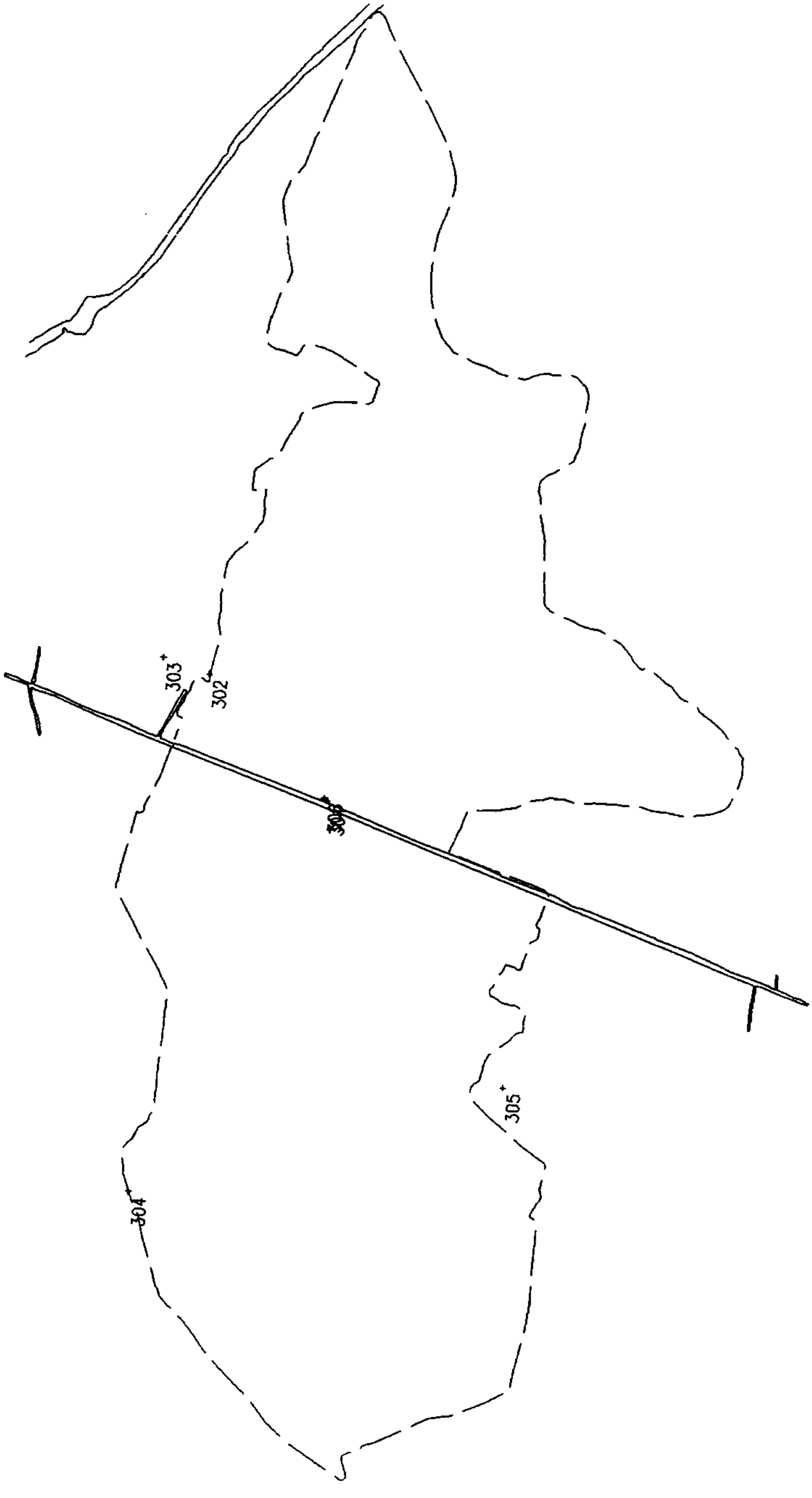

Figure 2.5: Location of Boreholes on Clara Bog

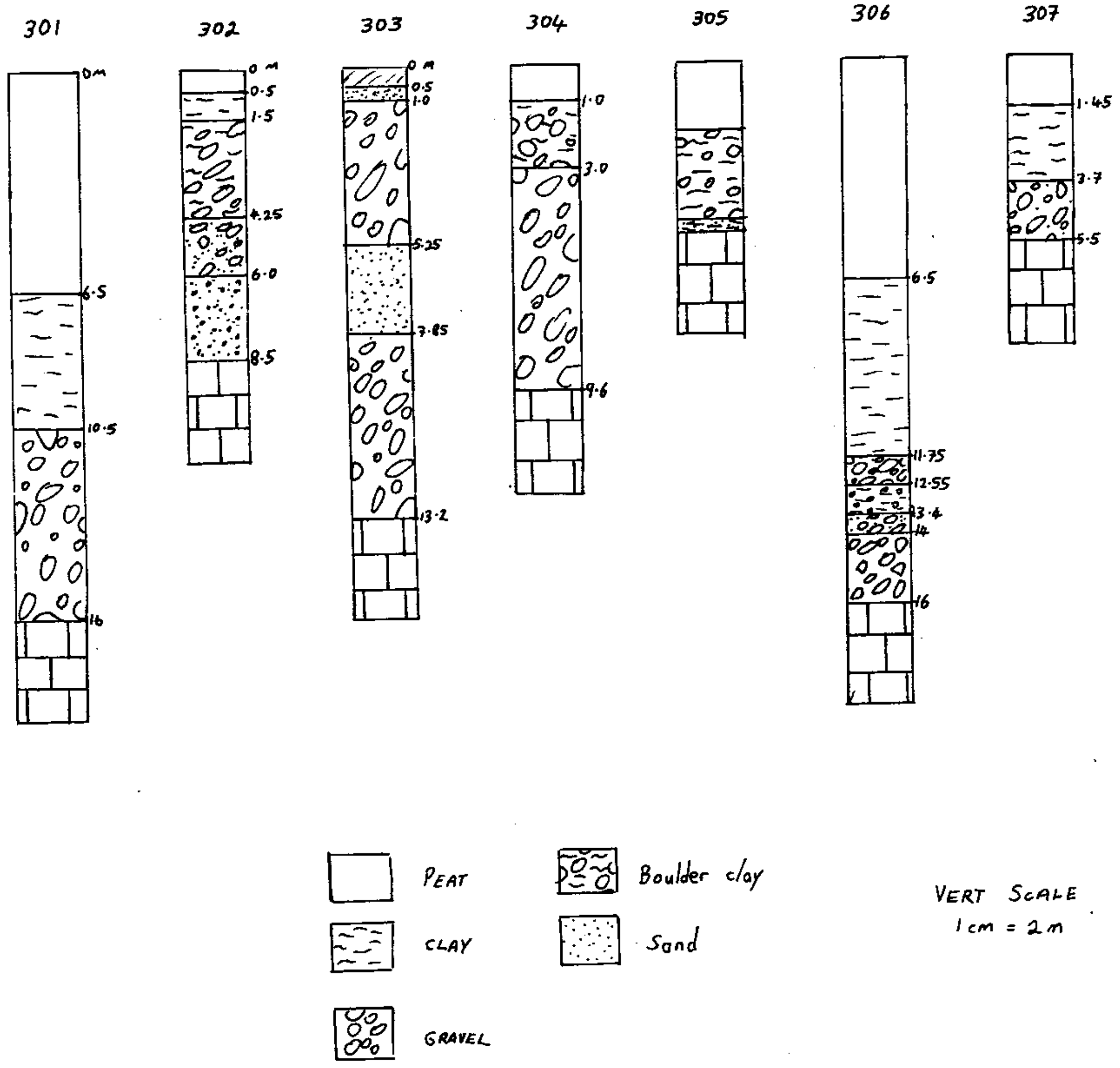

Figure 2.6: Borehole Logs for Clara Bog

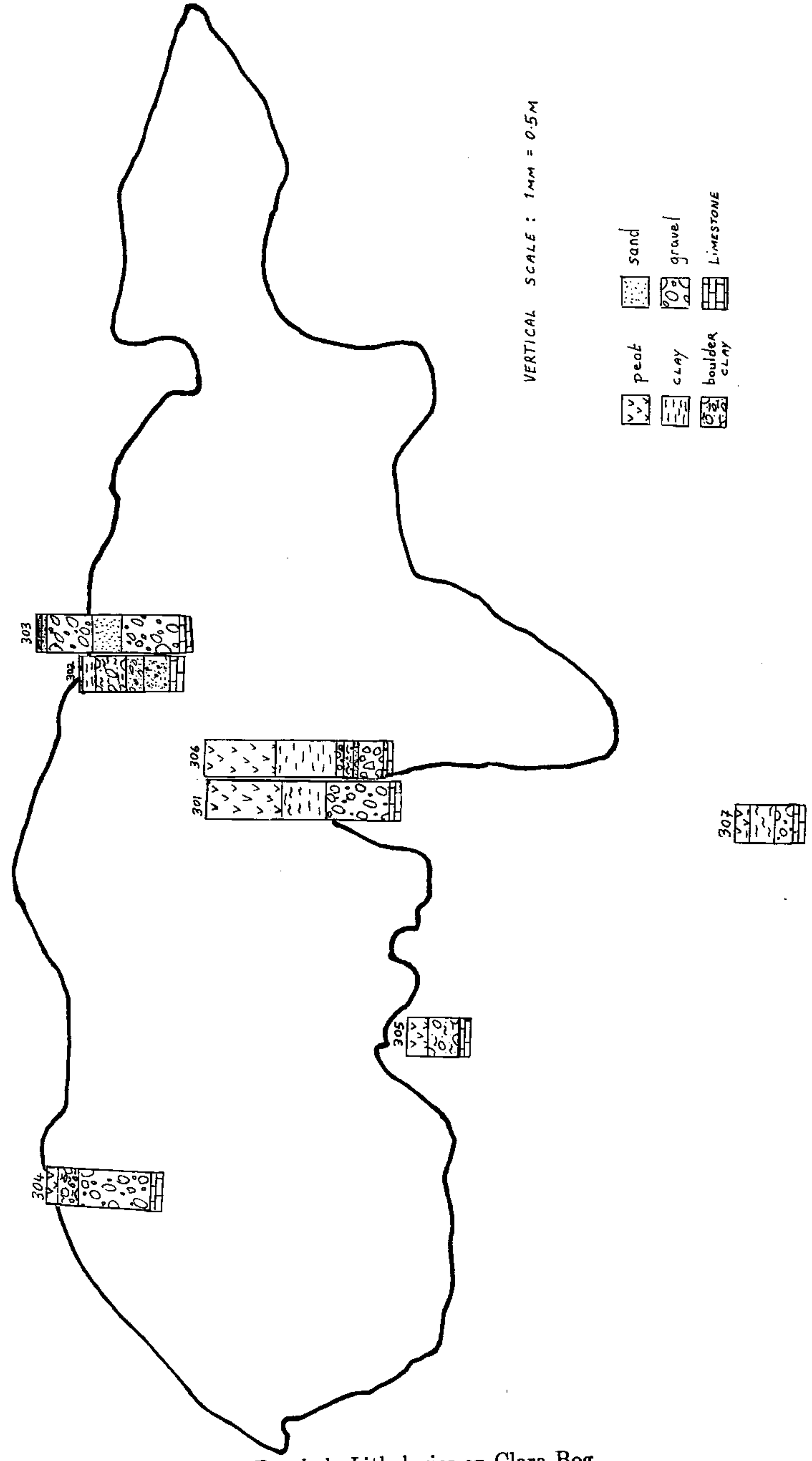

Figure 2.7: Map showing Borehole Lithologies on Clara Bog

a depth of 13.2m. However the gravel lithology is separated at a depth of 5.25m, by a sand layer 2.6m thick.

Situated at the base of the esker on the north west margin of Clara bog, borehole 304 encountered a peat covering of 1m. A boulder clay extending from 1m to a depth of 3m, rests on a 6.6m thick gravel lithology, which, in turn, rests on bedrock at a depth of 9.6m.

An area of cutaway peat to the south of Clara West, was the site chosen for borehole 305. 2m of peat overlies 2.6m of an extremely claey boulder clay. Below this, 0.3m of silty clay rests on bedrock at a depth of 4.9m.

A peat thickness of 6.5m is recorded at borehole 306, which is situated in the centre of the bog, 10m north east of 301. Lacustrine clay below the peat is 5.25m thick. At a depth of 11.75m, a 0.8m thick loose angular gravel is encountered. A stony clay of 0.85m is recorded at a depth of 12.55m, underneath which a thin sandy gravel layer of 0.6m lies. Between a depth of 14m and 16m loose angular gravel is situated, resting on bedrock. This latter lithology may be weathered bedrock, since the bedrock at this location is highly fissured.

The last borehole drilled in 1991, borehole 307, was located on farmland approximately 700m south of Clara bog, and 300m east of the road. A peaty topsoil of 1.4m overlies 2.3m of lacustrine clay. At a depth of 3.7m, a gravel layer 1.8m thick rests on bedrock, which is at a relatively shallow depth of 5.5m.

2.2 Electromagnetic Very Low Frequency - Resistivity (EM - VLF-R)

Details of the Very Low Frequency - Resistivity (VLF-R) survey are documented in the Departmental reports and theses (see Section 1.1 of this Report), therefore only a brief outline of the method will be discussed here. The VLF-R survey technique measures the apparent resistivity of the ground, and is an ideal means of quick reconnaissance mapping. The depth of investigation is given by:

$$d = 500\sqrt{(\rho/f)} \tag{2.1}$$

where d = depth of investigation, ρ= ground resistivity (ohm-m), f = frequency (Hz).

It follows then that as the resistivity of the ground increases, the depth of penetration will be greater. If the ground is very conductive, then the method will only investigate shallow depths. A till deposit with an apparent resistivity of 200 ohm-m will allow a maximum possible investigative depth of 55m, whereas a clay surface with an apparent resistivity of 20 ohm-m will only allow a possible maximum investigative depth of 17m.

2.2.1 VLF-R Contoured Resistivity Map

The VLF-R apparent resistivity contour map of Clara Bog is shown in Figure 2.8. Areas shown in dark shading indicate locations of high apparent resistivity, apparent resistivities being greater than 400 ohm-m. Very dark shading indicates apparent resistivities greater than 600 ohm-m. Non-shaded areas indicate extremely low apparent resistivities, of less than 100 ohm-m. Intermediate apparent resistivities between 300 ohm-m and 400 ohm-m are indicated by the light greyish colour. High apparent resistivity areas suggest shallowing bedrock, whereas the low apparent resistivity areas suggest relatively deep bedrock. The low apparent resistivity values less than 200 ohm-m, imply relatively deep bedrock in the central area of the bog. Bedrock shallows towards the margins where high apparent resistivities are shown. On Clara East a broad area of shallow bedrock towards the eastern margin is indicated, as generally high apparent resistivities are shown in the area. This pattern contrasts with Clara West, where bedrock topography is much more irregular. High apparent resistivities on the southern margin of Clara West imply extremely shallow bedrock. In the central area along the northern margin of the bog, low apparent resistivity values suggest a deepening of the bedrock. Shallow bedrock is indicated along the northern margin in the extreme west and in the east. An anomalous, elongated area of high apparent resistivity suggests shallow bedrock in the north central region of the bog.

In general, the VLF-R contoured apparent resistivities suggest bedrock shallowing towards the margin of the bog, with a central depression in the bedrock surface in the central of the bog. This is summarised in the maps in Figure 2.9 and Figure 2.10.

2.2.2 Phase Angle Contour Map

Figure 2.11 shows the contoured phase values from the VLF-R survey on Clara bog. A phase angle value below 45 degrees indicates a conductive upper layer on a resistive lower layer. Phase values over 45 degrees are indicative of the presence of a conductive layer beneath a relatively more resistive upper layer. Very low phase angles (less than 25 degrees) suggest a high contrast between the resistivity of the lower layer, with that of the conductive overburden. Phase values between 25 and 35 degrees indicate less of a contrast between the two resistivities, whereas values between 35 and 45 degrees represent a very small variation between the two resistivities. It follows then that as the phase angle increases, the resistivity of the upper conductive layer and lower resistive layer converge, until a phase angle value of 45 degrees indicates no resistivity contrast between the two layers (i.e. indicating a single layer to depth of investigation). As the phase angle increases upwards from 45 degrees, the resistivity contrast between the upper

Figure 2.8: VLF-R Resistivity Contour Map of Clara Bog

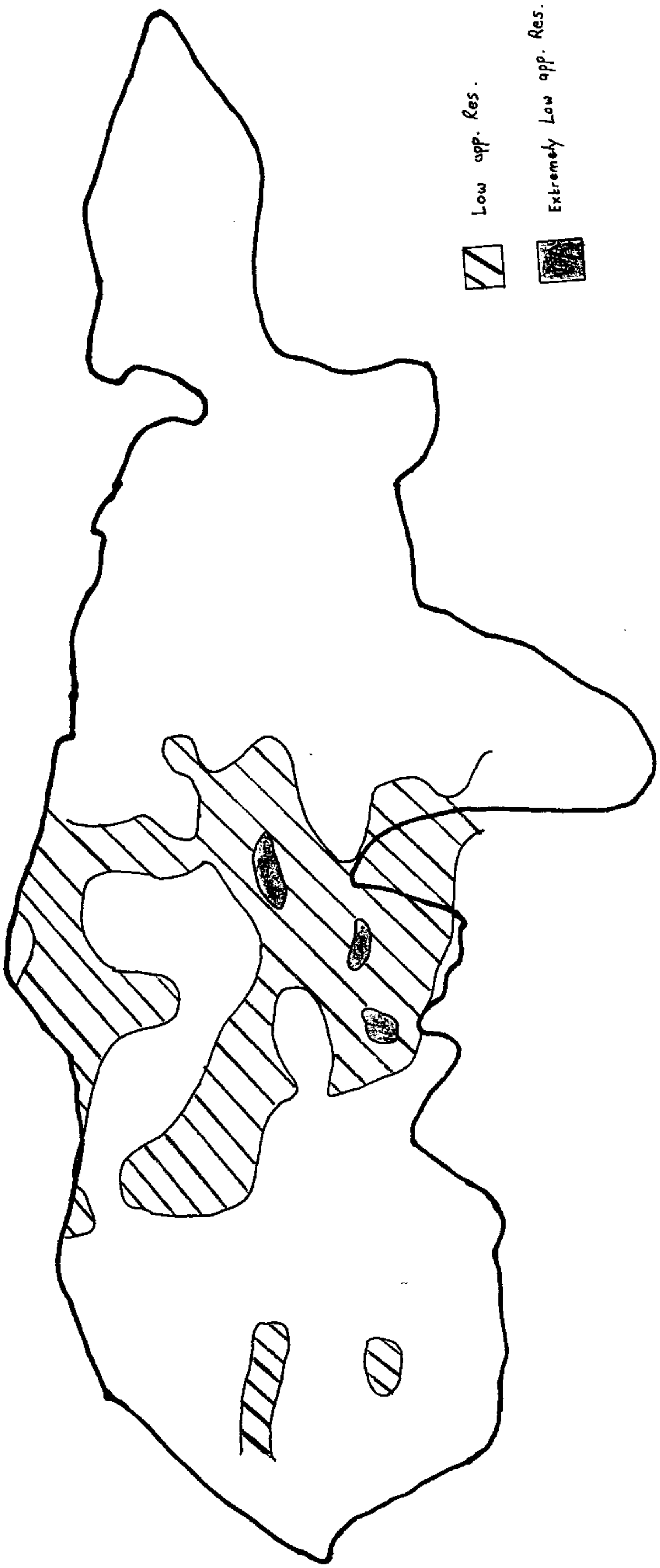

Figure 2.9: Summarised VLF-R Apparent Resistivity Lows

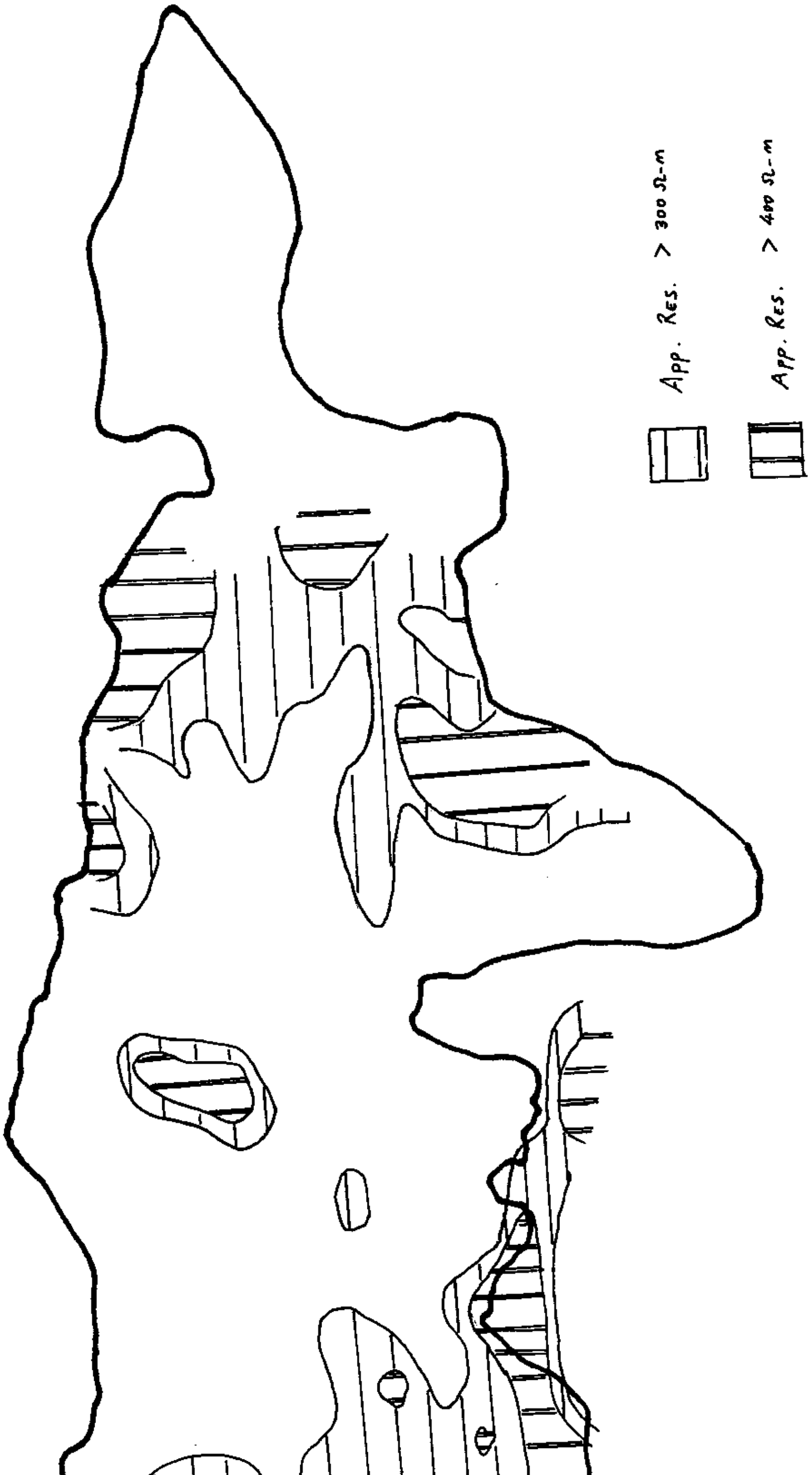

Figure 2.10: Summarised VLF-R Apparent Resistivity Highs

Figure 2.11: VLF-R Contoured Phase Angle Values of Clara Bog

resistive layer and the lower, less resistive layer, increases.

One noticable aspect of the Phase angle contour map for Clara is that the phase angle values all lie below 45 degrees (apart from 2 stations in the south-west). In the Clara situation, the low phase angle values would suggest the more conductive overburden of peat, clay and till resting on the more resistive bedrock.

In the north-central area of the bog, just west of the road, an area of low phase angle value (less than 25 degrees), corresponds to an area of high apparent resistivity shown on the VLF-R resistivity contour map (Fig 2.8). This would suggest an area of relatively shallow bedrock below the more conductive overburden. Another low phase value less than 25 degrees is shown in the area where the southern margin of the bog intersects the road. Here an apparent resistivity high is indicated on the unsmoothed VLF-R resistivity data, but not on the smoothed version (Fig 2.8), which tends to omit extreme values.

The entire east side of Clara bog shows phase values less than 25 degrees. A close correlation exists between this and the VLF-R resistivity contour map, which shows apparent resistivity highs in this area, indicating shallow bedrock. Minor pockets of phase values less than 20 degrees correspond to higher apparent resistivity values indicating relatively shallower bedrock.

The greater part of the central area of Clara bog, and Clara West, show phase values of the order of 25-35 degrees. This would suggest that bedrock is slightly deeper in these areas than on the east side. The resistivity contour map is in agreement with this assumption.

A phase value greater than 35 degrees is shown in the central area just east of the road, corresponding to a resistivity low on the VLF-R contoured resistivity map. In this area bedrock is relatively deeper, and possibly fractured, resulting in a low resistivity contrast between the upper and lower layers, indicated by the higher phase angle values. Approximatley 400m to the south, a similar phase value for the area occurs, corresponding to a resistivity low indicating deep bedrock. Likewise, 400m directly to the west, an area with the same phase value occurs, and similar correlations can be made with the latter area.

In the north-central area of Clara West, a high phase value of over 40 degrees is indicated. One station in this region showed a phase value of 45 degrees, suggesting no resistivity contrast between the upper and lower layers. Due to the low resistivity values shown in this area (Fig 2.8), the phase value suggests that bedrock is deeper than the technique penetrates, thus the 45 degrees suggests the relatively similar resistivity of the peat and till.

Along the southern margin of Clara West, phase values of 35 to 45 degrees are shown. Such values indicate very little contrast between the lower resistive layer and the less resistive upper layer. The presence of high apparent resistivity values (Fig 2.8), sounding results and drilling information indicate shallow bedrock in this area. Cutaway peat on the surface is relatively thin, with sandy gravelly glacial deposits underneath, resting on the bedrock. Fractured bedrock overlain with highly resistive sandy gravel deposits, is possibly responsible for such high phase values. Also the highly conductive cover of cutaway peat will reduce the depth of penetration. This is similar to the high phase values indicated along the northern margin where highly resistive esker sands and gravels overlie possibly less resistive material resting on bedrock.

In general low phase angle values on Clara Bog indicate shallow bedrock, whereas high phase values indicate relatively deeper bedrock. However a knowledge of the geology of the area is necessary before any firm conclusions can be drawn. Also a comparison of the phase values with other information such as resistivity VES, is necessary, as is the case in the south west where high phase values do not indicate deep bedrock.

2.3 Vertical Electric Soundings - VES

The theory of the various geophysical Electrical Resistivity methods is discussed in detail in the various departmental theses and reports (see Section 1.1 of this report). In this section the principle consequences of the techniques when applied in practice, will be discussed in order to appreciate the interpreted results presented here.

VES (Schlumberger and Offset-Wenner) techniques are used to measure the variation in the earth's resistivity, with depth. Electrode spacings are gradually increased about a central point, and thus the apparent resistivity of the ground at increasing depths below this centre point, is measured. In theory, the earth's resistivity is assumed to vary in depth only, as no lateral resistivity variations are assumed. This assumption does not hold true in practice, and therefore will influence the interpreted results. Areas with little lateral resistivity variation, such as horizontal or gently dipping sedimentary beds, are most suited to VES techniques. Strong lateral variations in the resistivity of the subsurface, such as areas of weathered bedrock, are less satisfactory for the implementation of VES techniques.

Another important consideration to note is that in practice, earth resistivity measurements are normally only accurate to within 5 per cent (Keller et al, 1979). This gives rise to ambiguity in the interpretation of soundings, as different apparent resistivity curves within 5 per cent, cannot be distinguished in practice.

A third factor to be considered is the problem of equivalence, which basically results in sets of different interpretations for layer thicknesses and resistivities. These sets are equally correct in theory, but only one situation exists in reality. The problem is deciding which is the correct one. Two types of equivalence problems are considered.

Example 1: Consider the case of a thin layer, which is highly conductive, and situated between two layers of considerably higher resistivity. Current flow within the earth concentrates in this middle layer, and flows parallel to it. The resistance R, to this current flow will remain constant if the relationship between the resistivity and the thickness of this layer remains constant (i.e. ρ/h is a constant). Any ρ and h for which this holds true are said to be electrically equivalent.

Example 2: Similarly, if the middle layer is highly resistive in contrast to the relatively lower resistivity of the layers it is situated between, then all layers for which ρh is constant are electrically equivalent.

Suppression of a layer is another factor to be considered when interpreting soundings. If the thickness of a layer is very small in comparison to its depth, then the effect of such a layer on the apparent resistivity curve is negligible. Such a layer is said to be suppressed. An example of suppression would be the case where a thin clay layer with very low resistivity, rested on bedrock at a considerable depth.

Interpretations of sounding curves involving five layer models can often be reduced to four layer models without any significant change in the apparent resistivity curve. Such is the case when two layers are merged into one layer with a resistivity averaging that of the two layers, and a thickness which is the sum of the thicknesses of the respective layers. An example of this problem is given in Parasnis (p.139, 1986). Also another factor to be considered is that the resistivity of a layer can change with depth. Pure clay progressing into pebbly clay with depth, will result in different resistivities being recorded for the upper and lower parts of this layer. An empirical example of this situation is discussed in Palacky et al (1990). These latter two problems reinforce the importance of geological information when determining the number of layers to be considered in sounding interpretation.

Interpreted results of the VES must be viewed in terms of the above problems. Geological information is fundamental to any sounding interpretation. Apparent resistivity curves lacking any geological input can be highly ambiguous and of little help to understanding the situation in reality. In order to resolve the problem of equivalence, giving rise to a range of interpretations for the thickness of the clay layer at certain soundings, borehole logs and VES in the vicinity of such soundings are used. Also, the inclusion of a contour map showing clay conductance values will give an indication of where variation in clay thicknesses can occur.

2.3.1 VES - Schlumberger Array

Figure 2.12 shows the location of the VES on Clara bog. All Schlumberger

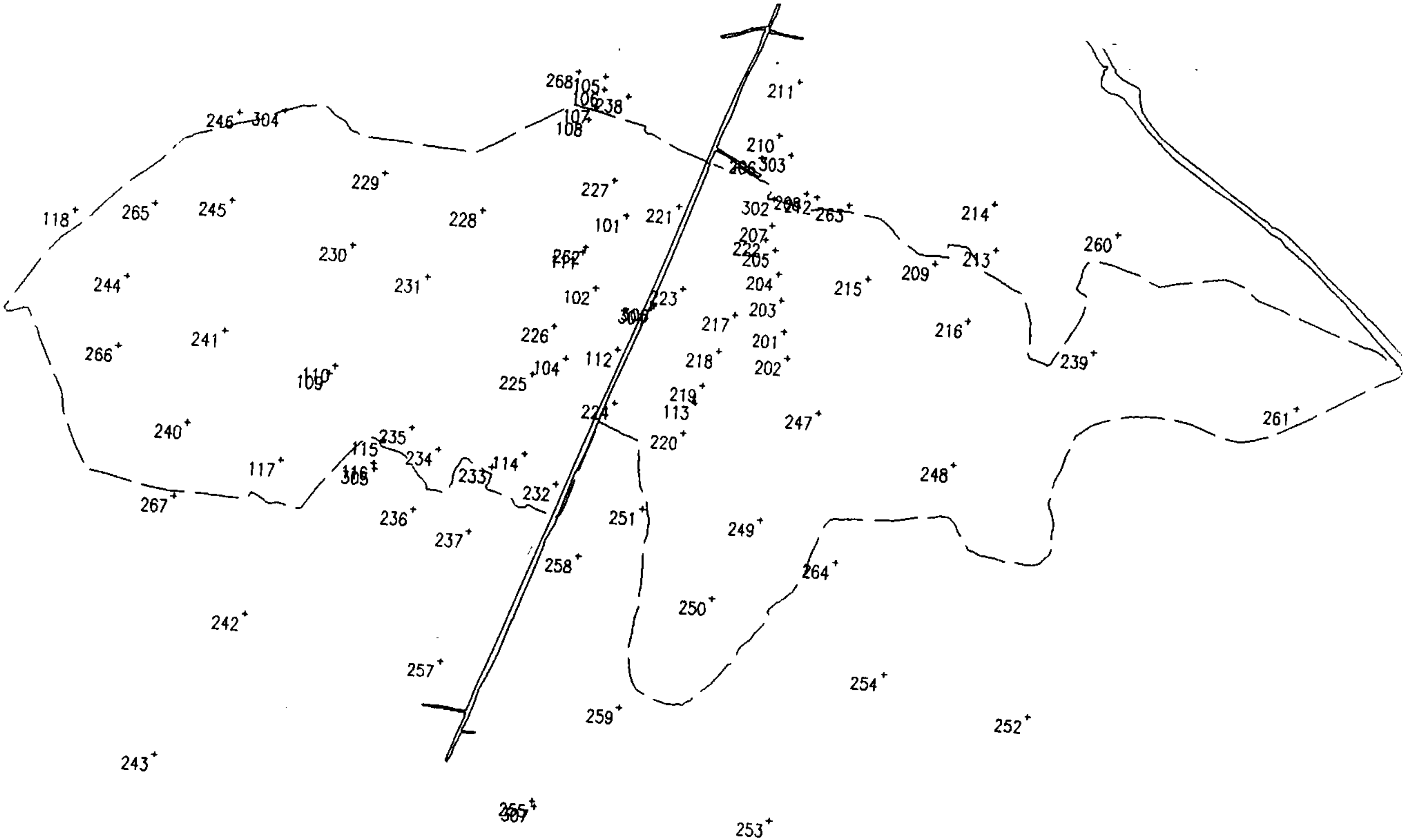

Figure 2.12: Location of Vertical Electric Soundings (VES) on Clara Bog

soundings are numbered in the 100 series (101,102,etc.). All 18 VES using the Schlumberger array (Smyth 1991) are here re-examined in light of additional geological information from drilling by the Geological Survey of Ireland (GSI), in the summer of 1991.

Most of the soundings remained unchanged, however a few had to be refined in light of the geological information. When interpreting the soundings, emphasis was placed on obtaining a theoretical curve to fit the general trend of the observed data curve. There were several steps in the analysis before a final model was presented. First, branches of the original data set were adjusted either up or down to obtain a smooth curve. In some cases dubious individual points were also moved or deleted. (Branch adjustments are necessary to correct for lateral heterogeneities (e.g. boulders, streams, etc.) when the potential electrodes positions are changed). The adjusted data set was then modelled using a constrained automatic inversion technique for a 1-dimensional layered earth model (Biewinga,D.T., 198*). The constraints were provided by apriori borehole geological information. After a suitable model was produced from this data set, its theoretical response was compared with the original (unadjusted) observed data and was refined if necessary.

In general, for soundings situated on the bog (VES 101, 102, 103, & 104), the peat is subdivided into two layers. The upper layer of spongy peat in general has a thickness of approximately 0.5m, and has a lower resistivity than the more compact peat beneath. Subdivision of the peat into two distinct layers allows the calculated theoretical curve to bend smoothly at the beginning, to imitate the observed data, and thus obtain a better fit. Only minor adjustments were made to the various parameters of soundings situated on the bog.

Sounding Nos. 101, 102 and 103 situated on the bog, give only one possible solution for the clay thickness, and thus provide good geological controls for the clay layer. However, the problem of equivalence occurs for the clay layer at sounding 104, 300m to the south of no. 103. Here a minimum clay thickness of 4m corresponds to an apparent resistivity of 21.6 0hm-m, while a thickness of 12m will correspond to an apparent resistivity of 64 ohm-m. Increasing apparent resistivities correspond to an increase in thickness, however there is no geological foundation for clay thicknesses much in excess of 7m. A clay thickness of 6.3m corresponding to an apparent resistivity of 35 ohm-m was decided based on VES in the vicinity of this sounding.

Sounding nos. 105 and 106 are situated on the south facing slope, of the esker to the north of the bog. A very high resistive layer (3000 ohm-m) with a thickness of 6m is indicated below the top 1m thick cover, at sounding no. 105. Such a high resistivity would indicate bedrock, but this is contradicted by the presence of a layer underneath, 5m thick and a resistivity of approximately 200 ohm-m, lying on assumed bedrock. Sounding 106 shows

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a layer 2m thick of resistivity similar to dry gravels (338 ohm-m), underlain by a 7m thick low resistivity (56 ohm-m) layer, which in turn rests on bedrock. It is likely that the chaotic esker sediments have strong lateral effects on the sounding data. No definite conclusions can be drawn about these two soundings, in the absence of geological controls, apart from they suggest that bedrock is relatively shallow, approximately 10m from the surface.

For soundings 107 and 108 the problem of equivalence is also present. For 107, clay thicknesses vary very little being between 1m and 2.5m. However for VES 108 clay thicknesses vary dramatically; an apparent resistivity range of 20 to 40 ohm-m corresponds to a thickness range of 4.5m to 9m. A thickness of 5.4m with a corresponding apparent resistivity of 24 ohm-m for the clay layer, is accepted based on a slight improvement in the fitting error for such a curve.

No definite solution could be obtained for sounding no.113. It is likely that lateral effects and the problem of equivalence have a major influence. No problems occur in the interpretation of the remainder of the Schlumberger VES. Only one possible solution exists for 109 and 110 situated on the mound, to the west of the soak. Both these soundings show till to directly underlie the thin peat cover. The remainder of the soundings give solutions which are geologically acceptable and in some cases controlled by boreholes.

2.3.2 VES - Offset-Wenner Array

A total of 68 vertical electric soundings were carried out on Clara bog and environs, using the Offset-Wenner array. Locations of these soundings are shown in Figure 2.12, numbered in the 200 series (201,202,etc.). Some of these soundings are not included in the final maps produced from sounding interpretations, due to errors in the data. Soundings 218, 223, and 227 are not included because the data were collected when problems were occurring with the instrument due to wet conditions and battery failure.

The larger number of soundings using the Offset-Wenner array, as opposed to the Schlumberger array, included a wider range of topographical variation over which the soundings were carried out. Like that of the Schlumberger VES, interpretation of Offset-Wenner soundings situated on the bog, involved the inclusion of a top spongy peat layer with lower apparent resistivity than that of the more compact peat underneath. Soundings situated on cutaway areas of peat, showed the surface layer to have relatively low apparent resistivities, due to disturbance of the top layer and possibly mixing of the peat with the subsurface material.

Offset-Wenner VES were interpreted using geological controls from boreholes and peat coring, where possible. The problem of equivalence occurred at a small number of soundings. Accepted geological interpretations for such soundings are based on logical assumptions of thicknesses and apparent resistivities, obtained from other VES in the vicinity.

2.3.3 VES Contour maps

Contour maps of the peat base, till surface, bedrock surface, clay thickness and till thickness, are compiled from the interpreted VES data and borehole logs. In the extreme southern area of the study region, some sounding information was omitted from the final maps because the area between here and the bog itself, is quite variable in terms of topographical elevation, and very little geophysical information is available for this area. Also the ground surface at these locations will have to be levelled in. Inclusion of such data would give a misleading impression about the broad geological model around the bog. Likewise, approximately 4 soundings in the north east situated on the esker slopes, were omitted because of similar problems, and more time is necessary to evaluate their full potential. These maps should be regarded as broad impressions of the general trend in the subsurface lithologies. Data points (some VES are as much as 500m apart) are too sparse to take into account localised variation in the subsurface geology.

2.3.4 Bedrock Surface Contour Map

Figure 2.13 shows the bedrock surface contours produced from the VES data. An elongated depression, orientated roughly south-west to north-east, is shown in the central area of the bog, enclosed within the 41 m O.D. contour line. Two smaller depressions lie within this main enclosure, in the south-west and north-east below 40m O.D. The maximum depth of the depression in the north-east is 33m O.D., whereas the one in the south-west reaches a maximum depth of 35m O.D.

In general the bedrock gets progressively shallower towards the northern margin of the bog. Eastwards from the central depression, the bedrock rises sharply towards the south-east, to form a shallow platform approximately 48m O.D., elongated south-west to north-east. The east side of the bog forms a broad shelf approximately 44m O.D. To the south-west of the central depression the bedrock shallows, steeply beyond the bog margin.

Bedrock shallows gradually towards the west, to a height of approximately 46m, where in the extreme west, a valley is formed by the converging steep rising bedrock to the north and south.

In the west, the 50m O.D. contour line approximates that of the south and north margin of the bog. This gives rise to a general depression in the bedrock towards the centre of the bog, with shallow bedrock around the bog margin. The bedrock shallows rather suddenly towards the margin as indicated by the close spacings of the contour lines.

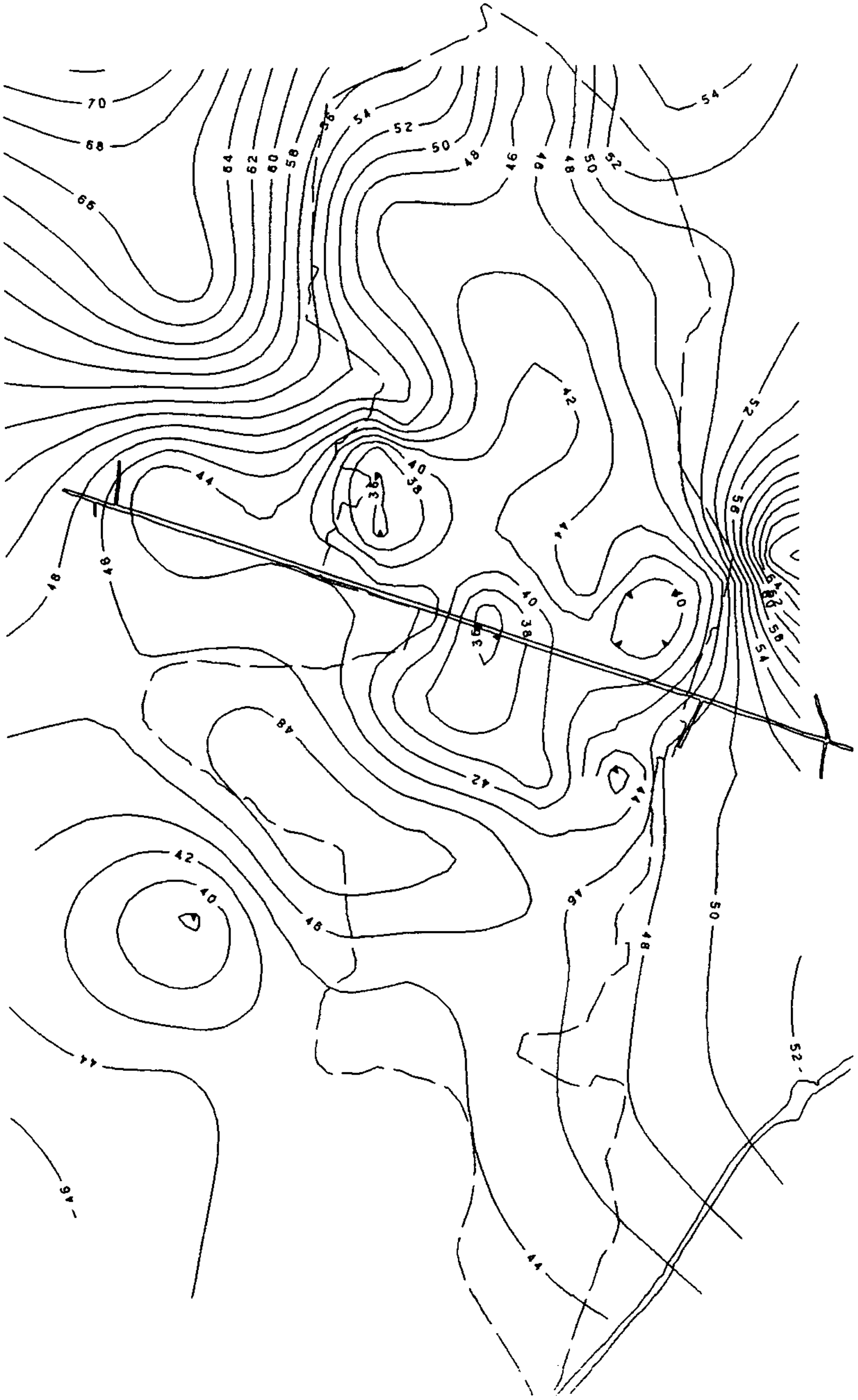

Figure 2.13: Bedrock Surface Contour Map

Data on the east side is too sparse to make definite conclusions about bedrock depths, although, there is a general shallowing of bedrock in the north. A deepening of the bedrock occurs in the cutaway to the south-east. However, in the south, just east of the road, an area of shallow bedrock is found. Figure 2.14 is a summary map of the areas of extremely shallow bedrock, where bedrock surface elevation indicated by the VES contoured data is greater than 48m O.D. Figure 2.15 summaries the areas of relatively deep bedrock, showing the central region of the bog to be less than 42m O.D.

2.3.5 Till Surface Contour Map

Till surface contours are shown in Fig 2.16. The till surface is defined to be the surface of the glacial deposits, which rest on the bedrock. In the centre of the bog a depression occurs in the till surface. This depression is bounded by the 50m O.D. contour line, and extends from the centre southwards. A rise in the elevation of the till surface occurs in the north-west corner of this main depression. This elevation along with a smaller elevation from the east, form a valley occurring in the till surface in the north and extending southwards through the centre of the bog, and then bifurcates towards the east and the south-west, in the southern area of the bog. These channels are enclosed within the 47m O.D. contour line, with minor deeper depressions occurring within them.

Till surface height varies very little eastwards, only rising gently from the 50m O.D. contour line to 54m O.D. along the northern margin of the bog. The south-east is enclosed within the 50m O.D. contour line, with one slight elevation of 51m O.D. towards the bog margin. Sparsity of data on the east side must be considered within these interpretations.

On the west side of the bog the till surface gets moderately deeper in a south-easterly direction, from 58m O.D. along the northern margin, to 50m O.D. towards the central depression. From the south-west margin the same trend occurs with the till surface lowering moderately from 60m O.D. at the margin, in a north-easterly direction, towards the centre at the 50m O.D. contour line. However in the south-west this pattern is upset by the presence of a circular till mound. This mound rises to 59m O.D. at its highest elevation, the till surface immediately surrounding the mound being between 55m and 56m O.D. Immediately south of Clara west, the till surface contour lines run perpendicular to the bog margin, i.e. running parallel to the former boundary of the raised bog in the south, now occupied by cutaway peat.

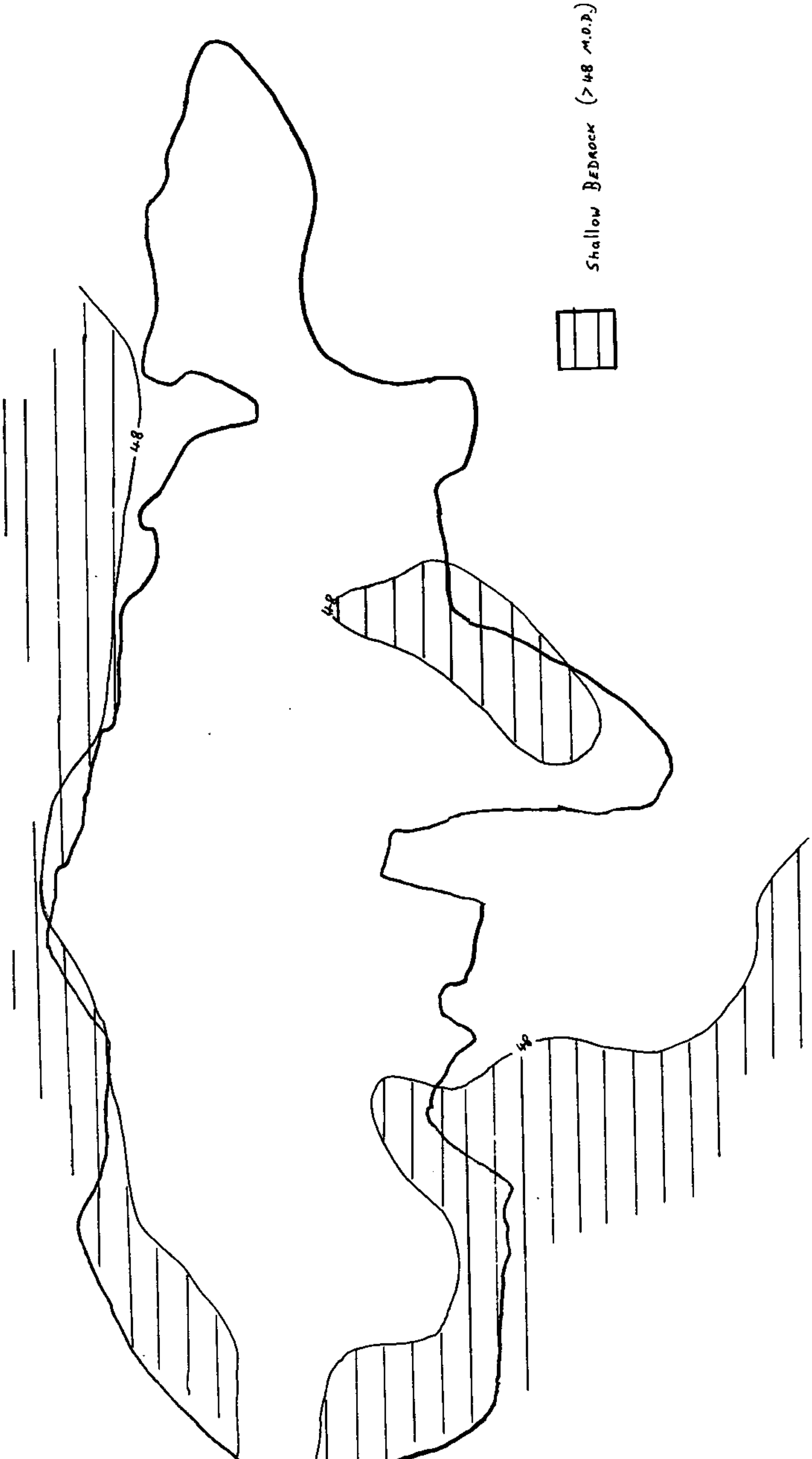

Figure 2.14: Shallow Bedrock Indicated From VES Data

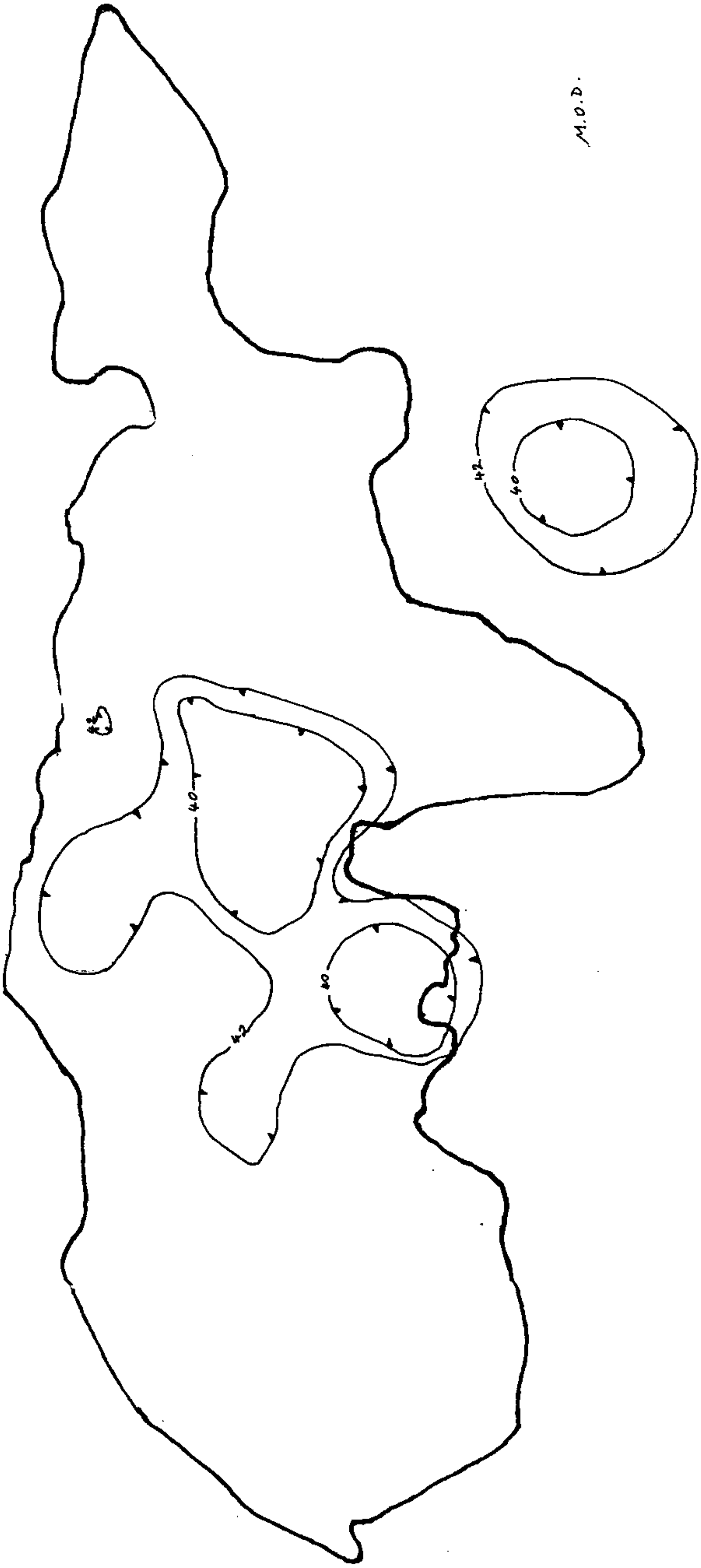

Figure 2.15: Deep Bedrock Indicated From VES Data

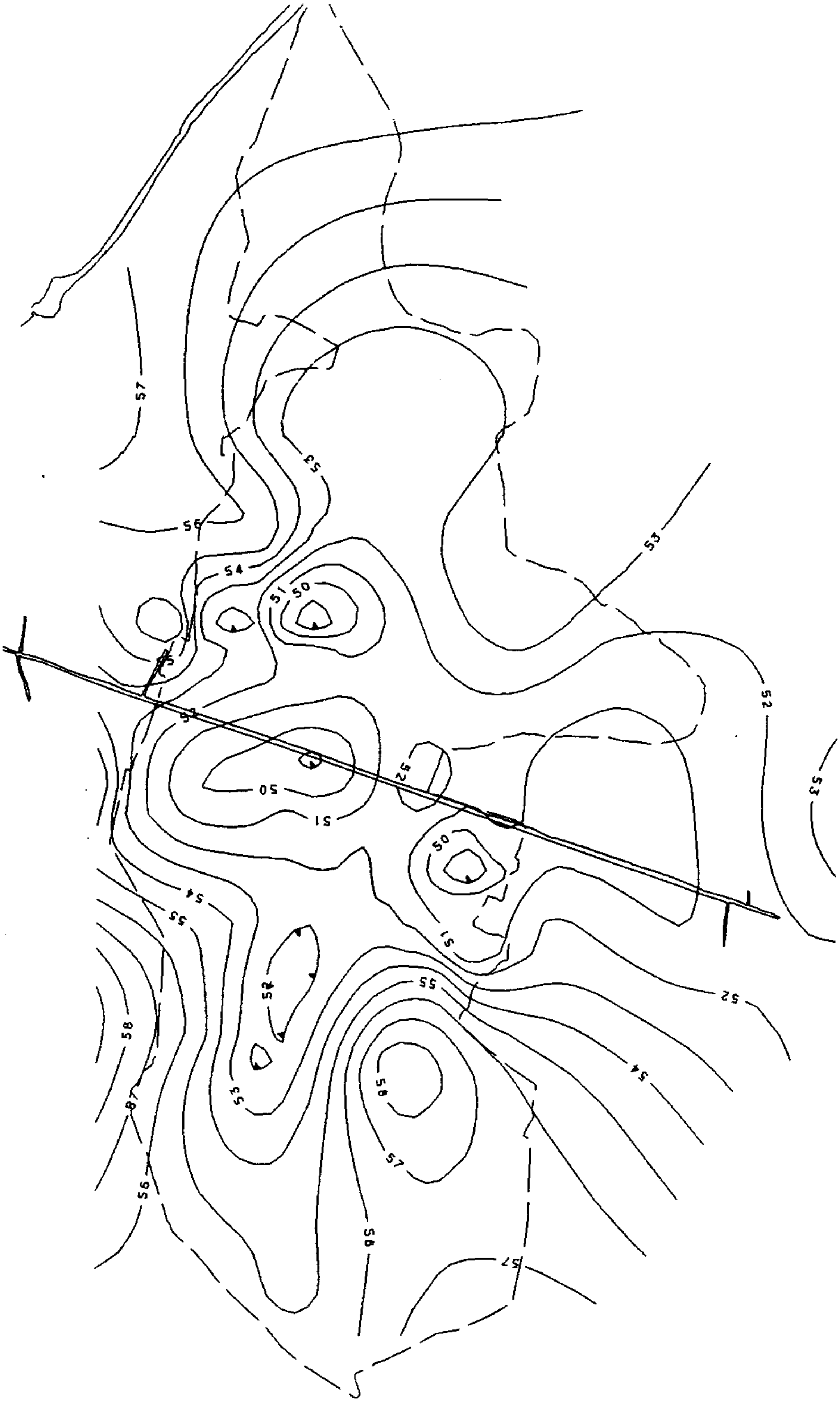

Figure 2.16: Till Surface Contour Map

2.3.6 Subpeat Surface Contour Map

The contour map of the subpeat surface shown in Fig 2.17 can be considered as an indication of the clay surface which underlies the peat. However the fact that clay is absent in a small number of areas underneath the peat, results in till forming the subpeat surface, and hence the term "Clay Surface" is misleading. A depression in the clay surface also occurs in the central region of the bog. This depression is enclosed by the 52m O.D. contour line. A narrow channel extends south from this depression, turning south-east just beyond the bog margin. This area represents the former extent of the raised bog, which once extended southwards in the area around the road. Minor deeper depressions occupy the main central low elevation area in the clay surface. These minor depressions occur to the south-west and north-east, varying in elevation from 47m to 49m O.D. In a north-east direction, from the central region, the clay surface elevation rises relatively steeply from 50m to 55m O.D. Contour lines in the east show the clay surface to be generally flat at around 52m O.D., again lack of data is a consideration here.

On the west side of the bog, clay surface contour lines rise gradually outwards towards the north-west and south-west, resulting in the formation of a channel below 55m O.D. extending to the west.

2.3.7 Till Thickness Contour Map

The term "Till" is used here as a collective term for the glacial deposits resting on the bedrock. Fig 2.18 shows the thickness of these deposits suggested from the VES data. A circular shaped area of thick till occurs towards the southern margin, in the central area of the bog. Here till reaches a maximum thickness of around 11m. Directly to the east, in the central area of Clara East, till thins out to below 5m forming a thin till cover less than 1m thick at the centre. A narrow channel of thin till cover extends southwards from here, towards the central area just south of the bog margin, till thickness being 2m to 3m. From the centre of Clara East, towards the north and east, till thickens gradually from approximately a 5m thick cover, to over 7m at the margin. South-east of the bog till cover thickens to form a circular shaped feature, increasing gradually on all sides to a maximum thickness of 12m.

The 5m contour line runs parallel to the south margin of Clara West, south of which till thins out to less than 3m, (less than 1m at its thinnest). On Clara East the 5m contour line intrudes northwards into the central area, showing an area where the till thins out to less than 1m.

In the west, another circular area of thick till cover exists, ranging in thickness from 8m to 13m. Apart from the above mentioned features, in general the till cover underneath the bog varies from 5m to 8m in thickness. Contour lines show an increase in till thickness as they extend northwards,

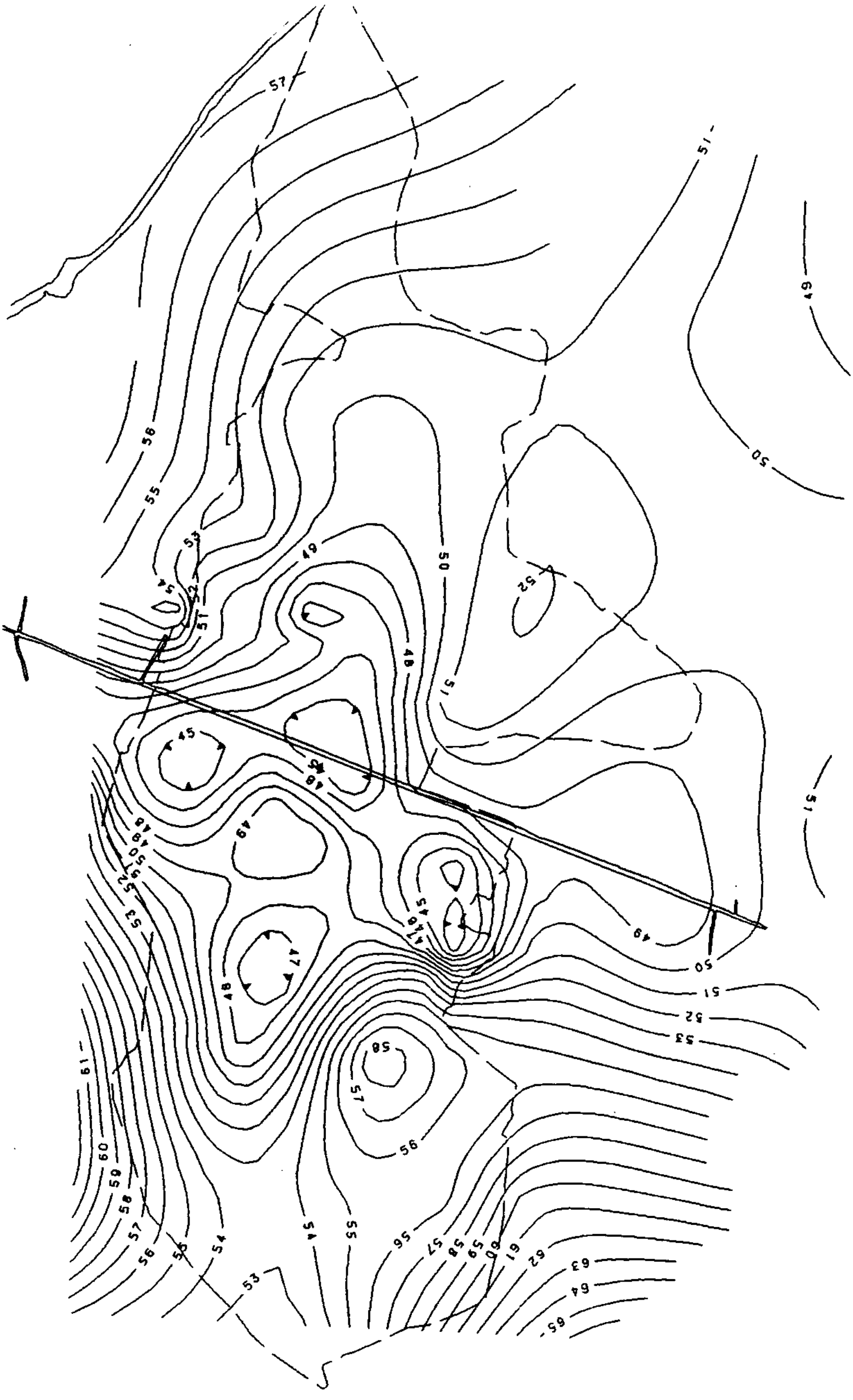

Figure 2.17: Subpeat Surface Contour Map

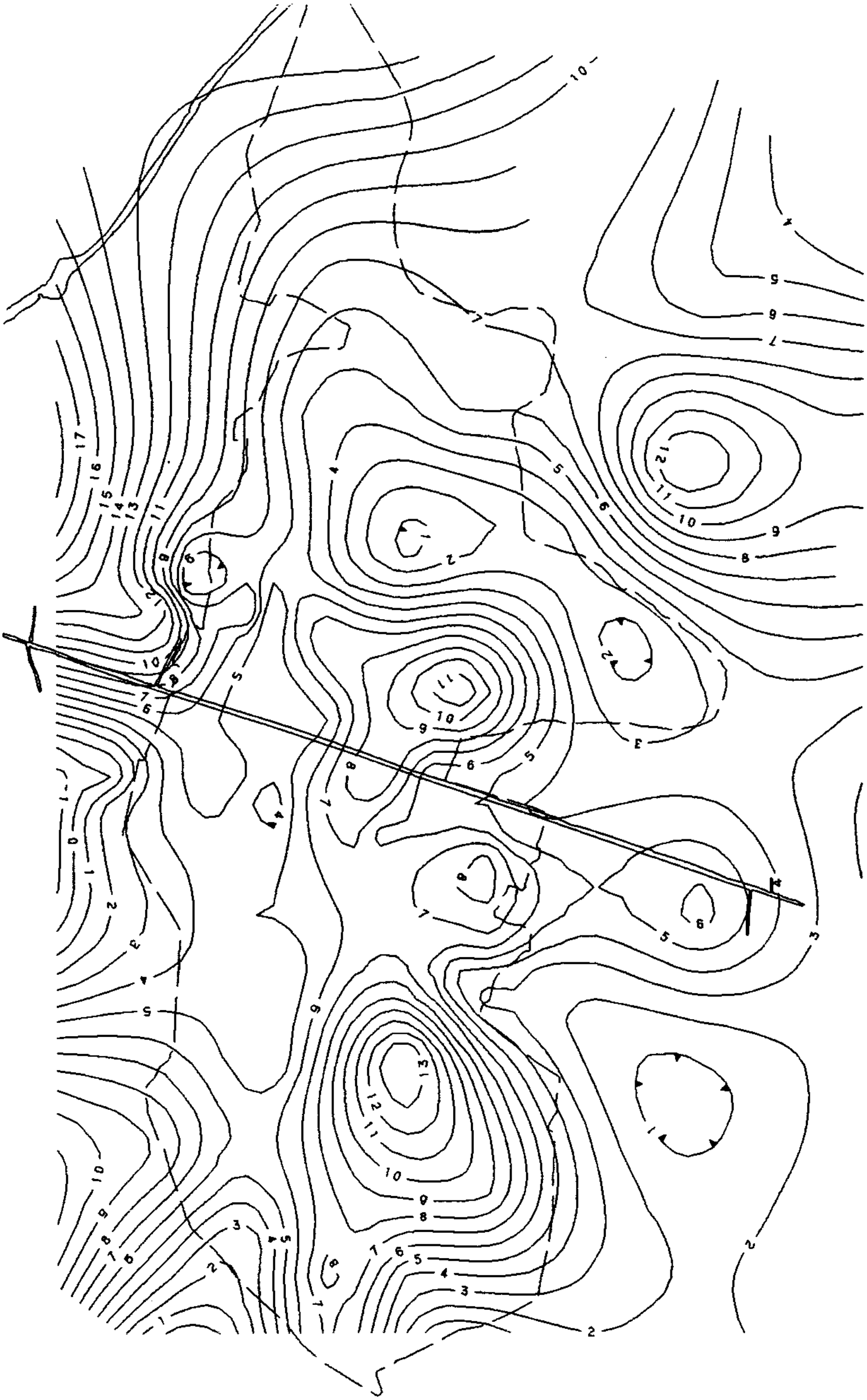

Figure 2.18: Till Thickness Contour Map

indicating the thicker cover of esker sediments to the north. This pattern is slightly interrupted by an area of thin till cover extending eastwards from the north-west, and by a second area situated in the north, a little left of centre.

2.3.8 Clay Thickness Contour Map

Clay Thickness Contours

Clay thickness contour lines compiled from the VES data are shown in Figure 2.19. In the central region of the bog, the area is enclosed from north to south by the 4m clay thickness contour line. Within this area of thick clay cover, one anomolous area of thin clay cover occurs, in the north central area. Here till cover is less than 2m thick. Four small circular areas of very thick clay cover surround this thin clay cover anomaly. Thickness of clay in these four areas range from 5m to 6m.

On Clara East, clay cover thickness varies very gradually, ranging from 4m in the centre to 2m at the margin. In the west, clay cover ranges in thickness from 1m to 2m. However this clay thickness is divided by a ridge running north to south where clay is very thin, being less than 1m thick. Clay cover is absent in the area of the mound, where gravelly till directly underlies the peat.

Clay Conductance Map

Values for clay thickness from the VES interpreted results, are contoured in Figure 2.19. However, due to the problem of equivalence at some sounding locations, referred to previously, clay thicknesses and apparent resistivities given for the respective soundings can vary, therefore the map in Figure 2.19 is our preferred model for clay thicknesses. The equivalence (see section 2.3) problem arises for the clay layer which is highly conductive, therefore, when the apparent resistivity of the clay layer is increased, the thickness also increases by the same proportion (i.e. ρ/h is constant). Hence, a clay layer of 2m thick with an apparent resistivity of 20 ohm-m, is equivalent to a 4m thick layer with an apparent resistivity of 40 ohm-m. Thickness variations are however, limited by the minimum and maximum apparent resistivities of the clay layer, which is approximately 20 to 60 ohm-m (see section 2.3.10 & Palacky et al., 1990).

In order to give an indication of the possible variations in clay thicknesses at the relevant VES locations, a clay conductance map has been produced (Figure 2.20). 2.20 By computing the conductivity of the clay layer with the corresponding value for clay thickness, at the respective soundings, a value for the conductance of the clay layer is arrived at. (Conductivity is the inverse of resistivity, units are in Siemen-m). If the apparent resistivity is to be increased by a certain amount, then the thickness will increase by the conductance times that amount (e.g. if apparent resistivity increase =

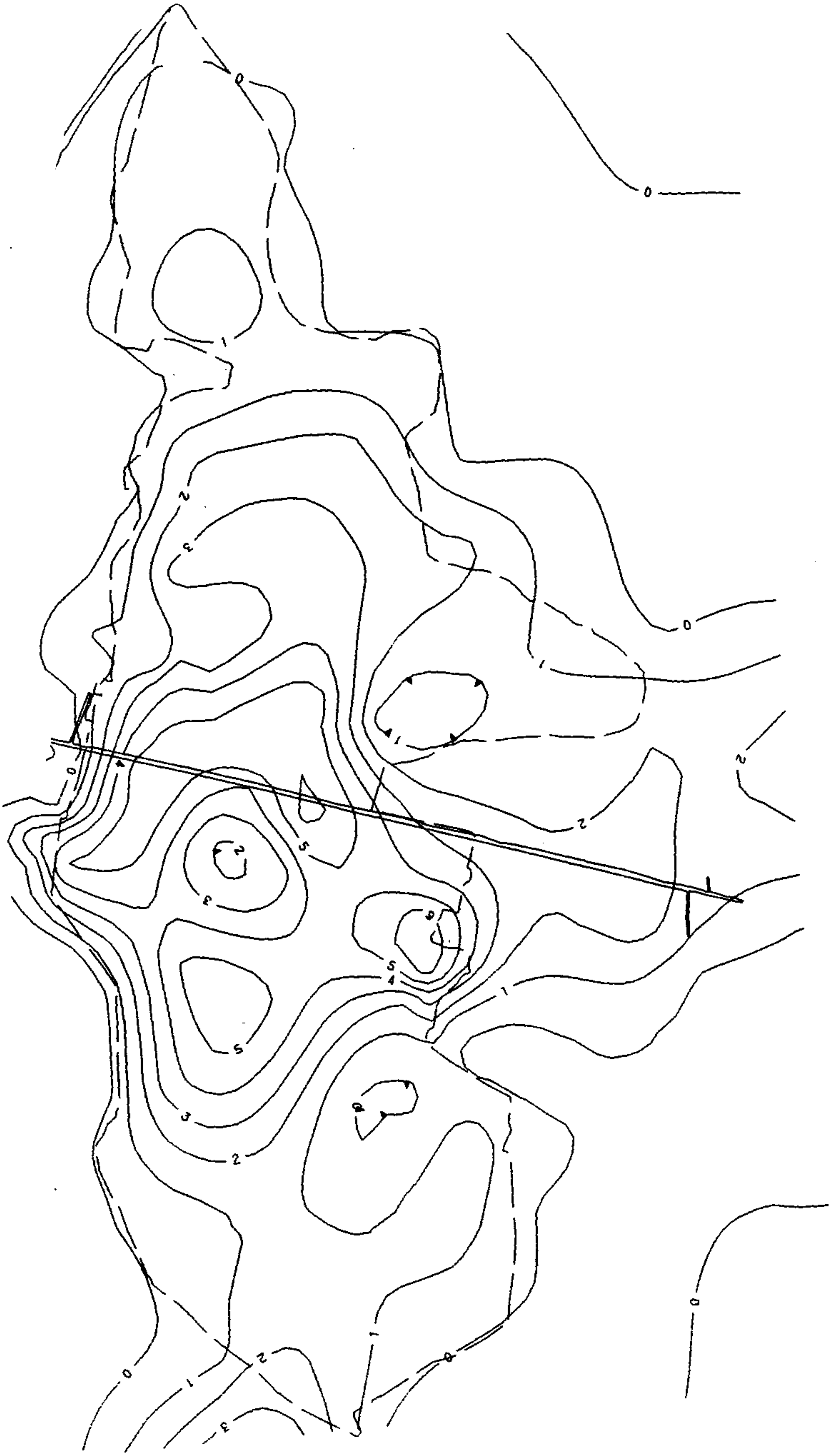

Figure 2.19: Clay Thickness Contour Map

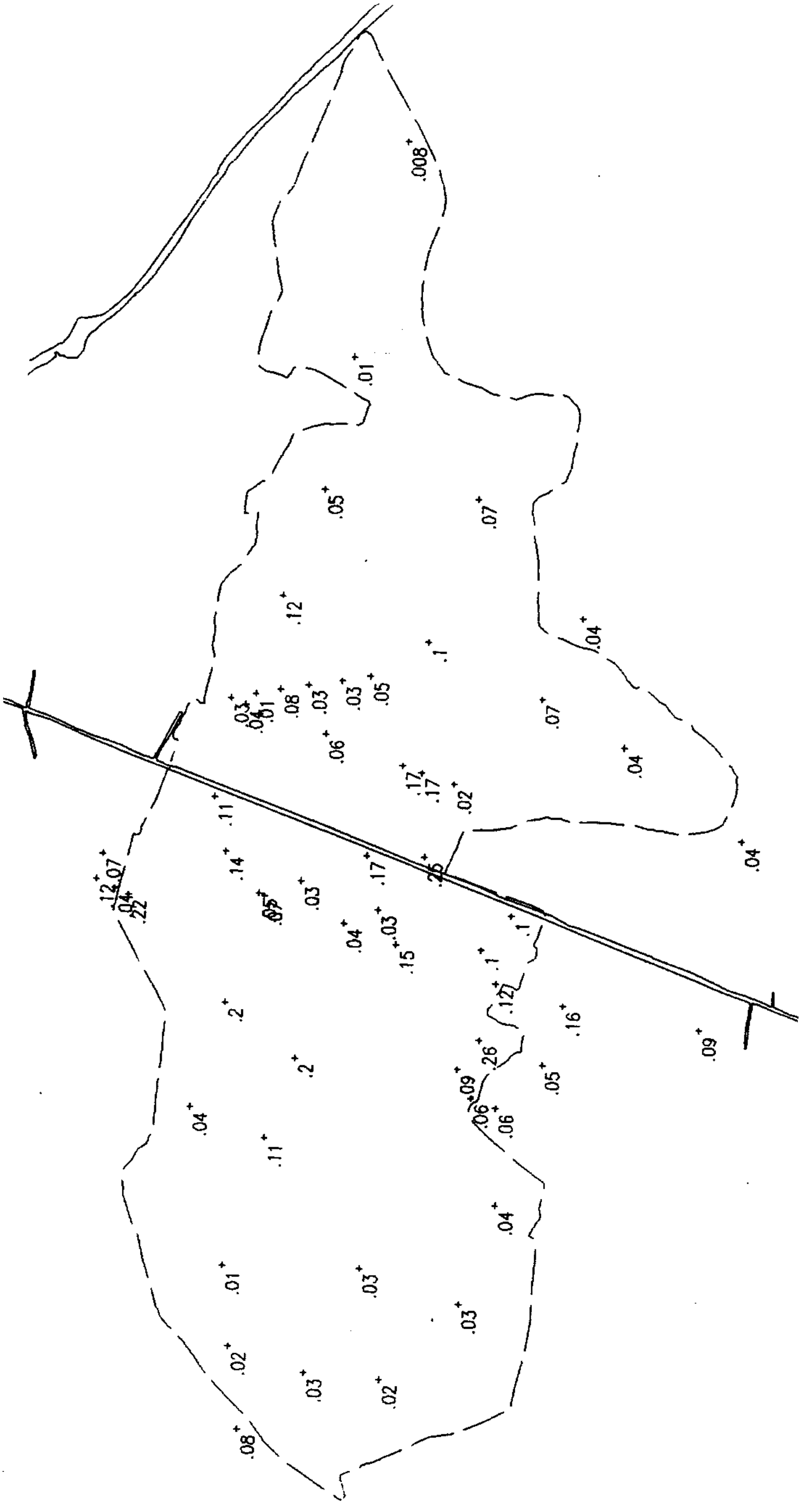

Figure 2.20: Clay Conductance Map

10 ohm-m, conductance value = 0.1 siemen, then thickness increase = 1m). Figure 2.20 shows conductance values varying from less than 0.01 siemens, to 0.26 siemens. These conductance values indicate the fraction by which clay thicknesses will increase in relation to an increase in the apparent resistivity. Large conductance values show locations where an increase in clay apparent resistivity will result in a large proportional increase in clay thickness; areas of low conductance values imply only small proportional increases in thicknesses. Conductance values are relatively high in the south central area of the bog, and in the northern area to the west of the road. On the east and west sides of the bog, low conductance values imply clay thicknesses are well constrained and the problem of equivalence is not significant.

2.3.9 Correlation of VES Contour Maps

To the south-west of the central area of the bog, a bedrock low orientated south-west to north-east, is represented by a similar shaped feature showing a depression in the till surface. Shallowing bedrock projecting from the north-west of the central area, in a direction south-west, is reflected by a similar elevation rise occurring in the till surface. In the north-east a projection southwards of shallowing bedrock, into the central area of deep bedrock occurs. This is again reflected in the till surface, showing an increase in elevation. The former and the latter shallowing features of the respective surfaces, are shown to be much more sharper in the bedrock surface, and more subtle in the till surface.

Directly south of the central area, the deep depression in the bedrock is mirrored by a more general broad featured depression in the till surface. However the steep shallowing of this bedrock depression to the west is reflected in the till surface. Similarly the gentler shallowing of this bedrock depression to the north-east, is represented by a broad shallower feature in the till surface.

Areas showing depressions in the bedrock surface tend to have a thick infill of till. This in turn has a thick cover of clay, as the till does not entirely smooth out the depression. This is particularly evident in the central area, towards the south-west and towards the east of the central area. At these two locations, depressions in the bedrock, till and clay surfaces, respectively, become less pronounced. This is reflected by the thick infill of till and clay in the two areas.

A little to the north-west of the central area, the rise in elevation of the respective surfaces is indicated by a thinning out of the till and clay cover, respectively.

In general, the central area of the bog corresponds to a depression in the bedrock surface, which is in turn reflected by a less pronounced depression in the till and clay surfaces, due to the thick infills of the latter deposits. This is emphasised by comparing the area of deep bedrock in Figure 2.15, with that of the areas where depressions occur in the subpeat and till surfaces, summarised in Figure 2.21 and Figure 2.22, respectively. Bedrock in general shallows towards the margins, which is the general trend of the till and clay surfaces, as the respective covers thin out.

2.3.10 Apparent Resistivities of Lithologies

Histograms shown in Figure 2.23 are compiled from the apparent resistivities of the respective geological layers, indicated by the VES (Schlumberger and Offset-Wenner arrays). 1a shows that the apparent resistivity of the surface spongy peat is around 80 to 140 ohm-m, with a maximum value of 180 ohm-m. The average apparent resistivity range for the compact peat underneath, is higher than that of the surface peat, normally ranging from 160 to 220 ohm-m (1b). Values for cutaway peat areas indicate low apparent resistivities of 60 to 100 ohm-m (1c), which is possibly due to disruption and possible mixture with other sediments, at the bog margins. Lacustrine clay sediments lying underneath the peat are highly conductive (1d). Apparent resistivities for this layer are generally within the 20 to 70 ohm-m range. Glacial deposits resting on the bedrock indicate apparent resistivities normally distributed about the 120 to 220 ohm-m range (1e), with higher and lower values suggesting an increase in gravel and clay content, respectively. Bedrock apparent resistivities lie within two distinct apparent resistivity ranges; 1000 to 4000 ohm-m and 5000 to 6500 ohm-m.

Clay and till apparent resistivity ranges obtained from the VES data for the study area, agree very favourably with the apparent resistivity ranges suggested in Palacky (1990). A clay apparent resistivity range of 30 to 60 ohm-m is given in this paper, with till apparent resistivities ranging from 60 to 210 ohm-m. Different resistivity values for the bedrock in the study area are possibly due to differential weathering of the bedrock.

2.4 VLF-R Resistivity Map compared with VES Bedrock Contour Map

A comparison of the bedrock surface contour map (Fig. 2.13) with that of the VLF-R resistivity contour map of Clara bog (Fig. 2.8), highlights the effectiveness of the technique as a quick reconnaissance method for mapping the sub-surface topography.

The longitudinal area of high apparent resistivity in the north central region of the map in Figure 2.8, corresponds to the area of shallowing bedrock shown in Figure 2.13. The shallow bedrock plateau in the east is indicated by the apparent resistivity high in this region. Just south of Clara West, an area

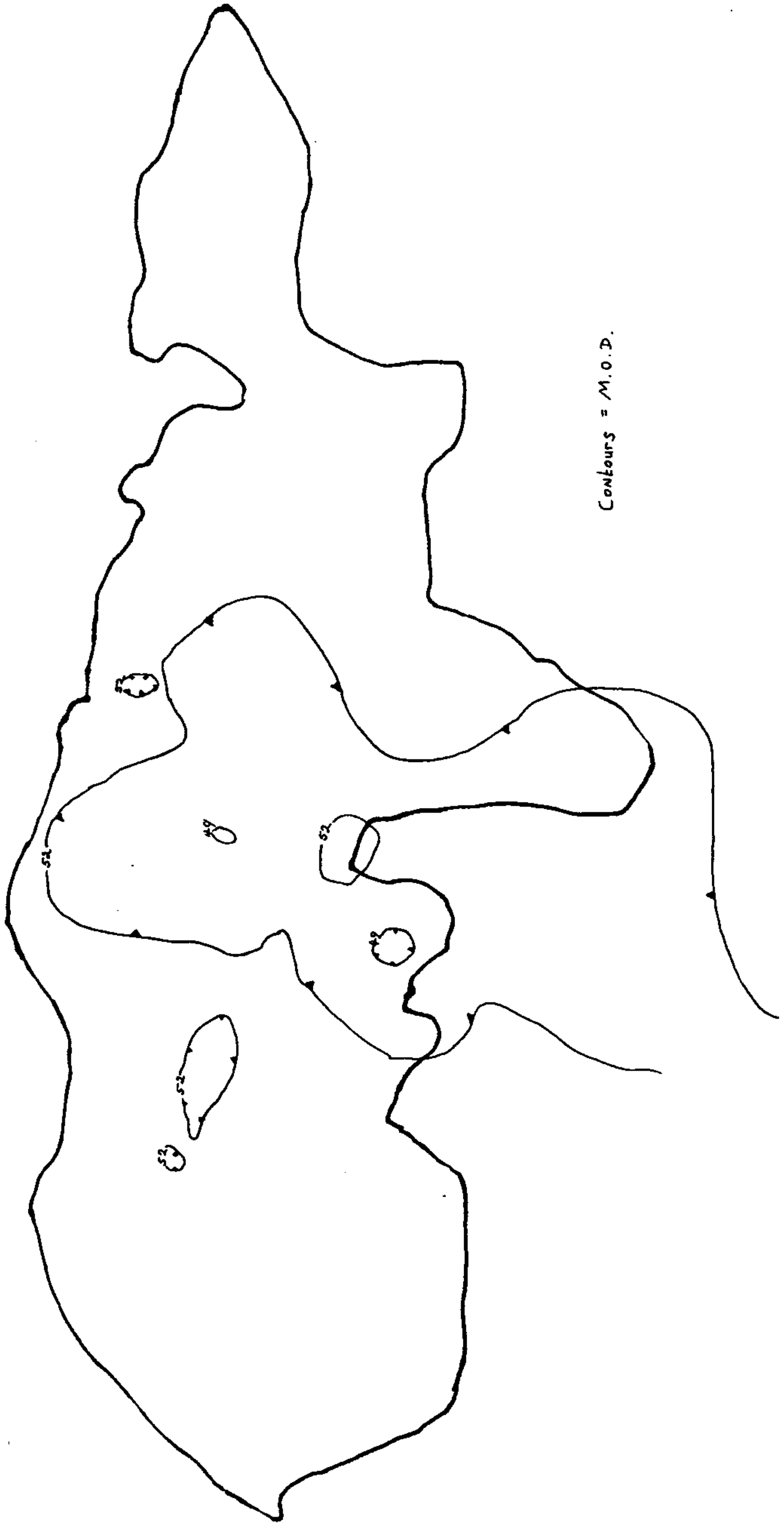

Figure 2.21: Summary Map of Depressions in Subpeat Surface on Clara Bog

Figure 2.22: Summary Map of Depressions in Till Surface on Clara Bog

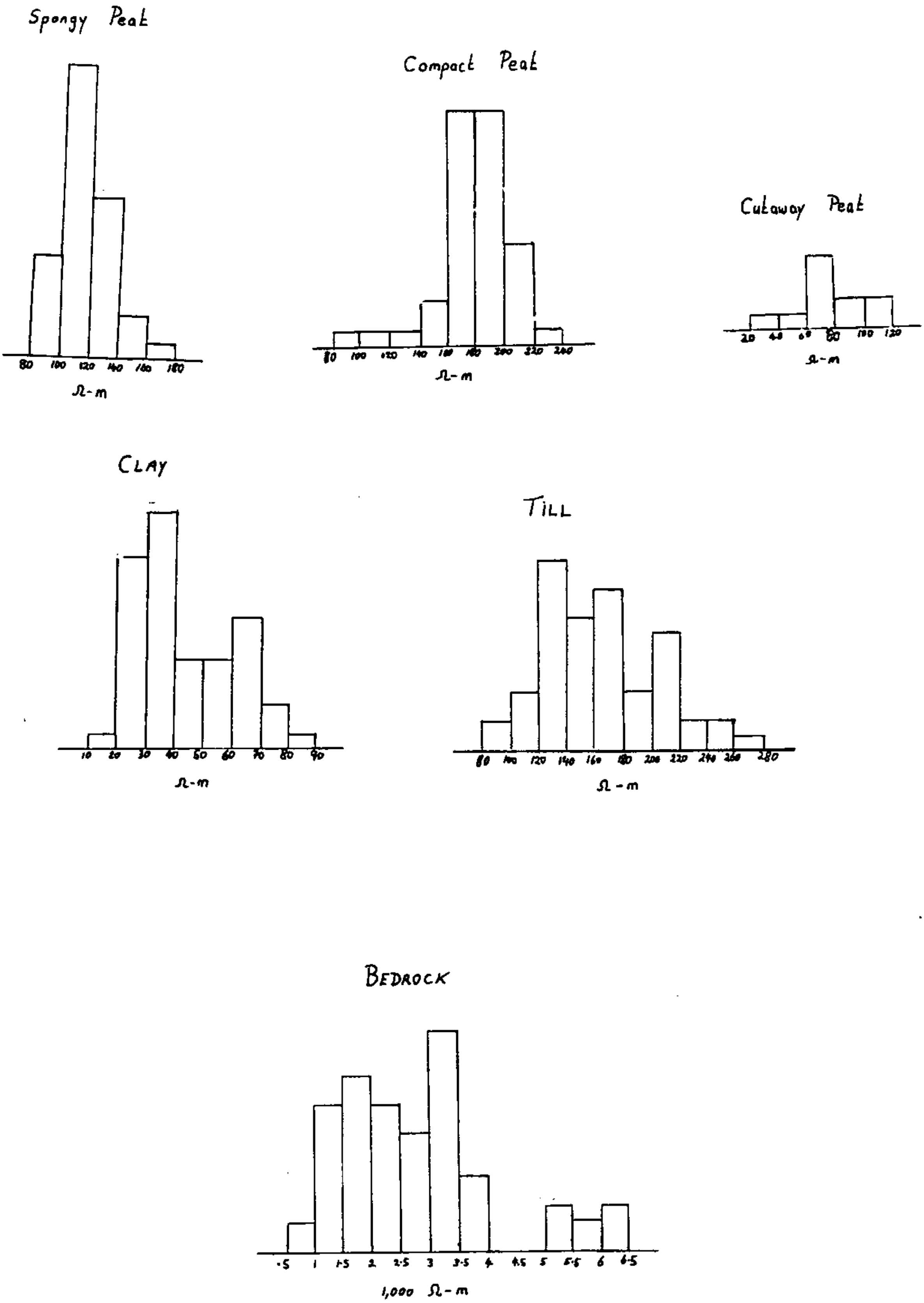

Figure 2.23: Histograms of VES Apparent Resistivities of Lithologies on Clara Bog

of high apparent resistivity running parallel to the bog margin, is connected to a ridge of high apparent resistivity perpendicular to it, and extending northwards into the centre of Clara West. Bedrock shallowing indicates this pattern. Similarly, shallowing bedrock intrusions from the north, and from the north-west, are reflected in apparent resistivity highs.

The central area of low apparent resistivity indicated by the VLF-R survey (Figure 2.8), corresponds to the central depression in the bedrock surface shown in Figure 2.13. This is emphasised by the similarities in the respective summary maps of Figure 2.9 and Figure 2.15. Minor areas of very low apparent resistivity correspond to minor, deeper, depressions in the bedrock.

2.5 Peat Base Contour Maps - VES data compared with BnM data)

As a result of the variation in the distribution of Bord na Mona data points with that of VES locations, the contoured maps of the peat base produced by the respective data sets will differ. However the general trend of the peat base should be similar in both maps. The maps will vary by a small amount but where the respective data points coincide, the VES interpretations were constrained by the Bord na Mona peat thickness values.

Bord Na Mona peat base contour lines (Fig. 2.4 show the peat base to be of lowest elevation in the south-central area. Here the peat base is below 50m O.D. The entire central area of the bog is enclosed by the 51m O.D. contour line, which extends out in a narrow channel to the west and east. A similar pattern is reflected by the 52m O.D. contour line of the bedrock surface contour map, compiled from the VES data (Fig. 2.13), as it too extends in an easterly and westerly direction. Closer, more regular spacing of Bord na Mona sampling stations, in comparison to that of the VES locations, results in more detailed information about the peat subsurface being displayed by the former data set. However, the broad pattern of the peat subsurface is evident in both maps.

A remarkable correlation between the two maps is evident on the east side of Clara Bog. Sub-peat surface elevation varies very little, from 52m to 53m O.D., on both maps, with contour lines showing similar patterns. In the north, just east of the road, the steep increase in subpeat surface elevation approaching the northern margin, is evident on both maps. Further to the east, the Bord na Mona data shows the high surface elevation along the northern margin to extend further southwards into the area of the bog. This subpeat surface high elevation is represented on the VES contour map, but the steepness of this elevation rise is not shown in the extreme north east because of lack of VES data in this area.

Elevation highs to the north west and south west of Clara bog are indicated on both maps, as is the channel-like depression in the peat subsurface, extending to the west. VES data extends further west than that of the Bord na Mona data, which is reflected in the higher elevation values extending further to the west than that of the Bord na Mona data.

2.6 Electrical Resistivity Profiling - Dipole-Dipole Technique

Electrical Resistivity Profiling techniques are used for mapping lateral changes in the earth's resistivity. It is particularly useful for locating a contact between two areas of contrasting resistivities, such as delineating geological boundaries, faults and cavities. The method involves measuring the apparent resistivity of the subsurface at various depths along a transect. Contours of the apparent resistivity of the subsurface are drawn along a profile, and this is called a vertical pseudosection of the ground. It is not a geological cross-section of the earth, as we are looking at apparent resistivity variations and cannot accurately quantify the depth to any anomaly from the pseudosection plots. Roy et al (1971) estimate the depth of investigation of the Dipole-Dipole electrical profiling technique to be approximately 0.195L, where L is the end to end length of the array. In the Clara and Raheenmore region, the depth of investigation is approximately 68m, end to end length of the array being 350 m.

Figure 2.24 shows the location of the six dipole-dipole pseudosections discussed in Dowling (1991), and the additional pseudosection discussed in Smyth (1991). Two electrical resistivity profiles were carried out parallel to the road, along line 300W and 300E of the OPW grid, respectively. Four additional profiles were carried out perpendicular to the road, these lines occupied stations 200S, 500S, 800S and 1000S respectively, and extended from line 300W to 300E. Locations of the six latter resistivity profiles were chosen in order to give detailed information about the area around the road, in the centre of the bog. In the summer of 1991 this area was the focus of a hydrogeological M.Sc. project carried out by Judith Bell (1991), and detailed information about the area was required for modelling purposes. The seventh resistivity profile was carried out along Line A, shown in Figure 2.24. The resistivity values along the respective profiles are contoured, and the results are assessed qualitatively.

Line 300W

Figure 2.25 shows the contoured apparent resistivity values along the pseudosection for Line 300W. Along the dipole-dipole profile from stations 50 to 200, the pseudosection suggests a moderately low apparent resistivity

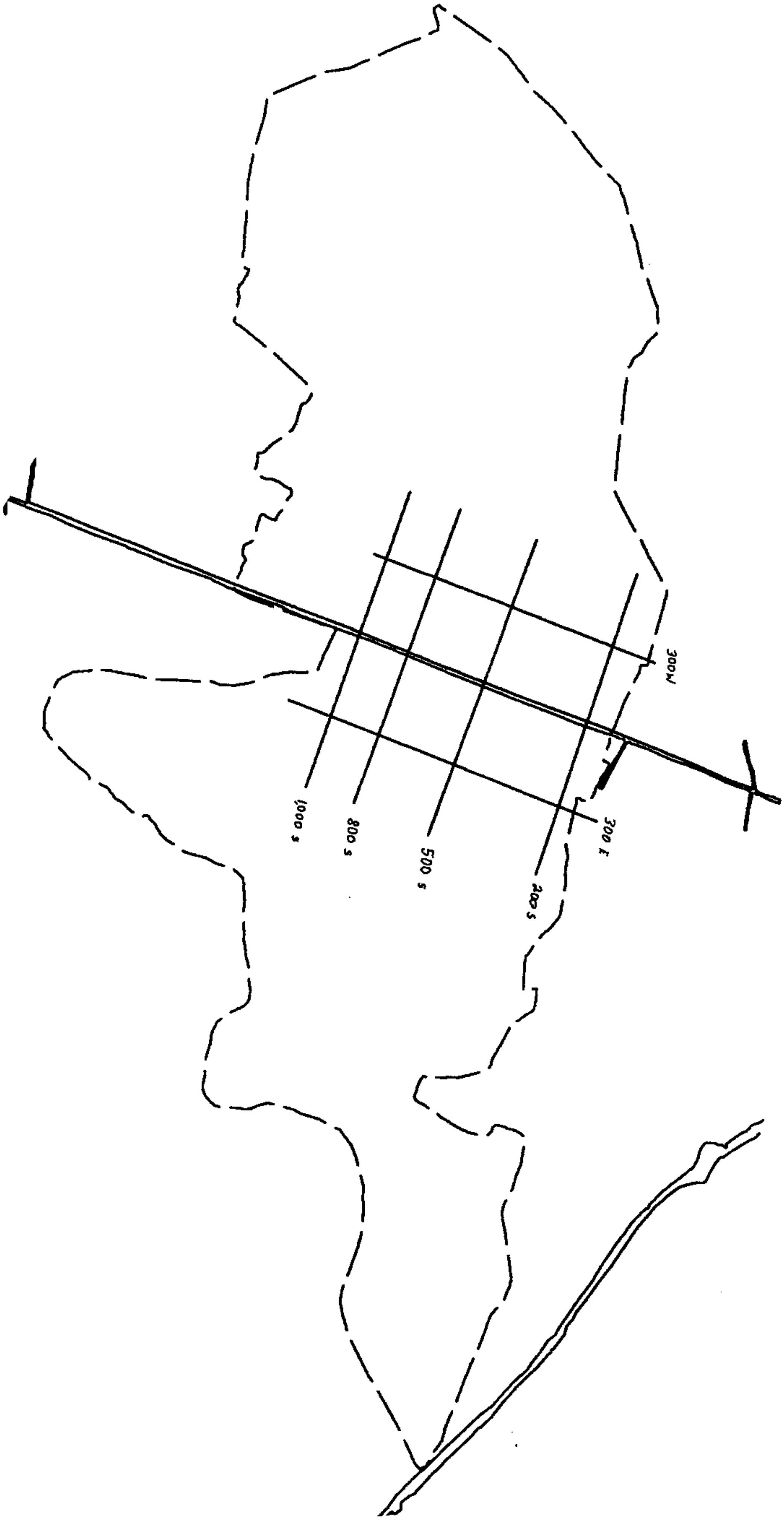

Figure 2.24: Location of Dipole-Dipole pseudosections on Clara Bog

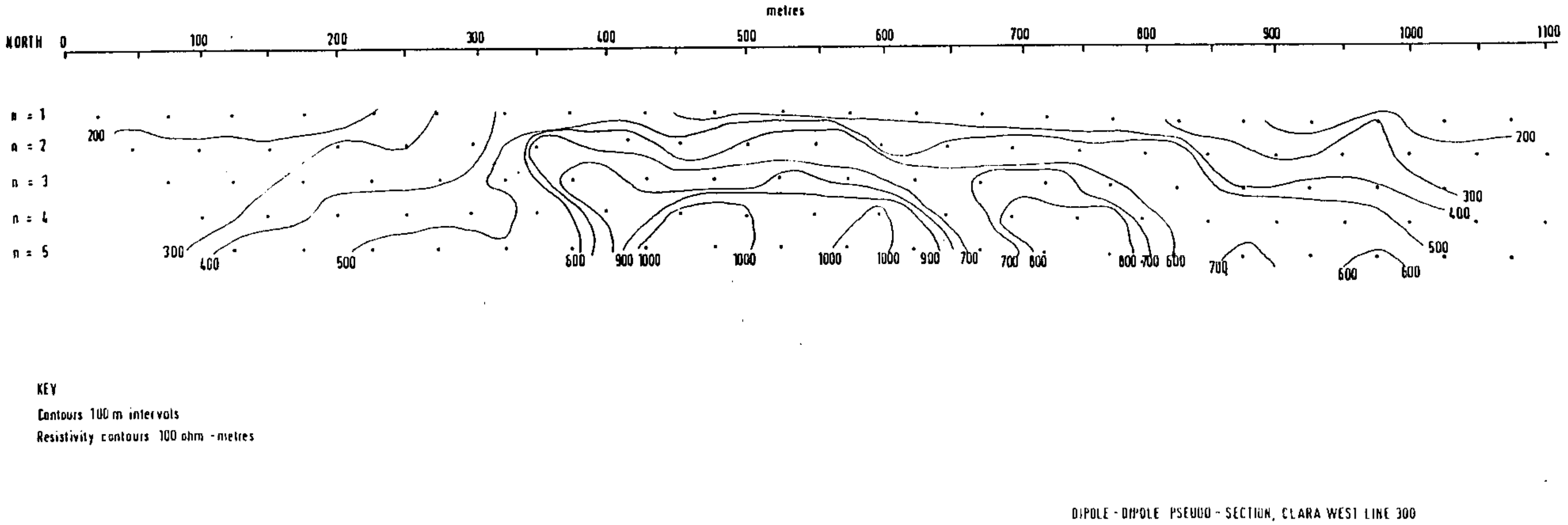

Figure 2.25: Dipole-Dipole pseudosection along line 300W

material of less than 200 ohm-m, is being encountered near the surface. Below this the technique penetrates to a maximum depth in material of relatively low apparent resistivity material. Such low apparent resistivities indicate that the bedrock is too deep at these locations to be penetrated.

Between stations 200 to 300, the apparent resistivity of the near surface material increases to between 200 ohm-m to 400 ohm-m, while the apparent resistivities of the deepest material is 500 ohm-m. Here bedrock is shallowing and the higher resistivities of the near surface material indicate that till is relatively nearer to the surface also. After station 300, the 500 ohm-m contour line rises almost vertically to the surface, indicating that the bedrock shallows dramatically in this area. Between stations 300 and 450 the 500 ohm-m contour line runs parallel to the surface of the pseudosection, indicating that bedrock in this area is extremely close to the surface, with very little covering of glacial deposits. From stations 450 to 800 the 500 ohm-m contour line is still relatively close to the surface, however the presence of the 400 ohm-m contour line running parallel above it, suggests that glacial deposits are thickening slightly, but are still relatively thin and resistive.

At location 850 along the pseudosection, the 500 ohm-m contour line descends to a lower depth, maintaining this depth until station 1000 where it descends again. Bedrock here is indicated to be deepening slightly, but is still relatively shallow. After station 850 the near surface apparent resistivity values decrease to less than 200 ohm-m, suggesting thicker clay deposits and glacial overburden.

The increase in bedrock depth does not occur quite as dramatically on the south side as it does on the north side of the transect. The highest apparent resistivities recorded, being in excess of 1000 ohm-m, occur between stations 425 and 500, and 550 and 600 respectively.

Line 300E

The resistivity pseudosection along Line 300E of the O.P.W. grid is displayed in Figure 2.26. Location 50 along this pseudosection shows values of 600 ohm-m nearest the surface, suggesting extremely shallow bedrock with very little overburden. The 600 ohm-m contour line is parallel to the surface until station 150, where it descends at an angle of approximately 45 degrees until station 450 where it forms a trough like depression. From location 450 the 600 ohm-m rises to form a relatively shallower area of high resistivity between location 250 to 450.

At station 100, the 500 ohm-m contour line appears at the surface and runs parallel to the 600 ohm-m contour line, until station 450, where it runs parallel to the base of the pseudosection. Between stations 525 to 575 a circular anomaly of greater than 600 ohm-m resistivity material near the base of the pseudosection causes the 500 ohm-m contour line to rise slightly, before it disappears completely.

Between locations 575 and 650 bedrock is relatively deep, as the highest

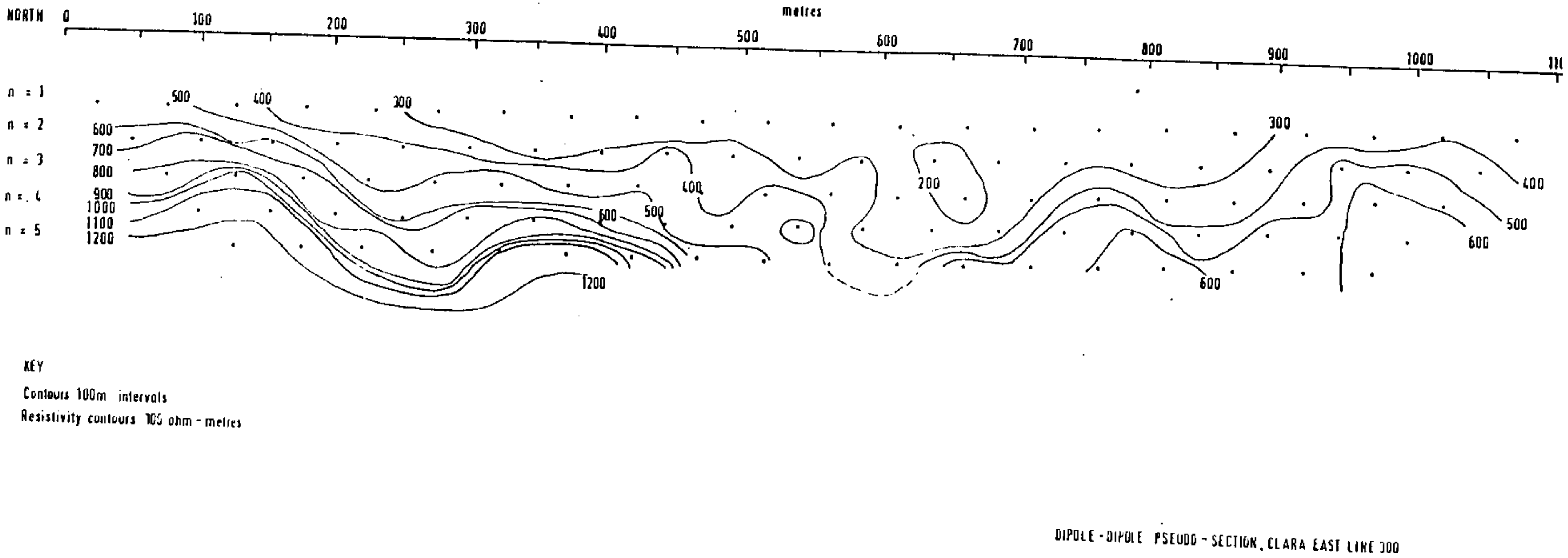

Figure 2.26: Dipole-Dipole pseudosection along line 300E

resistivity of the material penetrated by the dipole-dipole technique in this area is 300 ohm-m to 400 ohm-m. Near surface resistivities in this area are 200 ohm-m to 300 ohm-m. After station 650 the 500 ohm-m contour line appears again, running parallel to the base of the pseudosection. Bedrock is indicated to be shallowing further between locations 750 to 825 where the 500 ohm-m contour line forms shallow resistivity high area. At station 900 the 500 ohm-m contour line continues to rise, showing an extremely shallow bedrock near the surface, in the area from location 950 to 1050, at the end of the transect.

To summarise, bedrock is relatively shallow in the area between stations 0 and 575, and between 650 and 1050. Bedrock is extremely close to the surface at the beginning and end of the profile, between stations 0 to 175, and 950 to 1050. The technique has not penetrated bedrock between stations 575 to 650, as low resistivities are shown here. Resistivities along the surface of the pseudosection are relatively high, indicating till deposits near the ground surface.

Line 200S

The pseudosection along Line 200 S of the OPW grid, shows contoured apparent resistivity values every 100 ohm-m, in Figure 2.27. Beginning at station -450, the 500 ohm-m contour line starts midway between the surface and base of the pseudosection, and descends gently downwards until it disappears completely at station -150. This would suggest a relatively shallow bedrock, gently sloping. Between stations -150 to 0, the 500 ohm-m contour line appears again to show a high apparent resistivity anomaly near the base of the pseudosection, indicating a slight topographic high in the bedrock. At station 50 the 500 ohm-m contour line appears from the base of the pseudosection, rises almost vertically, and runs parallel to the surface. Between stations 100 to 450 it represents the lowest contour value at the surface.

In summary, bedrock is relatively shallow, gently sloping downwards, between stations 450 to 0. Bedrock is shown to be deep in the area between locations 0 and 75, as only low apparent resistivity materials are encountered here, indicating that bedrock was too deep for the technique to penetrate. From stations 75 to 450 an extremely shallow platform of bedrock is shown, by the high resistivity values close to the surface of the pseudosection. The almost vertical steepness at which the contour values ascend towards the surface at station 75, is indicative of some type of sharp contact within the bedrock. Extremely high apparent resistivities, greater than 1000 ohm-m, are shown from station 175 to the end of the transect at location 400.

Line 500S

The resistivity pseudosection along Line 500 S is displayed in Figure 2.28. Low apparent resistivities are shown at the beginning of this particular pseudosection. Between stations -450 and -375, apparent resistivities less than 200 ohm-m are indicated near the surface, while those at the base are less than

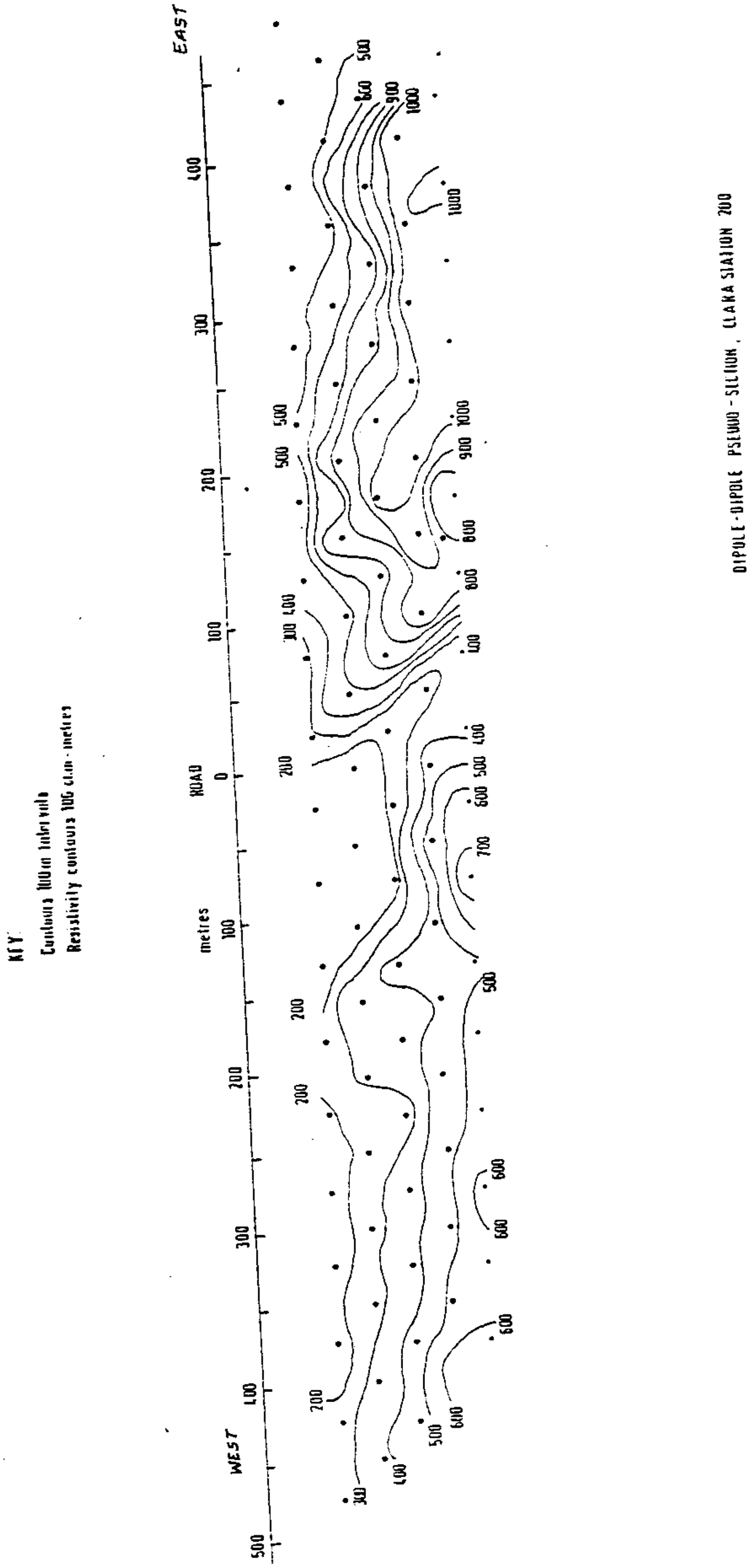

Figure 2.27: Dipole-Dipole pseudosection along line 200S

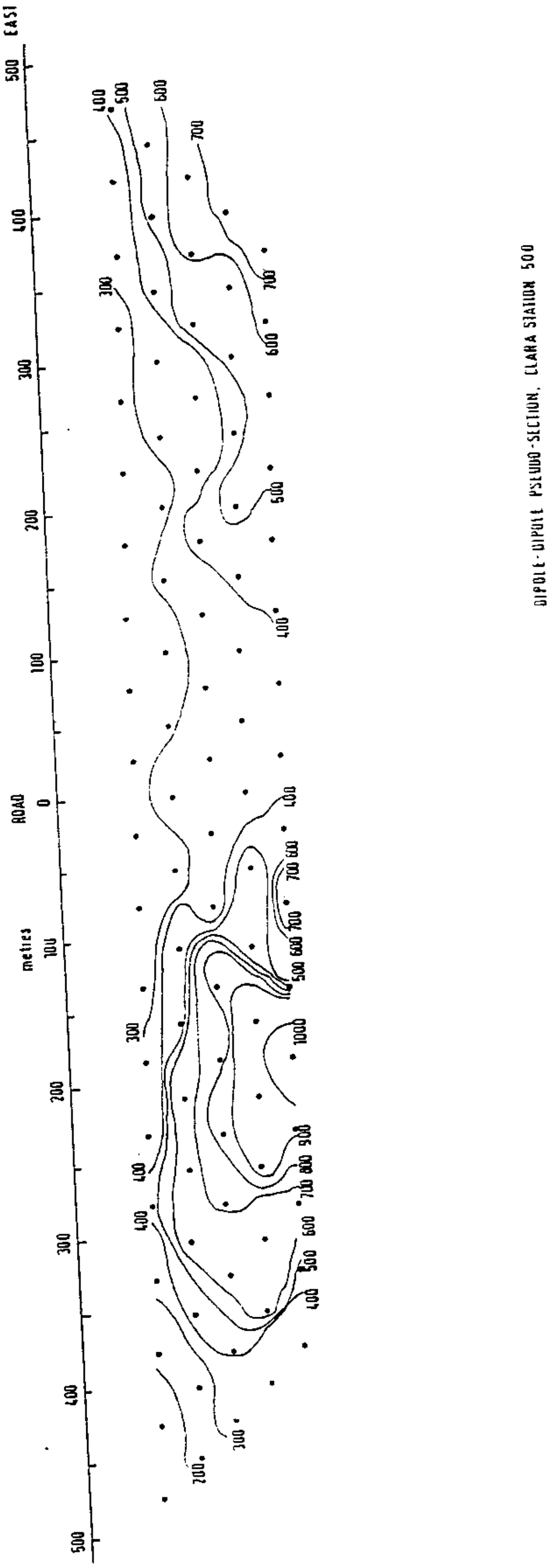

Figure 2.28: Dipole-Dipole pseudosection along line 500S

400 ohm-m. From station -375 to -50, a shallow anomaly of high apparent resistivity material, greater than 500 ohm-m, indicates near surface bedrock. The 500 ohm-m contour line rises sharply in a concave shape at station -350, continues very close to the surface between stations -300 to -100, and then descends a little less dramatically in a more convex shape between stations -100 to -50. In the area between stations -50 and 175, apparent resistivities at the surface and base of the pseudosection are very similar, values being around 300 ohm-m. Again, such low apparent resistivities would indicate bedrock depths to be too great for the dipole-dipole technique to penetrate. At station 175 the 500 ohm-m contour line appears at the base of the pseudesection indicating relatively shallow bedrock as far as station 275. At station 275 this same contour line continues to rise steadily until it comes close to the surface at the end of the transect, at station 450, indicating a rather steep rise in the bedrock.

In summary, bedrock forms a shallow isolated platform in the areas from -375 to -100, and 325 to 450. Bedrock is relatively deep in the areas from -450 to -375, and -50 to 175. In the area between location -250 to -125, extremely resistive bedrock of over 900 ohm-m is indicated at the base of the pseudosection. Near the surface of the pseudosection, apparent resistivities of the overburden are between 200 ohm-m to 300 ohm-m, except over the areas of very shallow bedrock, where apparent resistivities of around 400 ohm-m are recorded.

Line 800S

Contoured apparent resistivity values for the pseudosection along Line 800 S are shown in Figure 2.29. The 500 ohm-m contour line indicates that from station -550 to -100, bedrock is shallow, being extremely close to the surface between stations -450 and -250. Apparent resistivities of the deepest lithology encountered in the area between stations -100 and 275, are around 200 ohm-m to 300 ohm-m, suggesting bedrock depths are too great to be picked up in this profile. At station 275, the 500 ohm-m contour line appears at the base of the pseudosection, suggesting bedrock shallowing in this area. At station 350, the 500 ohm-m contour line rises rather steeply to near the surface, again indicating a relatively steep shallowing of the bedrock here. Surface material apparent resistivity values shown along the pseudosection are around 300 ohm-m, apart from the area between stations -200 and 125, where apparent resistivities are less than 200 ohm-m.

Line 1000S

In Figure 2.30 the contoured apparent resistivity values for the resistivity profile along Line 1000 S are shown. The first part of this pseudosection indicates material of very low apparent resistivity occurring at great depths. The 100 ohm-m contour line did not appear in the previous pseudosections, but here occurs close to the surface between stations -450 and -350. From station -450 to -50, the 200 ohm-m contour line occurs at a slightly greater

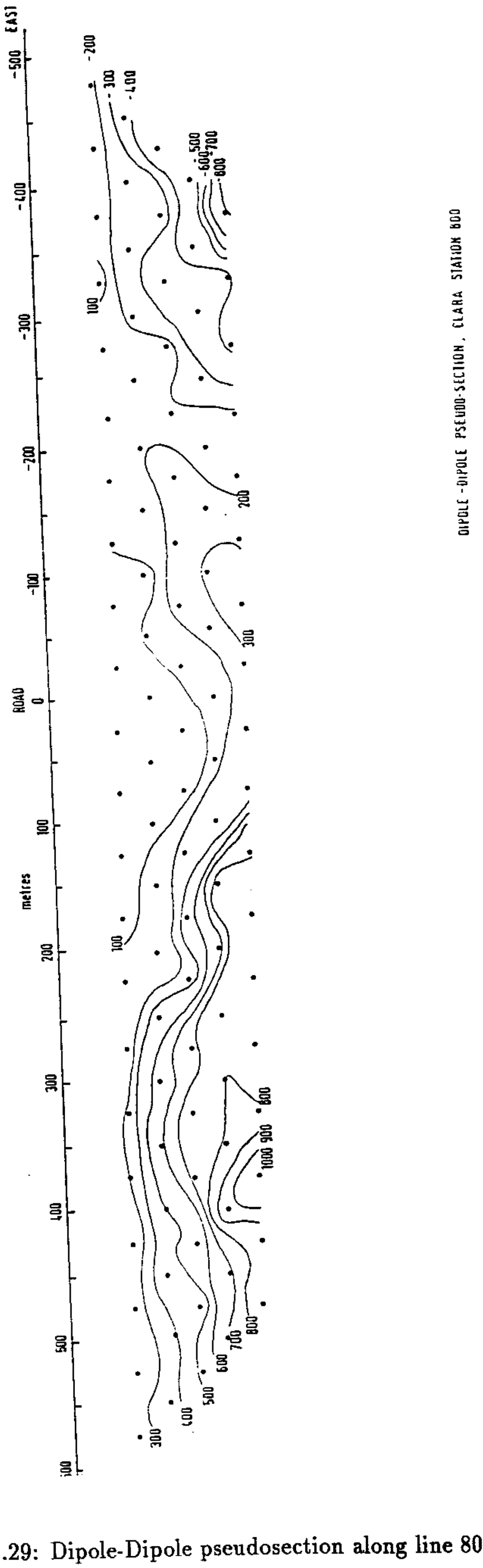

Figure 2.29: Dipole-Dipole pseudosection along line 800S

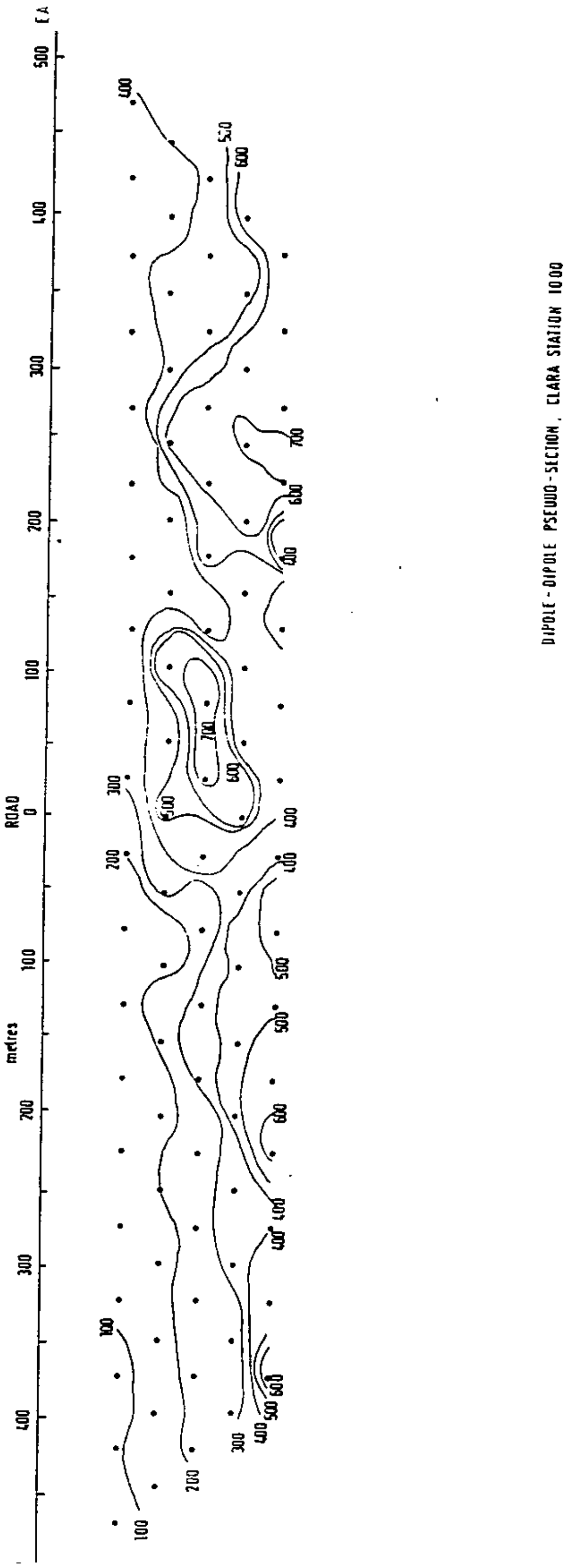

Figure 2.30: Dipole-Dipole pseudosection along line 1000S

depth than it did on previous pseudosections, indicating the glacial deposits to be much thicker in this area. From station 0 to 450 at the end of the profile, the apparent resistivities of the surface material is greater than 200 ohm-m, and greater than 300 ohm-m in some cases. The latter half of the pseudosection indicates much thinner glacial deposits covering the bedrock, as the higher contour apparent resistivity values are closer to the surface.

In the first part of the pseudosection (stations -450 to -50), the bedrock appears to be shallowing, indicated by intrusions from the 500 ohm-m contour line at the base of the pseudosection profile. These intrusions occur in the areas from station -450 to -350, -250 to -150, and -100 to -50. Between stations 0 and 100 an apparent resistivity anomaly of greater than 500 ohm-m occurs surrounded by apparent resistivities of around 40 ohm-m. This anomaly could possibly be indicating fractured bedrock. This is a likely possibility as the 500 ohm-m contour line appears again at the base of the pseudosection, just below this high apparent resistivity anomaly, indicating definite shallowing of bedrock. At location 175 the 500 ohm-m contour line rises almost vertically to form a very shallow bedrock area between stations 175 and 325. Directly under station 350, the bedrock deepens to form a slight depression, and then rises to a relatively shallow depth between stations 375 to 450.

Line A

Figure 2.24 shows the north-south orientated Dipole-Dipole electrical resistivity profile along Transect A. Beginning in a hollow in the esker ridges 800m north of the bog, this resistivity profile traversed the esker and extended into the centre of the bog as far as L.Roe.

Figure 2.31 shows the resistivity pseudosection for Line A. From the beginning of the transect to station 100, contour apparent resistivity values are not greater than 300 ohm-m, indicating deep bedrock. After station 100, the 500 ohm-m contour line rises towards the surface, suggesting extremely shallow bedrock between stations 150 and 350. Between 350 and 500 the 500 ohm-m contour line extends towards the base of the pseudosection indicating a deepening of the bedrock in this region. At station 550 the 500 ohm-m contour line rises sharply implying near surface bedrock between stations 550 and 700. The 500 ohm-m contour line descends towards the base of the pseudosection at an approximate angle of 45 degrees, disappearing at station 775. Ground apparent resistivities of 200 to 300 ohm-m between stations 775 and 800, imply relatively deep bedrock. The 500 ohm-m contour line rises again vertically after station 850, and runs parallel to the surface mid-way along the pseudosection, until it disappears vertically downwards at station 1050. Between stations 1050 and 100 ground apparent resistivities of 400m are indicated. At station 1100 the 500 ohm-m contour line rises vertically, before descending vertically again at station 1200, forming a shallow block of relatively high apparent resistivity, rising from the base to mid-way along the

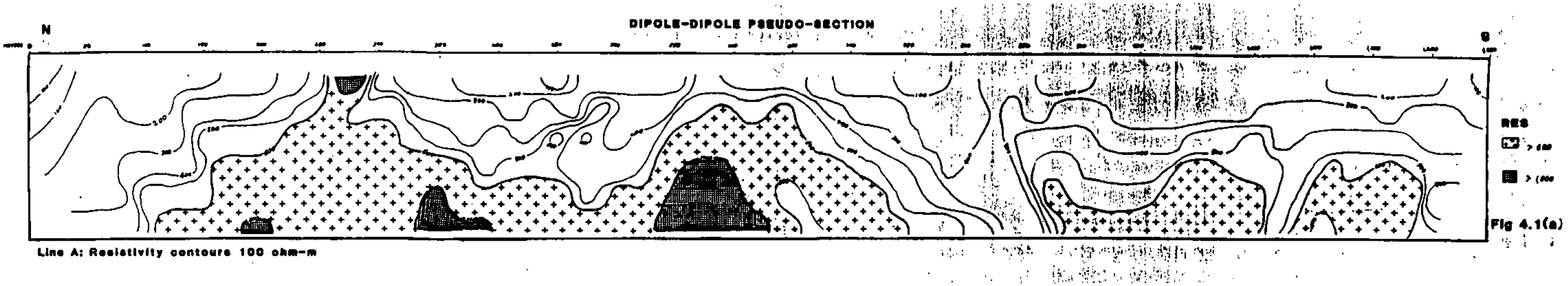

Figure 2.31: Peat Base Contours on Raheenmore Bog (Bord Na Mona Data)

pseudosection, between the respective stations. Apparent resistivity values decrease at station 1200, implying a deepening of the bedrock.

In summary, bedrock is relatively shallow in two main areas between stations 100 to 750, and between stations 850 to 1200. The latter area is split by a low apparent resistivity section between stations 1050 and 1100, possibly indicative of weathering. Low apparent resistivity values between stations 750 and 850 indicate dramatic deepening of the bedrock, again being possibly indicative of weathering. At the beginning and end of the pseudosection (before station 100 and after station 1200) low apparent resistivity values indicate bedrock deepening. The margin of the bog occurs about station 600, where bedrock is shallow. Bedrock deepens gradually southwards from the margin into the bog, before shallowing slightly again further south.

2.6.1 Summary of Dipole-Dipole Pseudosections

The map in Figure 2.32 gives a generalised summary of the areas of relatively deep and shallow bedrock, indicated from the various Dipole-Dipole pseudosections on Clara Bog. Bedrock displays a deep channel in the centre of the bog, where irregular bedrock highs exist to the east and west. A channel of deep bedrock running parallel to the northern margin, on the west side of the bog, connects this deep central channel. Also, an area of relatively deep bedrock extends out from the northern area, and runs in a southerly direction, parallel to the central depression on the west side of the bog. Irregular bedrock topography, emphasised along Line A to the the north east, betrays the effects of weathering processes on the bedrock surface.

The main bedrock topographical features implied from the Dipole-Dipole profiles, correlate quite well with that of the VLF-R apparent resistivity values and the VES bedrock surface contours. This is apparent by comparing Figure 2.32 with that of Figure 2.9 and Figure 2.15.

2.7 Conclusions

Results from the various geophysical surveys carried out on Clara Bog are quite favourable. Respective geophysical techniques complement each other, emphasising the importance of integrating the various survey techniques. General geological information about the area is necessary as a control in the processing and interpreting of the geophysics, as is illustrated very explicitly in the case of the VES interpretations. Without such geological knowledge, geophysical results are ambiguous, and often of little help in understanding the subsurface geology. Limitations to the various geophysical techniques must also be appreciated in the interpretations. While the geophysical methods give good general indications of the main lithological

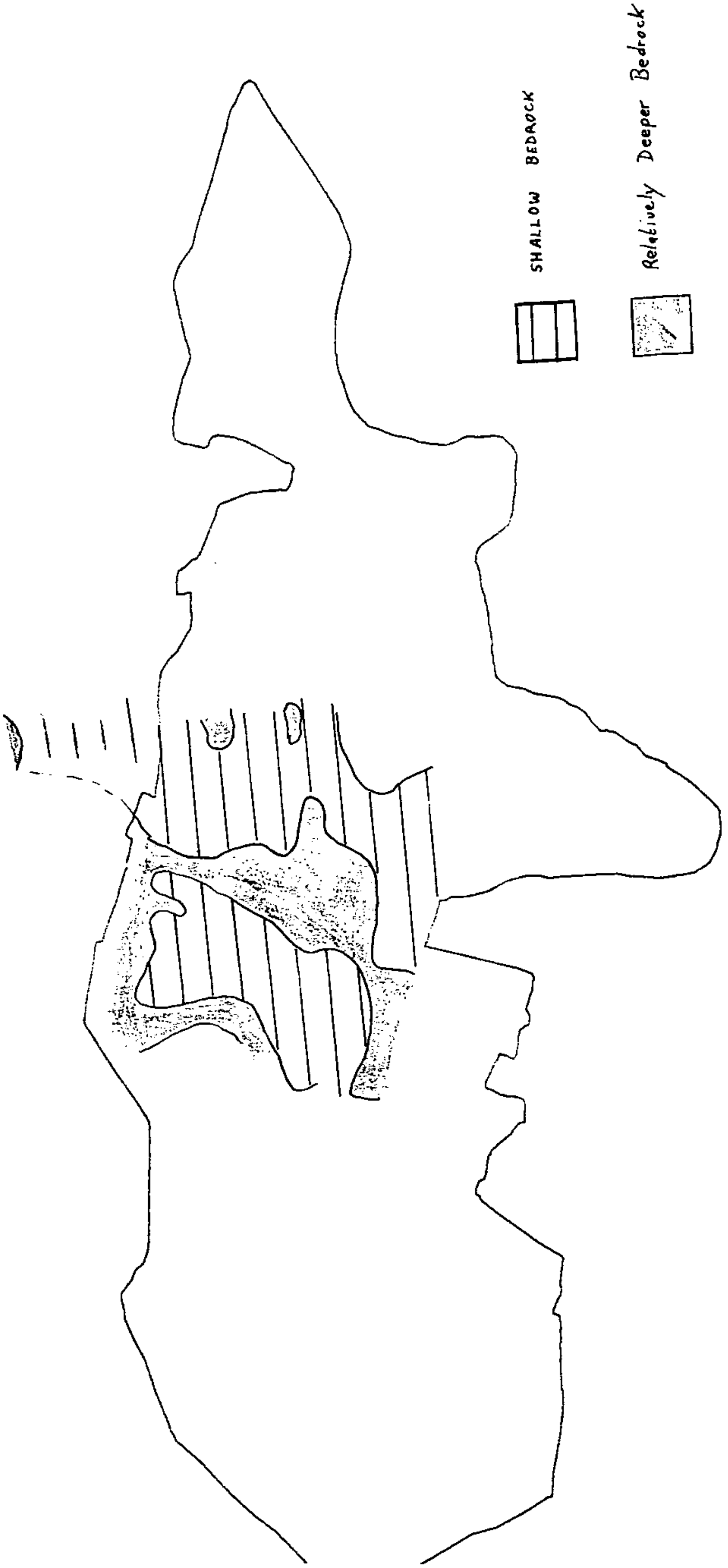

Figure 2.32: Summary Map of Bedrock Highs and Lows from Pseudosections on Clara Bog

variations, they cannot resolve all geological subtleties.

Chapter 3

Raheenmore

3.1 Geological Drilling Information

3.1.1 Peat Drilling

In 1948 Bord na Mona carried out a very extensive peat survey, for conservation purposes, on Raheenmore bog. A grid system was established over the area of the bog, shown in Fig 3.1, similar to the Bord na Mona peat survey carried out on Clara bog. Between the northern and the southern margins of the bog, four lines were orientated west to east, with a spacing of 200yds (1yd=0.9144m) between the respective lines. Three base lines orientated perpendicular to the east-west lines, were spaced 650yds apart. Stations were spaced along all lines in intervals of 100yds. Peat stratigraphy was recorded at different depth intervals, using the Hiller borer. Again, the Bord na Mona data were recorded in imperial units and converted to metric units at the Applied Geophysics Unit, using the "Geosoft" mapping package.

The map of the peat thickness, peat surface and subpeat base are shown in Figure 3.2, 3.3 and 3.4, respectively. In general the peat surface contours indicate the dome shaped raised Bog, with a high surface elevation in the central area and decreasing gently towards the margins. Two minor areas displaying slightly higher surface elevations are indicated in the north central area and in the southern area towards the west. A comparison of this Bord Na Mona peat surface map (Fig. 3.2) with that of the contoured OPW peat surface heights in Figure 3.5, show both maps to be similar. (The OPW surface elevations were recorded at stations along the grid shown in Figure ??). However the major variations between the latter two maps is that the effects of drainage in the north east has caused a reduction in the surface elevation of this area.

Peat thickness is greatest in the south western area (Fig. 3.3), where peat surface elevation is also greatest. Here peat reaches a maximum thickness of 13m. Peat thins out gradually towards the margins, mirroring the pattern

Figure 3.1: Bord Na Mona Survey Grid on Raheenmore Bog

Figure 3.2: Peat Surface Contours on Raheenmore Bog (Bord Na Mona Data)

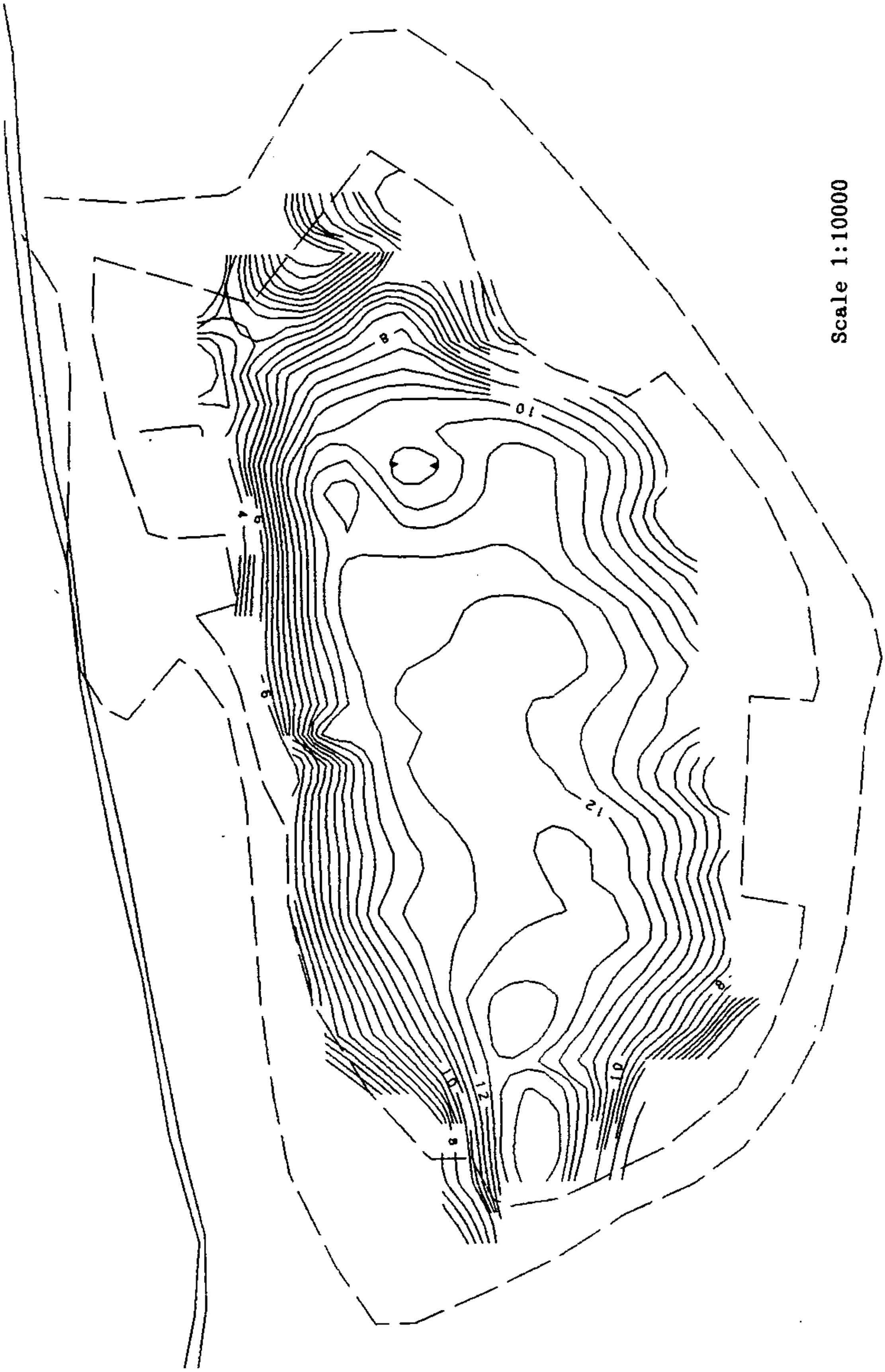

Figure 3.3: Peat Thickness Contours on Raheenmore Bog (Bord Na Mona Data)

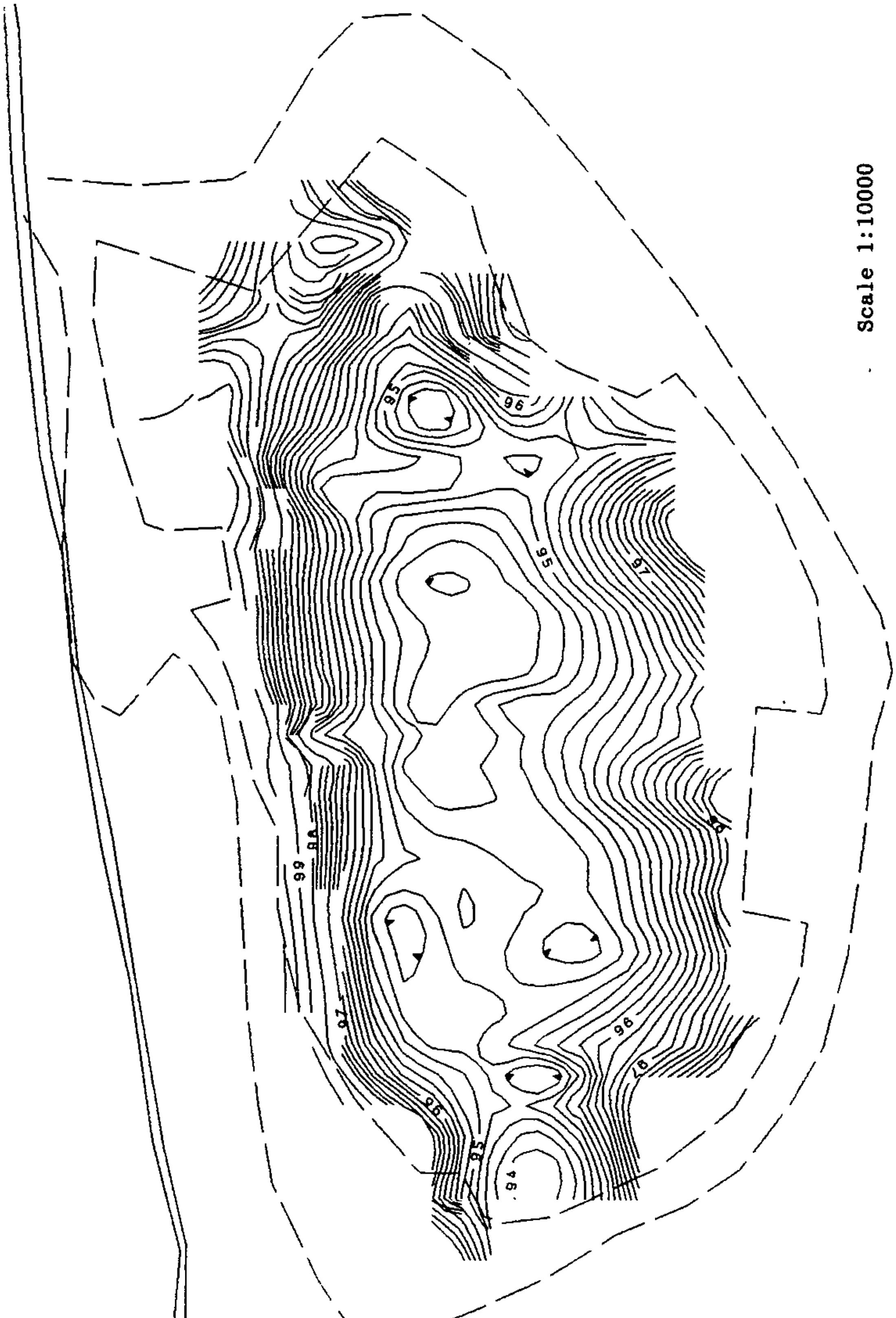

Figure 3.4: Peat Base Contours on Raheenmore Bog (Bord Na Mona Data)

Figure 3.5: Peat Surface Contours on Raheenmore Bog (OPW Data)

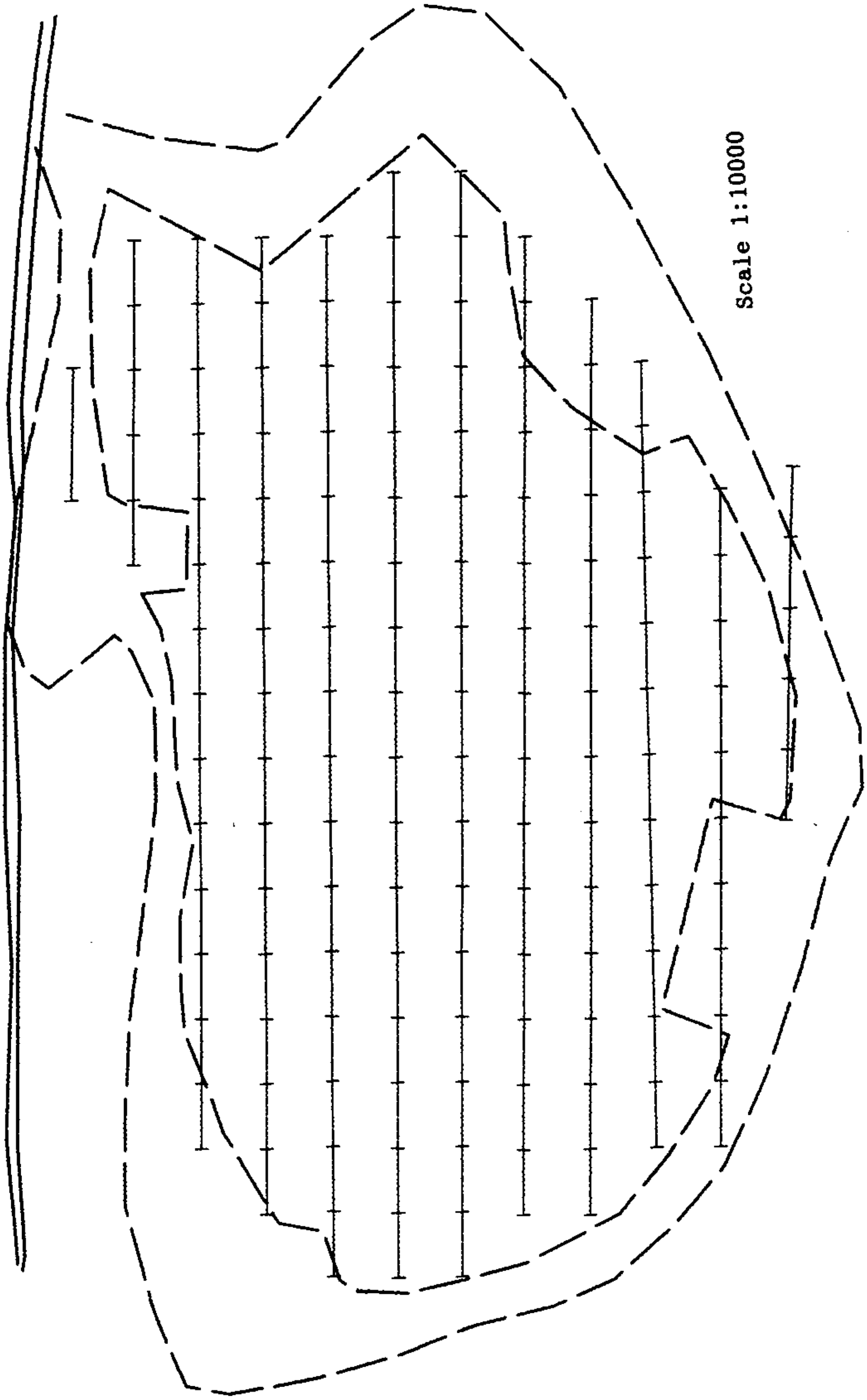

Figure 3.6: OPW Survey Grid on Raheenmore Bog

shown by the peat surface elevation. The peat base contour map in Figure 3.4, shows a depression contained in the central area of the bog. Two deeper areas within this depression exist to the west and to the east, of the central area. Shallowing towards the margins of the bog occur on all sides, displaying a classical depression for raised bog formation.

3.1.2 Bedrock Drilling

In conjunction with the drilling that took place on Clara bog by the GSI, a number of boreholes were also drilled on Raheenmore bog. Three boreholes were drilled in the summer of 1990, and one borehole was drilled in the summer of 1991. The shell and augering technique described in the drilling report for Clara (Smyth, 1991) was also used for drilling on Raheenmore. Figure 3.7 shows the borehole locations on Raheenmore bog, and the respective borehole logs are displayed in Figure 3.8. A map with the borehole lithologies is shown in Figure 3.9.

Borehole 301 is located mid-way along the northern margin of the bog. A thickness of 3.5m is recorded for the peat. Lacustrine clay with a thickness of 1.5m forms the subpeat lithology. At a depth of 5m, 1.75m of gravel is recorded. Below the gravel, a boulder clay lithology extends to a depth of 15.5m. Drilling ceased at 15.5m before bedrock was encountered. The slow rate of progress at this borehole, due to the absence of water and the difficulty in drilling through the boulder clay lithology, did not justify the expenditure of time necessary to reach bedrock.

On farmland 10m north of borehole 301, borehole 303 is located. Peaty topsoil constitutes the top 2.2m. Boulder clay directly underlies the top lithology, being 1m in thickness. 0.4m of gravel is encountered at a depth of 3.2m. From the latter gravel lithology to the "Calp" limestone bedrock at a depth of 19m, a boulder clay lithology is present. This boulder clay is greyish in colour to a depth of 15m, where brown iron staining occurs.

Midway along the southern margin of Raheenmore bog was the site chosen for borehole 302. The site is almost directly south of the previous two boreholes, thus giving good geological controls on north-south transects. Peat, 3.2m thick directly overlies a 0.7m thick boulder clay. Loose gravels occupy a 0.2m band from a depth of 3.9m to 4.1m. Below the gravel, 0.9m of dry pebbly clay overlies 0.6m of wet stony clay. Limestone bedrock is encountered at a depth of 5.6m.

In the central area of the eastern part of Raheenmore bog, at location 10 L of the OPW grid, borehole 304 was drilled. Peat thickness recorded during drilling was 7.5m. Lacustrine clay directly below the peat is 6.5m in thickness. At a depth of 14m to 15m a pebbly silt is present. Boulder clay occupies the 15m to 18m depth zone. Silty sandy gravel 2m thick, underlies the latter boulder clay lithology. From 20m to 27m very dense

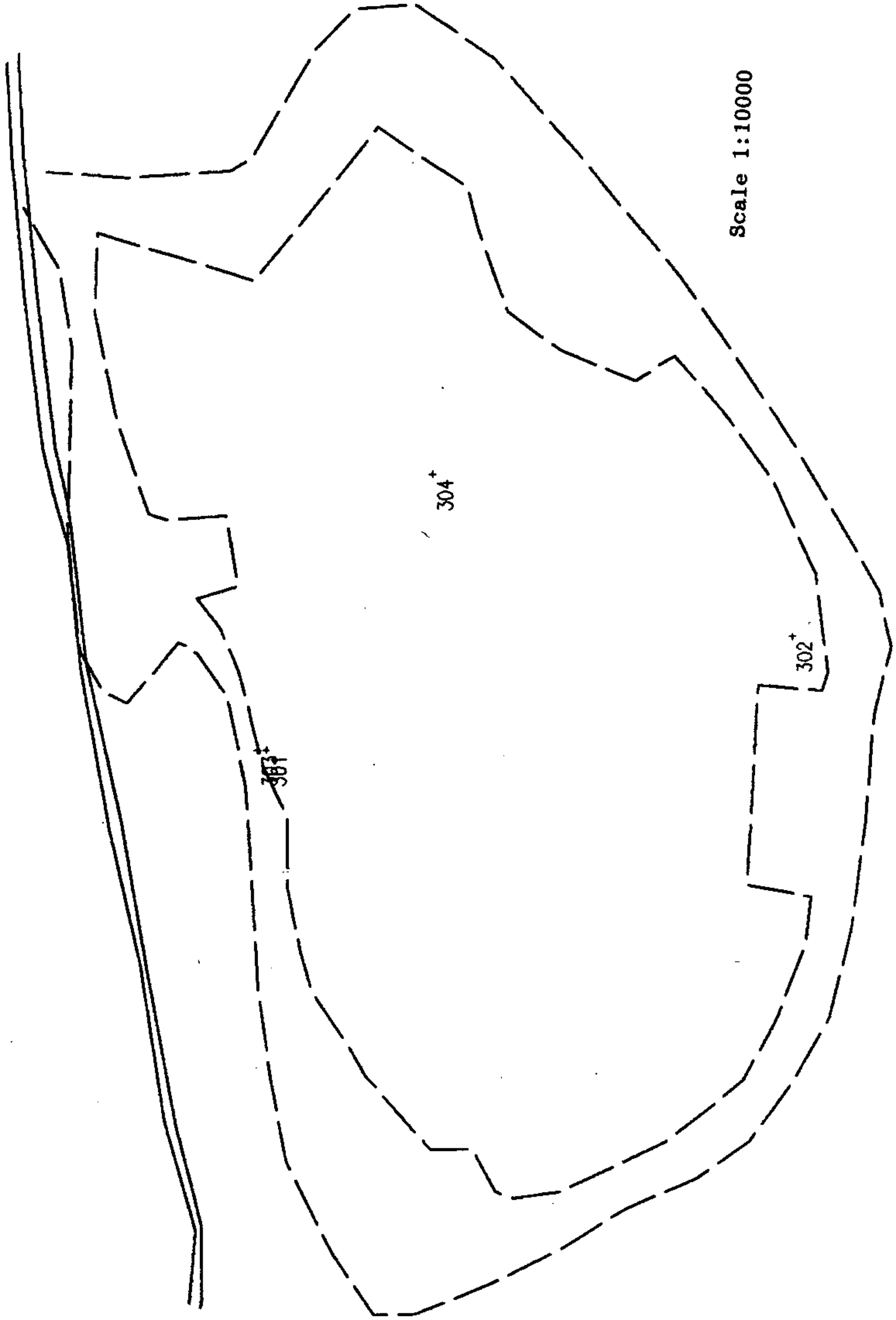

Figure 3.7: Borehole Locations on Raheenmore Bog

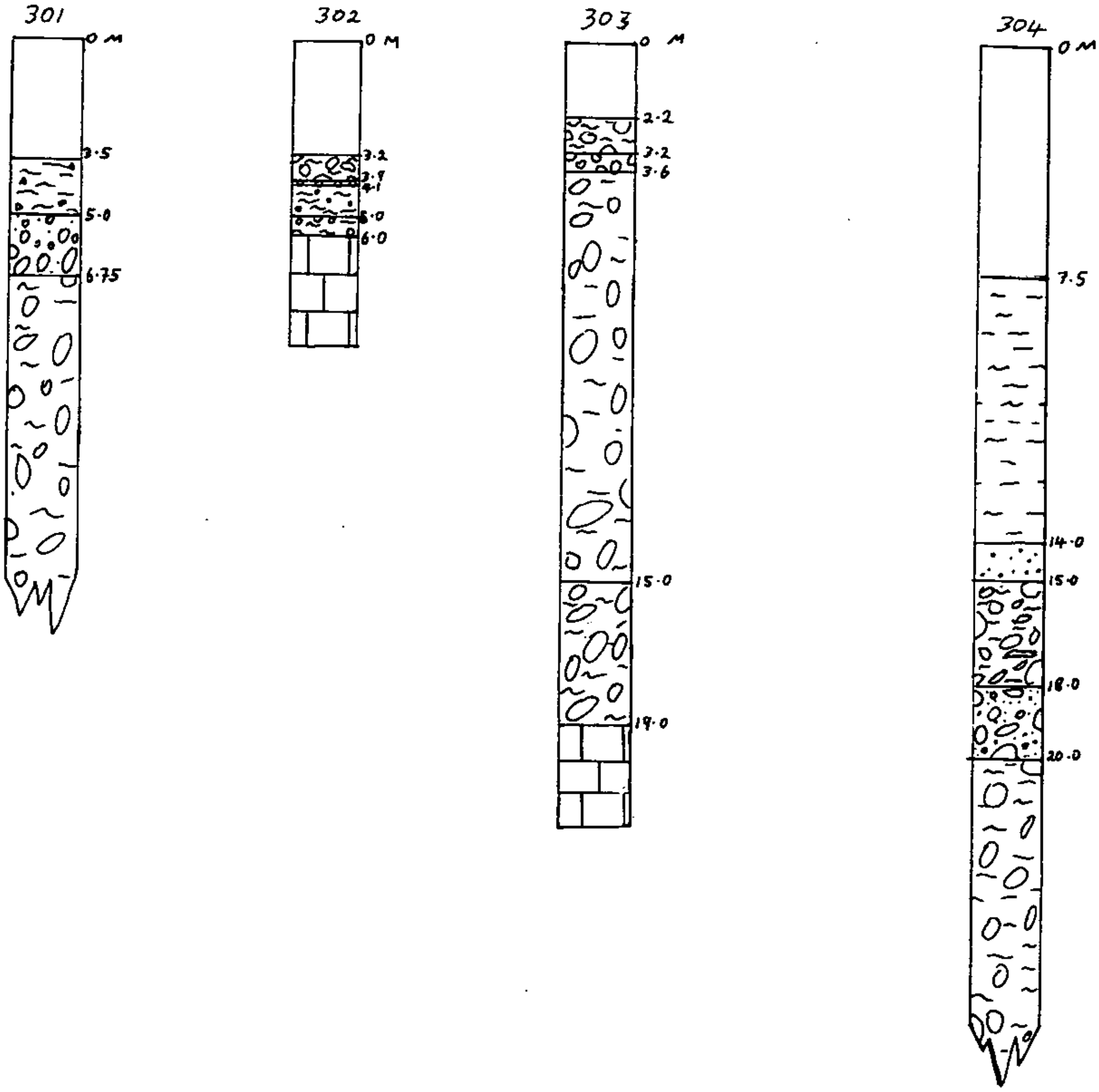

Figure 3.8: Borehole Locations on Raheenmore Bog

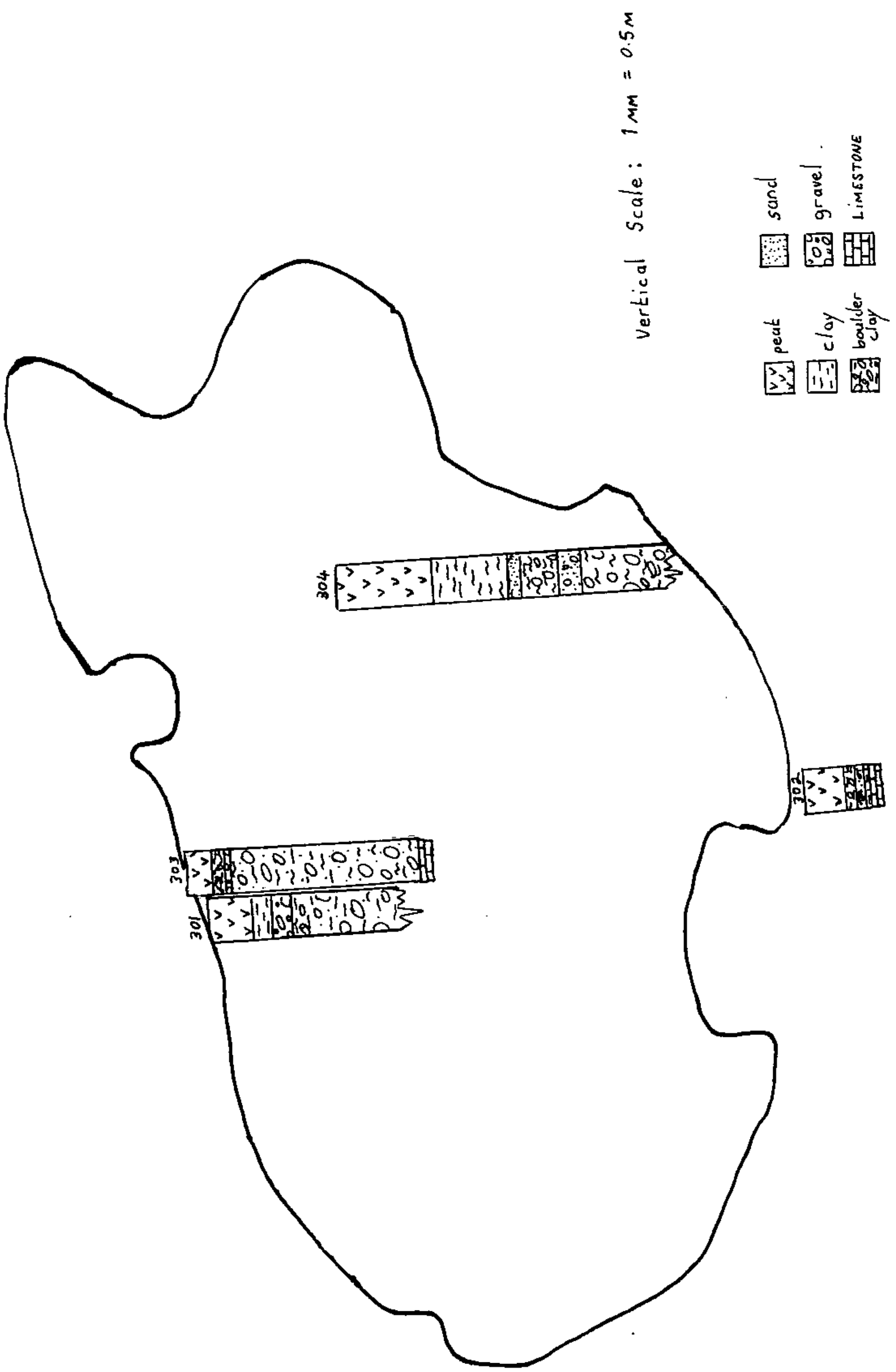

Figure 3.9: Map showing Borehole Lithologies on Raheenmore Bog

sticky boulder clay is present. Drilling ceased at this location at the depth of 27m, before bedrock was encountered. The unstable foundation of the bog for the drilling apparatus, in association with the difficult lithology encountered, was responsible for the termination of drilling at this stage.

3.2 Electromagnetic - Very Low Frequency-Resistivity (EM - VLF-R)

A VLF-R survey was carried out over Raheenmore bog along the grid shown in Figure 3.10. Station spacings were at 50m intervals along survey lines spaced 200m apart, and in some cases 100m apart. The survey lines occupied every second line of the O.P.W. grid shown in Figure 3.6.

3.2.1 VLF-R Contoured Resistivity Map

Apparent resistivity values are contoured and the resulting VLF-R resistivity map is shown in Figure 3.11. Dark shaded areas correspond to areas of high apparent resistivity, whereas the lighter areas correspond to areas of lower apparent resistivity. Figure 3.11 shows that the area within the bog margin shows extremely low apparent resistivity values of less than 200 ohm-m. In the central area to north of the bog, and in the south east and west, areas of less than 100 ohm-m apparent resistivities are shown.

In the south east, extremely high apparent resistivity values are indicated in an area orientated north east to south west, parallel to the south east margin of the bog. Apparent resistivity values here are greater than 1000 ohm-m, with a minor circular anomaly showing an apparent resistivity greater than 2500 ohm-m in the south west part of this ridge.

In the south west and west, two broad circular anomalies of high apparent resistivity occur. The anomaly to the west shows apparent resistivity values in excess of 1200 ohm-m, whereas in the south west values are in excess of 1500 ohm-m. Along the western area of the road which runs parallel to the northern margin of the bog, an elongated area of high apparent resistivity displays values in excess of 1000 ohm-m. Approximately 400m directly to the north east, another extremely high apparent resistivity area is indicated. This area is circular in shape and shows apparent resistivity values in excess of 5000 ohm-m. This area corresponds to a topographic high where limestone boulders are evident at the surface.

Between the high resistivity areas, channels of extremely low apparent resistivity values occur. In the north west two channels of apparent resistivity values less than 300 ohm-m, extend from the bog going north and north west around the area of high resistivity in the north. Another low apparent resistivity channel also occurs in the north west corner of the map. This

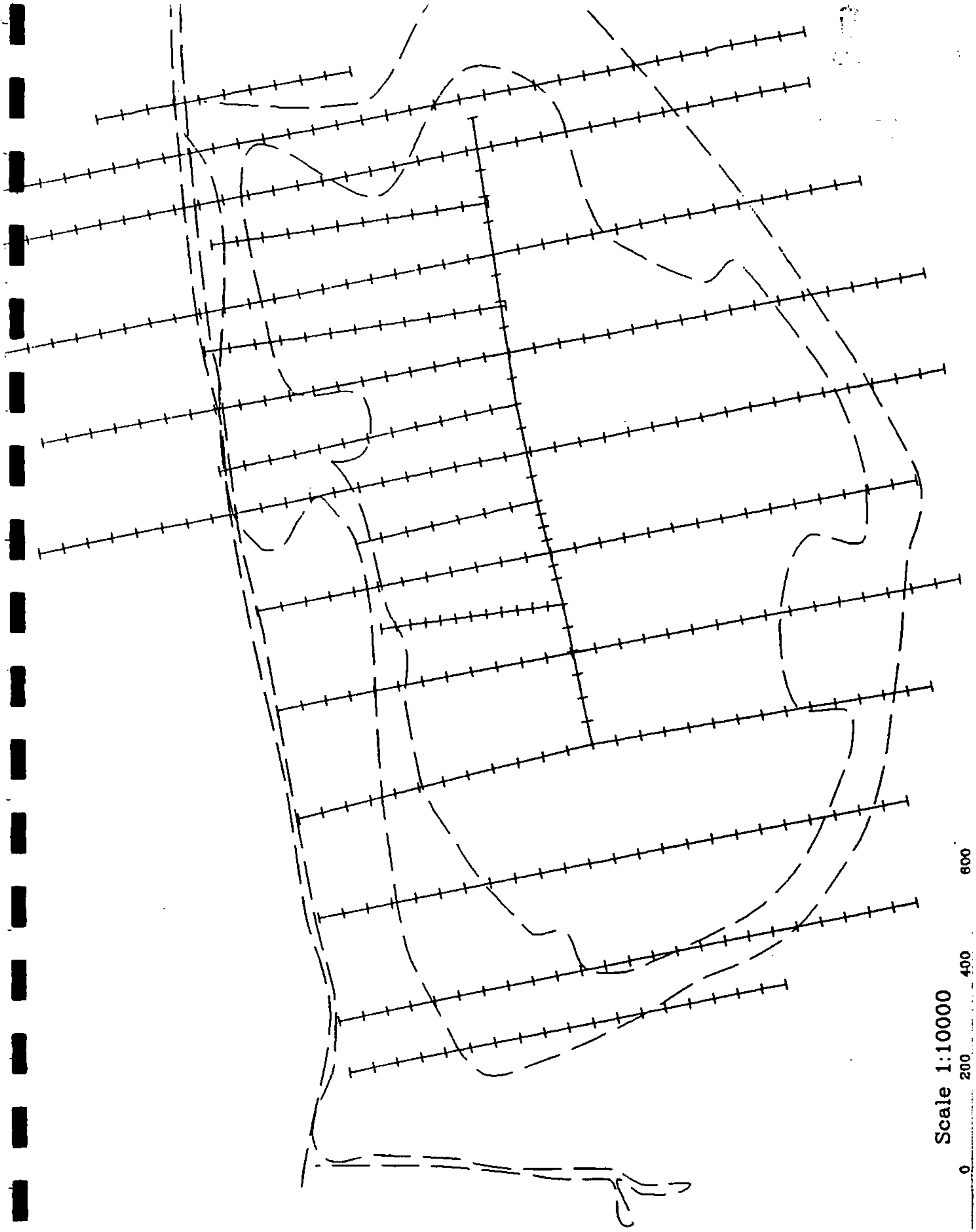

Figure 3.10: VLF-R Survey Grid on Raheenmore Bog

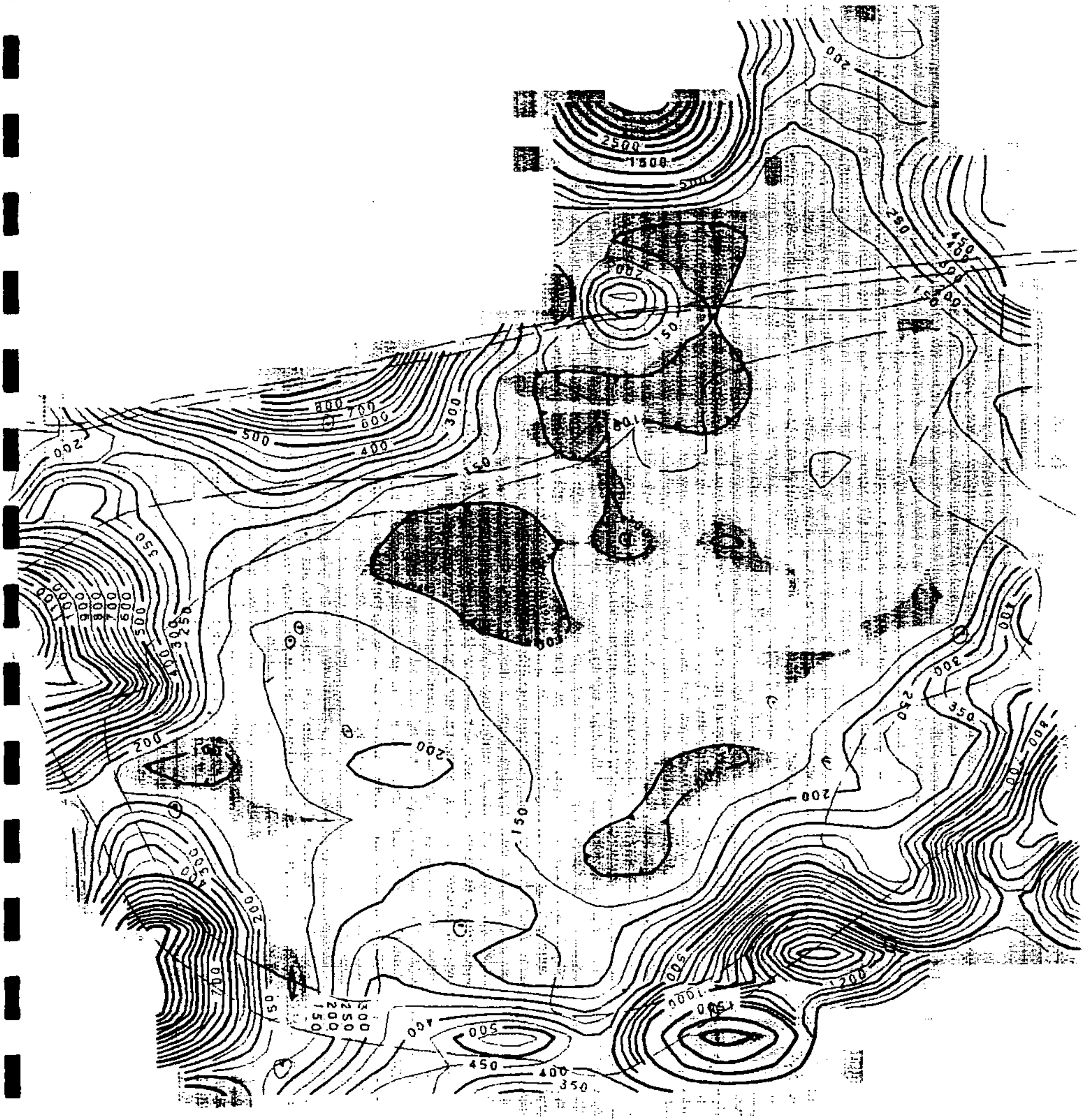

Figure 3.11: VLF-R Contoured Resistivity Map of Raheenmore Bog

channel is orientated north west to south east and occurs between the two apparent resistivity high areas to to the east and north west of the bog. Again apparent resistivity values here are less than 300 ohm-m.

The apparent resistivity high in the south west corner of the map is also enclosed by two low resistivity channels. One of these extends from the bog to the south west, the second extending to the south. Both channels are areas of low resistivity less than 200 ohm-m, with smaller areas of the channel floors indicating resistivities less than 100 ohm-m. The eastern margin of the bog shows very low apparent resistivities of less than 200 ohm-m, as far as the data extends.

In general bedrock is assumed to be relatively deep in the area within the bog margin, which indicates low apparent resistivity values. Shallow bedrock is assumed to surround the bog in the areas where high apparent resistivities are present. These resistivity high areas in general, correspond to topographic highs on the landscape. Therefore the VLF-R resistivity map shows the classic theoretical raised bog, which has a basin-like depression in the bedrock beneath the bog, and surrounding the bog, a rim of shallow bedrock.

3.2.2 Phase Angle Contour Map

Phase angle values from the VLF-R survey are contoured in Figure 3.12. The eastern part of the bog shows phase values in excess of 45 degrees. Towards the south west of the bog, a smaller area of high phase values occur in a north south direction. Two other areas of high phase angle data are in the south east, and a very small area in the extreme north east.

The greater area of the region has phase angle values less than 45 degrees, apart from the specific areas mentioned above. In the central area of the south margin of the bog, an area of very low phase angle values, less than 25 degrees, occurs. Directly northwards of this area, two small areas in the centre of the bog, and one on the northern margin, display similar phase values. Other areas of the bog showing phase angles less than 25 degrees are on the south east and south west margins, and on the extreme east margin. Away from the bog in the extreme north of the survey area, two areas of similar low phase values are shown, one around the road, and the second approximately 150m just north of this area.

In general, the greater area of the bog shows phase angles below 45 degrees, apart from the major high phase angle anomaly in the eastern area, and a smaller area in the south west. These low phase values under 45 degrees, correlate quite well with the low resistivity values indicated over the area of the bog. Here the relatively conductive overburden of peat, clay and till rests on the resistive bedrock. Extremely low phase angle values of less than 25 degrees, correspond to areas of intermediate and low resistivity val-

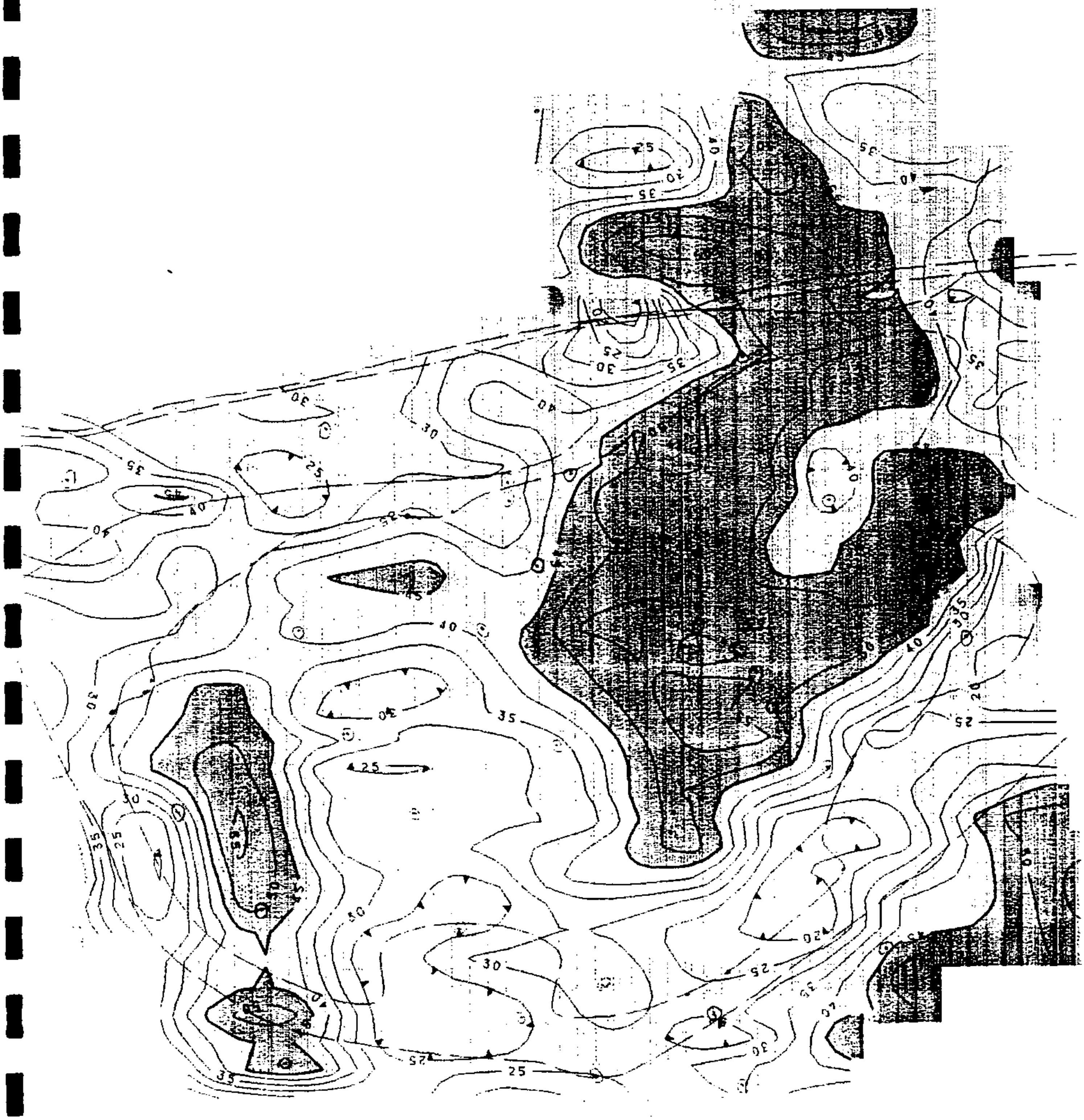

Figure 3.12: VLF-R Contoured Phase Angle Values on Raheenmore Bog

ues. Such low phase angle data suggest an extremely large contrast between the resistivity of the bedrock and that of the conductive overburden, as in the case of clay resting on bedrock.

With the exception of the area in the extreme south east, all areas where phase angle values are over 45 degrees, correspond to areas of very low resistivity. Phase values of this magnitude suggest a relatively more resistive upper layer resting on a more conductive layer beneath. Low resistivities would suggest a relatively deep overburden. Therefore low phase values and low resistivities values together, indicate an extremely conductive layer between the relatively deep resistive bedrock, and the less resistive overburden.

3.2.3 Summary of VLF-R survey

In order to the emphasise the main conclusions from the VLF-R apparent resistivity survey, the map in Figure 3.13 shows the extremely low apparent resistivity values, indicative of relatively deep bedrock. Deep bedrock is implied in the greater part of the bog, towards the north east, and in a narrow channel close to the western margin. VLF-R high apparent resistivities implying extremely shallow bedrock is shown in Figure 3.14. Extremely shallow bedrock surrounds the bog to the south east and south. To the west of the bog, two broad circular areas of shallow bedrock are suggested in the areas towards the north west and south west. Broad areas of shallow bedrock are also implied to the north of the bog, which correspond to topographic highs on the landscape.

A comparison of the two previous maps with that of the principle conclusions from the phase angle values on Raheenmore bog, show very favourable results. Areas where phase angle values are less than 30 degrees are shown in Figure 3.15, implying relatively shallow bedrock. This map correlates quite well with that of Figure 3.13 showing relatively shallow bedrock to the south and south eastern margins of the bog, and intruding northwards into the central area of Raheenmore West. Similarly, the phase values greater than 45 degrees shown in Figure 3.16, implying deep bedrock, compare equally favourably. What is most striking in the comparisons between Figure 3.16 and Figure 3.13, is the similarities in the large area of deep bedrock suggested in the north west, and the narrow channel of deep bedrock towards the extreme western margin.

3.3 Vertical Electric soundings - VES

A total of 36 vertical electric soundings (VES) were carried out on Raheenmore. All soundings carried out used the Schlumberger array. Figure 3.17 shows the location of these soundings.

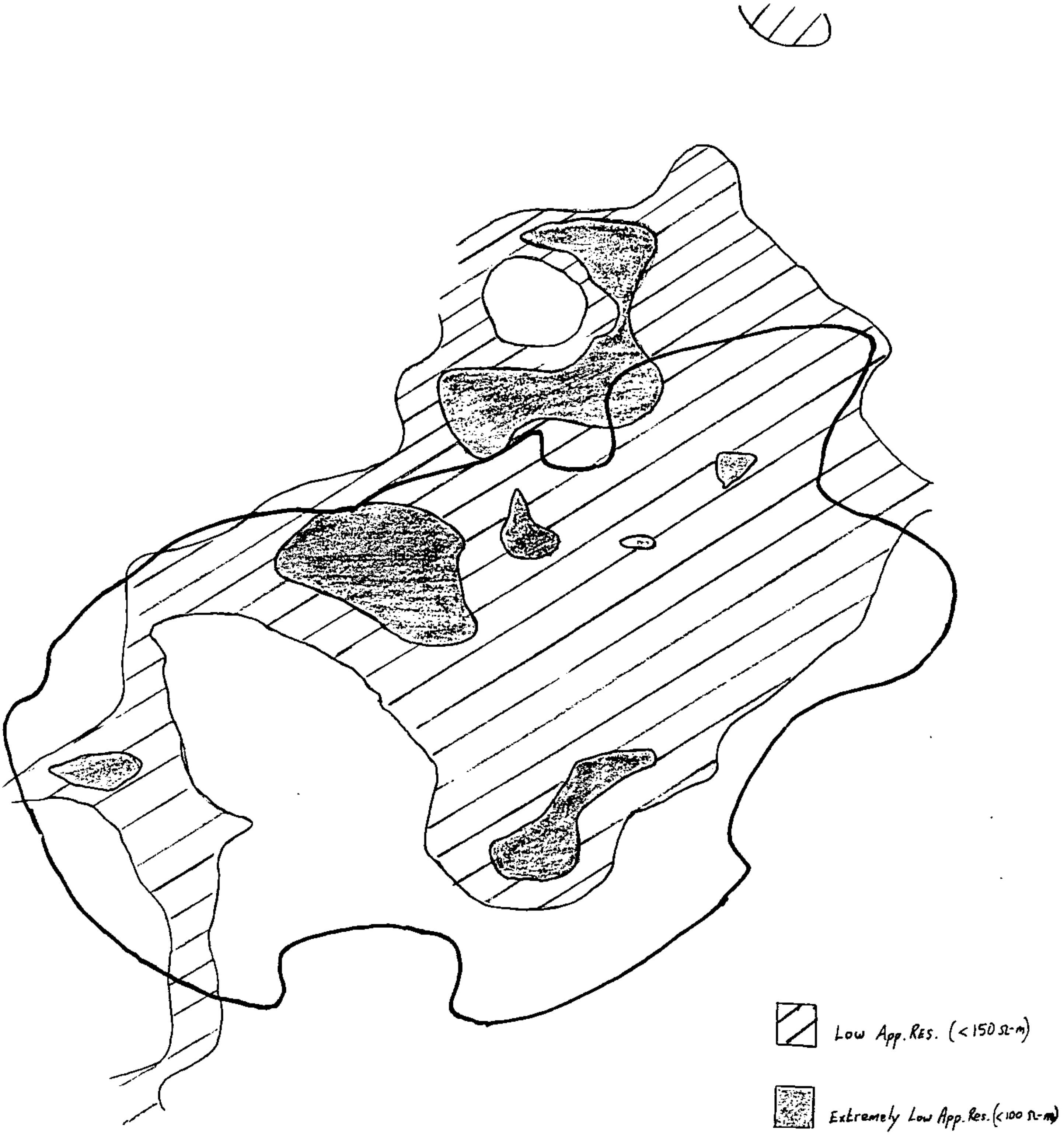

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Figure 3.13: Summary Map of VLF-R Resistivity Lows on Raheenmore Bog

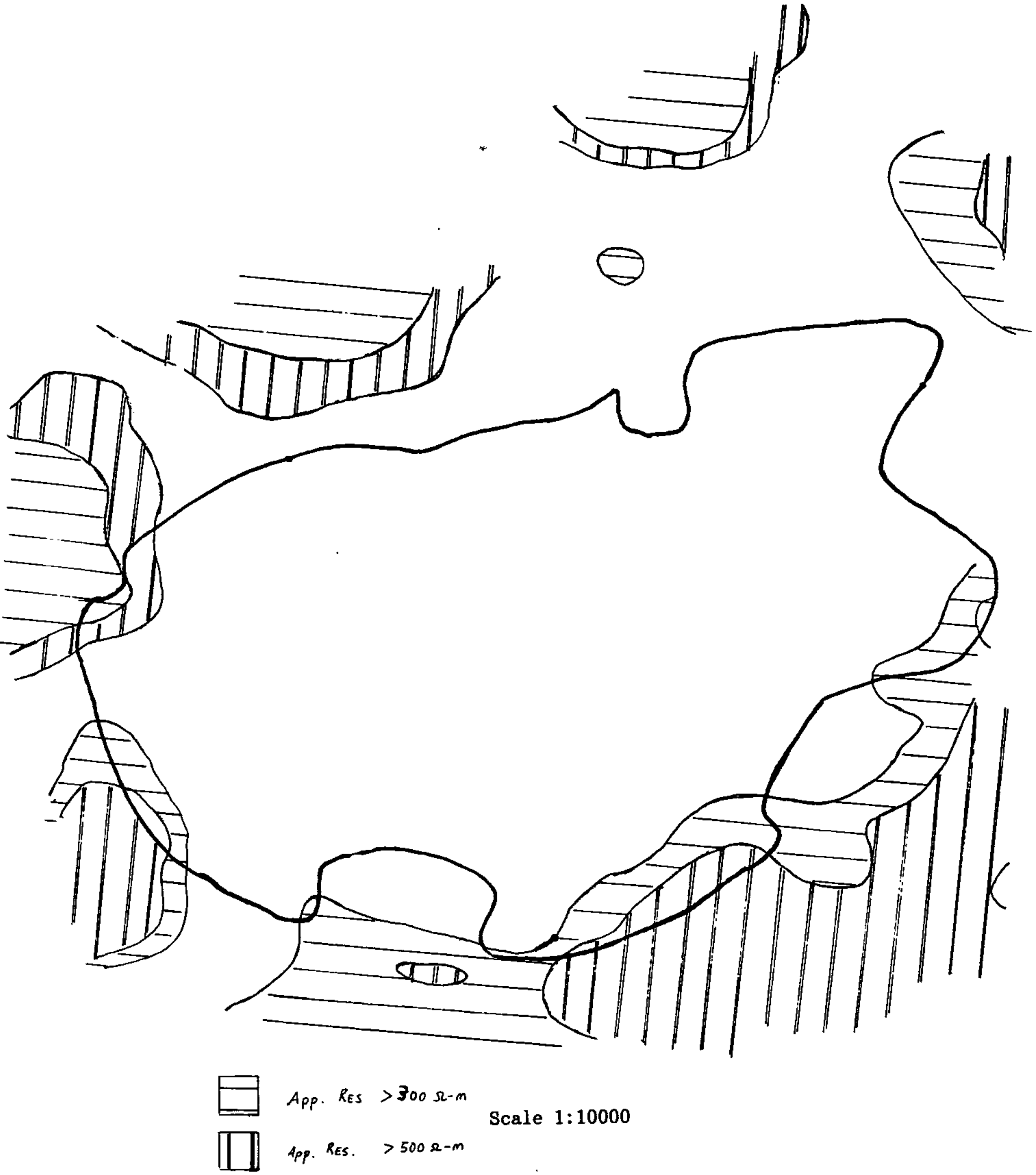

Figure 3.14: Summary Map of VLF-R Resistivity Highs on Raheenmore Bog

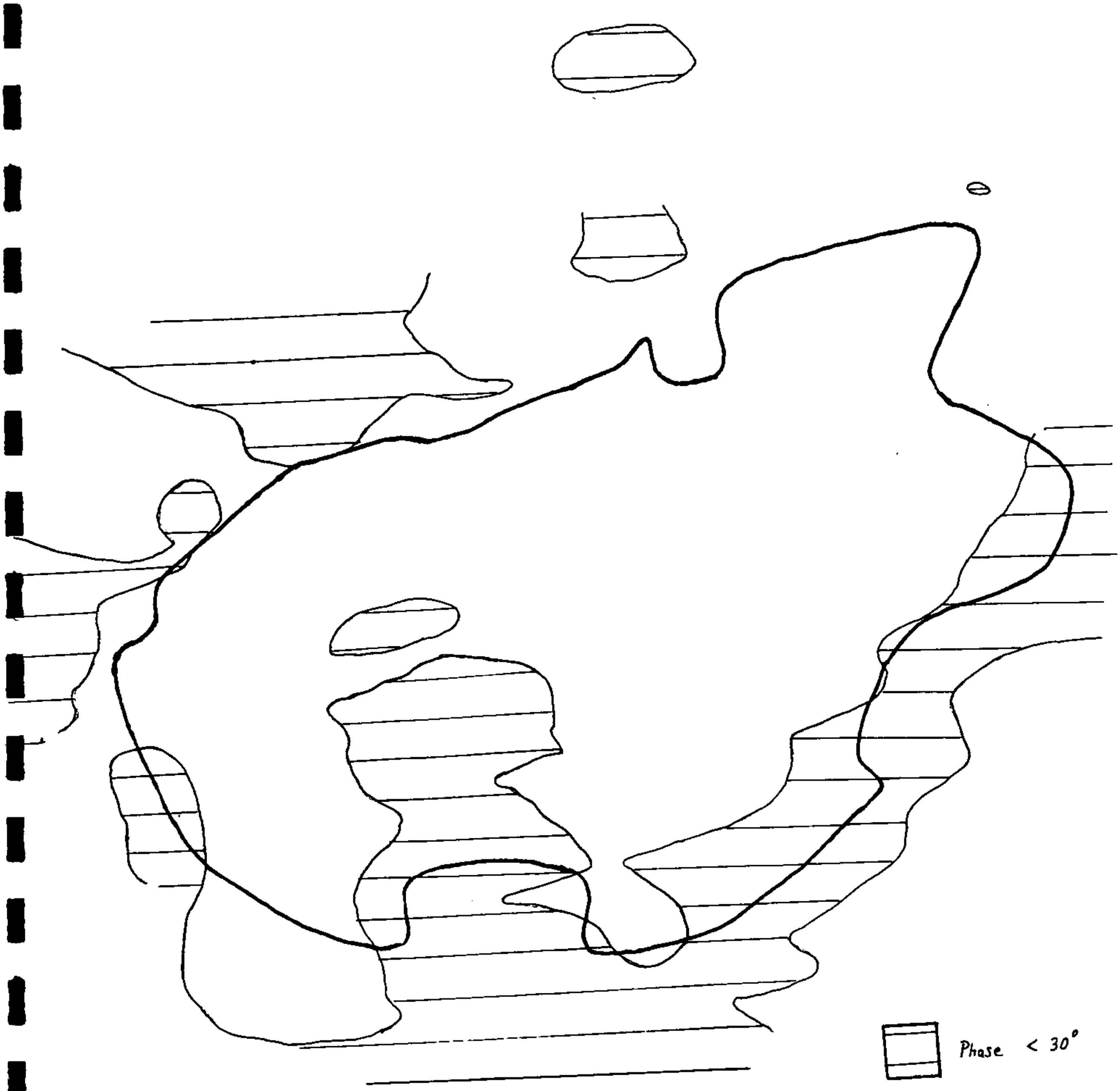

Figure 3.15: Summary Map of Low Phase Angle Values on Raheenmore Bog

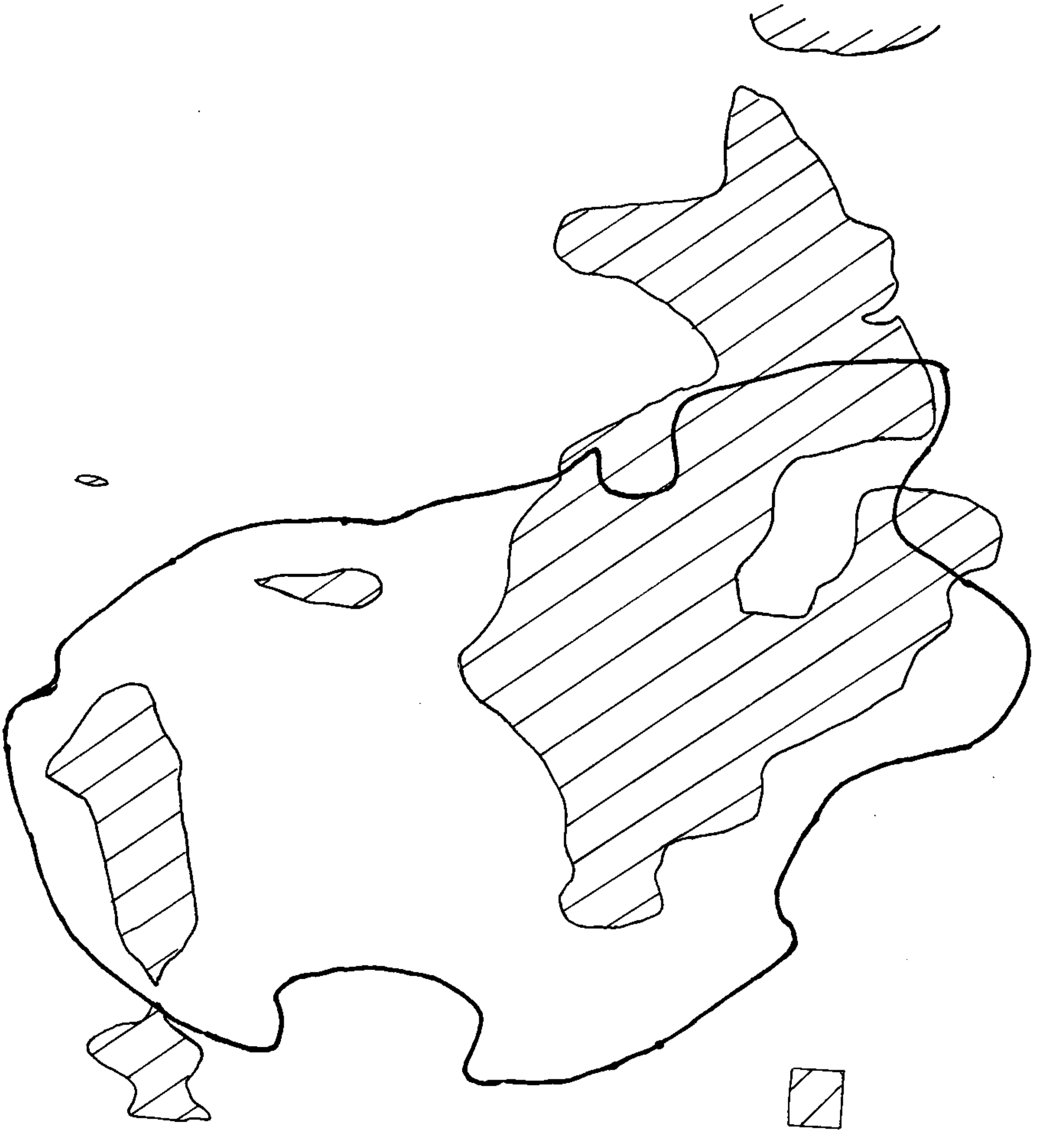

Figure 3.16: Summary Map of High Phase Angle Values on Raheenmore Bog

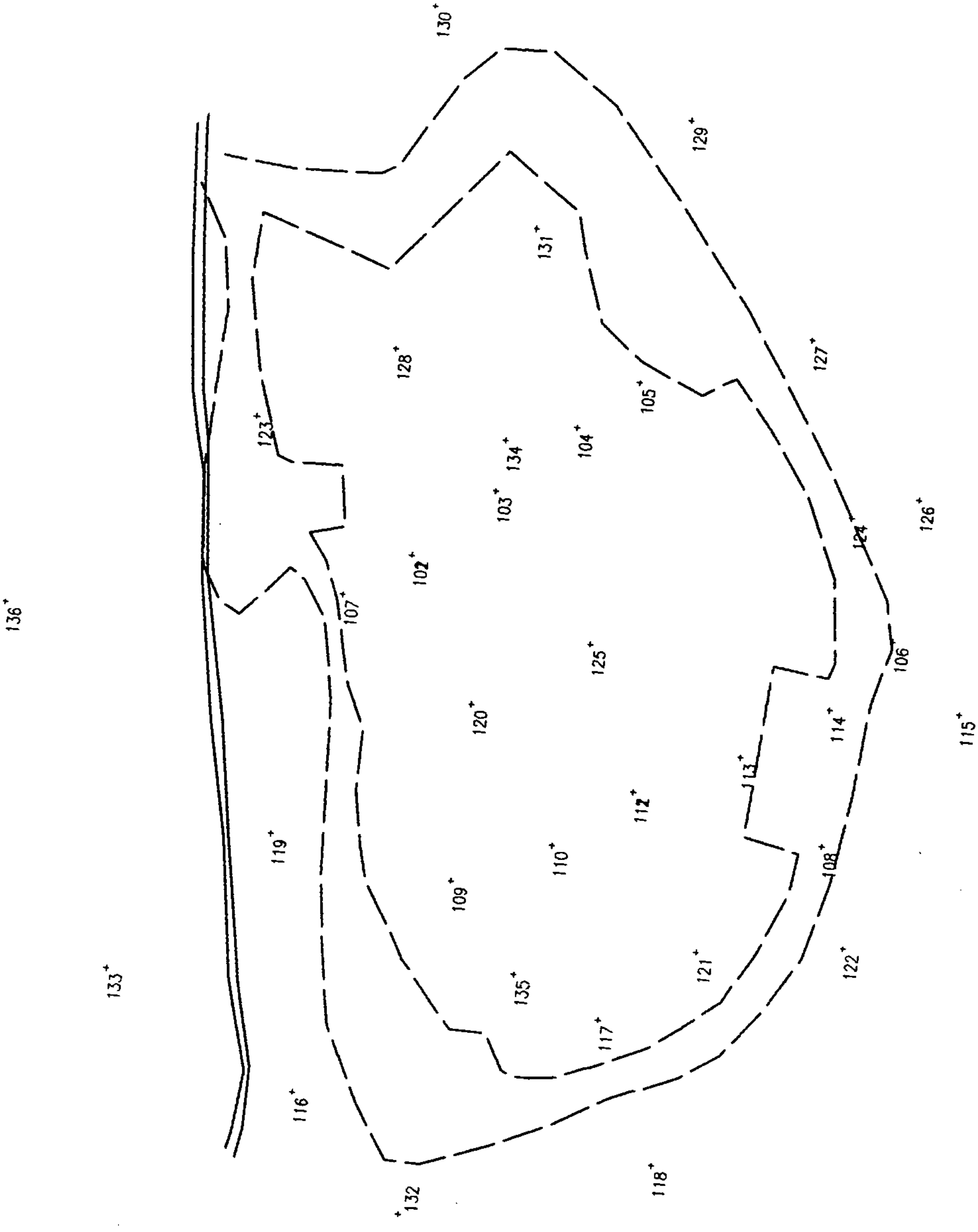

Figure 3.17: Location of Vertical Electrical Soundings (VES) on Raheenmore Bog

On the extreme south west of Raheenmore bog, soundings 117 and 121 are 250m apart. Resistivity values for VES 117 produce a very smooth curve apart from one dubious point between the bedrock and the layer resting above it. Interpretation of this sounding showed 9m of peat, with the top 0.5m of spongy peat being of lower apparent resistivity. Underneath the peat, a 2.5m thick clay layer has an apparent resistivity of around 65 ohm-m. Till over 55m thick shows an apparent resistivity of 130 ohm-m, and rests on bedrock at a depth of around 67m. Unlike the latter curve, the observed resistivity curve for VES 121 is slightly disjointed in the first parts of the curve, and is extremely chaotic in the latter part where high apparent resistivity values indicate bedrock. The general trend of the curve seems to be similar to that of VES 117. Interpretation of the data involved a theoretical curve which followed the general trend of the observed curve, however exact boundaries are not easy to define due to the nature of the data. 6m of peat showed a top spongy layer 0.5m thick with a lower apparent resistivity, than the more compact peat. A 2m clay layer beneath the peat indicated an apparent resistivity similar to that of the clay layer in VES 117. A till layer resting on bedrock is indicated to be about 50m thick, and again has an apparent resistivity similar to the corresponding layer of the latter sounding. Bedrock is interpreted at a depth of around 57m.

In the western side of Raheenmore bog, a transect from sounding 109 to 114 is orientated roughly north west to south east. Data for soundings 109 and 110 is very consistent, resulting in an extremely smooth curve, with only a slight irregularity in the high apparent resistivities, which indicate bedrock. Both soundings show peat over 11m. Sounding 109 shows a subpeat layer of less than 2m thick, compared with over 4m for sounding 110. Assumed to be lacustrine clay, this subpeat layer has an apparent resistivity of 60 ohm-m. Below the clay, VES 109 indicates glacial deposits with an apparent resistivity of 112 ohm-m, to be over 27m thick, resulting in relatively deep bedrock at a depth of 41m. Ves 110 interpreted glacial deposits at this location to have much higher apparent resistivities of around 230 ohm-m, and also to be much thinner at 15m, resulting in bedrock at the shallower depth of around 30m.

VES 111 and 112, were done at the same location in the central area of western Raheenmore, with the respective arrays perpendicular to each other. The remarkable consistency and similarity of the data in both observed resistivity sounding curves, (apart from the end part of VES 112) indicate that lateral effects are insignificant in this area as they do not influence the data. Both sounding interpretations are similar, indicating peat thicknesses over 11m, and a subpeat layer approximately 5.5m thick resting on bedrock, at a depth of around 17m. With apparent resistivities in the 40 to 50 ohm-m range, the subpeat layer is assumed to be lacustrine clay.

Situated towards the southern margin of the bog, the observed resistivity sounding curve for VES 113 is very consistent, the only discontinuity in the

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data being with one of the branches indicating bedrock resistivities. Peat 8.5m thick, rests on a 6m thick clay layer with an apparent resistivity of around 60 ohm-m. Bedrock is at a depth of 14.5m. Till is not present at this location as sounding 113 shows clay resting directly on the bedrock.

Near the southern margin of the bog, peat shrinkage has occurred due to drainage and peat cutting in the past. Sounding 114 is situated in this area of peat subsidence. Resistivity data for this sounding produces a perfectly smooth curve. A 7.2m thick peat layer is shown to rest on a clay layer 4.5m thick, and an apparent resistivity of around 40 ohm-m. Again, no till is indicated to be present, with the clay layer lying directly on bedrock at a depth of 11.7m.

To the south east of the previous sounding, VES 106 is situated on farmland just south of the bog marginal drain. Resistivity values display a sounding curve which is a classic example of shallow bedrock. A peaty topsoil 0.7m thick rests on a 2.4m thick clay layer with an apparent resistivity similar to the clay layer of the previous sounding. Bedrock is at a depth of around 3m, and again no till layer is present.

Borehole 302 drilled approximately 50m north from VES 106, proves the shallow bedrock in the area around the southern margin of the bog. Bedrock at this location is 5.6m deep. A stony clay 1.5m thick rests on the bedrock, and is overlain by 1m of a bouldery clay type lithology. Peat is 3.2m thick. A short array on flat tilly farmland 200m south of the bog also indicated shallow bedrock (VES 115). Here a top layer less than 1m thick covers a till layer of around 4m thick, which rests on bedrock at a depth of 5m.

VES 124 is situated on the southern margin of the bog, approximately 300m north east of VES 106. The apparent resistivity values produce an excellent sounding curve showing extremely shallow bedrock at a depth of 3m. 2.5m of till with a resistivity of around 170 ohm-m, rests on bedrock, and is covered by 1.5m of peat.

Sounding 126 situated approximately 150m south-south east of VES 124, also indicates the extremely shallow bedrock to the south of the bog. Here bedrock is shown at a depth of 3m. The latter part of the resistivity sounding curve is rather inconsistent, showing very scattered data, however the data for the first part of the curve is very consistent, and clearly indicates bedrock. The irregularities in the data for the outer spacings are probably due to lateral effects.

Returning to the bog, sounding 125 is located in the very centre of the bog. Relatively deep bedrock is indicated by this sounding curve. However, the resistivity data at the greater depths are too disjointed and scattered to give an indication of the actual depth to bedrock, which is likely to be somewhat greater than the 43m depth, indicated by this sounding. Peat and clay thicknesses of 10.4m and 4.8m respectively, are probably true indications, as the resistivity data produces a very uniform curve for the inner array spacings. The apparent resistivity values for the outer array spacings are totally disjointed and scattered, therefore it is impossible to indicate the general trend of the curve. Possibly, strong lateral changes in the geology at greater depths have a strong influence on the outer spacings of the curve.

A greater problem is displayed in sounding 120, which is situated on the bog 250m north west of VES 125. The various branches of resistivity data for the inner array spacings are disjointed, while the resistivity data for the outer spacings are very scattered. The theoretical curve has been constructed to follow the general trend of the resistivity data, however it is not possible to define layer boundaries. Sounding 120's most valuable contribution is possibly that it is indicative of strong lateral changes in the geology of this area.

150m north east of VES 120, sounding 135 is situated 150m south of the northern margin of the bog. Resistivity values produce an excellent sounding curve which is consistent throughout. Peat is indicated to be 7.7m thick, and is underlain by a 5.5m thick layer, assumed to be clay with an apparent resistivity of around 70 ohm-m. Below the clay, almost 34m of till with an apparent resistivity of around 130 ohm-m, rests on bedrock at a depth of over 46m.

A borehole was drilled (location 303) beyond the northern margin of the bog, roughly 160m north of the previous sounding. Bedrock was recorded at a depth of 19m. A surface peaty layer of over 2m was underlain by chiefly bouldery clay deposits resting on the bedrock. A thin gravel lens of around 0.5m thick was encountered near the top of the boulder clay.

150m west of borehole 303, a resistivity sounding curve at location 108 shows extremely good continuity in the data. A top layer 2.6m thick and an apparent resistivity of 45 ohm-m is possibly a peaty clay lithology. Below this a possible till layer with an apparent resistivity of around 180 ohm-m, is indicated to be almost 47m thick. Bedrock is shown to be at a depth of over 49m.

150m to the east of borehole 303, sounding 107 shows a resistivity curve almost identical to that of 108. 2.7m of peat is shown to rest on 2m of clay. The apparent resistivity of the clay layer being 45 ohm-m. A 72.5m thick till layer, with an apparent resistivity of around 200 ohm-m, rests on bedrock at a depth of 77m.

Soundings 101 and 102 are at the same location, with the respective sounding arrays perpendicular to each other. The are situated on the bog, roughly 200m south east and east of VES 107 and 135, respectively. The resistivity sounding curve of VES 101 is too scattered to indicate layer boundaries, however the general trend in the curve indicates deep bedrock, greater than 40m. Unlike the latter sounding, VES 102 displays a very smooth curve, with resistivity values being extremely consistent. However the array only extended out to 175m on either side because of difficult terrain along the northern margin. Bedrock was not reached with this length array, thus indicating it to be very deep. A peat thickness of 5.4m and a clay layer 3m thick with an apparent resistivity of 75 ohm-m, suggested for sounding 102 are probably accurate due to the consistent smoothness of the curve. Beyond the clay layer all the curve indicates is that bedrock is deep. Both curves provide a valuable indication of lateral effects in the geology of the area.

200m south east of the previous soundings, 103 is situated in the centre of the eastern side of the bog. Peat 11m thick overlies a clay layer 6.5m thick. The clay layer shows an apparent resistivity of around 80 ohm-m, and a borehole at location 304 confirmed clay was present in this region. Below the clay, a 82m thick layer with an apparent resistivity of around 140 ohm-m rests on bedrock at a depth of almost 100m. Resistivity data produce a very smooth curve, apart from some high resistivity values at the outer spacings, indicating bedrock. Here data is sparse and slightly scattered indicating lateral effects only in the deeper geology.

200m further to the south west, resistivity data for VES 104 produce an extremely smooth curve. Peat is interpreted as 13m in thickness. Clay underneath the peat shows an apparent resistivity of around 80 ohm-m and a thickness of 4m. A till layer 60m thick with an apparent resistivity of around 120 ohm-m rests on bedrock at a depth of over 76m.

Between the previous two soundings and about 100m to the east, VES 134 is situated beside borehole 304. An interesting fact is that when the resistivity sounding curve at this location overlies the previous two sounding curves, it is almost identical, indicating extremely deep bedrock. The main difference is that this sounding curve shows scattered data points in the low resistivity materials, which overlie bedrock, and the bedrock is suggested to be slightly deeper. As this sounding is located beside borehole 304 we can interpret the top lithologies. Peat less than 12m thick overlies a 5.5m thick clay layer with an apparent resistivity of 90 ohm-m.

Borehole 304 showed a clay layer in excess of around 7m underneath the peat. Clay thickness is considerable even though the peat thickness may have been underestimated at this borehole. Underneath the clay, a sandy pebbly layer was recorded at a depth of 14m to 15m. Boulder clay was encountered at 15m, with silty, sandy gravels causing a break in the boulder clay at a depth of 18m to 20m. Boulder clay extended to a depth of 27m, at which point drilling ceased because of difficulties previously mentioned.

Sounding 105 was carried out just north of the south east margin of the bog. A very smooth curve displays the consistency of the resistivity data. Peat is shown to be 6.5m thick, the top spongy layer of 0.5m thick showing a lower apparent resistivity than the more compact peat underneath. Below the peat, clay with a thickness of 5m and an apparent resistivity of around 60 ohm-m, is shown to rest on bedrock ar a depth of 11.6m. No till is indicated to be present at this location.

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Approximately 300m south east of this location, VES 127 indicates around 0.6m of overburden resting on an assumed gravelly till 12.4m thick. The apparent resistivity of this till layer is around 230 ohm-m. Bedrock is indicated to be at a depth of around 13m, although resistivity values are very scattered at the outer spacings, due to possible lateral effects in the bedrock. The resistivity values for the inner spacings display a smoother curve and are thus not affected by lateral variations in the subsurface geology.

In the north east of the area, VES 123 is situated on cutaway peat just north of the bog margin. Resistivity data display a very smooth curve until approximately the AB/2 spacing of 100m, where a low apparent resistivity layer is indicated to rest on the resistive bedrock. Here the data is slightly scattered, before the somewhat more regular high resistivity values of the bedrock. Over 2m of peat are shown to overlie 1.5m of clay. The apparent resistivity of the clay being 75 ohm-m. Below the clay 19m of a till material is indicated. 40m of a low apparent resistivity material of 80 ohm-m, comparable to that of clay, rests on bedrock. The consistency and smoothness of the resistivity curve up to the third layer, tells us that there is a definite "peat-clay-till" sequence. However another layer of low apparent resistivity material is indicated below the till, (even though the resistivity data points are somewhat irregular in this region) resting on the bedrock.

Sounding 128 is situated in the north east of Raheenmore bog. 300m south east of VES 123, sounding 128 shows a pattern very similar to that of the latter sounding. Resistivity data for this sounding displays a very consistent, smooth curve, except towards the end of the curve. Here resistivity data seem to fall to relatively low values, before rising almost vertically to indicate the high apparent resistivities of bedrock. The steep rise in resistivity values may be an indication of a sharp contact where the bedrock suddenly rises. Interpretation of this curve shows a 3.5m peat layer resting on a clay layer of 2.4m thick. A till layer underlies the clay. The till layer is indicated to be 23m thick, but is likely to be thicker. Bedrock is at a shallow enough depth to be penetrated by the sounding array, and is clearly indicated by the high resistivity values at the end of the curve. Because of the irregularity of the resistivity data indicating the layer below the bedrock, it is difficult to define an exact depth, other than to say the sounding curve indicates bedrock is likely to be deeper than the 29m suggested here.

In the extreme eastern area of the bog, sounding 131 is located approximately 400m south east of VES 128. Even though maximum array spacing was only 100m (AB/2) for this sounding, bedrock was sufficiently shallow to be clearly indicated on the resistivity curve. Resistivity data is very consistent, producing a highly regular smooth curve. 7.4m of peat overlies almost 5m of clay, which has an apparent resistivity of around 60 ohm-m. A till layer over 11m thick rests on bedrock at a depth of just under 24m.

100m beyond the south east margin of the bog, VES 129 is situated on gravelly farmland, 400m south east VES 131. Resistivity values display an extremely smooth, regular curve for the inner spacings, clearly indicating very shallow bedrock. Bedrock is covered by over 2m of till with an apparent resistivity of just under 200 ohm-m. Outer array spacings indicate very chaotic resistivity values, which is probably an indication of lateral effects in the subsurface geology.

Gravelly till produces a topographic rise to the east of Raheenmore bog. VES 130 is located in this area, approximately 200m east of the bog margin. The resistivity data produces a smooth curve apart from one disjointed data branch where the high resistivities indicate bedrock. A surface deposit 0.5m thick covers a 250 ohm-m apparent resistivity till layer, with a thickness of 3m. Beneath this a lower apparent resistivity till layer of 100 ohm-m, is less than 11m thick. Bedrock is encountered below this layer, at a depth of 14m. Topography over which the array was laid out, varied quite significantly, however it does not seem to have influenced the sounding data.

Returning our attention towards the south west region, VES 122 is situated on a topographic high ridge orientated approximately west to east. The resistivity sounding array was orientated along the ridge top. The resistivity data displays a very smooth curve. 1m of a surface layer covers a till layer 27m thick. Bedrock is indicated at a depth of around 28m.

200m west of Raheenmore bog, VES 118 is located on a till slope, rising to the west. The sounding curve is relatively smooth apart from a dubious data point before the very high resistivity data points of the bedrock. Resistivity values indicating bedrock are a bit inconsistent, but not significantly scattered. 8.5m of till with an apparent resistivity of around 160 ohm-m, is covered by 0.5m of surface deposit. Below the till almost 15m of a material with a low apparent resistivity similar to that of clay, rests on bedrock at a depth of almost 24m.

Towards the north, VES 132 is situated 400m west of the bog. This area of deposits rises gently towards the west. A surface covering 1m thick rests on a clay layer 1.6m thick, which has an apparent resistivity of about 60 ohm-m. Till 16m thick, with an apparent resistivity of 290 ohm-m rests on bedrock at a depth of over 18m.

In the area of the north west, VES 116 is located on till deposits 100m south of the road which runs in a west-east direction north of the bog. Here a surface layer 0.6m thick covers a layer of material 15.6m thick, and has an apparent resistivity of 1400 ohm-m which suggests bedrock. However after this layer the curve descends to indicate a layer of low apparent resistivity material 15.2m thick, resting on bedrock at a depth of 31m. Apart from one dubious point in the third layer where the graph descends, the resistivity data is extremely consistent, displaying a very smooth overall trend in the graph. Interpretations of the third layer in the graph are however extremely ambiguous. Possible solutions range from very conductive thin layers 1m

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thick, to very thick layers of 80m with apparent resistivities in the 500 ohm-m range, thus indicating the problems of equivalence displayed in this resistivity curve. Therefore it is impossible to interpret this sounding in the absence of geological controls.

500m east of the latter sounding, VES 119 is situated in similar till topography. This sounding curve displays very consistent data showing a very smooth resistivity curve, apart from slightly scattered high resistivity values at the end of the curve. Interpretation of this sounding showed 1m of surface deposits resting on 15.6m of till, with an apparent resistivity of around 180 ohm-m. Below this a layer over 18m thick rests on bedrock at a depth of almost 35m. The apparent resistivity of this latter layer is around 90 ohm-m, which is similar to that of clay.

In the extreme north of the area, a little to the west, VES 133 is situated on a hill which is roughly 10m above the surrounding area. The resistivity curve indicates extremely high apparent resistivity gravelly material (315 ohm-m) resting on bedrock. Resistivity values for the outer array spacings are a bit chaotic due to extreme topographic variation, which is probably an indication of the lateral variation in the bedrock.

In the central area 400m north of the road, VES 136 is situated on a valley floor between two extremely high hills to the east and west. A very smooth resistivity curve shows a surface layer, with an apparent resistivity of around 360 ohm-m, indicating gravelly deposits. This layer rests on bedrock at a depth of 3.5m.

3.3.1 Apparent Resistivities of Lithologies

Histograms shown in Figure 3.18 are compiled from the apparent resistivities of the respective geological layers, indicated by the VES using the Schlumberger array.

1a shows that the apparent resistivity of the surface spongy peat is around 100 to 180 ohm-m. The average apparent resistivity range for the compact peat underneath, is slightly higher, normally ranging from 160 ohm-m to 240 ohm-m (1b). These latter two layers show the majority of apparent resistivity values to be on average, greater than that of the values of the corresponding layers for Clara bog, even though the range of values are similar. Lacustrine clay sediments lying underneath the peat are highly conductive (1c). Apparent resistivities for this layer are generally within the 40 to 80 ohm-m range. No apparent resistivity values for the lacustrine clay layer on Raheenmore bog lie within the 20 ohm-m to 40 ohm-m range, which contrasts greatly with that of Clara, where over half the apparent resistivity values of the clay lie within the 20 ohm-m to 40 ohm-m range. Glacial deposits resting on the bedrock indicate apparent resistivities distributed abut the 110 to 210 ohm-m range (1d), with values suggesting in general, slightly

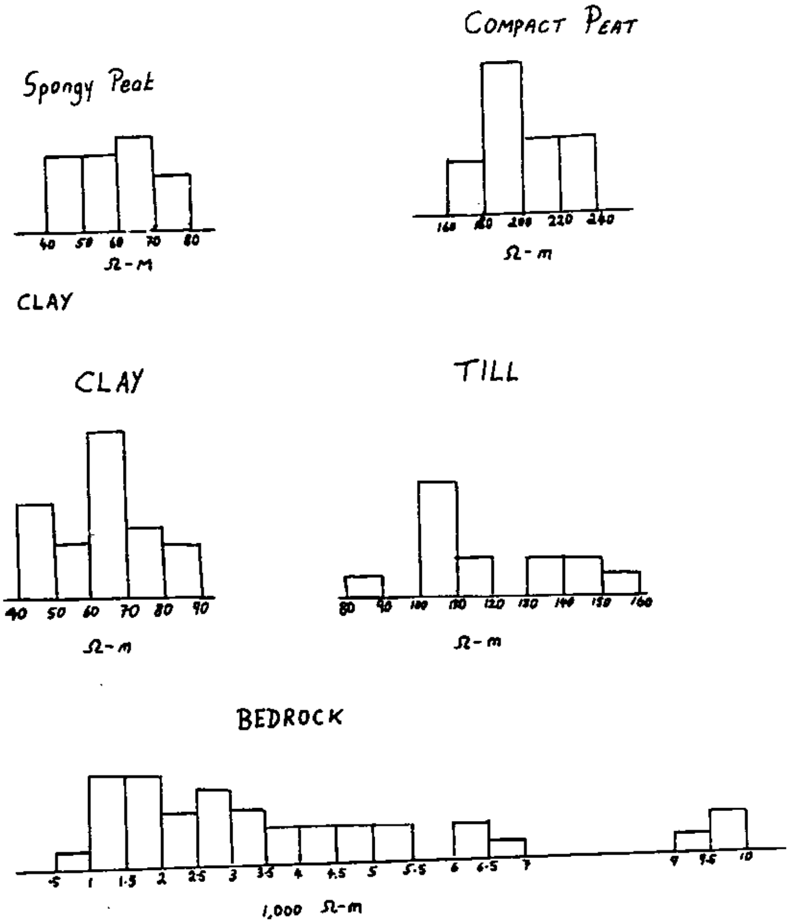

Figure 3.18: Histograms of VES Apparent Resistivities of Lithologies on Raheenmore Bog

lower apparent resistivity values than that of the corresponding layer on Clara Bog. Bedrock apparent resistivities display a broad apparent resistivity range. Lowest apparent resistivities for the bedrock are around the 1000 ohm-m to 1500 ohm-m range, with the majority of values occurring between here and 3500 ohm-m. A significant number of values occur between 3500 ohm-m and 5500 ohm-m, while a small number occur around 6500 ohm-m and 9500 ohm-m, respectively.

3.3.2 Results of VES Survey

Unlike Clara bog, where bedrock is not much greater than 20m at its maximum depth, interpreted results from the VES on certain areas of Raheenmore bog indicate areas where bedrock is extremely deeper, in excess of 50m. However, due to the limitations of the VES technique, discussed in Section 2.3, such as lateral effects and problems of equivalence, it is difficult to define actual depths to bedrock, with certainty. Interpretation of VES suggest extremely deep bedrock in the central area of Raheenmore East (see locations for VES 103,104 and 134), but these soundings could equally be interpreted showing a shallower bedrock, by altering the apparent resistivities. Thus, the problem of equivalence is a very significant factor in influencing the interpreted bedrock depth at these locations. The only way to resolve this problem is by drilling through the lithologies to bedrock, in an area on the east side of the bog, representative of the area where these soundings are situated. Since bedrock was not reached at 27m in the east side of the bog at borehole 304, the sounding indications of deep bedrock are reflecting a real contrast in bedrock depths between the west and east side of the bog.

Because no definite conclusions can be made about a number of VES (soundings where extremely deep bedrock is suggested), contour maps of the surface and thickness of the respective lithologies cannot be compiled to give a general impression of the subsurface geology, like those from the VES data on Clara. A map giving a general summary of areas of relatively deep and shallow bedrock suggested by the VES is shown in Figure 3.19. Shallow bedrock is indicated to encircle the bog from the east, around the south east and southern margins, projecting northwards to form an area of shallow bedrock in the west central area of the bog. Extremely deep bedrock is suggested in the north and the greater part of the eastern area of the bog. In the extreme west of the bog, deep bedrock is also implied.

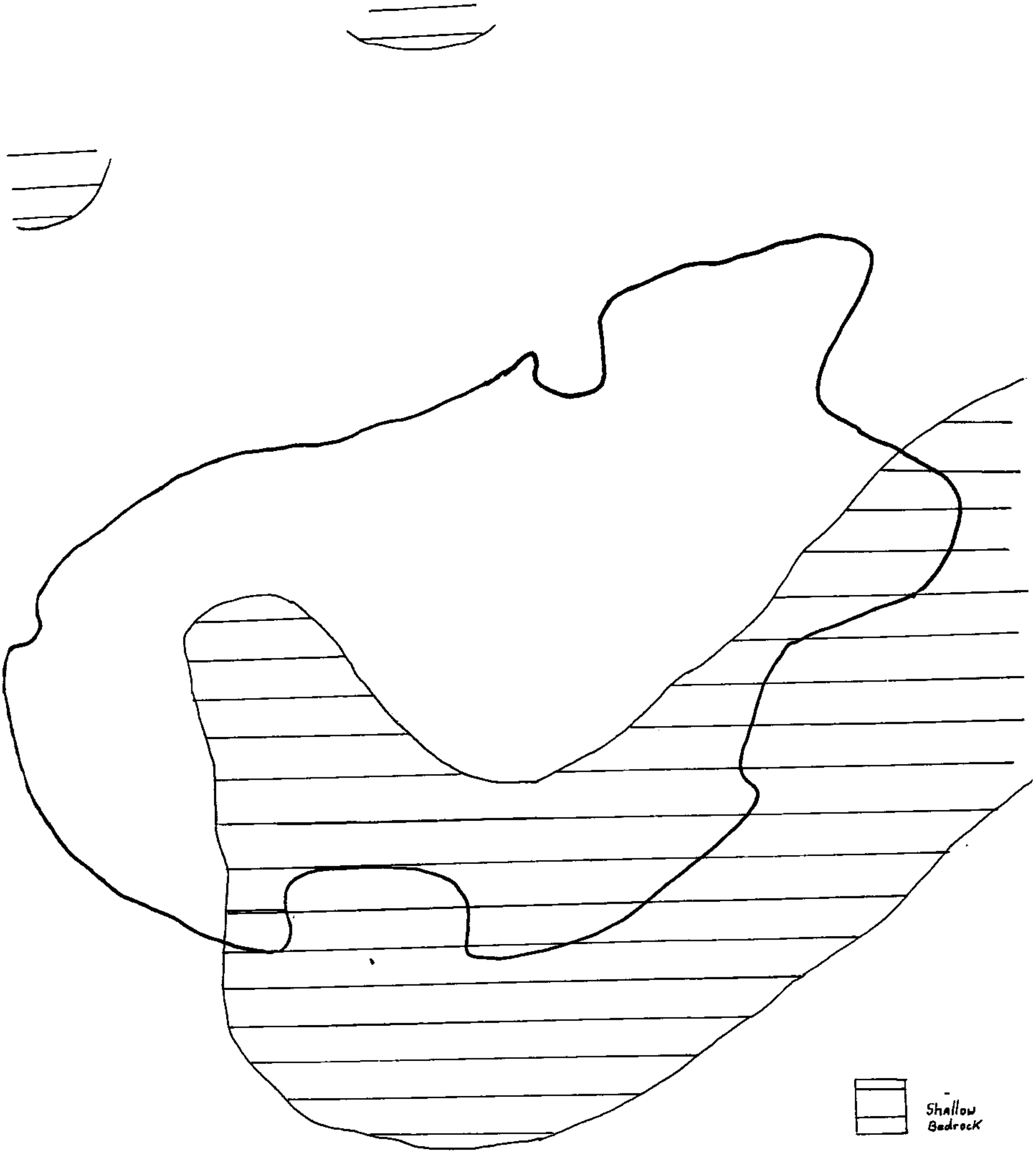

Figure 3.19: Areas of Shallow and Deep Bedrock on Raheenmore Bog - VES data

3.4 Electrical Resistivity Profiling - Dipole-Dipole Technique

Along (100N) of the O.P.W. grid, a dipole-dipole resistivity profile (Fig. 3.20) was carried out roughly in a west to east direction, from station -200 (200W) to station 1500 (1500E). The dipole-dipole resistivity pseudosection in Figure 3.21 shows the contoured resistivity values of the subsurface.

From station -200 to station 200, the 200 ohm-m apparent resistivity contour line extends quite deep, indicating a thick cover of overburden. The 300 ohm-m and 400 ohm-m contour line are only present for a short space at the start of the pseudosection, indicating that the overburden is getting deeper westwards. At station 200, the 300 ohm-m contour line rises almost vertically, then runs parallel to the surface of the pseudosection, before descending to the base at an angle of 45 degrees, between stations 525 and 600. The 400 ohm-m contour line runs below the 300 ohm-m contour line, and parallel to it. The vertical edges of the 400 ohm-m contour line suggest that there is a sudden shallowing of this high resistivity material on the west and east side. The high resistivities underneath, gradually increasing up to 1000 ohm-m, suggest bedrock.

3.4.1 Summary of Dipole-Dipole Pseudosection

A summary of the bedrock highs and lows, indicated from the Dipole-Dipole resistivity pseudosection, is given in Figure 3.22. The transect shows that the central area of Raheenmore East is indicated to have relatively deep bedrock, surrounding a central area of much deeper bedrock. An area of relatively deep bedrock is also implied to exist in the central area near the western margin. Shallowing bedrock is shown in the west central region of the bog, surrounding a relatively shallower area of bedrock. The extreme western and eastern ends of the Dipole-Dipole Profile show shallowing bedrock.

3.5 Conclusions

A correlation of the VLF-R, VES and Dipole-Dipole resistivity surveys carried out on Raheenmore Bog, emphasise that relatively deep bedrock exists in a large area towards the north east, and in a narrow elongated area towards the extreme western area of the bog. When comparing the summary maps of the respective surveys (Figure 3.13, Figure 3.14, Figure 3.15, Figure 3.16, Figure 3.19 and Figure 3.22), this becomes apparent. Geological controls are required, particularly in these deep areas, to refine the geophysical methods. General conclusions can be drawn from the geophysics, as the techniques complement each other, and proved extremely useful in delineating

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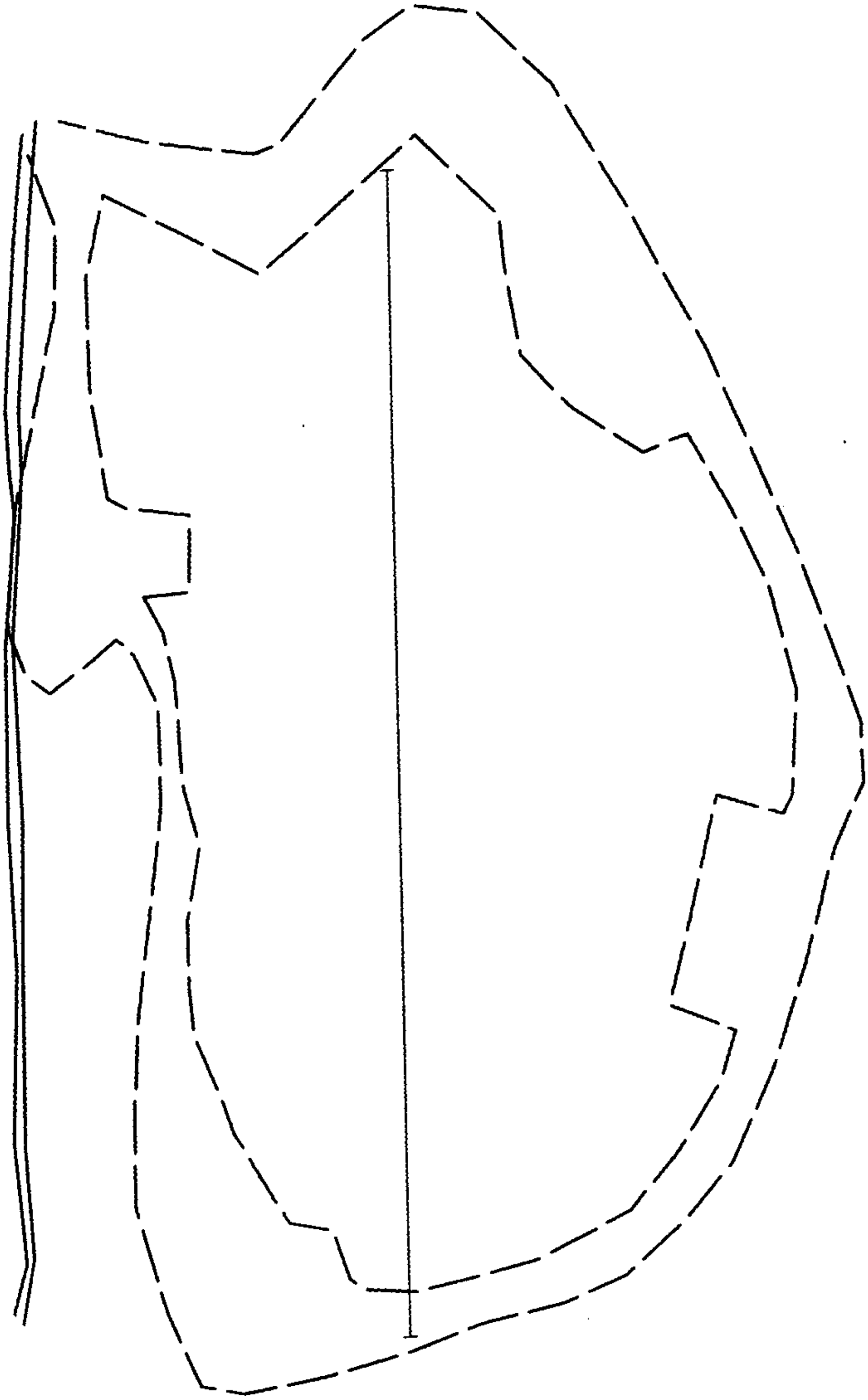

Figure 3.20: Location of Dipole-Dipole Resistivity Profile on Raheenmore Bog

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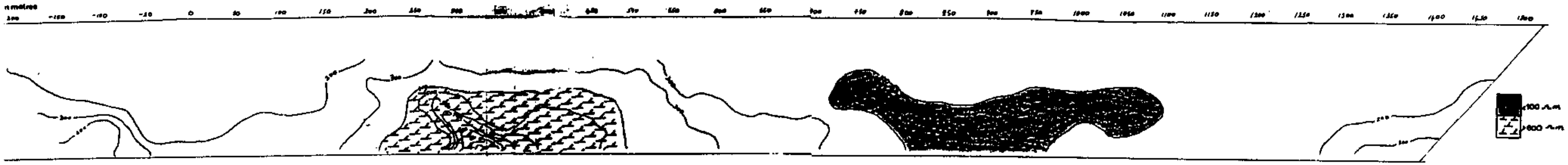

Figure 3.21: Dipole-Dipole Resistivity Pseudosection on Raheenmore Bog

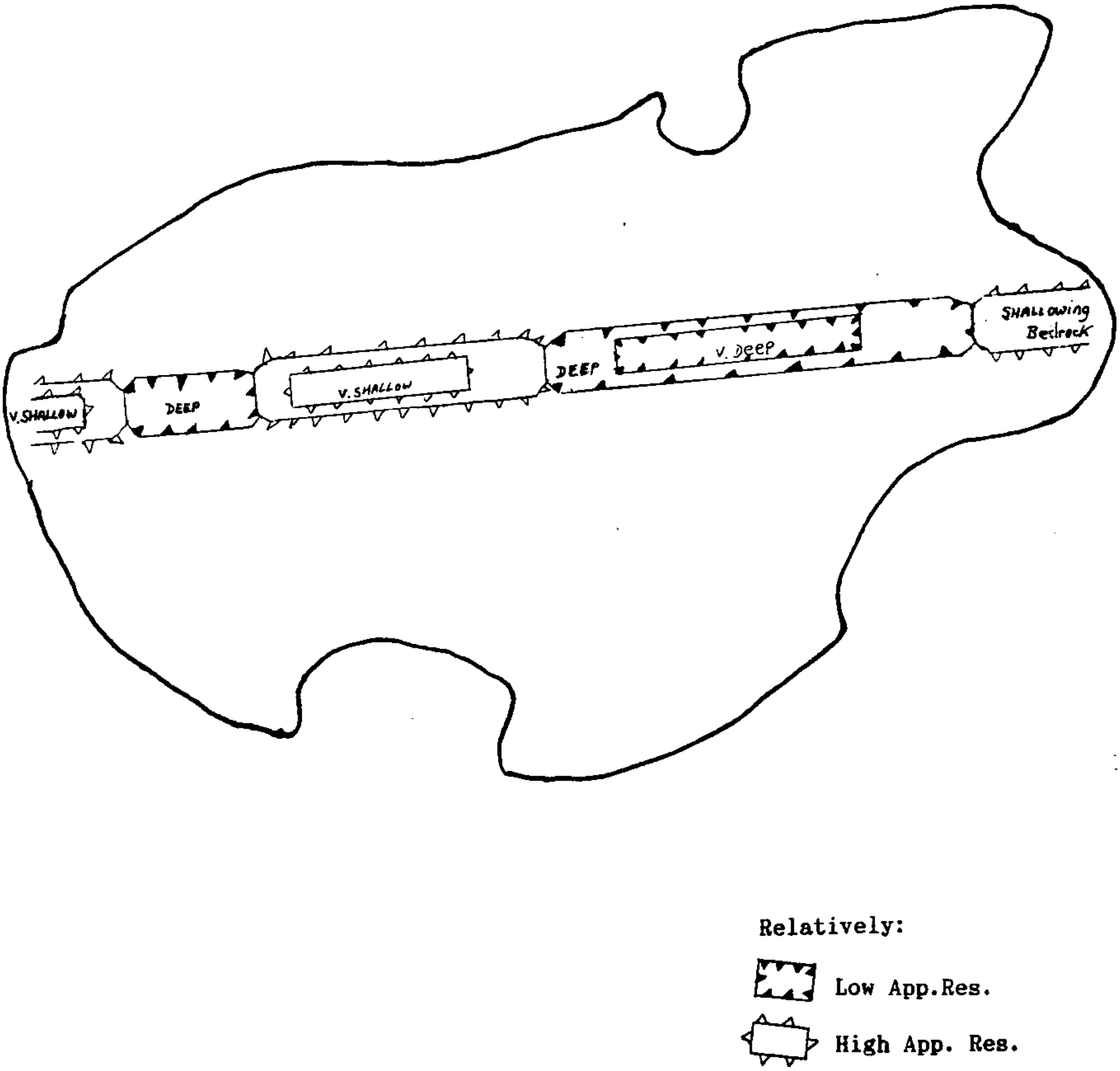

Figure 3.22: Summary of Dipole-Dipole Resistivity Profile on Raheenmore Bog

contrasting geological areas. In order to use the geophysical data to their full potential, a minimum of one extra geological borehole is essential.

Chapter 4

Recommendations

An apparent scarcity of VES on the east side of Clara Bog, contrasts with the numerous soundings on the west side of the bog. If funding and personnel are available, it is recommended that additional VES be carried out on Clara East, to fill in and further constrain the 3-D geological model. As a lower order of priority, it would be desirable to carry out a small number of additional VES in the northern area of Clara West, and one or two VES in the central area of Clara West, where VES stations are also sparce.

VES interpretation will have to be refined as more geological information becomes available from drilling. A minimum of one additional borehole, drilled to bedrock, is essential for the interpretations of the VES on Raheenmore bog. Figure 4.1 shows recommended sites for future boreholes. Problems encountered with locating boreholes, such as access to sites on the bog, are accounted for. Borehole sites are numbered in order of priority. Site 401 is located towards the north east margin of Raheenmore bog. This area of reclaimed farmland would allow access by a large drilling rig, and thus reduce the drilling time required by the previous boreholes. Two other sites at locations 402 and 403 are desirable for borehole locations, but not as important as that of 401.

Peat drilling information by Oscar Bloetjes (in the early part of this year) was acquired while this report was being written up. Data was not in a compatible form to be readable on the computer in Galway. Future work will take account of this dataset and integrate it with the geophysical results.

Due to time constraints the geophysical results have not been used to their full potential. More detailed examination of the datasets is required. VLF-R datasets and Dipole-Dipole pseudosections have been assessed qualitatively, however the respective data sets need to be assessed quantitatively with the relevant computer modelling programmes, to give information on depths of the various lithologies.

Some analysis of the VES apparent resistivities are displayed in Figure 2.23 and Figure 3.18. More detailed analysis of the variables would allow more conclusive statements about the various parameters, which would aid interpretations greatly.

Geophysical surveys carried out in the two study areas such as the EM34-3, seismics and VLF, have not been assessed here, again due to time constraints. It is recommended that these datasets be assessed in more detail and integrated with the other geophysical datasets.

A wealth of regional Gravity and Magnetic data exists for the Irish Midlands. A detailed examination of these data sets would provide the regional structural setting and also, aid the interpretation of the localised geological variations in the respective study areas. Some of the Gravity data have been assessed by Keohane (1991), however a considerable number of additional maps for the Offaly area are available on "Open File" in the Geological Survey, and have yet to be assessed. A minimum time period of 4 to 6 months is required to interpret the the geophysics datasets.

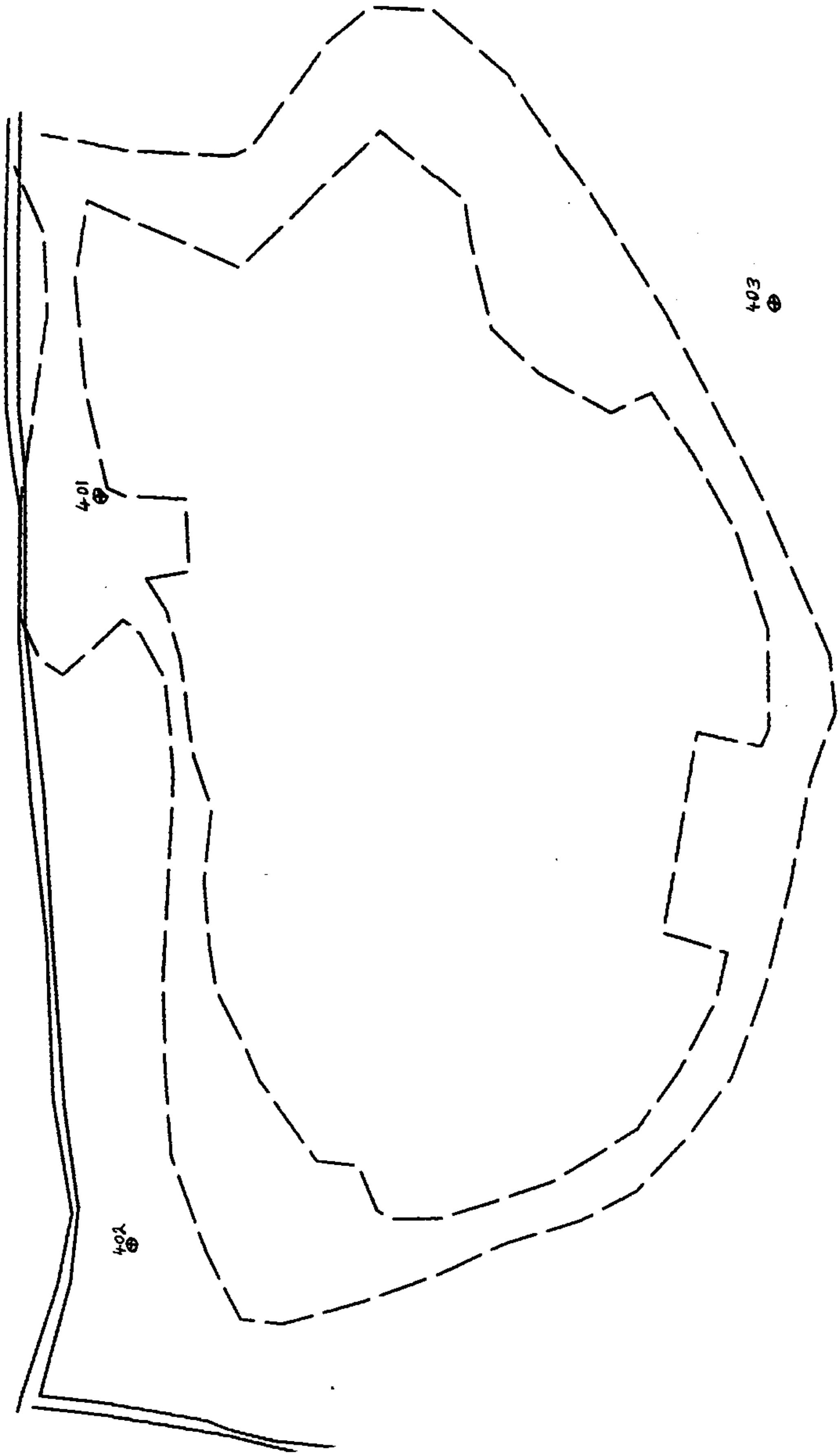

Figure 4.1: Proposed Drilling Sites - Raheenmore Bog

Acknowledgements

I wish to thank the students and supervisors involved in the Irish-Dutch Geohydrology and Ecology Study Group, for their help on the Project.

A very sincere word of thanks to Kevin Barton and Colin Brown for their generous time and assistance with data processing and compilation of this report, and to Prof. Brock for his helpful suggestions.

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Appendix A

Sounding Curves

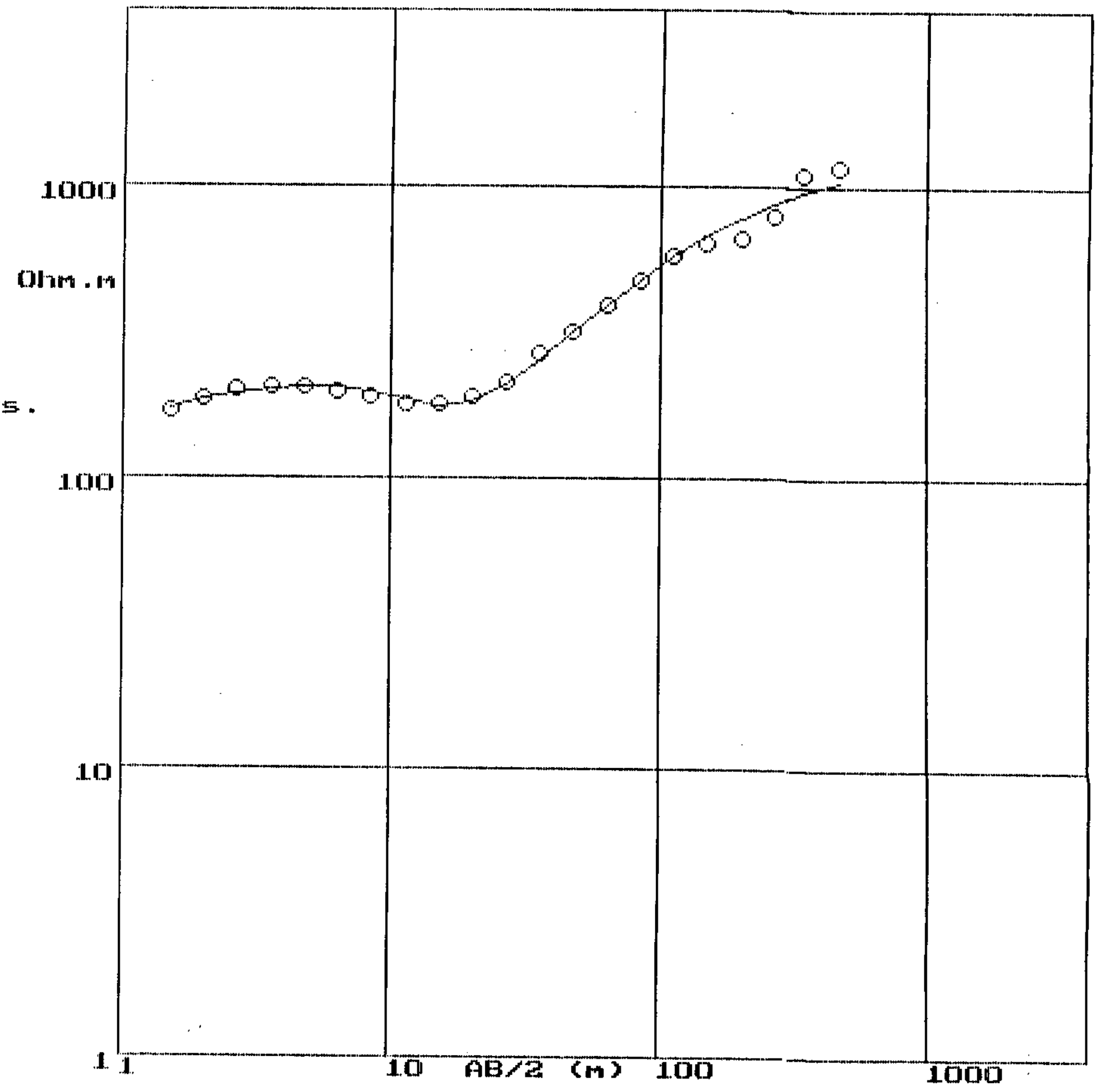
SOME SAMPLE SOUNDINGS FROM CLARA AND RAHEENMORE

No. 5

```
nr  thick  nr   resis
1    0.6   4    143.1
2    6.0   5    225.5
3    5.0   6     59.7
           7   1216.7
```

```
 New RMS error :  6.1

What do you want to do :
1 : Change parameters.
2 : Change number of layers.
3 : Automated fitting.
0 : Go back to main menu.
Choose a number ...
```

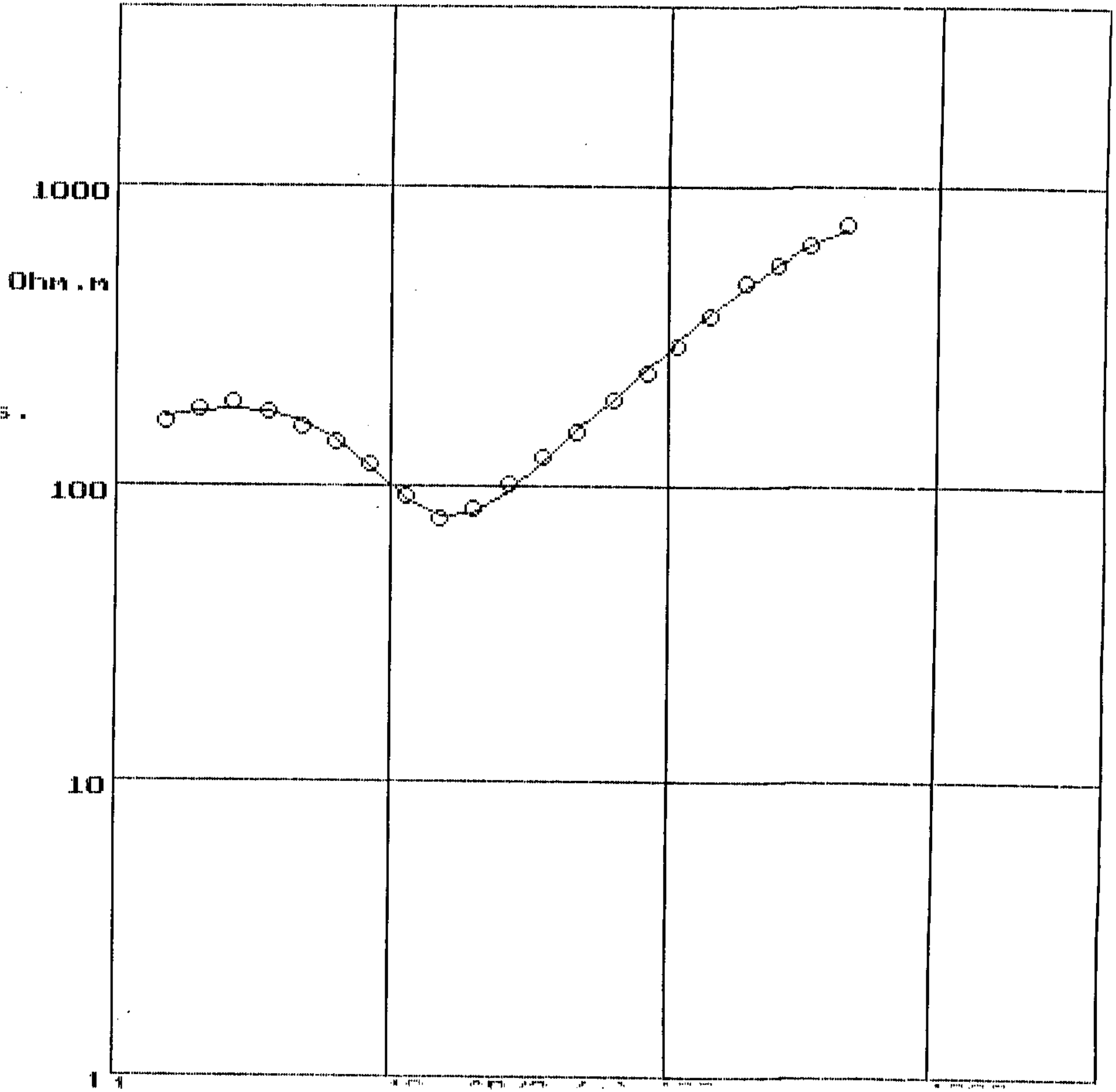
RAHEENMORE.



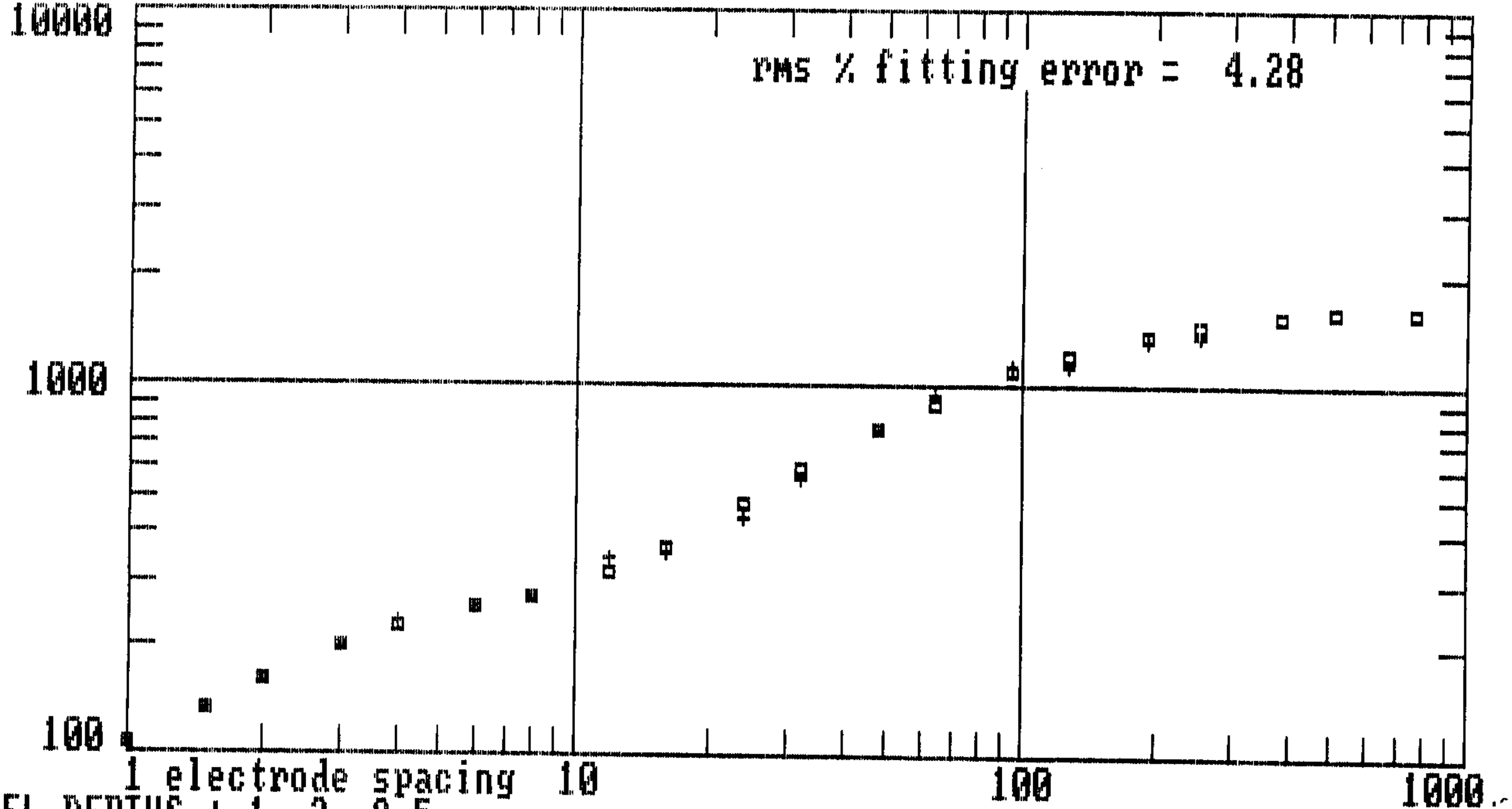
No. 112

```
 nr  thick  nr  resis
 1    0.6   5    150.5
 2    3.2   6    204.8
 3    6.7   7     39.4
 4   10.3   8    126.1
            9   1058.2


  New RMS error :   3.2

What do you want to do :
1 : Change parameters.
2 : Change number of layers.
3 : Automated fitting.
0 : Go back to main menu.
Choose a number ...
```

CLARA BOG.



No. 46



```
MODEL DEPTHS : 1  3  9.5
RESISTIVITIES : 82  500  185  1650
ENTER MODEL PARAMETERS
ENTER NUMBER OF LAYERS, 1 to shift curve down, 0 to quit
```

CLARA BOG.