CLARA

UCG

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IRISH-DUTCH PEATLAND STUDY

GEOHYDROLOGY AND ECOLOGY

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- *National Forest Service, Utrecht*

AGP 91/2
A Preliminary 3-Dimensional Space Form
Model of Clara Bog, Co Offaly.

by

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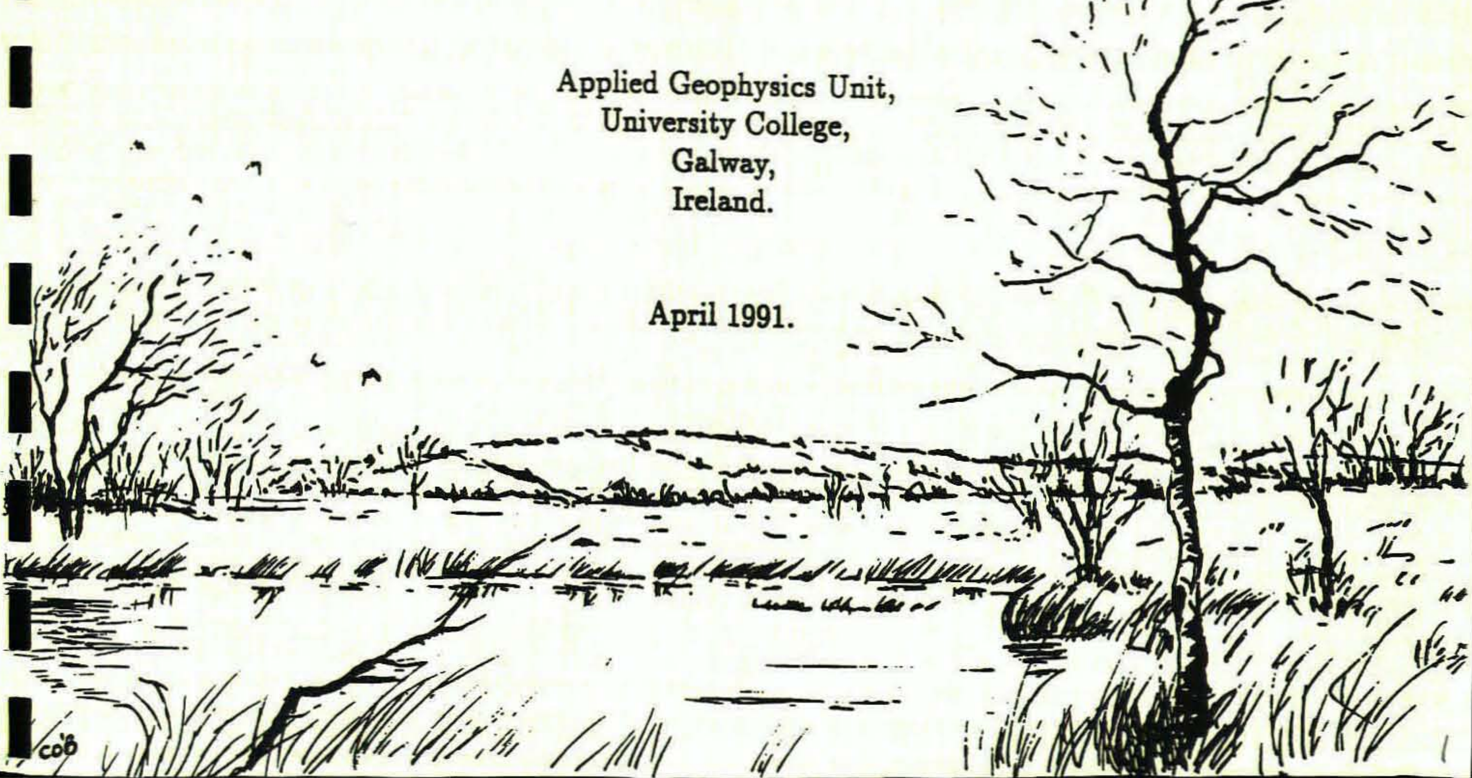
April 1991.



Contents

2

3

Chapter 1

Introduction

The geophysical surveys carried out on Clara bog, in chronological order, are as follows: February to April 1990, Resistivity Vertical Electric Soundings (VES) using the Schlumberger array, and EM 34-3 profiles; June 1990, Offset-Wenner VES and Resistivity profile using dipole-dipole array; September 1990, EM VLF/VLF-R profiles; January 1991, Schlumberger VES. The internal reports and thesis dealing with these surveys are given in the Bibliography, except for a report on the EM VLF work, which is being prepared.

From the above geophysical mapping techniques carried out on Clara bog, a preliminary 3-Dimensional space form model of the bog can be constructed. This preliminary 3-Dimensional model will serve as a working hypothesis for the hydrological study being conducted, as part of the Irish-Dutch Peatlands project.

At this stage in the geological study the model will be limited in many respects. Data acquired on the east side of the bog is insufficient to compile a more thorough model of the subsurface geology. The absence of a grid on East Clara restricted the acquisition of geophysical data to a considerable extent. The EM VLF-R (Electro-Magnetic Very Low Frequency-Resistivity) survey conducted on Clara bog (Madden, 1990), did not extend to the Eastern margin of the bog because of positioning problems due to the absence of a grid. Likewise, the V.E.S.(Vertical Electric Soundings) were restricted to West Clara, with one exception, where the grid was put out close to the road on the East side.

Three geophysical mapping techniques are employed in the production of the 3-Dimensional model of the subsurface geology of Clara bog; Resistivity Sounding (VES), using the Schlumberger and Offset-Wenner array; EM VLF-R; Resistivity profiling using the dipole-dipole array. In addition, peat depths recorded by Bord na Mona, using a Hiller Borer to explore the depths to the base of the peat, were used to produce a topographical map of the underlying surface of the bog. Information obtained from various drilling locations, and the Bord na Mona peat thickness data, were used to calibrate the geophysical techniques.

More extensive application of geophysical mapping techniques will take place in June 1991, when the grid is completed on the East side of the bog. The work will be carried out by three M.Sc. students from the Applied Geophysics Unit, U.C.G.. When this work has been completed, a more detailed 3-Dimensional Spaceform model of the bog will be produced.

In this report the O.P.W. (Office of Public Works) grid, which uses a combination of letters (eastings) and numbers (northings) to define grid co-ordinates, has been transformed into a conventional exploration grid. The origin of this grid is at the northwestern side of the northern end of the road bisecting Clara Bog. North-South traverse lines running west of the origin are numbered 100W, 200W, etc., whilst those to the east are likewise numbered 100E, 200E, etc. Station numbers along each traverse line run from the origin southwards and are numbered 0, 100S, 200S, etc.

Chapter 2

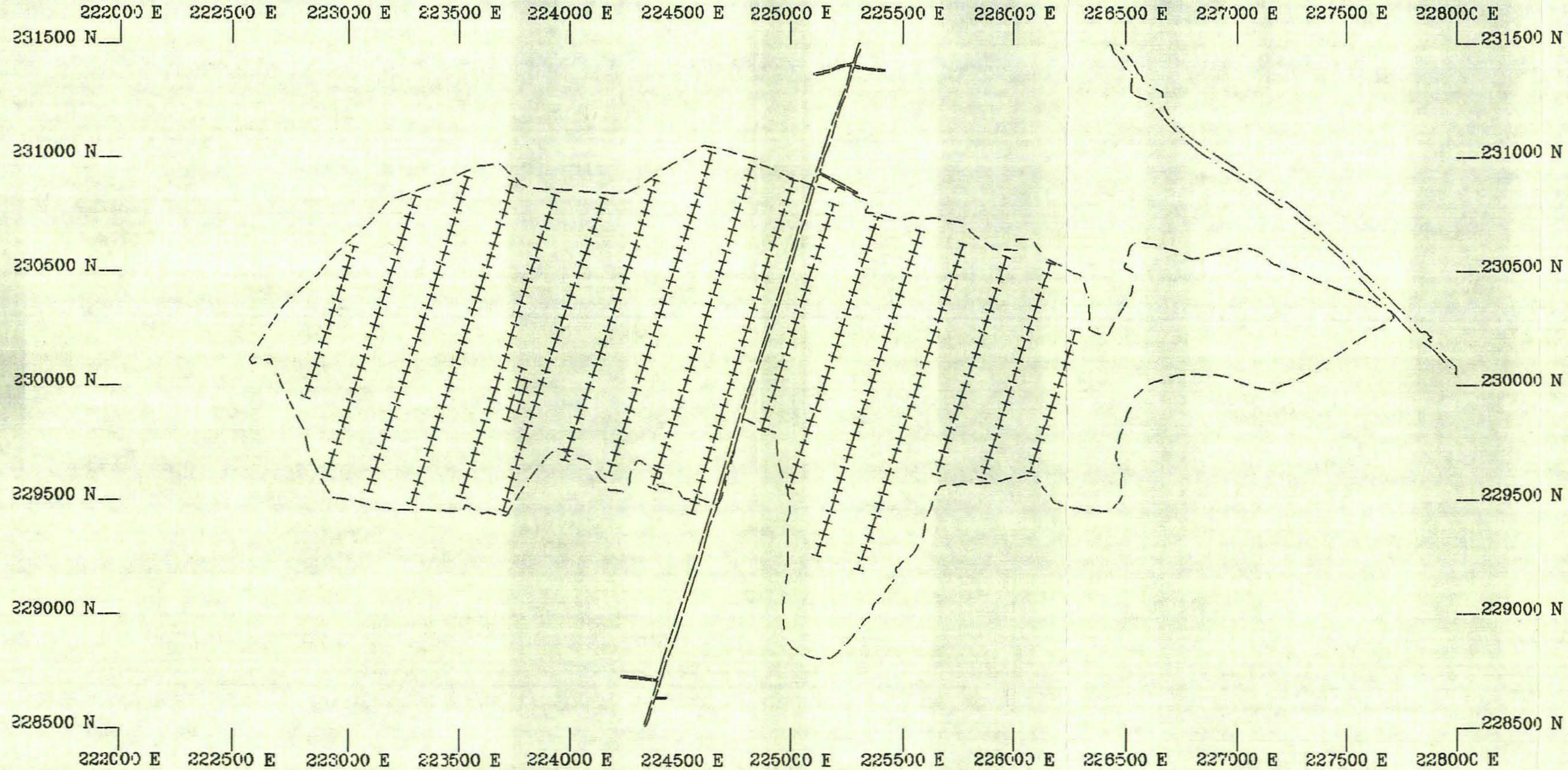
Geophysical Techniques

The three geophysical methods employed in the production of the space form model for this report are the EM VLF-R; Resistivity Profiling using the dipole-dipole array; Resistivity Sounding (VES) using the Offset-Wenner and Schlumberger arrays. At this stage it has not been possible to integrate the EM 34-3 data into the model, EM 34-3 data will be used at a later date. Geophysical interpretation of the subsurface lithologies is controlled by information about the subsurface geology, obtained from various sites where drilling was carried out. Drilling information available provides some calibration for the model. However more widespread drilling locations are required for a more rigorous interpretation of the geophysical techniques employed in the area.

The following numbering system is used to denote the various borehole and Resistivity VES locations on the map; Schlumberger VES locations are numbered in the one hundred series, e.g. 101, 102, etc.; Offset-Wenner VES locations are numbered in the two hundred series, e.g. 201; Borehole locations are numbered 301, 302, etc.

2.1 EM VLF-R

Detailed information on the VLF-R survey is given in Madden (1990). It is sufficient to say that the VLF-R survey was carried out along a series of lines parallel to the road (Fig.2.1). These lines are spaced 200m apart, occupying every second line of the O.P.W. grid. Station spacings are 50m apart along each line. EM VLF-R Resistivity values are discussed in Chapters Three and Four.



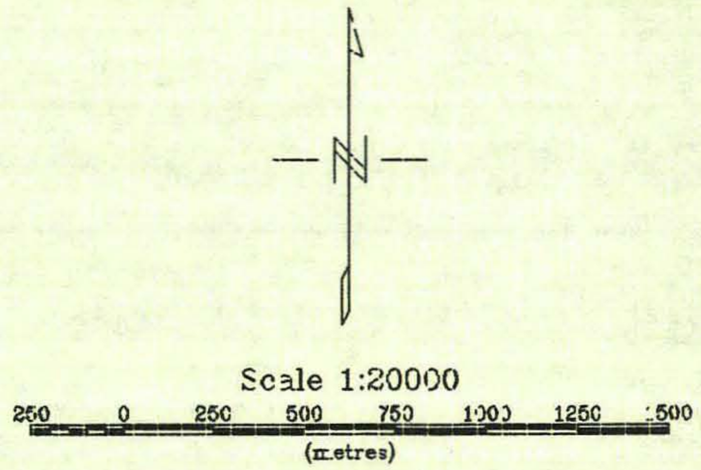


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FIG.2.1 CLARA BOG
EM VLF-R SURVEY GRID.

LINE SPACING 200m, STATION SPACING 50m ALONG EACH LINE.
Survey lines occupy every second line of O.P.W. grid lines.
Survey conducted in September 1990.

Mary Smyth *April 1991.*

2.2 Resistivity-Vertical Electric Soundings

2.2.1 VES-Schlumberger array

The Schlumberger soundings (Nos. 101 to 110) carried out on Clara bog in February 1990 are dealt with in detail in reports by Smyth et al, (1990) and Farenhorst and Biewinga, (1991). An additional eight soundings were carried out in February 1991 (soundings No.111 to 118), (Fig.2.2). Interpretation of the Schlumberger soundings was done using a programme called "Resint31" (Biewinga, 198?). Drilling information and peat thickness data were used to calibrate the Schlumberger sounding models, in a re-interpretation of the ten original Schlumberger soundings (discussed in the above mentioned reports), and also in the interpretation of the eight additional soundings carried out on the bog in February 1991.

2.2.2 VES-Offset-Wenner array

The resistivity Offset-Wenner array is a vertical electric sounding technique which produces a one-dimensional image of the subsurface geology. Soundings carried out at various intervals along a transect were used to produce a two-dimensional image of the subsurface lithology (Flynn, 1990).

Fourteen soundings using the Offset-Wenner array were carried out, both on the bog itself, and on the esker slopes to the north (Fig.2.3). Results obtained with this array are interpreted with the aid of drilling investigations.

2.3 Resistivity Profiling using Dipole-dipole array

The Resistivity-dipole-dipole array method is used as a profiling technique to produce a resistivity pseudo-section. This pseudo-section cannot be considered to directly reflect the sub-surface geology, but can be interpreted to indicate the general configuration of sub-surface features such as bedrock, layering, faults, etc. Beginning in a hollow on the esker ridges, 800m to the north of the bog (Fig.2.3), the dipole-dipole pseudo-section extended across the esker ridges, into the centre of the bog as far as Lough Roe.

The information revealed about the underlying geology is evaluated in this report with the aid of the Offset Wenner results (Flynn, 1990), in addition to various drilling investigations. The field array and the theoretical aspects of the dipole-dipole method are dealt with in Flynn (1990).

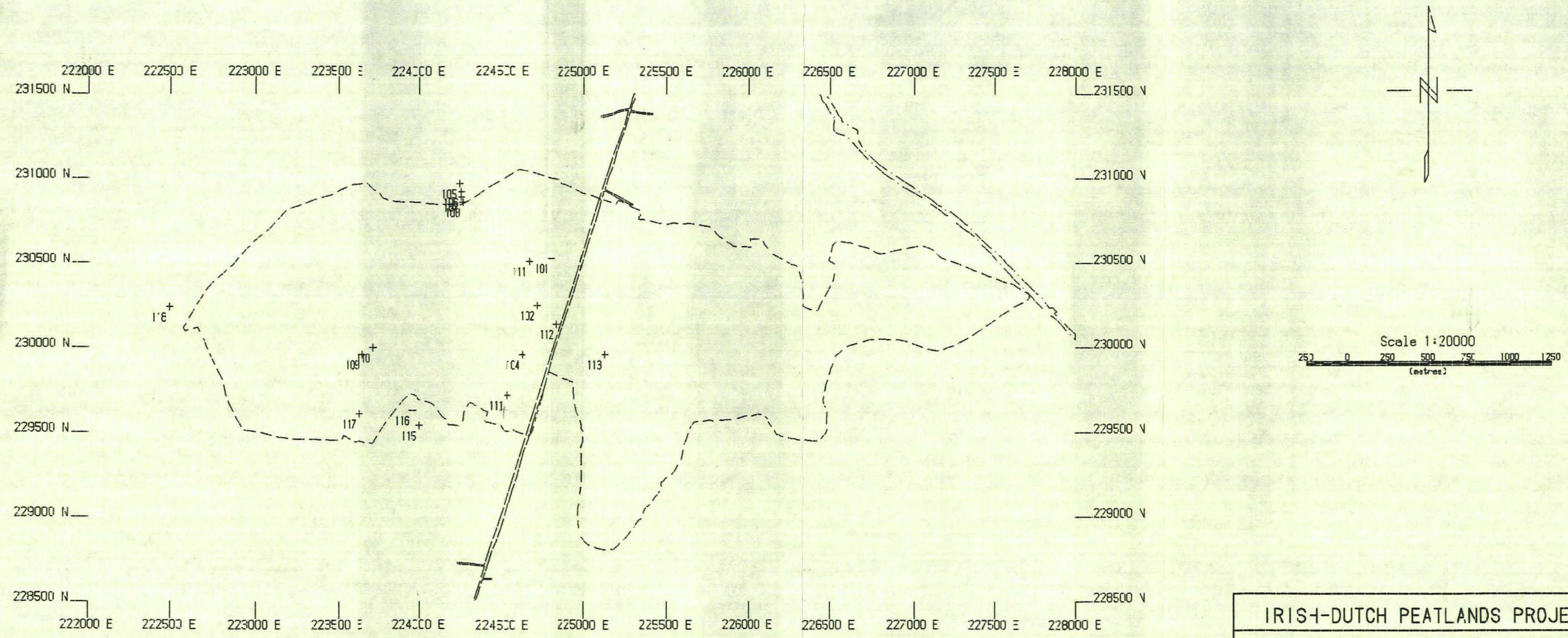

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FIG. 2.2 CLARA BOG
SCHLUMBERGER VERTICAL ELCECTRIC SOUNDING LOCATIONS.

MAX. AB/2 SPACING OF 500m.
Soundings carried out in March 1990 and February 1991.
Survey concentrated on west side of bog.

Mary Smyth **April 1991.**

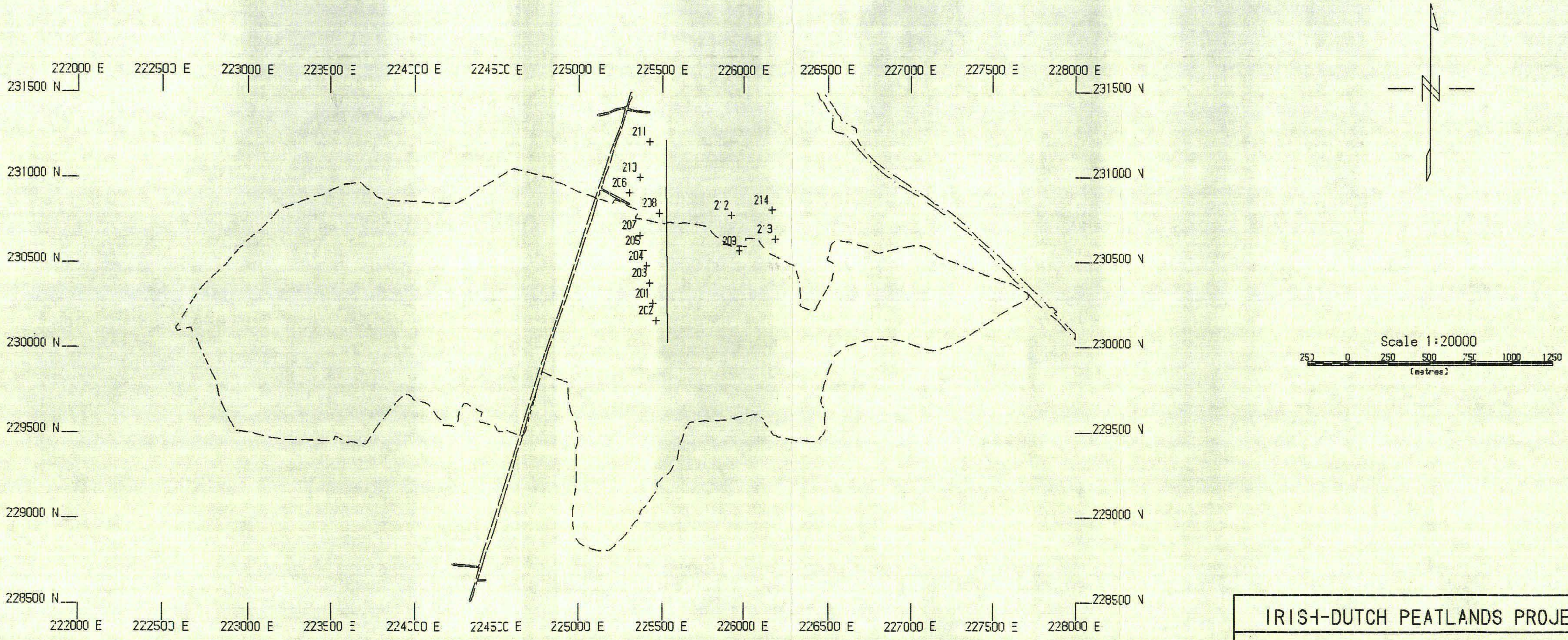

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FIG. 2.3 CLARA BOG

OFFSET-WENNER SOUNDING LOCATIONS & DIPOLE-DIPOLE TRANSECT.

DIPOLE-DIPOLE PROFILING TECHNIQUE; a=25, n=6
OFFSET-WENNER SOUNDING; Max. spacing 128m.
Surveys carried out in June 1990.

Mary Smyth April 1991.

Chapter 3

Interpretation

3.1 Peat Drilling Data

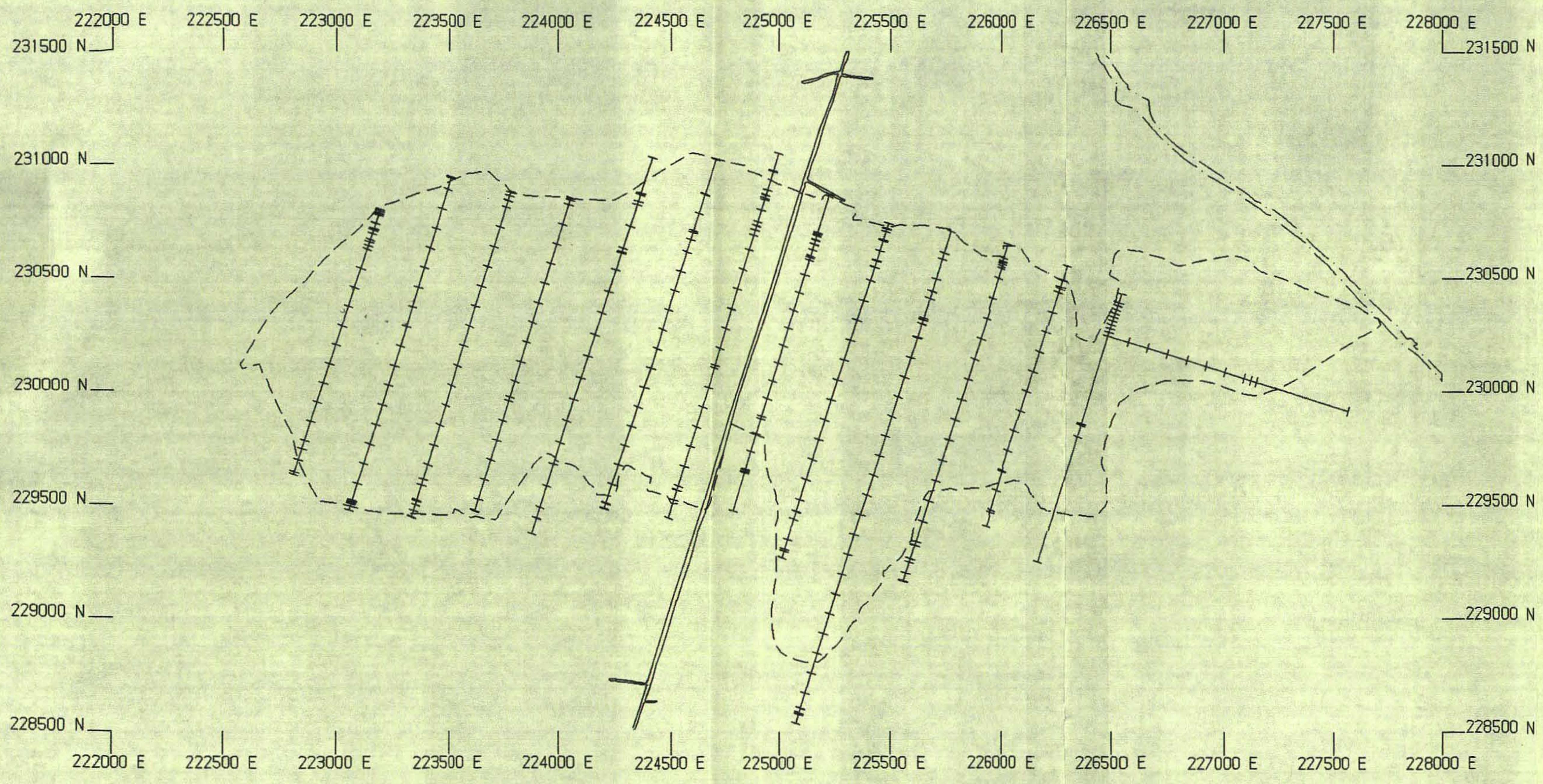
In 1981 Bord na Mona carried out a very extensive investigation of the peat depths on Clara bog. In this survey, a grid was established with lines orientated to run parallel to the road. Line spacings were 100 yards (1 yard = 0.9144m) apart (Fig.3.1). Station spacings along each line were irregularly situated, at maximum intervals of 100 yards, and minimum intervals of 10 yards apart. At each station location the surface height of the peat was recorded in feet (O.D.). Using the Hiller borer, drilling took place to record the depth to the base of the peat. Peat thickness recordings were then subtracted from surface height data in order to obtain the O.D. level of the base of the peat.

All Bord na Mona data were recorded in Imperial units of feet. Using the "Geosoft" mapping package in the Applied Geophysics Unit, UCG, contour maps of the peat data were produced in metric units. Firstly, the respective measurements were converted from feet to metres. The data were then gridded using a cell size of 100m, in order to produce contour maps of the peat thickness, surface and base respectively. All maps were contoured in intervals of 0.5m. Initially, the contoured map had a very angular appearance, thus to aid interpretation, and for aesthetic reasons, the contoured maps were smoothed using the "Hanning Filter" on the Geosoft package.

3.1.1 Peat Thickness Contour Map

A first glance at Figure 3.2 shows two obvious areas where peat is thickest; one in the centre of Clara East, the second in the centre of Clara West. Peat thicknesses in both these areas are 8m to 9m, the 8m contour line running parallel to the road, indicating the effect of drainage and peat cutting along the road.

Peat thins out quite sharply towards the edges of the bog, this being particularly evident in the northern and eastern margin of the bog. The data does not extend out far enough on the west side of the bog, to indicate if peat thins out



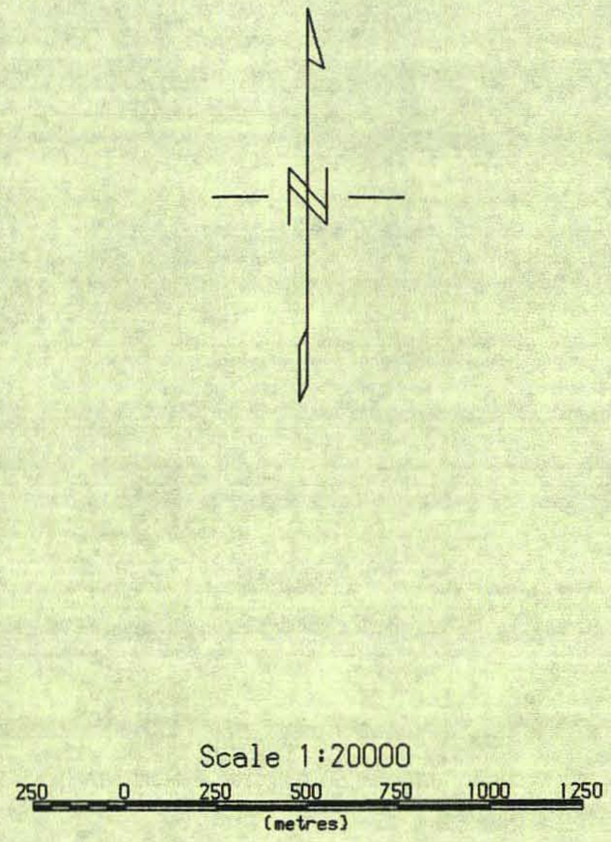


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FIG. 3.1 CLARA BOG
BORD NA MONA SURVEY TRANSECTS

LINE SPACING 300 YARDS.
IRREGULAR STATION SPACINGS; MAX.=100 YARDS, MIN.= 10 YARDS.
SURVEY CARRIED OUT IN 1982.

Mary Smyth APRIL 1991

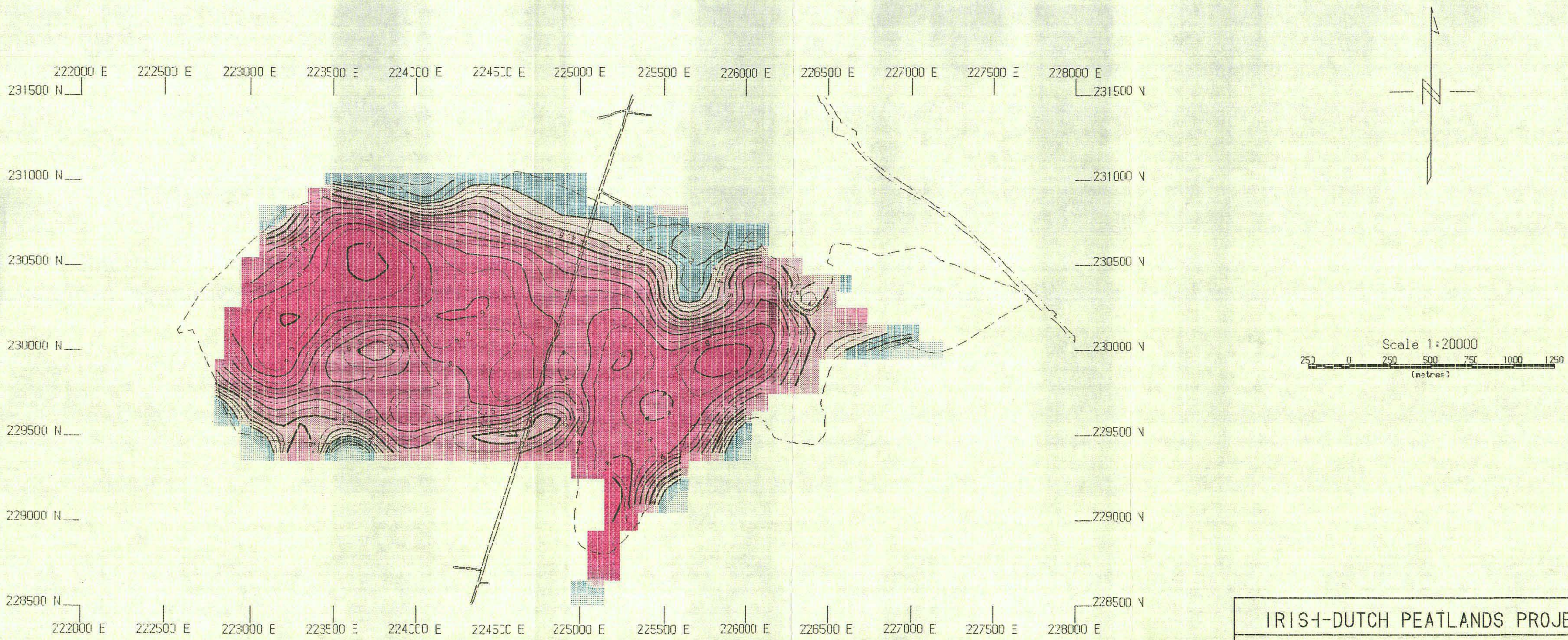

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FIG. 3.2 CLARA BOG
BORD NA MONA PEAT THICKNESS CONTOURS.

GRIDDED AT 100M. CONTOURED AT 0.5m.
LINE SPACING 300yds. STAT. SPAC. MAX=100yds. MIN=10yds.
SURVEY CARRIED OUT IN 1952.

Mary Smyth

APRIL 1991

sharply or not on this side. However it is likely that the peat thins out sharply on the west side, in a similar manner to that on the other sides.

3.1.2 Peat Surface Contour Map

Original elevation heights of the raised bog surface are changed considerably by peat cutting and drainage. However contoured surface height values in Figure 3.3 give a good indication of the general trend. The 59m contour line extends from the northern margin southwards along the west side; it then turns eastwards across the centre of the bog, and makes its way towards the north-east corner of the bog. South of this line, the surface elevation is highest, at elevations of 59m to 60m O.D.

Lowest elevations of 55m to 52m O.D. occur on the northern margin of Clara East. The contour lines in the centre of the bog are distorted southwards along the road due to extensive drainage and peat cutting southwards along the road.

3.1.3 Peat Base Contour Map

Extending from mid-way along the northern margin to the central area of the bog, Figure 3.4 shows that the base of the peat is at its lowest elevation, below 50m O.D. Contour lines surrounding this depression show that the sides of the depression rise gently on all sides, especially in a westerly and easterly direction.

Steep topographical highs are indicated along the margin, particularly in the north west, south east and south west. These areas show the base of the peat to slope quite steeply downwards, deepening by 4m to 5m over a horizontal distance of 200m. Two minor topographical high areas with an O.D. elevation of 54m are indicated towards the north east and south west of the main central depression.

An overall general impression of the peat base suggests a shallowing towards the margins of the bog. This shallowing is particularly evident in the north west and south east, and along the east margin. Deeper channels are shown to exist, extending from the central depression towards the west margin, and also towards the southern margin of Clara East.

3.2 Drilling Sites

Bedrock drilling was carried out by the Geological Survey of Ireland (GSI), at three sites in the study area. A full account of the drilling investigations is covered in reports by Henderson (1991) and Smyth (1991). Location of sites where drilling to bedrock was carried out are indicated on Figure 3.5.

Borehole 301 is situated approximately 15m from the road, at the car park in the centre of the bog. Drilling at this borehole encountered bedrock at a depth of 14.8m, (Fig.3.6(a)). Above the limestone, 2.6m of a stoney diamicton was

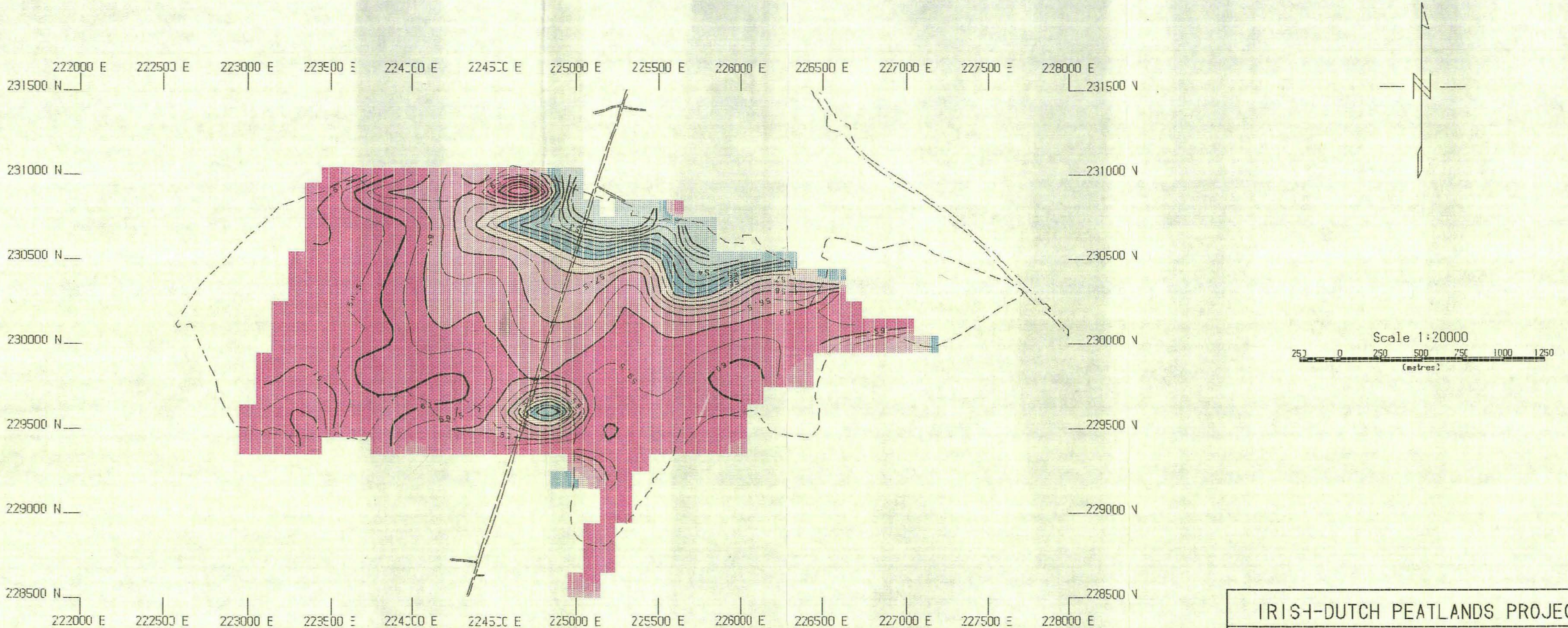

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FIG. 3.3 CLARA BOG

BORD NA MONA PEAT SURFACE CONTOURS.

GRIDDED AT 100M. CONTOURED AT 0.5m.
LINE SPACING 300yds. STAT. SPAC. MAX=100yds. MIN=10yds.
SURVEY CARRIED OUT IN 1982.

Mary Smyth

APRIL 1991

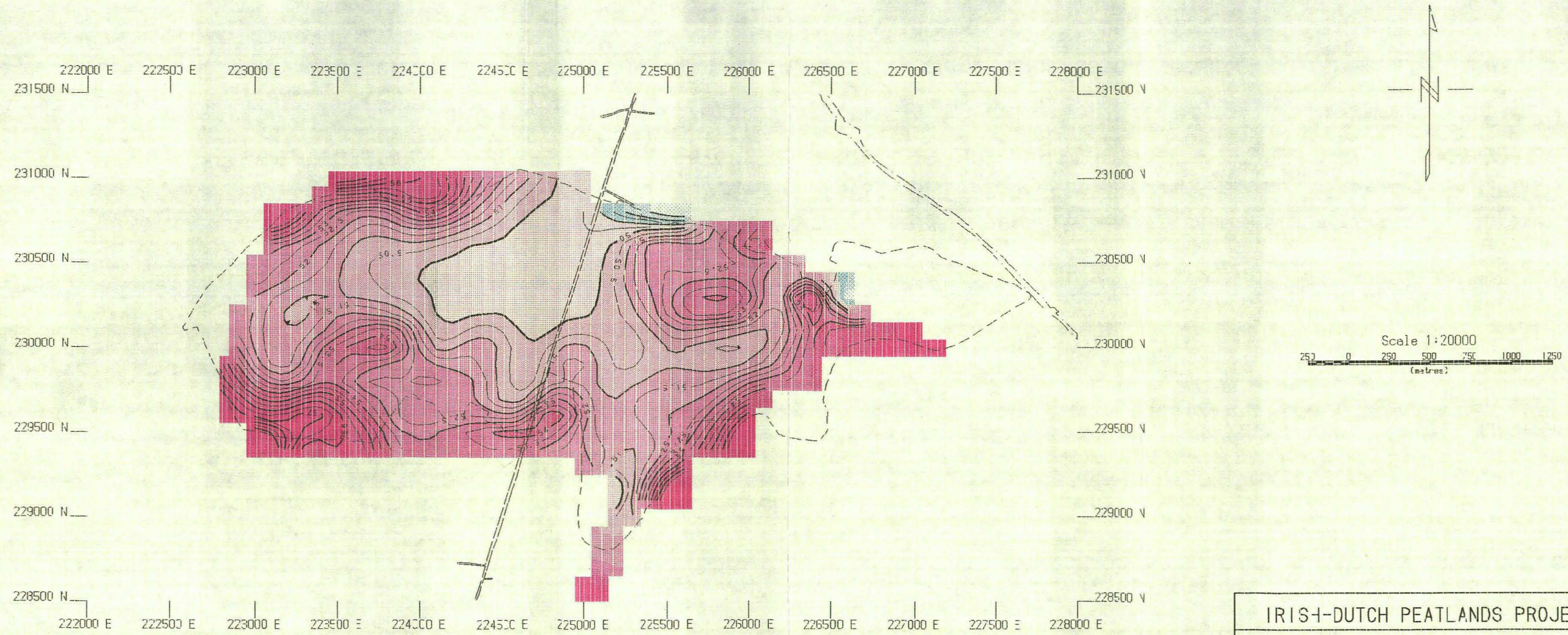

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FIG.3.4 CLARA BOG
BORD NA MONA PEAT BASE CONTOURS.

GRIDDED AT 100M. CONTOURED AT 0.5m.
LINE SPACING 300yds. STAT. SPAC. MAX=100yds. MIN=10yds.
SURVEY CARRIED OUT IN 1982.

Mary Smyth *APRIL 1991*

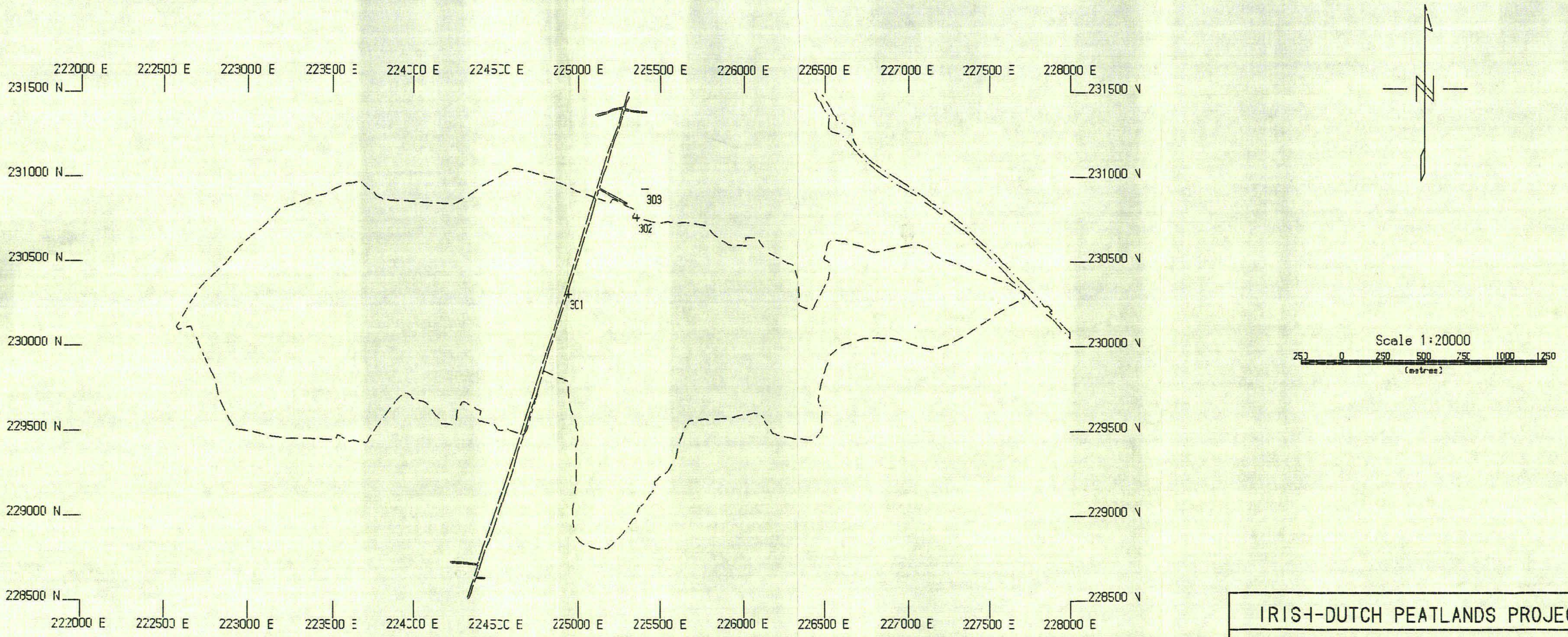

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FIG.3.5 CLARA BOG
BOREHOLE LOCATIONS.

DRILLING BY GEOLOGICAL SURVEY OF IRELAND.
BOREHOLES DRILLED TO BEDROCK.
DRILLING TECHNIQUE: SHELL AND AUGER, ROTRARY THROUGH BEDROCK.

Mary Smyth *April 1991.*

drilled, recovery being greater as stones became larger at 14m. Dark grey mud with stones occupies the layer from 10.65m to 12.2m. The mud which overlies this, is a silty clay with some fine sand and shell fragments towards the top. Due to difficulties which arose from the drilling, the exact boundary between the peat and the latter layer is not precisely defined. However the peat is known to be approximately 7m in depth. Geophysical logging of each borehole using natural gamma logs, would help to delineate the approximate boundary between the individual subsurface layers.

At Clara East, on the northern margin of the bog, 302 was drilled. Here bedrock was encountered at a depth of 8.35m. Overlying this was a layer of sandy till, with a thickness of 2.45m. Loose gravels were encountered at depths between 4.3m and 5.9m. Above the loose gravels, a layer of clayey gravels occupies depths between 1.1m and 4.3m. A clay layer with a thickness of 0.8m was encountered at 0.3m and extended to 1.1m. The surface layer consisted of cutaway peat with a thickness of 0.3m, (Fig.3.6(b)).

180m to the north of 302, borehole 303 is situated on one of the esker ridges. Topsoil at this borehole is 0.3m thick. Clayey sand is encountered at a depth of 0.3m, and is only 0.2m thick. A layer of sand and gravel occupies the layer between 0.5m and 2m. Underneath this is a layer of fine gravelly sand which extends to a depth of 5.2m. Silty sand with clay lenses occupies the layer between 5.2m and 8m. At 8m sand and gravel is encountered. At 12.7m, this latter layer gives way to a layer of coarse gravel 0.75m thick, which overlies the bedrock at a depth of 13.45m, (Fig.3.6(c)).

3.3 EM VLF-R

The contoured resistivity map from the VLF-R survey is given in Figure 3.7. This qualitative information will aid in the preparation of the spaceform model of Clara bog in Chapter Four. Areas of higher resistivity (resistivity values greater than 450 ohm-m) indicate bedrock likely to be closer to the surface. Areas shown in red indicate that the resistivity of the subsurface is above 450 ohm-m. The central area of the bog shows bedrock to be deep, with a low resistivity below 200 ohm-m. Bedrock shallows towards the edges, where higher resistivity values are shown. The east side shows a wide, stepped plateau of shallowing bedrock towards the edge of the bog, whereas on the west side bedrock topography is much steeper and more irregular. The centre of the northern margin shows bedrock to be quite deep. Data are needed further out from the margin in this area.

BOREHOLE LITHOLOGIES

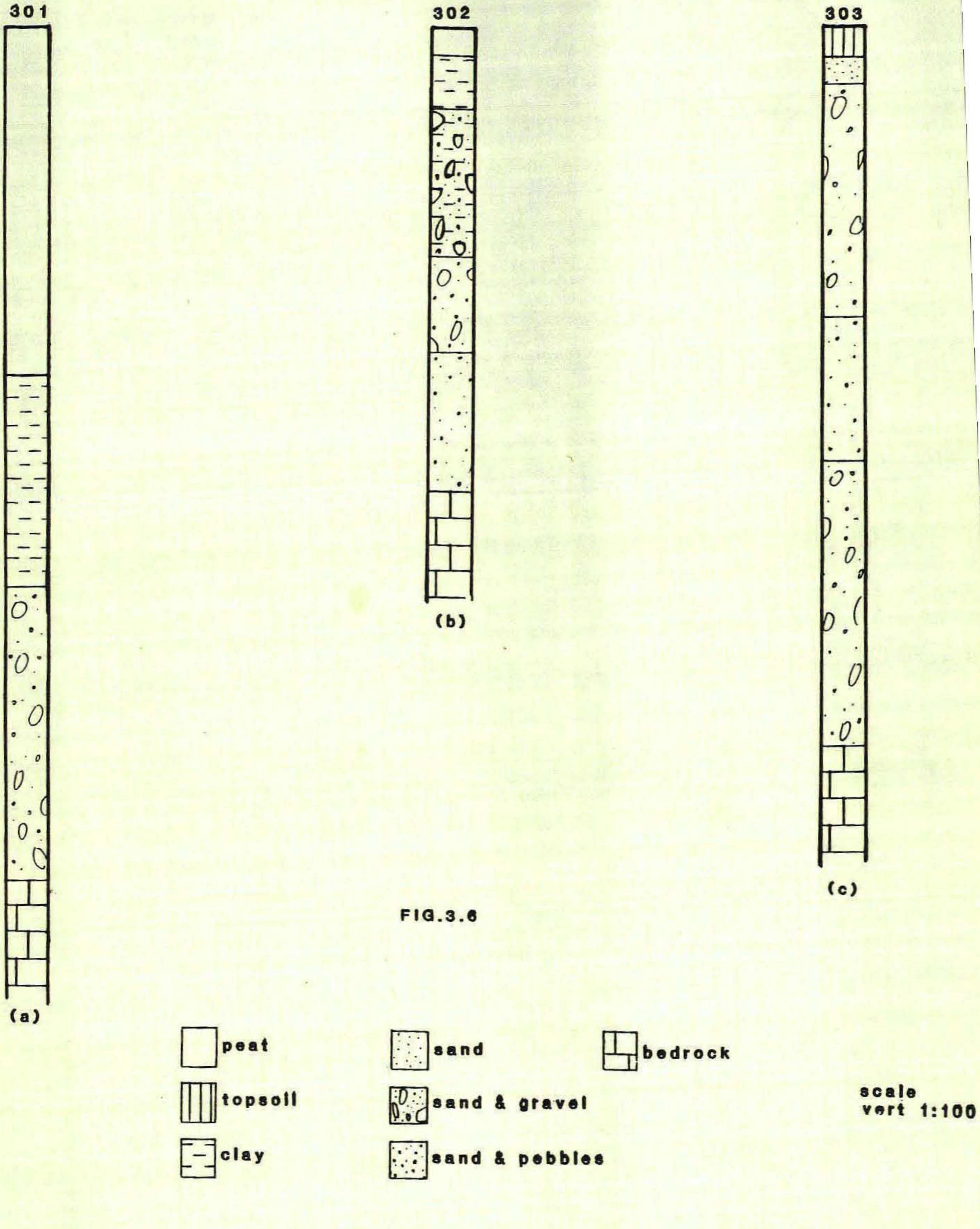

FIG.3.6

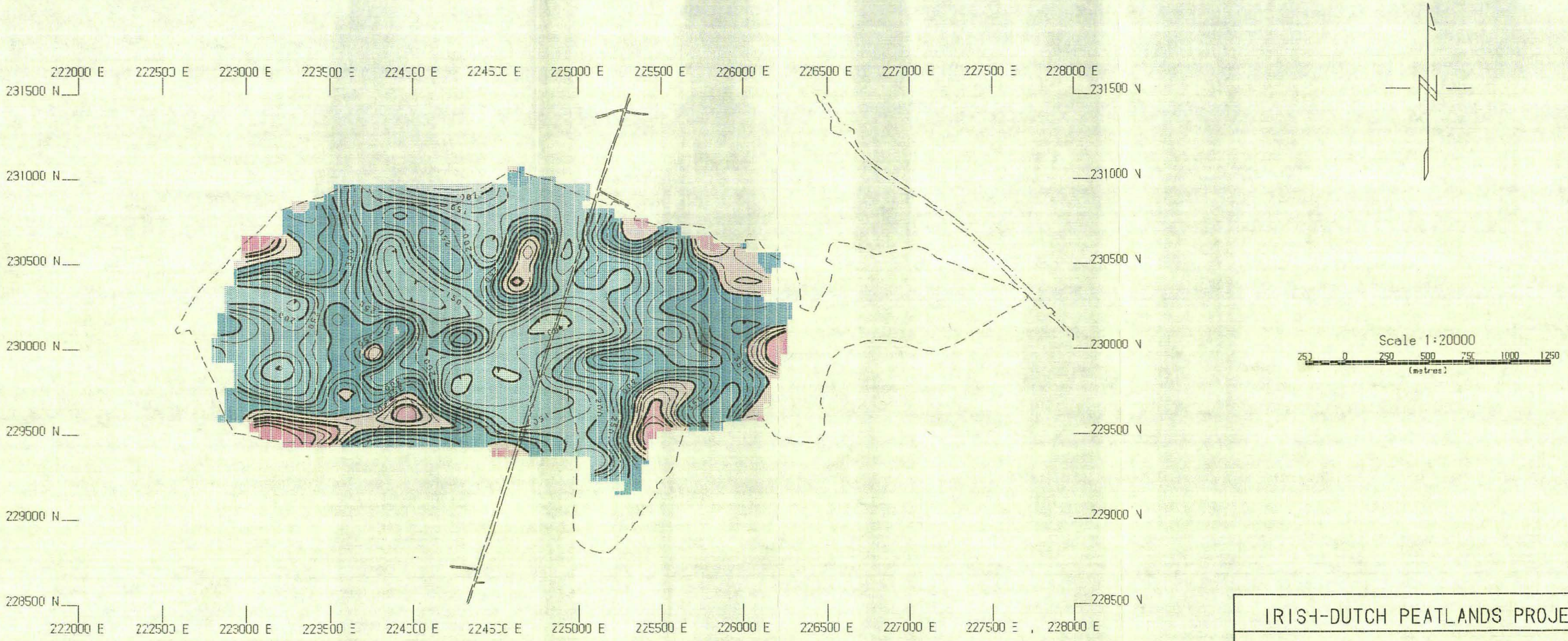

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FIG. 3.7 CLARA BOG
Smoothed Resistivity Contour Map.

Data Collected using Geonics EM16-R.
Data gridded at 50m, contour intervals 25 ohm-m.
Rugby (GBR) transmitter used.

Mary Smyth *April 1991.*

3.4 Resistivity-VES, Schlumberger array

Figure 2.2 shows the location of the Schlumberger soundings in the study area. The interpreted results of each of the eighteen soundings using the "Resint31" programme are in Appendix A at the back of the report. All sounding depths are relative to ground level, however approximate surface heights from field observations, have been taken into account in Chapter Four, when comparing the results for each sounding.

3.4.1 Interpretation of Soundings on the Bog

Sounding No.101

Sounding No.101 is located approximately 150m west of the road margin. Peat thickness at this location is shown to be 10m. A top layer 0.5m thick, of spongy peat, is shown to have a resistivity of almost 100 ohm-m. Underneath the peat is more compact, being compressed under its own weight, and thus the resistivity is much higher being approximately 160 ohm-m. Below the peat, a layer 3m thick is encountered. This layer has a resistivity of around 20 ohm-m. This low resistivity reading and drillings at various locations at the base of the peat, indicate that this layer is lacustrine clay. At a depth of 13m, a resistivity of roughly 150 ohm-m is associated with a layer 2.2m in thickness. Evidence from the surrounding landscape and various drillings suggest this layer to be of a till nature. Bedrock is shown to be at a depth of 15.2m, with a resistivity greater than 2000 ohm-m.

Sounding No.102

300m south of Sounding No.101, sounding 102 is located. Here bedrock is at a depth of 13.4m, with a lower resistivity than that of Sounding No.101, at around 1400 ohm-m. Total peat thickness is 7.5m, again having a spongy layer 0.5m thick at the surface. Resistivity readings for the spongy peat and the compact peat are around 120 ohm-m and 160 ohm-m respectively. Assumed lacustrine clay underlying the peat is over 1m thick. The apparent resistivity of 35 ohm-m for the clay is similar to that given in sounding No.101. Overlying the bedrock, the 4.7m thick layer of 260 ohm-m is again assumed to be till.

Sounding No.103

Sounding 103 was done on exactly the same centre as sounding No.102, but the electrode array was layed perpendicular to that of 102. Bedrock is shown to be 3.4m deeper than that of the previous sounding. This discrepancy is probably due to the non-homogeneous nature of the surface topography over which the array was orientated. Peat thickness of 7.5m corresponds exactly with sounding No.102, and resistivities of around 120 ohm-m and 180 0hm-m for the spongy peat and compact peat, respectively, comparing very favourably. Lacustrine clay with a thickness of 2m, is almost 1m thicker than that of Sounding No.102, however its resistivity of the order of 50 ohm-m compares favourably. Till overlying the bedrock has a similar resistivity value in both soundings, being around 260 ohm-m. Till is interpreted as having a thickness of over 7m. This latter layer is 2.6m thicker in comparison with that of the corresponding layer in sounding No.102.

The small inconsistencies in the comparisons between sounding Nos.102 and 103, illustrate the caution which must be exercised in interpreting sounding data collected over ground which is likely to be in-homogeneous in nature.

Sounding No.104

Sounding No.104 is located 300m further south than sounding No.102. Spongy peat at the surface is indicated as 0.4m thick, and the more compact peat underneath is given as 6m thick, having resistivities of the order of 100 ohm-m and 200 ohm-m respectively. Here the lacustrine layer of over 3m thick has a very low resistivity of around 20 ohm-m. The till layer overlying the bedrock has a resistivity of 270 ohm-m which is similar to that of the previous two soundings. Limestone bedrock at a depth of around 12m has a resistivity of the order of 2450 ohm-m.

Sounding No.111

This sounding is situated roughly 100m south-west of sounding No.101. Bedrock is interpreted as being at a depth of 13m, with a resistivity of around 1000 ohm-m. This slightly lower resistivity for bedrock may be due to fissures in the rock. Till is 2.7m thick with a resistivity of 320 ohm-m. Drilling using the Hiller Borer revealed lacustrine clay at a depth of 9m with a minimum thickness of at least 1m. The sounding curve gives this clay layer a thickness of 1.3m and a resistivity of 20 ohm-m. Peat thickness known from Hiller Borer coring was fixed at 9m when interpreting the sounding, and this showed the spongy peat and the compact peat to have resistivities of around 110 ohm-m and 200 ohm-m respectively.

Sounding No.112

This sounding is situated beside the road, 150m south east of sounding No.102 and 103. Here bedrock has a resistivity of 1200 ohm-m and is at a depth of almost 19m, showing it to be almost 2m deeper than that of sounding No.103. The surface layer of peat is shown to be 0.5m thick, having a resistivity of 80 ohm-m, the low resistivity being due to the very wet nature of the peat when doing the sounding. Underneath the surface layer, there is a layer just under 1m thick with a resistivity of 530 ohm-m. Since this site is an area of cutaway peat, the high resistivity of this latter layer may suggest very dried out peat which has been compacted from turf cutting activities. A layer over 17m thick, having a low resistivity of 60 ohm-m, rests on the bedrock. The resistivity of this layer would suggest lacustrine clay, however the great thickness of the layer would rule this out. Topography over which the electrode array was laid parallel to the road, was very irregular due to turf cutting activities in the past. This is likely to have a considerable effect on the readings.

Sounding No.113

Situated on East Clara, this sounding is roughly 300m south east of the previous sounding. When interpreting this sounding, peat thickness of 9.5m was controlled by Bord na Mona data available for the site. Spongy surface peat and subsurface compact peat have the usual resistivities of 130 ohm-m and 180 ohm-m respectively. No clay layer is indicated at this location, instead a very thick layer of 52m, with a resistivity of 360 ohm-m is given, implying till. Bedrock is shown to have a depth of 63m below the surface.

Sounding No.114

Located 200m west of the road on the southern margin of W.Clara, this sounding is sited on very dry cutaway peat. Since there is no spongy peat at this site, total peat thickness of almost 5m has a resistivity of 140 ohm-m. A clay layer of 3.6m underneath the peat has an expected resistivity of around 20 ohm-m. Resting on the bedrock, is a 7m thick layer with a resistivity of 120 ohm-m, suggesting till. Over 15m below the surface bedrock is encountered, with a resistivity of the order of 1850 ohm-m.

Sounding No.115

On the southern edge of W.Clara, sounding No.115 was carried out on an area of bog to the south west of the soak system. Spongy surface peat and compact subsurface peat have thicknesses of 0.5m and 3m, with resistivities of 80 ohm-m and 160 ohm-m respectively. A layer 12.5m thick with a resistivity of approximately 50 ohm-m, rests on bedrock interpreted to be at a depth of 16m. With such a low resistivity of 50 ohm-m, the subpeat layer may suggest saturated weathered till due to its proximity to the soak. 1200 ohm-m is the interpreted apparent resistivity of the bedrock. The relatively low resistivity of the bedrock may reflect limestone subjected to weathering.

Sounding No.116

Sounding No.116 is located 150m south east of the previous sounding. The site is an area of cutaway peat. Drilling took place at this site giving depths of peat, dry coarse sand and till at 1.9m, 0.7m and 2.3m respectively. At roughly 5m, limestone was encountered and drilling was terminated. From the interpretation of this sounding, a high resistivity of 2500 ohm-m indicates bedrock to be at a depth of 5m. Peat, sand and till have resistivities of around 62, 100 and 700 ohm-m respectively.

Sounding No.117

Returning to the raised bog proper, this site is situated 300m west of the last site mentioned. The electrode array only extended outwards by 250m on each side, from the centre. Expected resistivities of the order of 120 and 200 ohm-m are given for the spongy top layer and the compact subsurface peat, respectively. Respective thicknesses for the latter two layers are 0.5m and over 3m. Clay underlying the peat is shown to have a thickness of 1.3m and a resistivity of 30 ohm-m. Till 6.5m thick resting on the bedrock, has a resistivity of around 240 ohm-m. At a depth of almost 12m, bedrock is shown to have a resistivity of 3850 ohm-m.

Sounding No.109/110

Towards the centre of W.Clara, a low mound of dry peat rises approximately

10m above the surrounding peat. The mound roughly resembles the shape of a drumlin, with its steep stoss side and its gentle sloping lee side, dimensions being approximately 100m by 170m. Sounding No.9 is sited on the very top of the mound and sounding No.110 is sited on the gentle sloping lee side, approximately 100m apart. The electrode array of the former sounding extended out to the full 500m on each side of the centre, however the latter sounding's electrode array only extended outwards by 100m on each side. Both soundings show that no clay underlies the peat. Peat on top of the mound has a thickness of 2.4m, while on the gentle slope at sounding No.110, peat is interpreted as having a thickness of only 1.5m. The resistivity of the peat in both cases being around 100 ohm-m. Bedrock at sounding 109, situated on top of the mound, is at a depth of 18.5m and has a lower resistivity of 2880 ohm-m, than the bedrock at sounding 110 on the slope of the mound, which has a resistivity of 6000 ohm-m, at a depth of over 14m. The intermediate layer for the respective soundings is around 16m and 13m thick, with resistivities of 250 and 200 ohm-m suggesting till.

Sounding No.118

Drilling on an area of cutaway peat to the extreme west of Clara bog allowed depth calibration of this sounding. Due to rough terrain it was not possible to extend the electrode array of this sounding beyond 250m on either side of the centre. Peat and clay thicknesses of 1.2m and 2.4m were recorded, the respective resistivities of these layers being not unusual at around 90 and 30 ohm-m. The till encountered has a thickness of almost 4m and is shown to have a resistivity of around 230 ohm-m.

3.4.2 Interpretation of Soundings on the Esker

Four short soundings were carried out on the eskers on the northern margin of W.Clara. Sounding No.105 was carried out on top of the esker ridge. The high degree of variability of the topography, and likely chaotic layering of the sediments produced very noisy data. Sounding No.105 indicates bedrock at a depth of over 13m, which is not unusual in comparison to a similar depth at borehole 303, which was drilled on the opposite side of the road (referred to in Ch.3). The surface layer is shown to be only 1.2m thick, while the two underlying layers are both approximately 6m thick. The surface layer and the third layer have the same resistivity of around 190 ohm-m, similar to that expected for till or a sandy layer. An unusually high resistivity of 3950 ohm-m is shown for the subsurface layer, much higher than the 1700 ohm-m given for the bedrock.

Southwards, 60m down the esker slope from sounding No.105, bedrock with a resistivity of the order of 4100 ohm-m, is located at a depth of almost 8m below the surface. Given that the surface elevation of both soundings No.105 and 106 differ by roughly 5 or 6m, the bedrock topography does not vary between both soundings. A surface layer of loose gravel shows a depth of almost 1m corresponding to a resistivity of 70 ohm-m. Again a subsurface layer, of higher resistivity than the layer immediately above and below it, is represented here. The thickness of this layer is over 2m, and at 330 ohm-m, has a more normally expected resistivity than that associated with the corresponding layer in the previous sounding. A low resistivity of 40 ohm-m, associated with the layer 4.6m thick resting on the bedrock, may suggest a saturated zone, since there is water lying on the ground surface, at the base of the esker.

On the bog, just below the margin of the esker, roughly 0.5m of a peaty surface layer is shown to have a resistivity of 130 ohm-m. Below this lies a layer over 1m thick, of possibly sandy-gravely esker material, having a resistivity of 280 ohm-m. Underneath this, a layer 13m thick with a resistivity of around 100 ohm-m, may suggest a saturated till zone. Bedrock is shown to have a resistivity of 675 ohm-m, at a depth of almost 15m. This low bedrock resistivity may represent the weathered crust of the limestone. If the current electrode spacing extended beyond 75m on either side, the bedrock may be shown to have a higher resistivity.

50m south of the bog margin, the peat has a thickness of nearly 7m, at sounding No.108. Peat is interpreted as having a resistivity of 170 ohm-m. An unusually high resistivity of 19600 ohm-m is given for bedrock at a depth of approximately 13m. A resistivity low of around 20 ohm-m is shown for the 6.1m thick intermediate layer. Clay of this thickness is highly unlikely, therefore the low resistivity may represent the saturated zone.

3.5 Resistivity VES, Offset-Wenner array

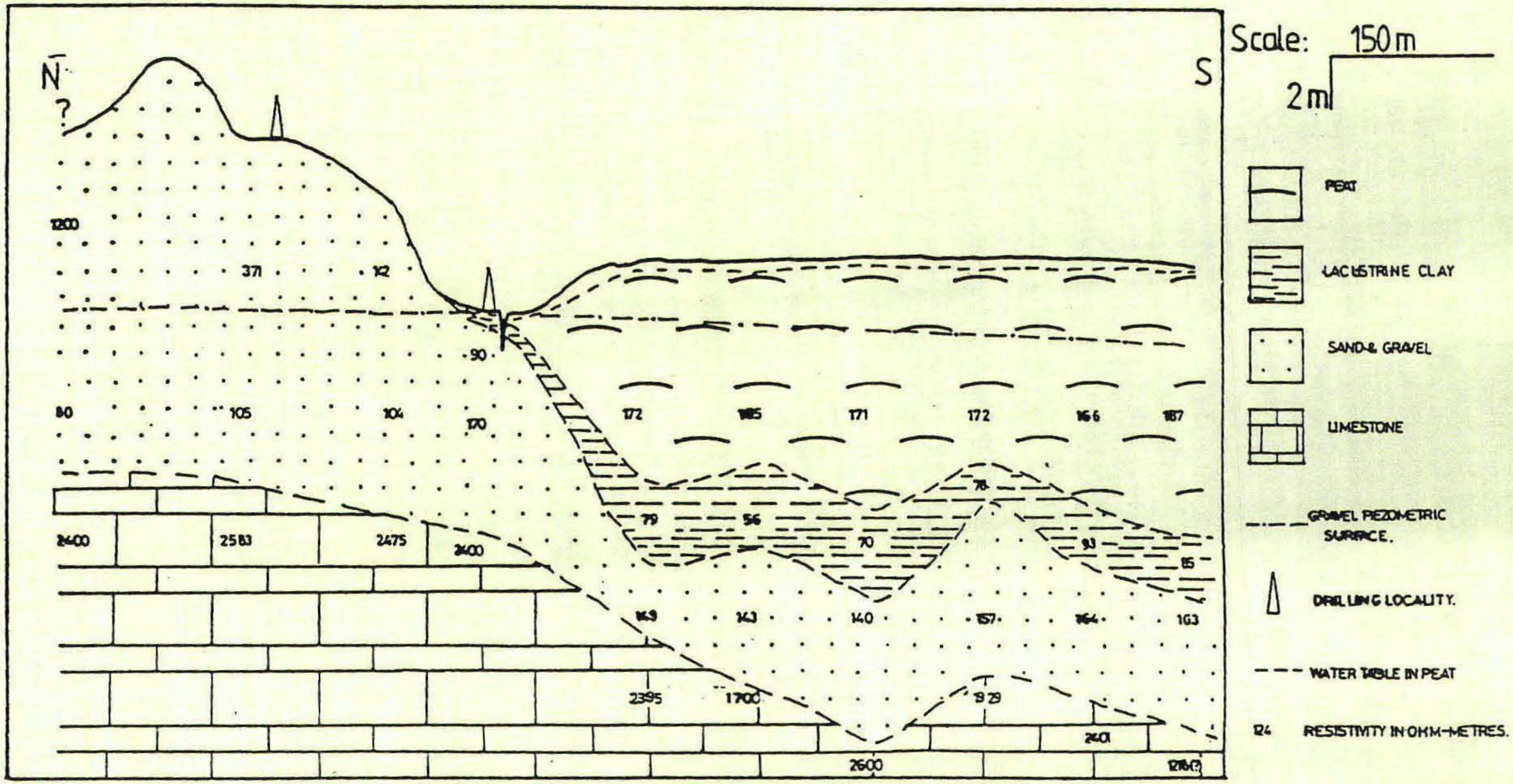
In June 1990, resistivity-vertical electrical soundings, were carried out using the Offset-Wenner array. The apparent resistivities were calculated using the PS/2 computer in the field office in Clara. Interpretation of the soundings was done by Ray Flynn as part of his Hydrogeology M.Sc. in the University of Birmingham. Interpretation was done using the program "Resplot", and the soundings were calibrated using the information available from borehole drilling in association with peat coring depths. The interpretation of each sounding along the transect is compiled in diagramatical form by Flynn (1990), as shown in Figure 3.8.

As shown in the diagram, the resistivities of the bedrock vary roughly between 1600 ohm-m and 2400 ohm-m. Underneath the esker sand and gravel ridges, bedrock falls very gently southwards, towards the bog. Over the 180m between boreholes 303 and 302, the total bedrock fall is only 1.1m. From the margin of the bog, the bedrock falls more steeply southwards towards the centre of the bog, dropping approximately 8m over a horizontal distance of 360m. The bedrock then rises by almost 2m over the next 100m, from where it again continues to fall southwards. Results show that bedrock underneath the bog is at its shallowest at the margin of the bog, where it is at a depth of approximately 8.5m. Bedrock is at its deepest 360m into the bog, where it is located at a depth of over 17m.

Sands and gravels overlying the bedrock have apparent resistivities between

Fig 3.8 A CROSS SECTION OF CLARA BOG AND ADJACENT ESKER

COMPILED FROM GEOLOGICAL AND GEOPHYSICAL DATA.



SECTION COMPILED FROM GEOLOGICAL & OFFSET WENNER GEOPHYSICAL DATA

(Flynn, 1990)

140 ohm-m and 160 ohm-m in the area underneath the peat. Esker sand and gravels have much greater variation in resistivities, varying between 90 ohm-m and 370 ohm-m, and in one particular case a resistivity as high as 1200 ohm-m was recorded. The thickness of the sand and gravel layer was interpreted as varying from 7m at the edge of the bog, to between 3m and 6m underneath the bog.

Lacustrine clay underlying the peat is shown to be thinnest at the margin of the bog, where its thickness is indicated as being less than 1m at borehole 302. The clay layer gradually becomes thicker as one progresses southwards into the bog, interpreted as varying approximately between 1.5m and 3m in thickness underneath the peat. Resistivities of the lacustrine clay are low, varying between 60 ohm-m and 90 ohm-m.

Hand augering using the Hiller Borer showed peat thicknesses to be on average 7m to 8m, along the profile, reaching a maximum depth of 10m at L.Roe. Resistivity values for the peat are very constant, varying roughly between 170 ohm-m and 190 ohm-m.

3.6 Resistivity Profiling: Dipole-Dipole array

In the vicinity of the Offset-Wenner transect, the dipole-dipole profiling technique was carried out along Line A (Fig.2.3), orientated in a north-south direction. Little analysis has been done to date apart from contouring the resistivities along the profile. In Chapter Four a pseudo-section is constructed from the dipole-dipole resistivity data. The data are contoured in intervals of 100 ohm-m (Fig.4.1(a)). A comparison of the contoured resistivity values will be made with the information from the EM VLF-R survey done along Line A, and the results of the Offset-Wenner along Line B.

Chapter 4

Preliminary Spaceform Model of Clara Bog

From the various geophysical and geological information available in this report, a preliminary 3-dimensional Spaceform model of the subsurface geology of Clara bog can be constructed. Clearly the model is a preliminary one due to the sparce nature of data in some areas. However it will put into perspective the geological information available, in addition to that which needs to be investigated in greater detail.

The model will serve as a working hypothesis for the hydrogeological study, subject to refinement in light of further information becoming available, from the on-going geophysical and geological studies.

4.1 Spaceform Model

4.1.1 Clara East

Figure 2.3 shows the location of Transect A, along which the dipole-dipole profiling technique was used. An EM VLF-R survey was also carried out along Transect A. A comparison of the EM VLF-R data and the dipole-dipole pseudo-section can be seen in Figure 4.1.

Two resistivity peaks, between stations at 150m and 300m on the graph of the EM VLF-R data, correspond to a high resistivity block shown by the 600 ohm-m contour line, along the dipole-dipole pseudo-section. Here both transects suggest bedrock to be close to the surface. There is a remarkable comparison between stations from 300m to 500m along both the EM VLF-R graph and the dipole-dipole pseudo-section. At these locations, the resistivity graph for the EM VLF-R shows that the values drop to between 200 and 300 ohm-m. The 600 ohm-m contour line on the dipole-dipole pseudo-section drops to greater depths showing a low resistivity depression. Low resistivity values indicate that a thick

DIPOLE-DIPOLE PSEUDO-SECTION

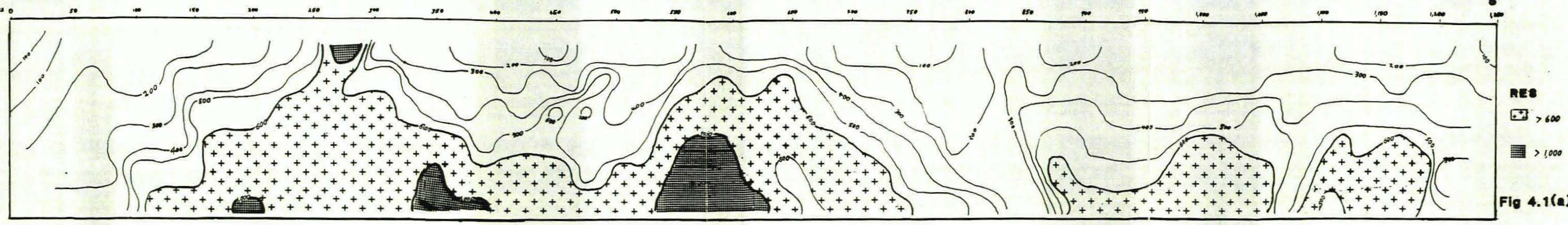


Fig 4.1(a)

Line A: Resistivity contours 100 ohm-m

EM VLF-R

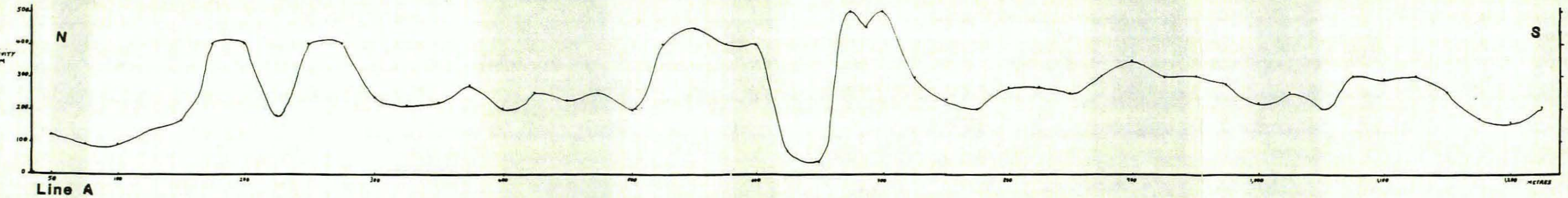


Fig4.1(b)

Line A

Scale
50m

OFFSET-WENNER

Bedrock Topography

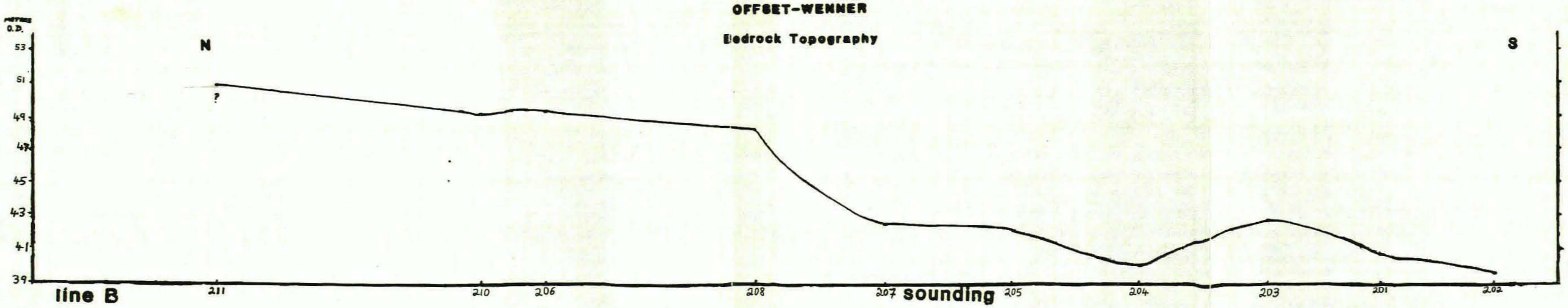


Fig 4.1(c

line B

sounding

overburden, of possibly esker sands and gravels, may overly the bedrock, which falls to greater depths at this location.

After station 500m, the 600 ohm-m contour line appears again, showing a block of high resistivity material between stations 525m and 725m along the dipole-dipole pseudo-section. Here the 600 ohm-m contour line rises close to the surface, showing two minor peaks. Both of these peaks correspond to two anomalies below the 600 ohm-m contour line. The first of these anomalies is a block of higher resistivity material, over 1000 ohm-m; the second is a lower resistivity anomaly, below 500 ohm-m, which probably gives rise to the depression between the two resistivity-high peaks on the 600 ohm-m contour line. High resistivity values close to the surface suggest bedrock shallowing. More competent, less fractured bedrock probably gives rise to the high resistivity anomaly of over 1000 ohm-m. Similarly, the low resistivity anomaly, less than 500 ohm-m, may be due to fracture in the bedrock. A correlation with the EM VLF-R graph shows that the low resistivity depression (50 ohm-m) at station 650m, corresponds to this low resistivity anomaly along the dipole-dipole pseudo-section. Two strong resistivity peaks of between 400 and 500 ohm-m, on either side of the latter depression on the EM VLF-R graph, similarly correspond to the two latter peaks of the pseudo-section. Such rapid fluctuations of the EM VLF-R graph, suggest that the technique is excellent for picking up "edges", which may indicate the varying nature of the subsurface topography.

Material of low resistivity, below 600 ohm-m, is shown to underlie the surface between stations 750m and 850m of the dipole-dipole pseudo-section. Here the 600 ohm-m contour line disappears to greater depths below the surface. Sharp falls in resistivity such as the above, would suggest fluctuations in the bedrock depth, such as that expected in a Karstic region. After station 850m, the 600 ohm-m contour line appears again to show two high resistivity anomalies; one between 850m and 1050m; the second between 1100m and 1200m. Between these two anomalies with resistivity above 600 ohm-m, lies a low resistivity depression; the 600 ohm-m contour line is not represented here and thus showing the subsurface material having a resistivity below 600 ohm-m. Both high resistivity blocks again indicate shallowing of the bedrock, with a deep depression separating the two shallow bedrock areas. From station 1200m to the end of the line at 1250m, the 600 ohm-m contour line is not represented below the subsurface either, indicating bedrock falling to greater depths once more.

The EM VLF-R graph shows the general trend indicated by the dipole-dipole pseudo-section from station 750m to the end of the transect. However the features are less pronounced in the case of the EM VLF-R graph. Two minor peaks of high resistivity, one centred at station 900m with a resistivity of 350 ohm-m, the second between stations 1075m and 1150m with a resistivity of 300 ohm-m, can be correlated to the resistivity highs at these locations along the pseudo-section. Similarly, a small depression on the EM VLF-R graph at location 1050m, shows a resistivity low of 200 ohm-m, which can be correlated to the resistivity low on the pseudo-section at this location. However in the case of the EM VLF-R graph, the resistivity low is less distinct in comparison.

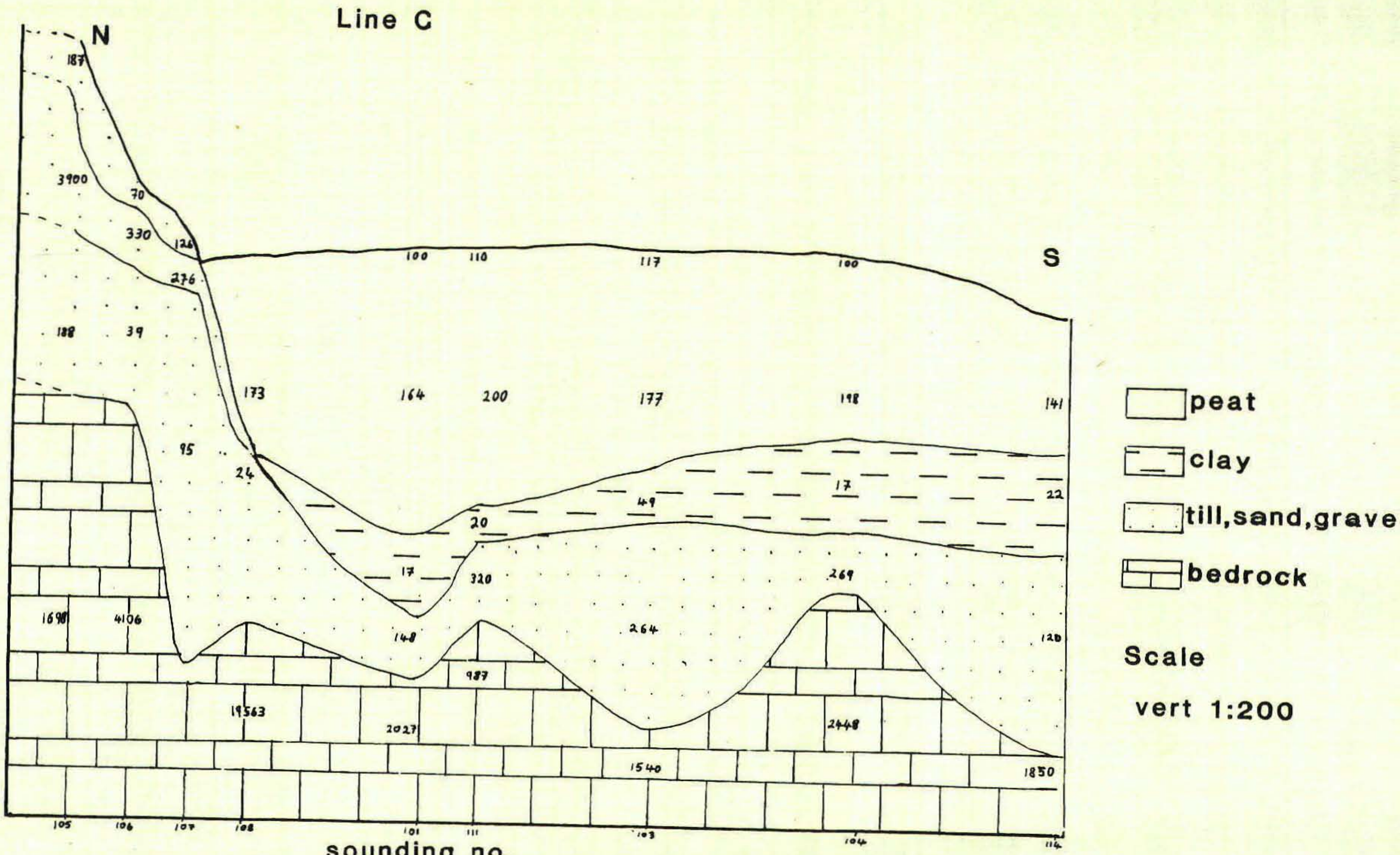
Offset-Wenner sounding locations are shown in Fig.2.3. Interpretation of the soundings allowed a cross-section of the subsurface geology to be produced by Flynn (1990), (see Fig.3.8.). Even though the soundings were not done exactly on Transect A, they are situated significantly close to allow a correlation of the sounding interpretations with that of Transect A. Soundings No.211 to No.208 show bedrock to form a high plateau above 47m O.D. This area roughly corresponds to that shown by the 600 ohm-m contour line along the dipole-dipole pseudo-section between stations 125m and 750m. A 6m fall in bedrock is shown between No.208 and No.207, which can be correlated to the slope of the 600 ohm-m contour line which disappears at station 750m on the dipole-dipole pseudo-section. The bedrock falls to 39m O.D. at sounding No.204, rises to almost 42m O.D. at sounding No.203, falling again to depths of below 40m and 39m O.D. at No.201 and 202 respectively. Shallower bedrock of 42m at sounding No.203 seems to average out the two anomalies indicated on the pseudo-section between stations at 850m and 1200m.

Almost no strong correlation can be drawn between the Offset-Wenner profile of the subsurface geology and that of the EM VLF-R profile apart from one particular location. Soundings No.208 and 207 which show a rapid fall in bedrock of 6m, can be roughly correlated to the 650m location along the VLF-R profile, which shows an extreme drop to 40 ohm-m between high resistivity peaks of 400 and 500 ohm-m. This suggests that the EM VLF-R technique may be best used for indicating the "edges", of either depressions, or bedrock topography highs.

4.1.2 Clara West

Figure 4.2 shows a subsurface geological transect compiled from the Schlumberger sounding interpretations. The transect takes into account sounding Nos.105, 106, 107 and 108 on the esker to the north of the bog, and sounding Nos.111, 101, 103, 104, and 114 on the west side of the main road. The information from the soundings is used to approximate a straight line parallel to the road for the geological transect in Figure 4.2. An approximate surface height of the soundings, in relation to each other, has been taken into account in the construction of the geological transect in Figure 4.2. This height estimate is based on field observations and is thus very crude. VES sounding centres need to be levelled, in order that more precise sections can be drawn.

The diagram shows that the lower layer, which is assumed to be bedrock, falls steeply southwards by approximately 9m, at the northern margin of the bog. 50m southwards at sounding No.108, bedrock rises again by about 1.5m. Over an approximate horizontal distance of 300m, bedrock falls by 2m at No.101. At sounding No.111 the bedrock rises by 2m, the distance between the two soundings being approximately 200m. further southwards at sounding No.103, bedrock


Line C
N
S
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3900
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49
17
22
17
320
269
1690
4106
148
264
120
987
19563
2027
2448
1540
1850
105
106
107
108
101
111
103
104
114
sounding no.
peat
clay
till,sand,gravel
bedrock
Scale
vert 1:200

Fig 4.2

deepens by almost 4m, before it rises again, sharply by 5m to a depth of approximately 12m below the surface at sounding No.104. 400m further southwards along the transect, bedrock falls by 5.5m to its greatest depth along the transect, where it is at a depth of 15.3m below the surface at sounding No.114.

Transect C shows that the till overlying the bedrock seems to fill in the depressions in the bedrock, thus smoothing over the topographical variation indicated from the bedrock profile. The clay layer beneath the peat follows the general pattern of the underlying till topography. Clay thickens where depressions occur in the topographical surface of the till. Surface topography of the clay tends to approximate that of the till, except that it is much gentler. Peat is thickest where depressions occur in the underlying clay topographical surface, and shallowest where the underlying topography is relatively shallow.

Figure 4.3 shows resistivity values along lines 100W and 300W of the EM VLF-R survey. Comparisons between lines 100W and 300W show that in both cases, high resistivity peaks occur at stations 350m, 450m and 600m. Also both lines show a huge increase in resistivity at the end of the line. Line 100w which is closest to the road, shows the base of the central depression to undulate much more than that of line 300W, which tends to have a smooth base.

A correlation of Transect C and Figure 4.3, shows that the bedrock shallowing at soundings No.108 and No.111 correspond to the resistivity high at stations 100m and 600m, along lines 100W and 300W. The lateral variation of subsurface topography is apparent at station 600m, line 300W showing a resistivity of 700 ohm-m, whereas that of line 100W only showing a peak of 280 ohm-m.

Both lines in Figure 4.3 show resistivity lows fluctuating above and below 100 ohm-m, between stations 600m and 1500m along both transects. Soundings No.103 shows a bedrock depth to be significantly deeper than that of the soundings on either side, giving this depression. Sounding No.104 is situated at location 900m between lines 100W and 300W. This latter sounding shows a shallowing of bedrock, which does not correspond to line 300W, but a slight rise in resistivity is indicated along line 100W. Sounding No.114 indicates a very significant deepening of bedrock, whereas the VLF-R resistivity curve shows these two locations to be on the edge of small depressions. The variation between sounding No.104 and No.114 is not shown. This indicates significant topographical variation across lines 100W, 200W and 300W of the Clara grid. The EM VLF-R lines are extended beyond the margin of the bog, in the south, showing resistivity highs, indicating bedrock shallowing towards the margin. This shallowing towards the southern margin is similar to that suggested at the northern margin from Transect C.

The resistivity profiles for both lines indicate highly irregular variation in the subsurface geology. Since the resistivity readings give excellent qualitative information, it is essential that drilling to bedrock be carried out at some of the sounding locations, to produce better quantitative information about the subsurface geology.

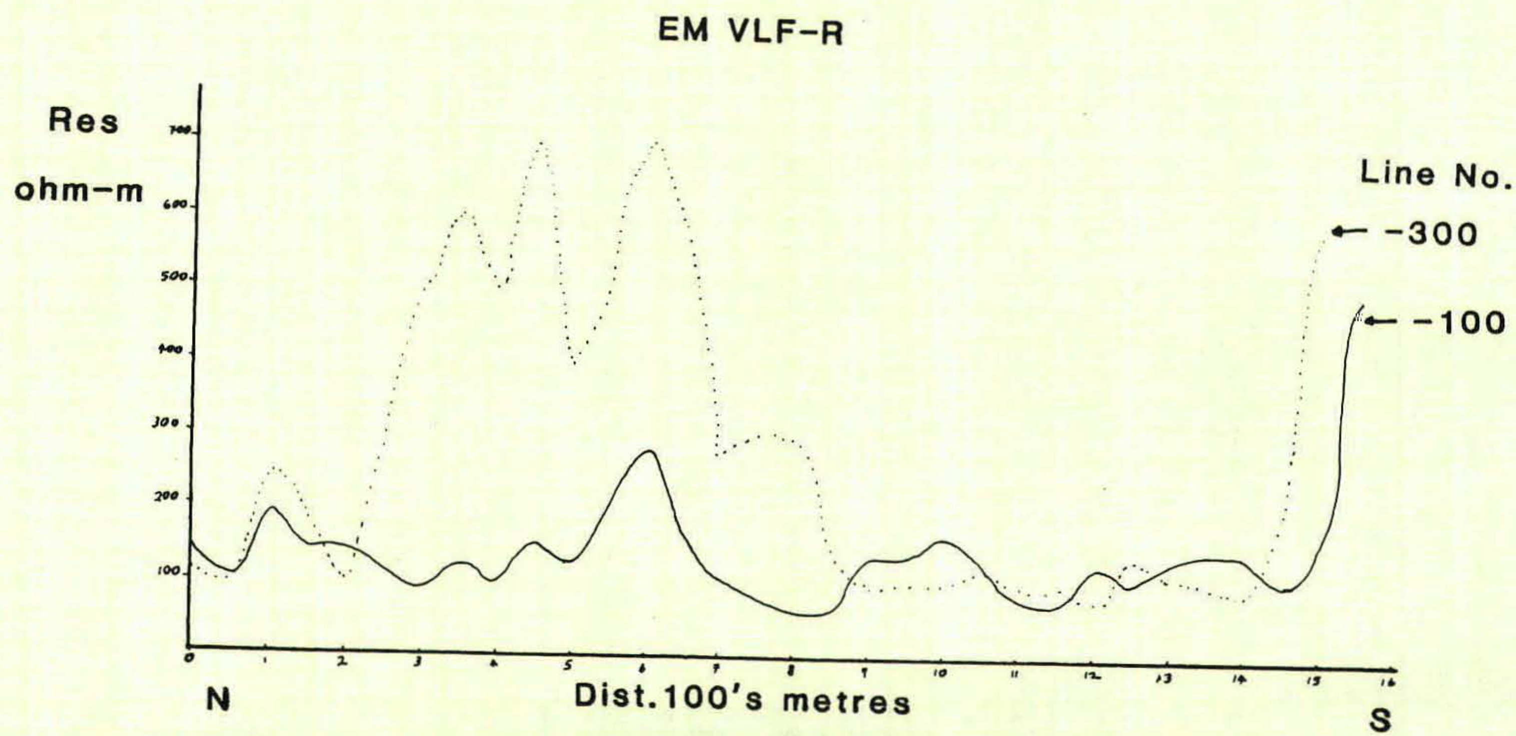


Fig 4.3

Transect D produced from soundings No.104,112 and borehole 301, gives a good indication of the east-west lateral variation in the subsurface topography Figure (4.4). A deepening of the bedrock by 5.4m occurs in the 100m between No.114 and No.112. Bedrock rises again, abruptly, by 4.5m at borehole 301, situated approximately 200m away (see Fig.3.5).

Figure 4.5 shows the lithological logs of the Schlumberger soundings on West Clara. On the southern margin of the bog, sounding No.117 shows bedrock to be only 12m below the surface. Bedrock deepens by over 4m, over a horizontal distance of 450m at No.115. Although sounding No.116 indicates very shallow bedrock, 5m below the surface, the high resistivity reading may be due to very dry till. Evidence from the surrounding landscape suggests large limestone boulders, thus drilling at locations like this is essential to determine the subsurface geology accurately. Augering showed that no clay underlies the peat at sounding No.116. This is also shown to be the case at sounding No.115, where till is 12.5m thick underneath the peat.

Soundings No.109 and No.110 are situated on a peat mound approximately 10m above the surrounding bog. No direct correlation can be made between these soundings and those at the southern margin of the bog, until their surface elevation can be tied in with that of the other soundings. However, the surface topography of the mound slopes very steeply, by about 5m, between Nos.109 and 110, following the general trend of the till's topographical surface. Bedrock only falls by about 0.6m between the two soundings.

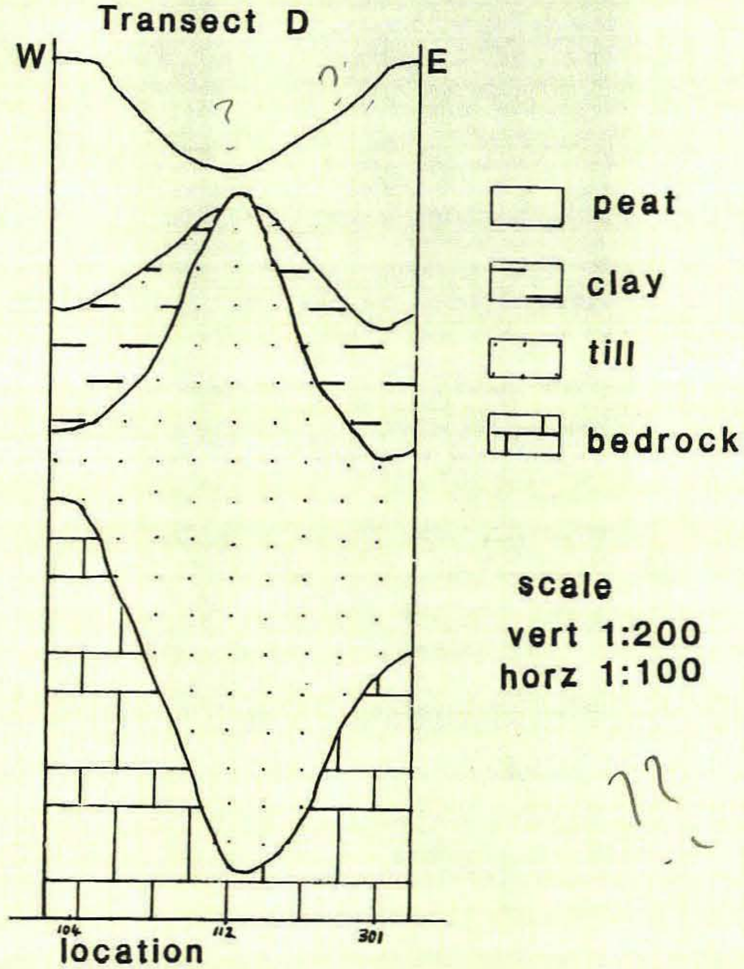
Sounding No.118 situated on an area of cutaway bog, shows that the bedrock shallows at the western margin of the bog, being only 7.3m below the surface. Till is also thinning out, being less than 4m thick, beneath a clay layer with a thickness of 2.4m.

Shallowing of the bedrock around the margins of the bog is again reinforced by taking a profile of the underlying geology along an east-west transect. Figure 4.6 is a graph of resistivity values from the EM VLF-R survey at station 800m along lines 1700W, 1300W, 1100W, 700W, 300W, 100W, 100E, 300E, 500E, 900E and 1100E. The graph shows that the bedrock falls to greater depths between line 1700W and 1100W.

4.1.3 Peat Data Contour Maps

A comparison of the maps produced from Bord na Mona peat data (Fig.3.2, 3.3 and 3.4), show that the North Central area of the bog is an extensive area of thin peat with a relatively lower elevation of below 57m O.D. in comparison to the rest of the bog. However, Fig 3.4 indicates that this area also corresponds to the lowest elevation of the peat base, below 50m O.D.This would suggest that the drainage and peat cutting along the road and the northern margin of the bog has had a considerable affect on peat growth.

The low depression of the peat base, in the central area of the bog, indicated


Transect D
W
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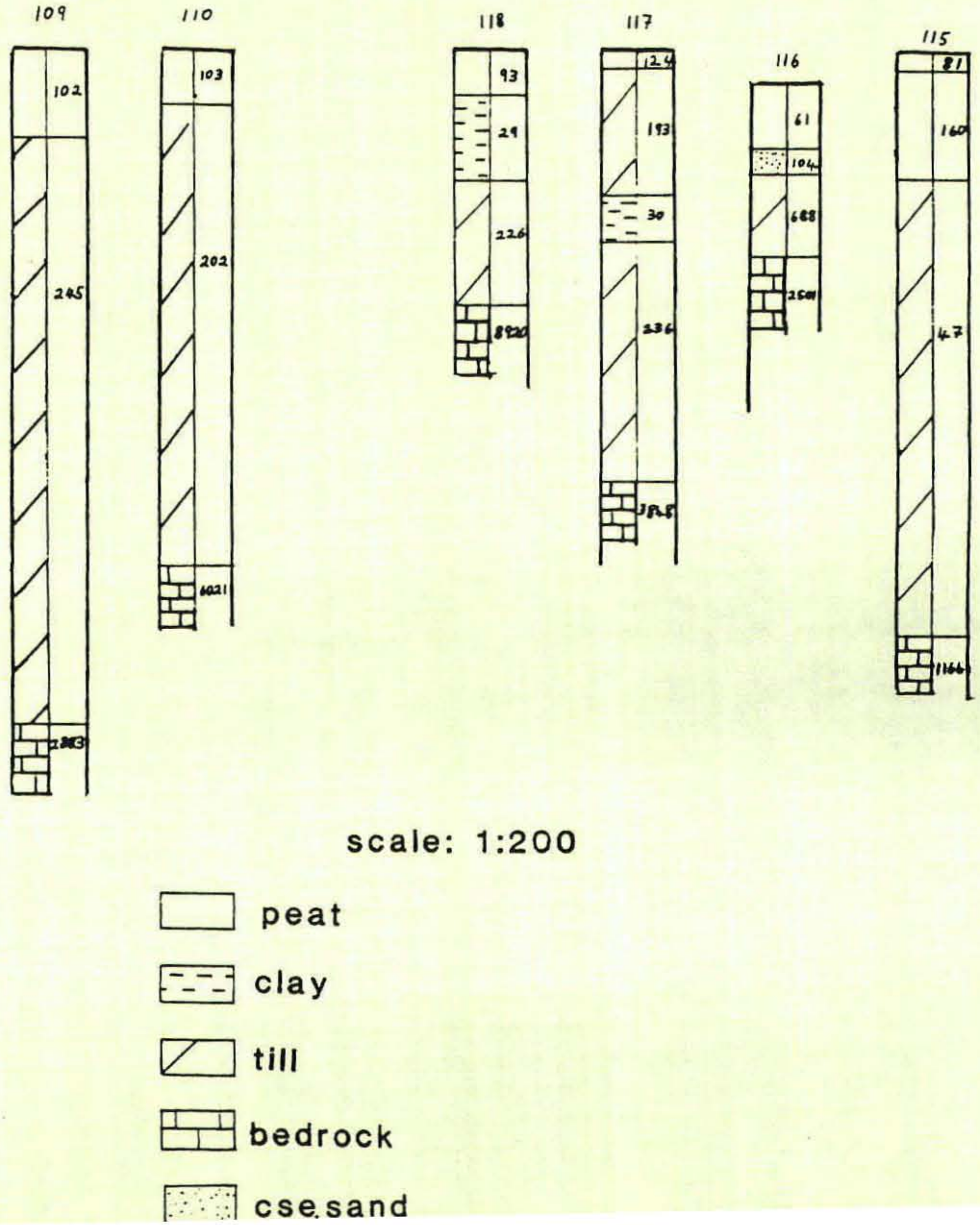
104
112
301
location

Fig. 4.4

Schlumberger Sounding Locations

FIG 4.5



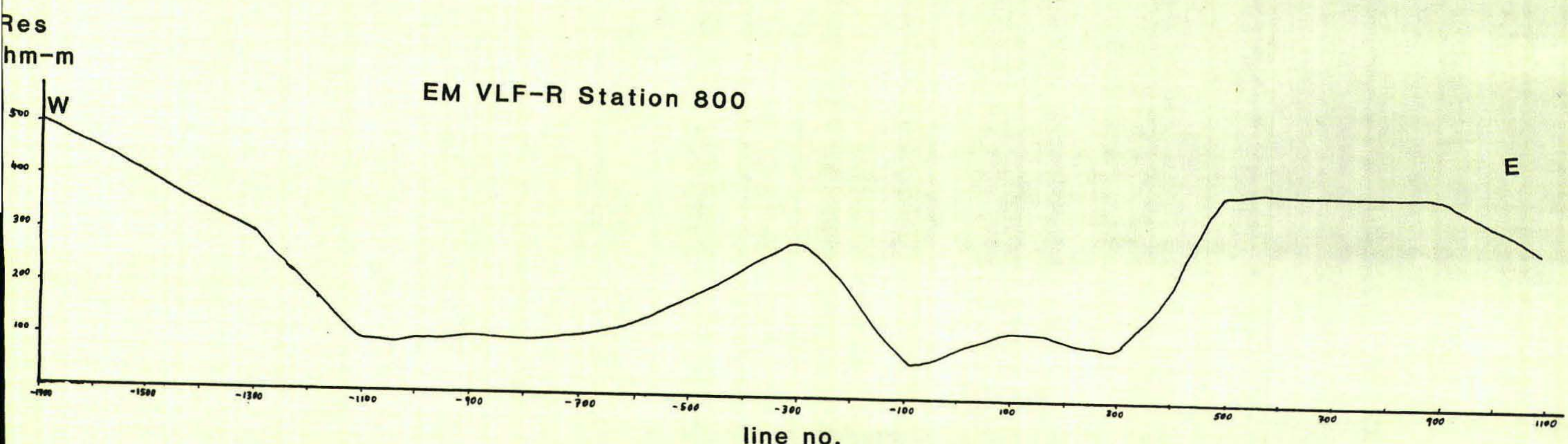

Res
hm-m
EM VLF-R Station 800
W
E
500
400
300
200
100
-1700
-1500
-1300
-1100
-900
-700
-500
-300
-100
100
300
500
700
900
1100
line no.

Fig. 4.6

38

in Figure 3.4 shows a remarkable correspondence with that of the area where peat is thickest. The 52m O.D. peat base contour line (Fig.3.4) mirrors that of the 8m peat thickness contour line in Figure 3.2.

A peat mound to the south west of the central area of the bog, has dimensions 170m long, 10m high and 60m long, and is represented by an anomaly on all three maps. Peat base with an O.D. elevation of 54m at this location, is shown to be 2m above that of the surrounding underlying topography (Fig.3.4). Peat thicknesses of less than 6m is similar to that at the margins where the same O.D. elevation level for the peat base occurs.

A summary of the peat data maps indicates that peat is thickest where the base is deepest and thus corresponds to a higher surface elevation due to the upward growth of peat. However extensive drainage and peat cutting along the road and margins of the bog, distorts this correlation. This is particularly evident in the centre of the bog where both peat surface contours, and peat thickness contours, are distorted southwards parallel to the road.

4.1.4 EM VLF-R and Peat Base Comparisons

A correlation with Figures 3.7 and 3.4 show that the area where the peat base is lowest corresponds to the low resistivity area below 200 ohm-m, in the central area of the bog. An anomaly of high resistivity in the north-central area of the bog is the only discrepancy in this area between the two maps. Both maps show that the central area of low resistivity and deepest peat base, on the respective maps, extends outwards in two channels, one to the west edge, and the other to the southern margin of Clara East. The shallowing of the subsurface geology in the north west, south west and south east corners, are very similar on both maps, both showing very steep contours.

4.2 Summary

Geophysical and geological information indicate that the general underlying geology of the peat forms an irregular basin. The margins of the bog have quite shallow bedrock, dipping steeply from the edge towards the centre of bog. Although the centre of the basin is a generalised depression, with shallow surrounds, the interior of the bog is a series of undulating hills and hollows, as is shown by the various transects of the subsurface geology. Transects A, B, C and D show the high degree of lateral variation in subsurface geology. Till appears to level off the varying bedrock topography created by depressions and hills, as indicated in the various geological cross-sections.

Generally clay tends to thicken towards the centre, however the topographical surface of the clay also tends to mirror that of the underlying till, with clay thinning where the underlying till is thinnest. This similarity was shown to be the case from the various Schlumberger and Offset-Wenner Sounding transects. Similarities between the contour map of the peat base and the EM VLF-R contoured resistivity map also support this association between the clay and till topography.

Undulating hills of till deposits to the south of the bog, give a good indication of the the type of topography occurring, at a lower level, underneath the bog.

Chapter 5

Recommendations and Future Work

One of the most obvious requirements in order to improve the spaceform model, is the necessity for more resistivity Vertical Electric Soundings, backed up by limited drilling sites, for calibration purposes. The invaluable information provided by drilling sites, in the interpretation of the geophysical soundings, makes additional drilling on certain sounding locations a necessity.

There is an obvious lack of Vertical Electric Soundings on the east side of Clara bog, and also in the interior of the bog on the west side. Access problems encountered during the course of the Schlumberger survey prevented soundings being done in certain areas. The West side of Clara bog was very wet when the fieldwork was being carried out in winter 1991, and thus it was too dangerous to work there. Locational problems prevented the soundings from being carried out on East Clara. The absence of a grid on this side of the bog is a major hindrance in conducting surveys due to the lack of distinct landmarks on the bog. Soundings planned for this summer include both sides of the bog, as well as the surrounding area. On West Clara, the bog will be much drier making walking easier and less dangerous. The survey grid on the East side is scheduled to be finished before the summer, thus allowing the fieldwork to go ahead in June.

Qualitative information revealed in the VLF-R survey puts forward a very strong case for the extension of the survey lines beyond the margin of the bog. This would give a generalised overview of the bedrock attitude in the area surrounding the bog. Hence conclusions about bedrock controls on the formation of the bog could then be drawn. Information in Keegan and Barton (1991), and Keegan et al. (1991), based on open file mineral exploration data, postulates an east-west fault, either at the southern margin or south of the bog. An extension of the EM VLF-R survey to the south, is important to prove this fault.

Extensive fieldwork planned for June include a variety of geophysical methods; an extension of the EM VLF-R survey; more intensive coverage of the area with the Resistivity Profiling technique using the dipole-dipole array, and Resistivity-

Vertical Electric Soundings (Schlumberger array and Offset-Wenner array); Seismic Reflection and Refraction on the bog margins. The necessity for extending the EM VLF-R survey was discussed in the previous paragraph. Resistivity profiling is proposed along a series of geophysical transects, taken from the EM VLF-R survey lines (Fig.2.1). Approximately six transects are proposed; five running parallel to the road, and one transect running perpendicular to these latter transects, extending from the western margin to the eastern margin of the bog. Resistivity Vertical Electric Soundings will also be done along these lines, thus providing quantitative information about the underlying geology. Seismics (Reflection and Refraction) on the margin of the bog, at the ends of these transects, are proposed in order to map the attitude of the bedrock surface as it passes under the bog.

The variety of geophysical techniques carried out along these transects, will allow a comparative analysis of each method, in relation to its suitability in resolving the subsurface geology.

A 2-Dimensional space form model of the bog is being prepared from the data acquired in the existing EM VLF-R survey. Data were extracted from a total of six of these EM VLF-R transects; three transects from the west side, two transects on the east side, and one transect extending from the western margin to eastern margin of the bog were chosen (Fig.2.1). This data set formed the input data for the OCCAM2 inversion programme which will be used to produce a 2-Dimensional model of the subsurface geology of the bog. OCCAM2 is a modified version of the programme by C.deGreet-Hedlin and S.Constable titled "OCCAM's Inversion to Generate Smooth, Two Dimensional Models from Magnetotelluric Data". Information about the thickness and resistivity of the respective subsurface lithologies, acquired from the interpretation of the Schlumberger soundings, will be input to the OCCAM2 inversion programme. The resultant 2-Dimensional model will then be calibrated from the Schlumberger sounding interpretations.

The complexity of the "OCCAM2" programme results in much preparation of the data, in addition to the lengthy duration involved in running the programme, to produce a 2-dimensional spaceform model. Due to these two factors, the 2-dimensional space form model of Clara bog based on VLF-R readings was not available in time for this report. This work will be given in the end of year report for 1991.

Chapter 6

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Chapter 7

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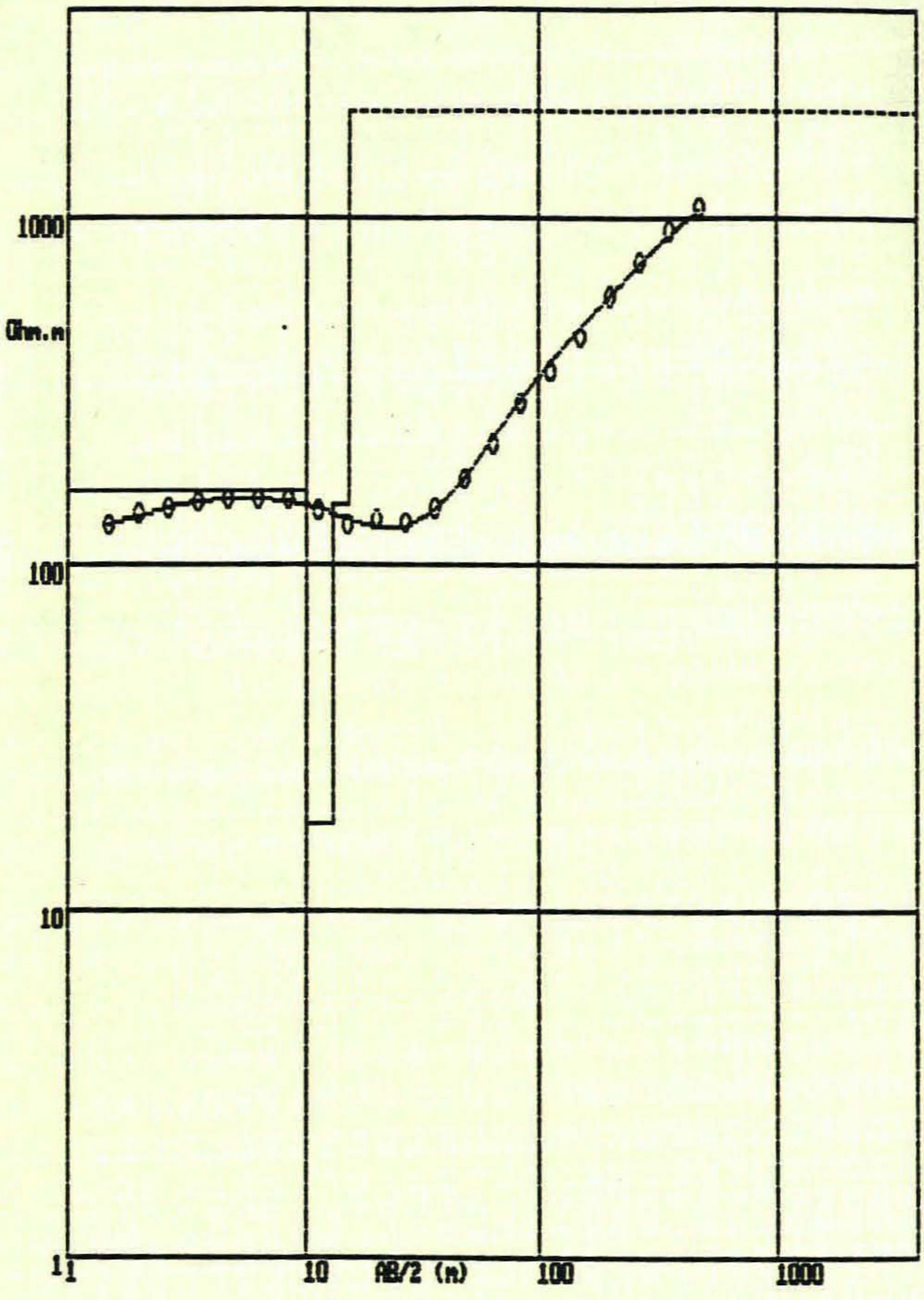
Appendix A

Calculated Apparent Resistivities for Schlumberger Soundings

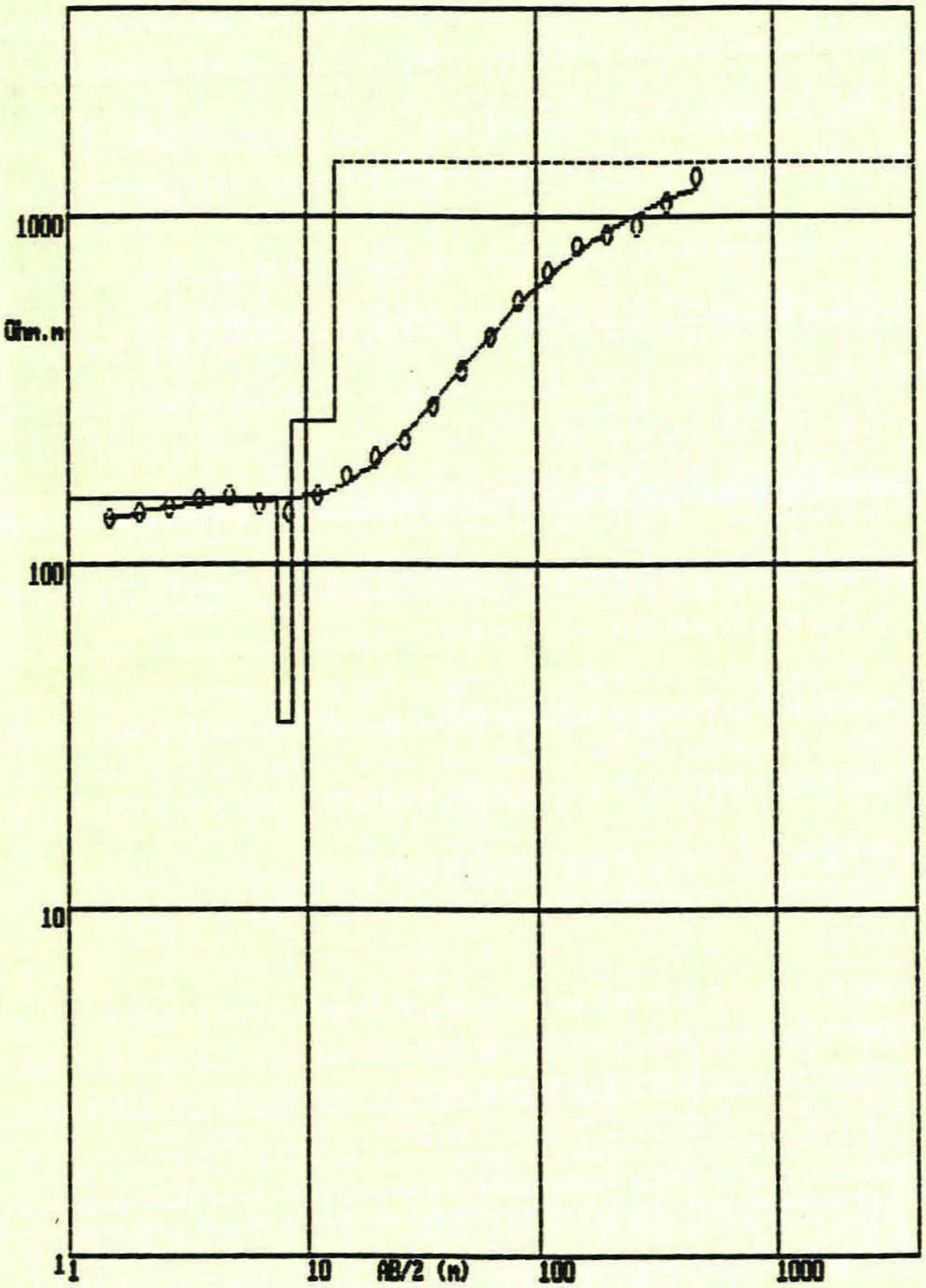
Date of the measurement	:	MAR'90
Location	:	W.CLARA
Map nr.	:	B3
Measuring station nr.	:	C01
Curve Fitting RMS Error	:	2.8 %



Model parameters :

Layer	Thickness	Resistivity	Interpretation
1	0.5	99.9	
2	9.5	164.0	
3	3.0	17.8	
4	2.2	147.8	
5	INF.	2027.1	

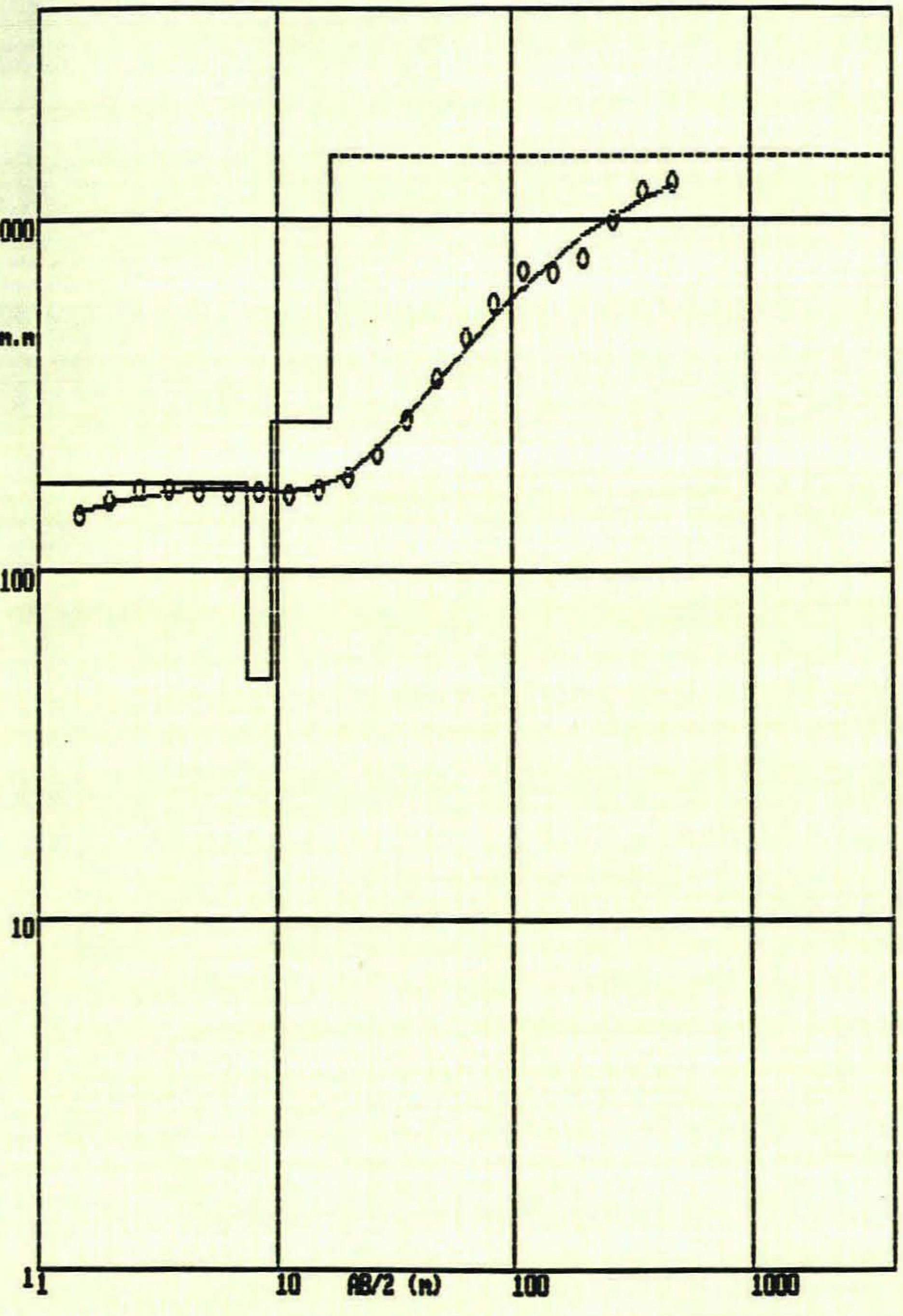
Date of the measurement	:	FEB 90
Location	:	W.CLARA
Map nr.	:	B6 GRID
Measuring station nr.	:	C02
Curve Fitting RMS Error	:	4.1 %



Model parameters :

Layer	Thickness	Resistivity	Interpretation
1	0.5	115.9	
2	7.0	155.9	
3	1.2	35.0	
4	4.7	261.2	
5	INF.	1431.9	

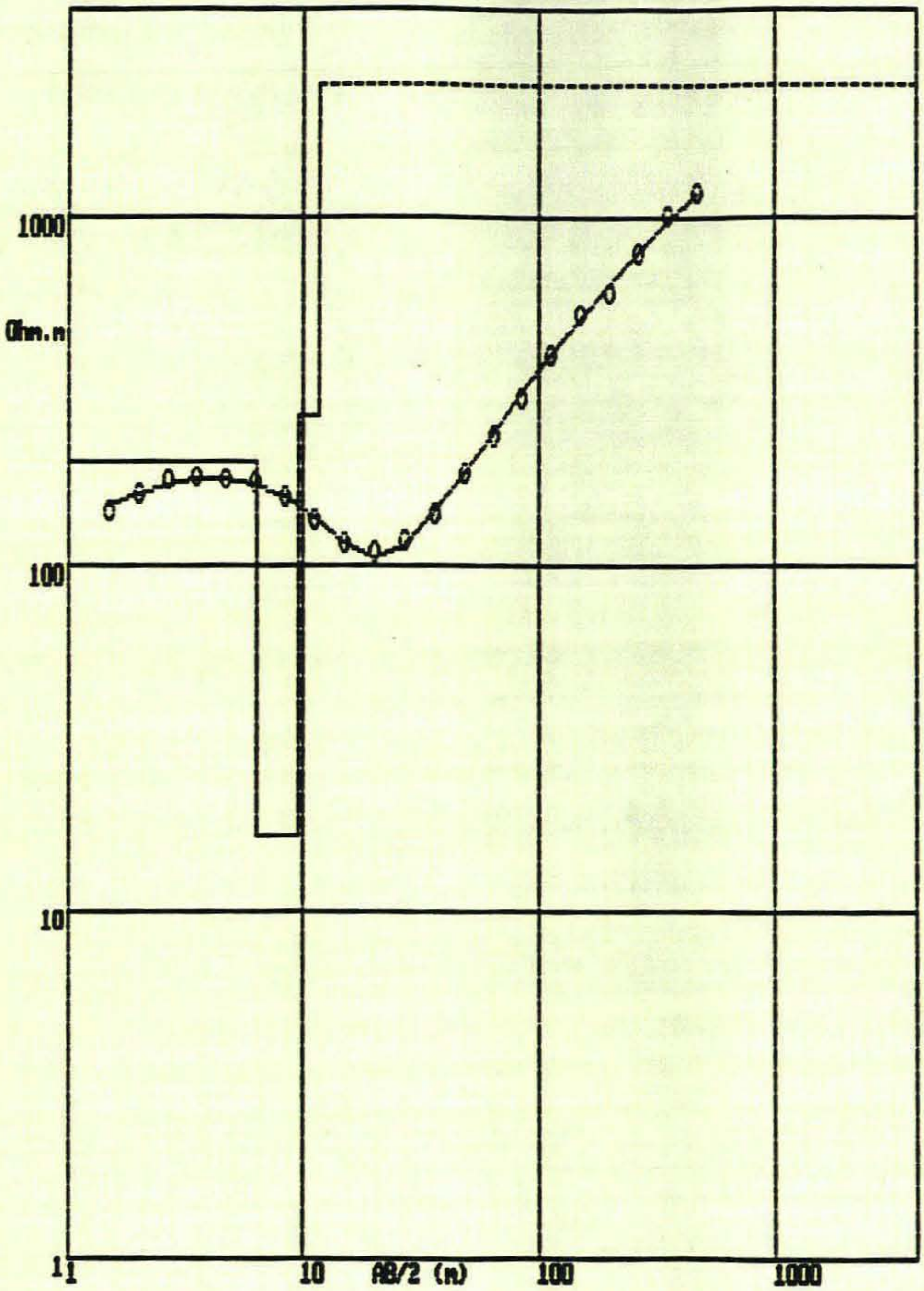
Date of the measurement	:	FEB 90
Location	:	W.CLARA
Map nr.	:	B6 GRID
Measuring station nr.	:	C03
Curve Fitting RMS Error	:	5.6 %



Model parameters :

Layer	Thickness	Resistivity	Interpretation
1	0.5	117.8	
2	7.0	177.4	
3	2.0	48.9	
4	7.3	263.9	
5	INF.	1539.5	

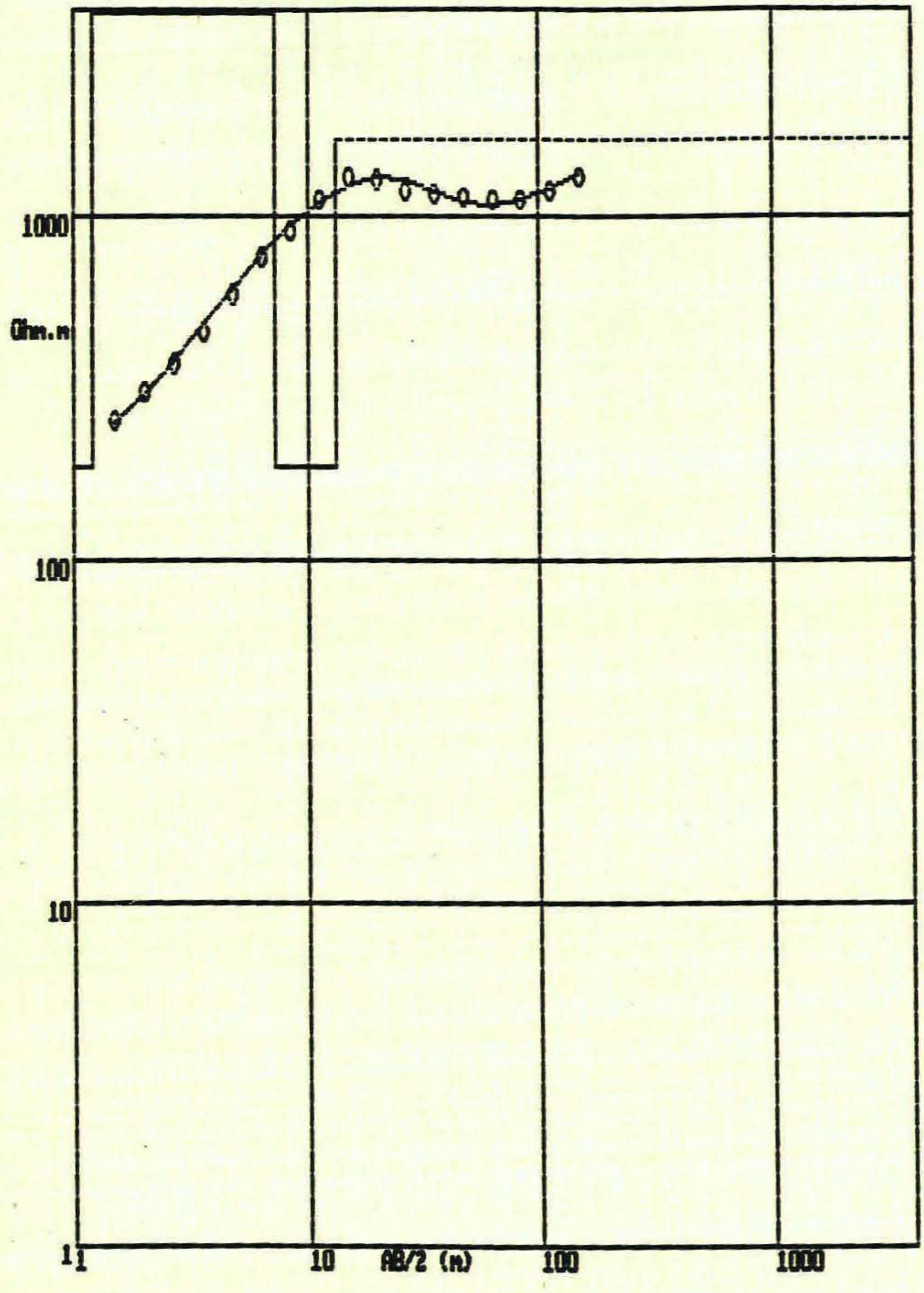
Date of the measurement : FEB 90
Location : W.CLARA
Map nr. : B9 GRID
Measuring station nr. : C04
Curve Fitting RMS Error : 2.5 %



Model parameters :

Layer	Thickness	Resistivity	Interpretation
1	0.4	99.1	
2	6.0	198.1	
3	3.3	16.6	
4	2.1	269.3	
5	INF.	2447.7	

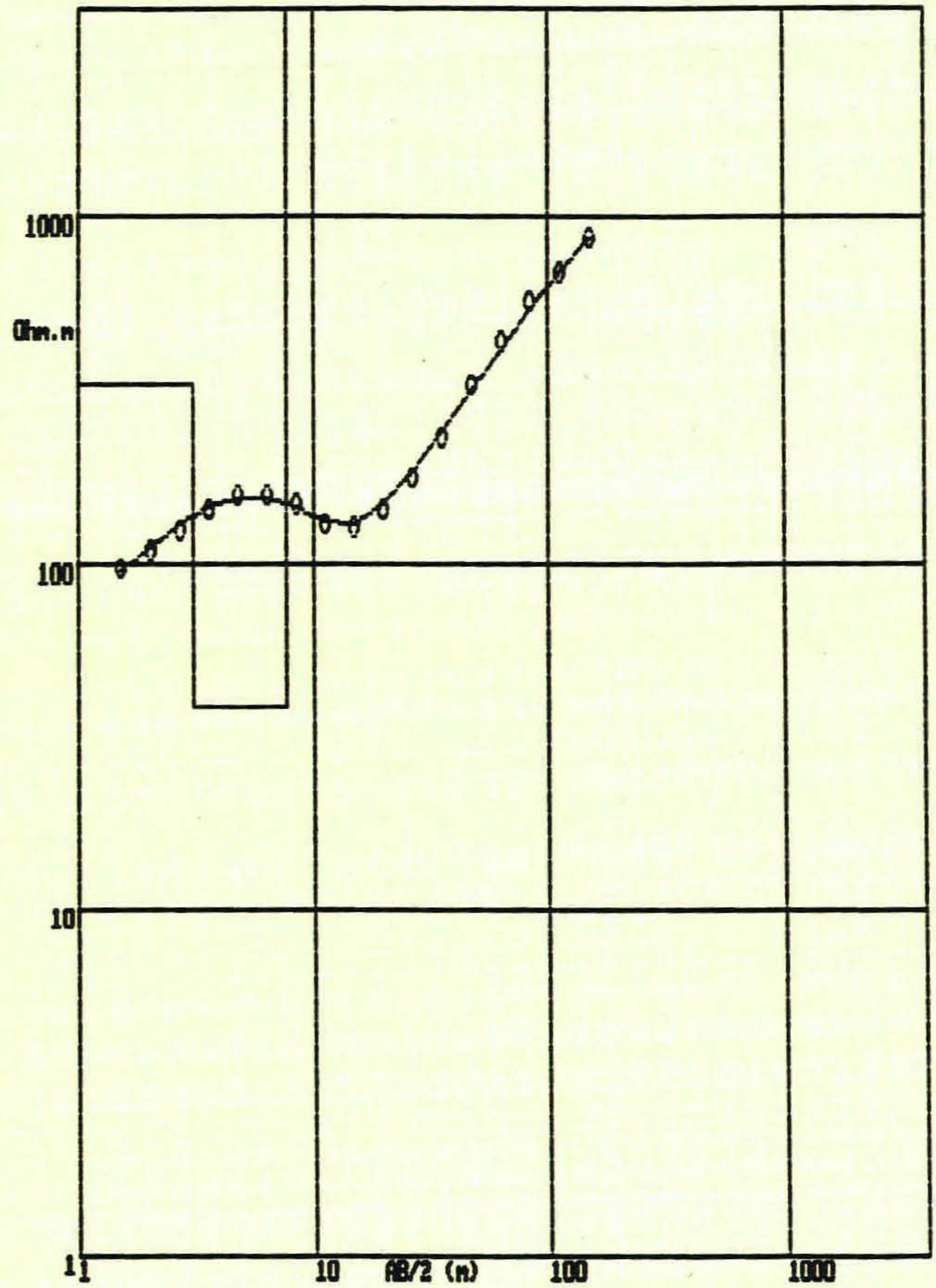
Date of the measurement	:	FEB 90
Location	:	ESKER
Map nr.	:	40M STH.OF ROAD
Measuring station nr.	:	C05
Curve Fitting RMS Error	:	3.4 %



Model parameters :

Layer	Thickness	Resistivity	Interpretation
1	1.2	187.6	
2	6.1	3946.5	
3	5.9	188.1	
4	INF.	1698.7	

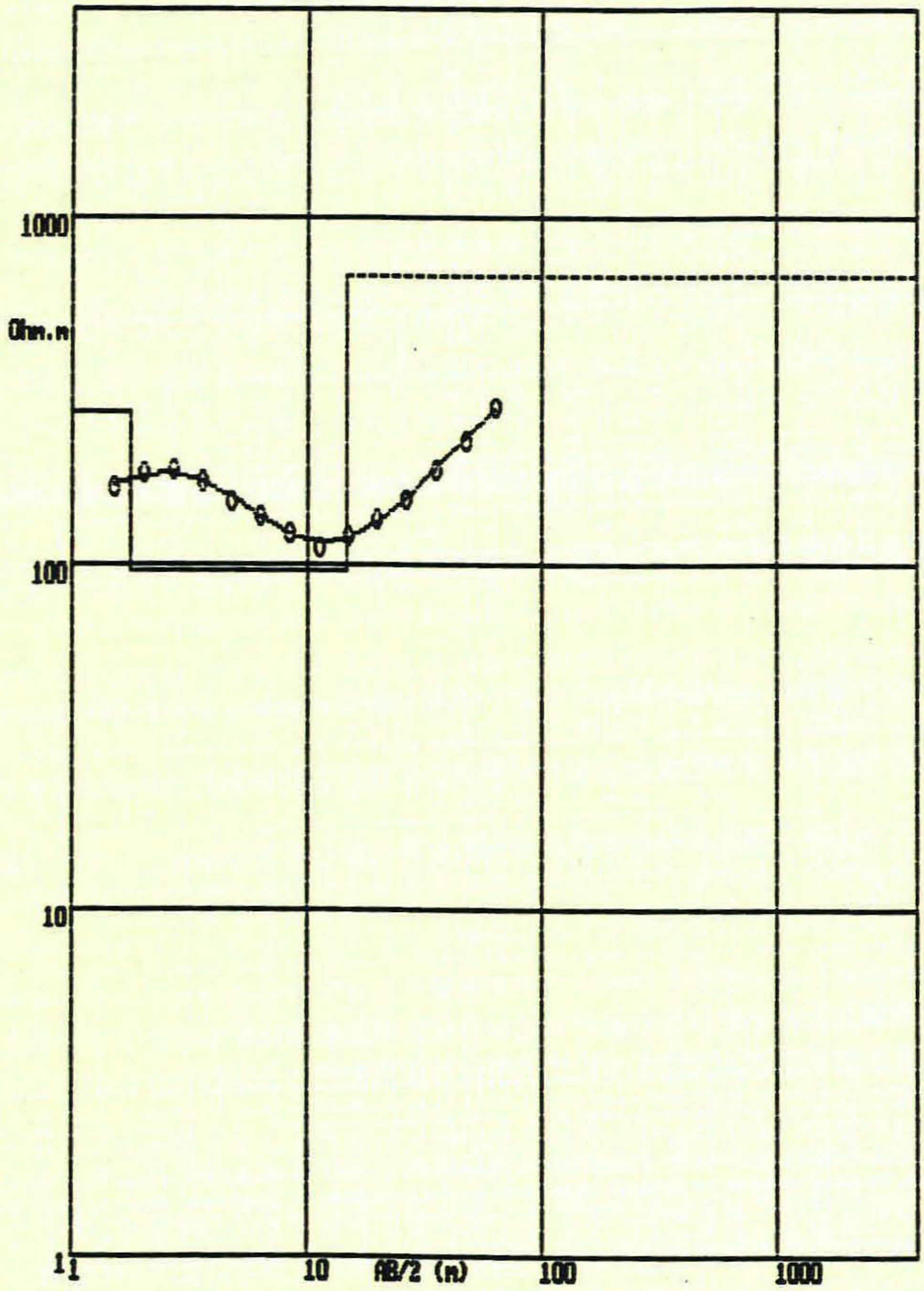
Date of the measurement	:	FEB 90
Location	:	ESKER
Map nr.	:	60m S.OF C05
Measuring station nr.	:	C06
Curve Fitting RMS Error	:	3.0 %



Model parameters :

Layer	Thickness	Resistivity	Interpretation
1	0.9	69.7	
2	2.2	329.9	
3	4.6	38.7	
4	INF.	4106.5	

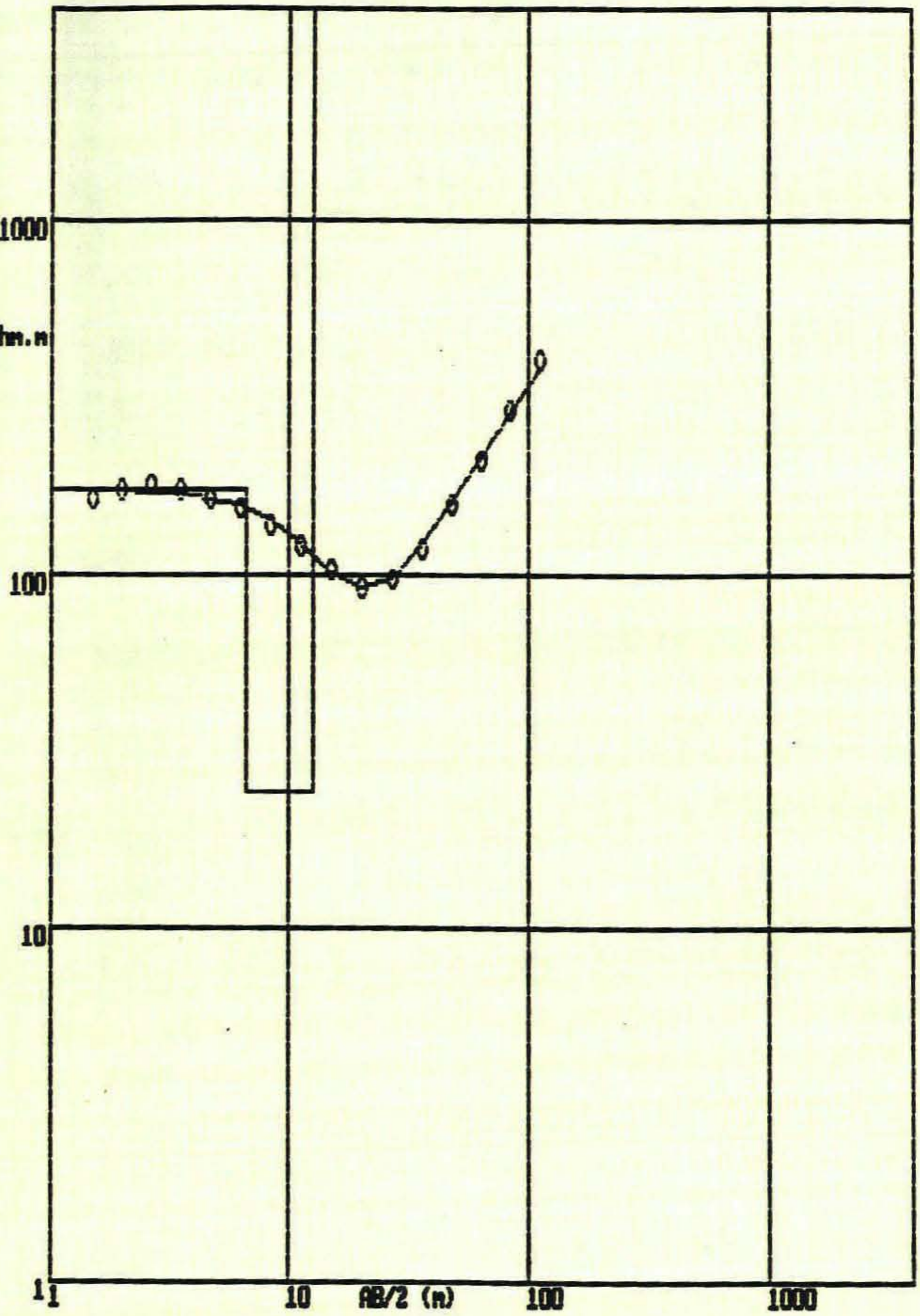
Date of the measurement	:	FEB 90
Location	:	ESKER MARGIN
Map nr.	:	BOG MARGIN
Measuring station nr.	:	C07
Curve Fitting RMS Error	:	2.0 %



Model parameters :

Layer	Thickness	Resistivity	Interpretation
1	0.6	126.0	
2	1.2	276.1	
3	13.0	95.1	
4	INF.	674.8	

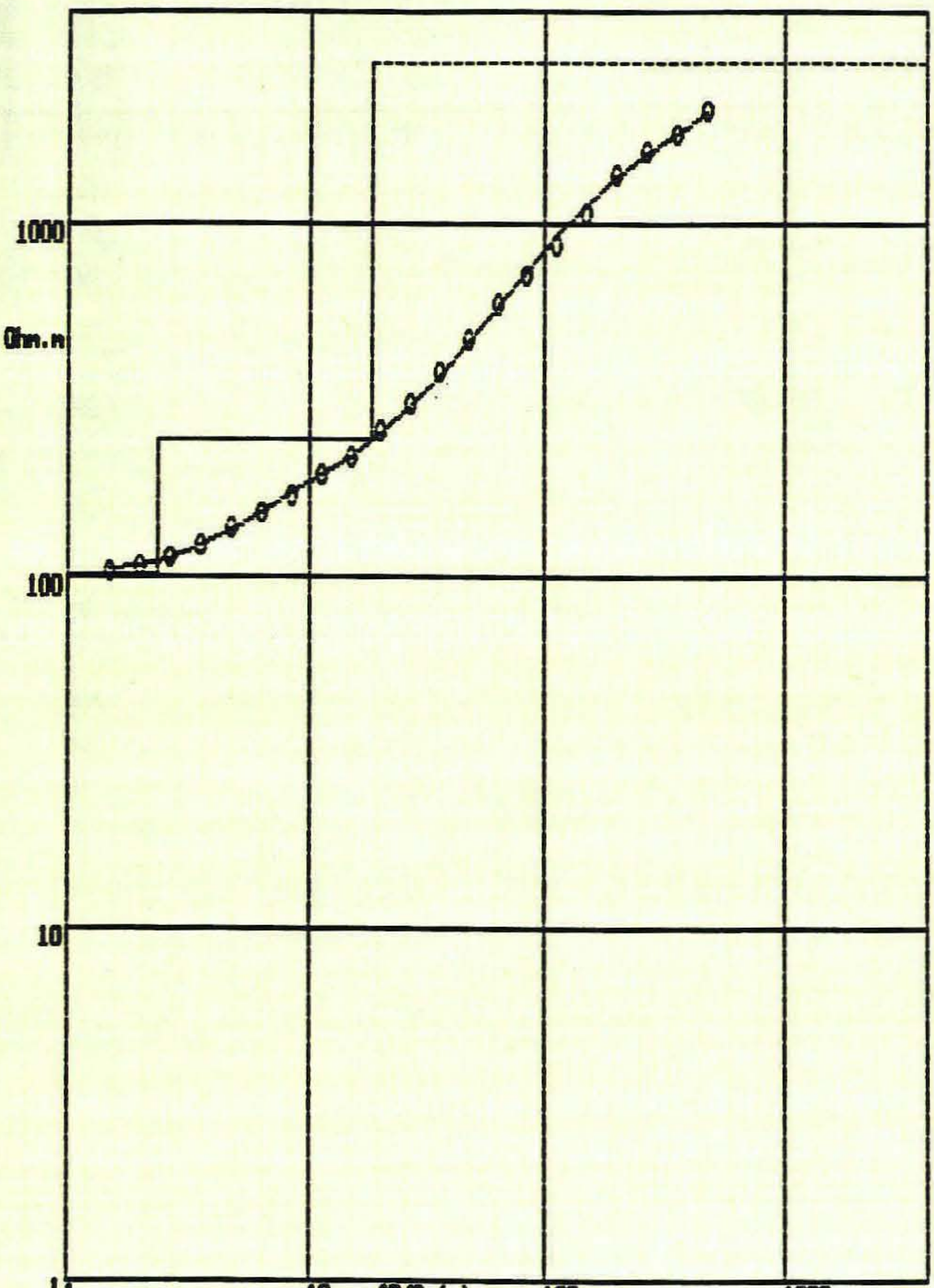
Date of the measurement	:	FEB 90
Location	:	BOG MARGIN
Map nr.	:	50M INTO BOG
Measuring station nr.	:	C08
Curve Fitting RMS Error	:	2.9 %



Model parameters :

Layer	Thickness	Resistivity	Interpretation
1	6.7	173.2	
2	6.1	24.3	
3	INF.	19563.7	

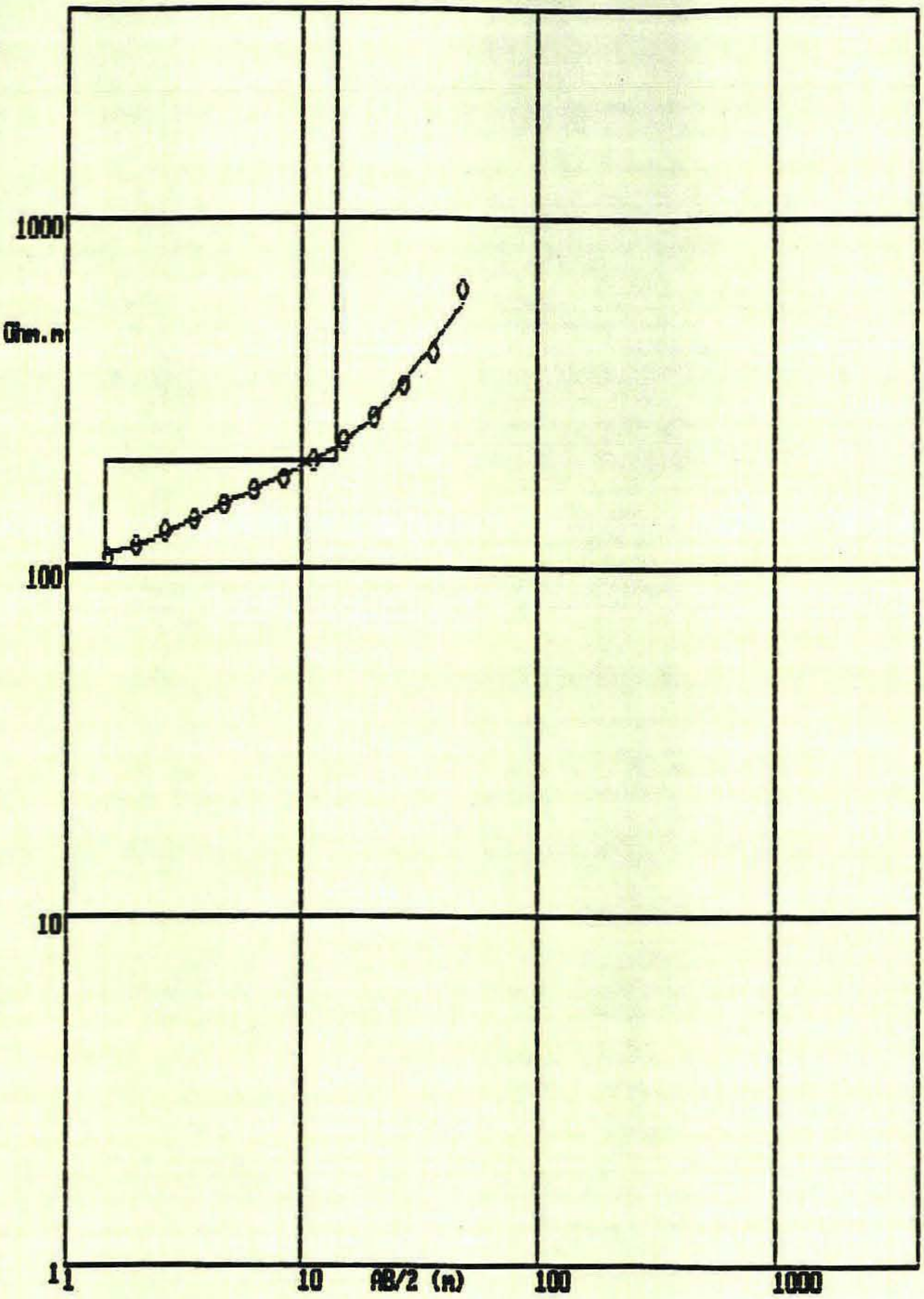
Date of the measurement	:	FEB 90
Location	:	W.CLARA
Map nr.	:	RIDGE TOP
Measuring station nr.	:	C09
Curve Fitting RMS Error	:	2.1 %



Model parameters :

Layer	Thickness	Resistivity	Interpretation
1	2.4	102.3	
2	16.1	245.1	
3	INF.	2882.9	

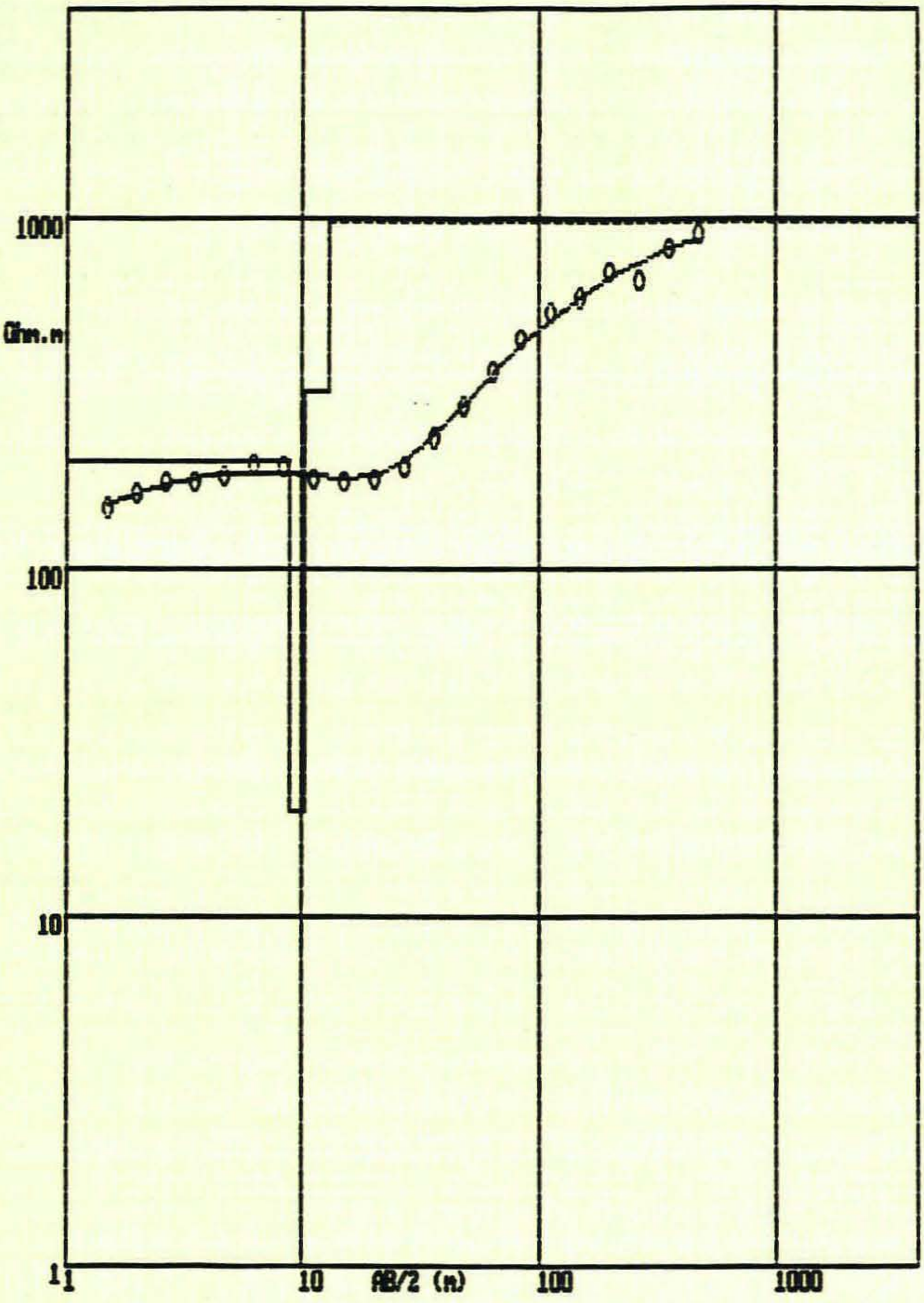
Date of the measurement	:	FEB 90
Location	:	W.CLARA
Map nr.	:	RIDGE SLOPE
Measuring station nr.	:	C10
Curve Fitting RMS Error	:	3.3 %



Model parameters :

Layer	Thickness	Resistivity	Interpretation
1	1.5	103.7	
2	12.6	202.7	
3	INF.	6020.5	

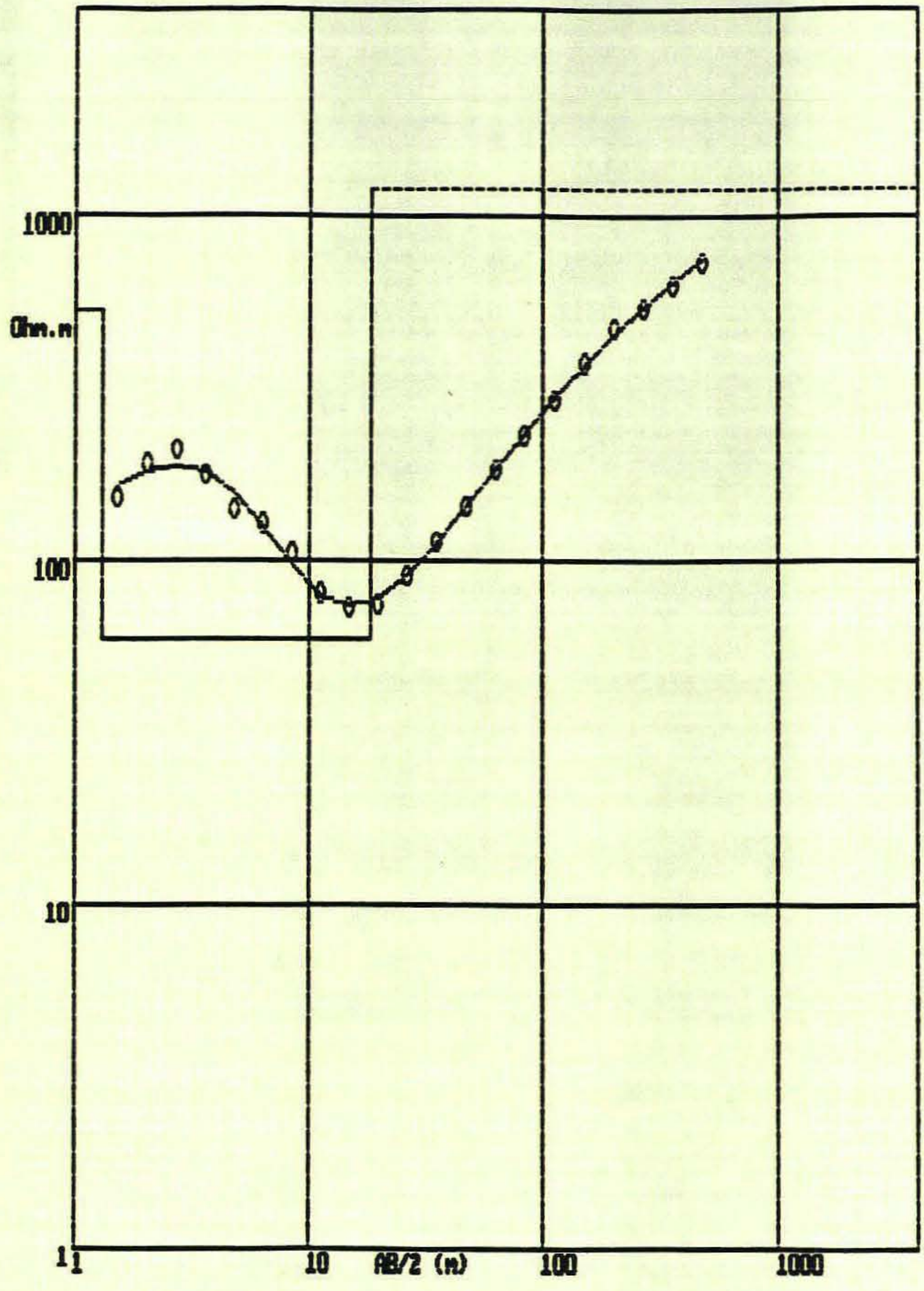
Date of the measurement	:	0
Location	:	GRID C5
Map nr.	:	W.CLARA
Measuring station nr.	:	CLSVES11
Curve Fitting RMS Error	:	4.0 %



Model parameters :

Layer	Thickness	Resistivity	Interpretation
1	0.5	110.8	
2	8.5	200.8	
3	1.3	19.9	
4	2.7	320.5	
5	INF.	986.9	

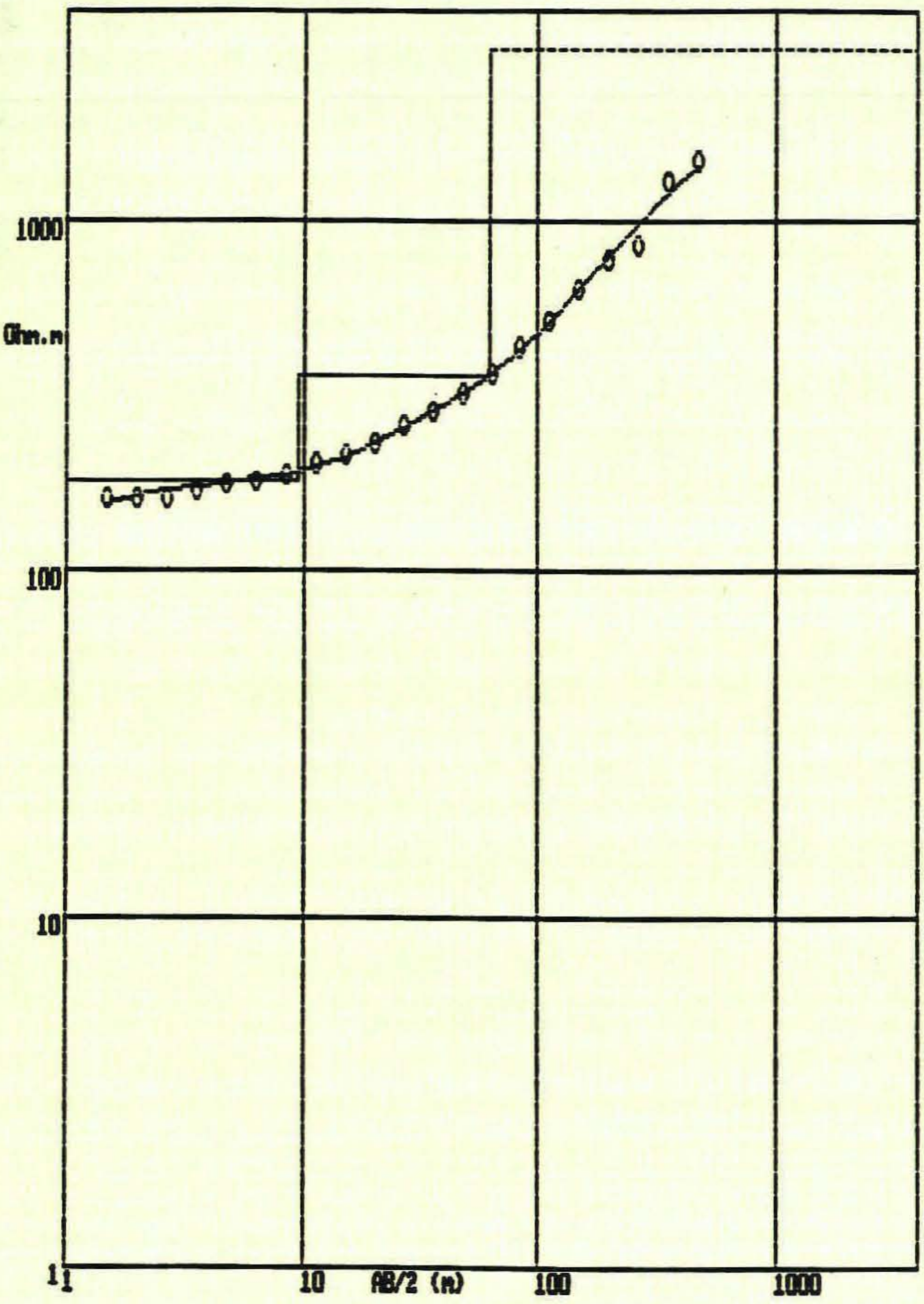
Date of the measurement	:	FEB 91
Location	:	W.CLARA
Map nr.	:	GRID O 8
Measuring station nr.	:	CLSVES12
Curve Fitting RMS Error	:	4.7 %



Model parameters :

Layer	Thickness	Resistivity	Interpretation
1	0.5	80.3	
2	0.8	527.2	
3	17.4	59.6	
4	INF.	1203.5	

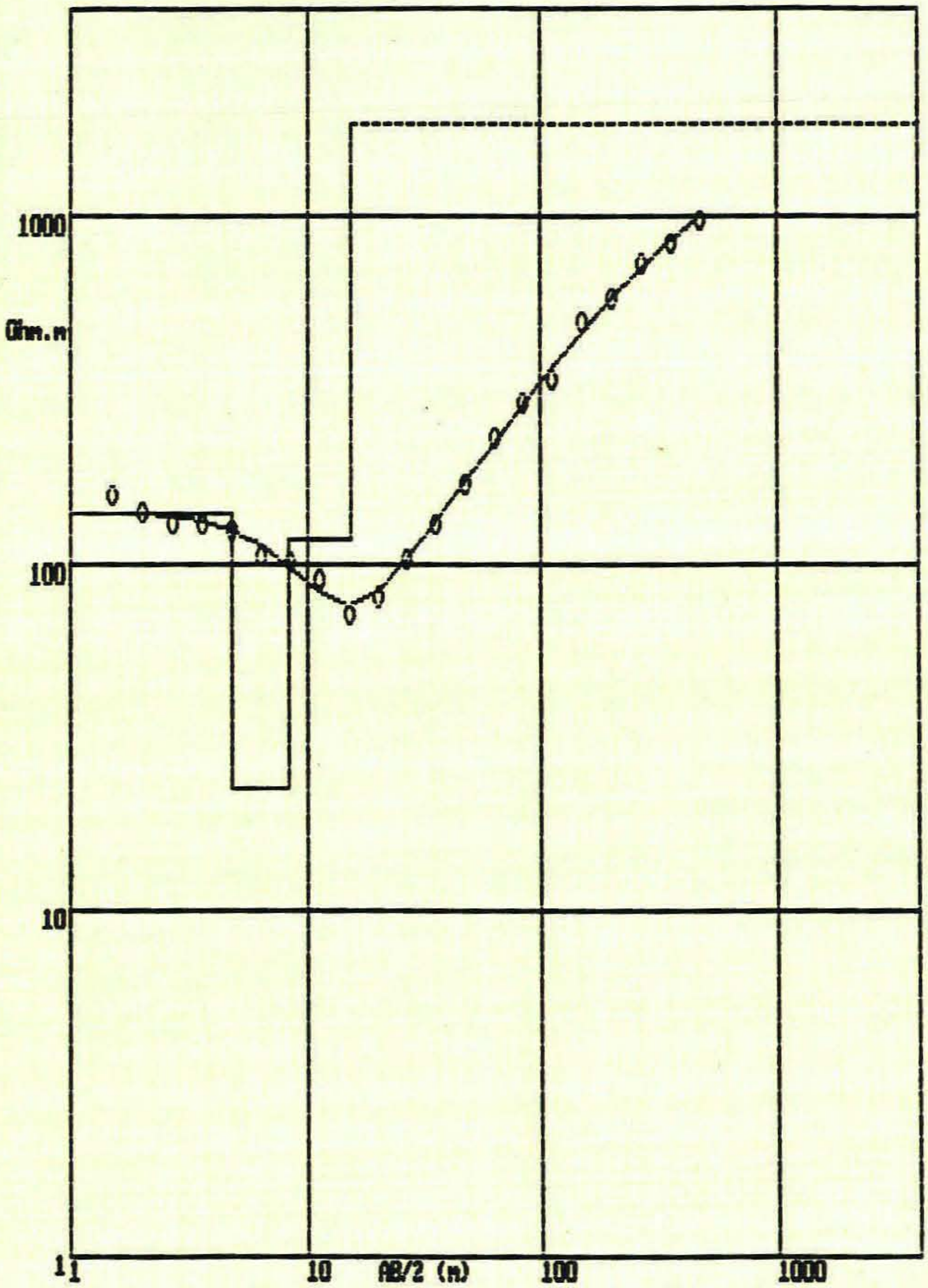
Date of the measurement : FEB 91
Location : GRID C'9
Map nr. : E.CLARA
Measuring station nr. : CLSVES13
Curve Fitting RMS Error : 4.1 %



Model parameters :

Layer	Thickness	Resistivity	Interpretation
1	0.5	127.2	
2	9.0	182.2	
3	52.3	359.9	
4	INF.	3120.4	

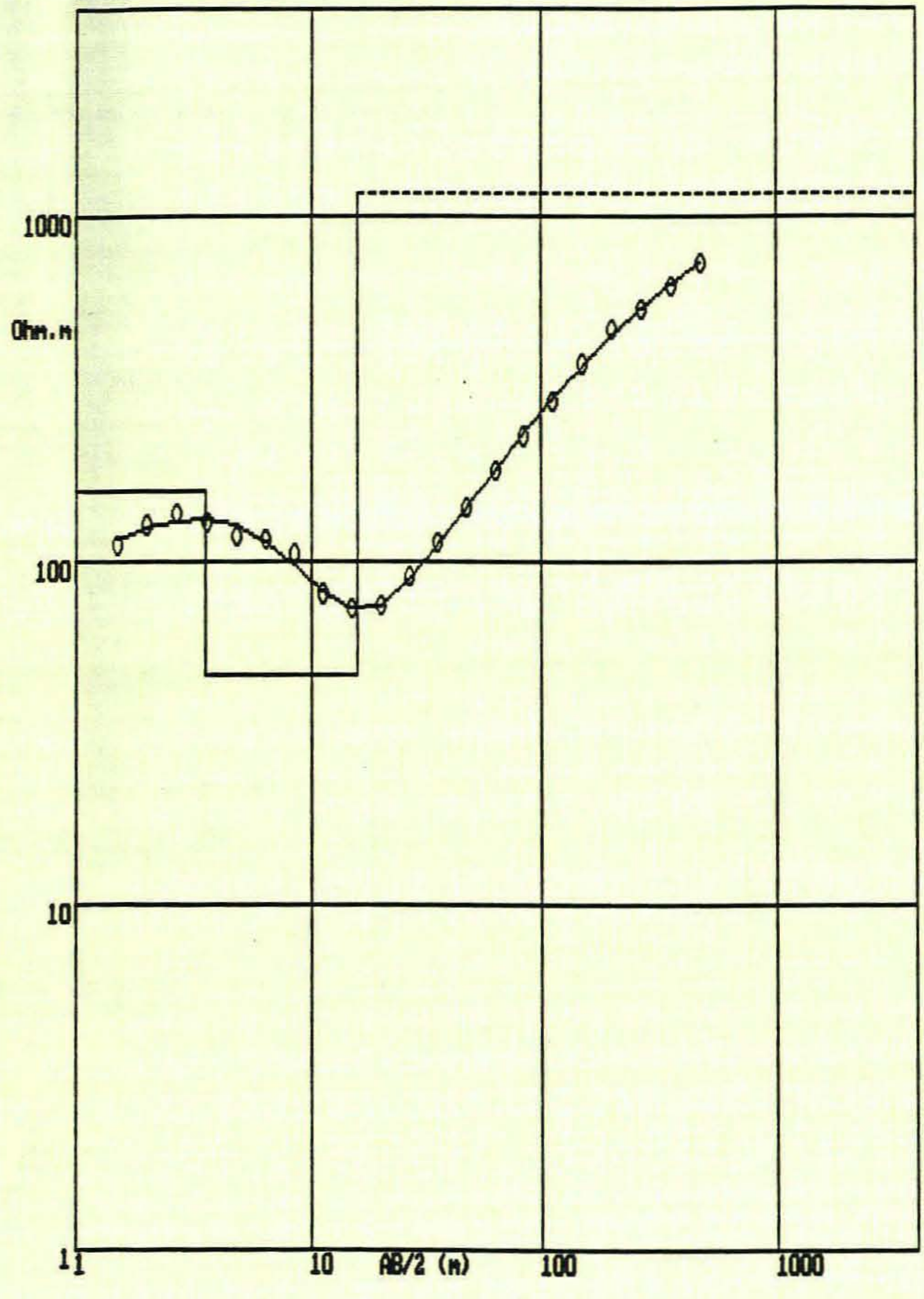
Date of the measurement	:	FEB 91
Location	:	W.CLARA
Map nr.	:	GRID B13
Measuring station nr.	:	CLSVES14
Curve Fitting RMS Error	:	4.8 %



Model parameters :

Layer	Thickness	Resistivity	Interpretation
1	4.7	141.3	PEAT
2	3.6	22.5	CLAY
3	7.0	119.1	TILL
4	INF.	1850.7	BEDROCK

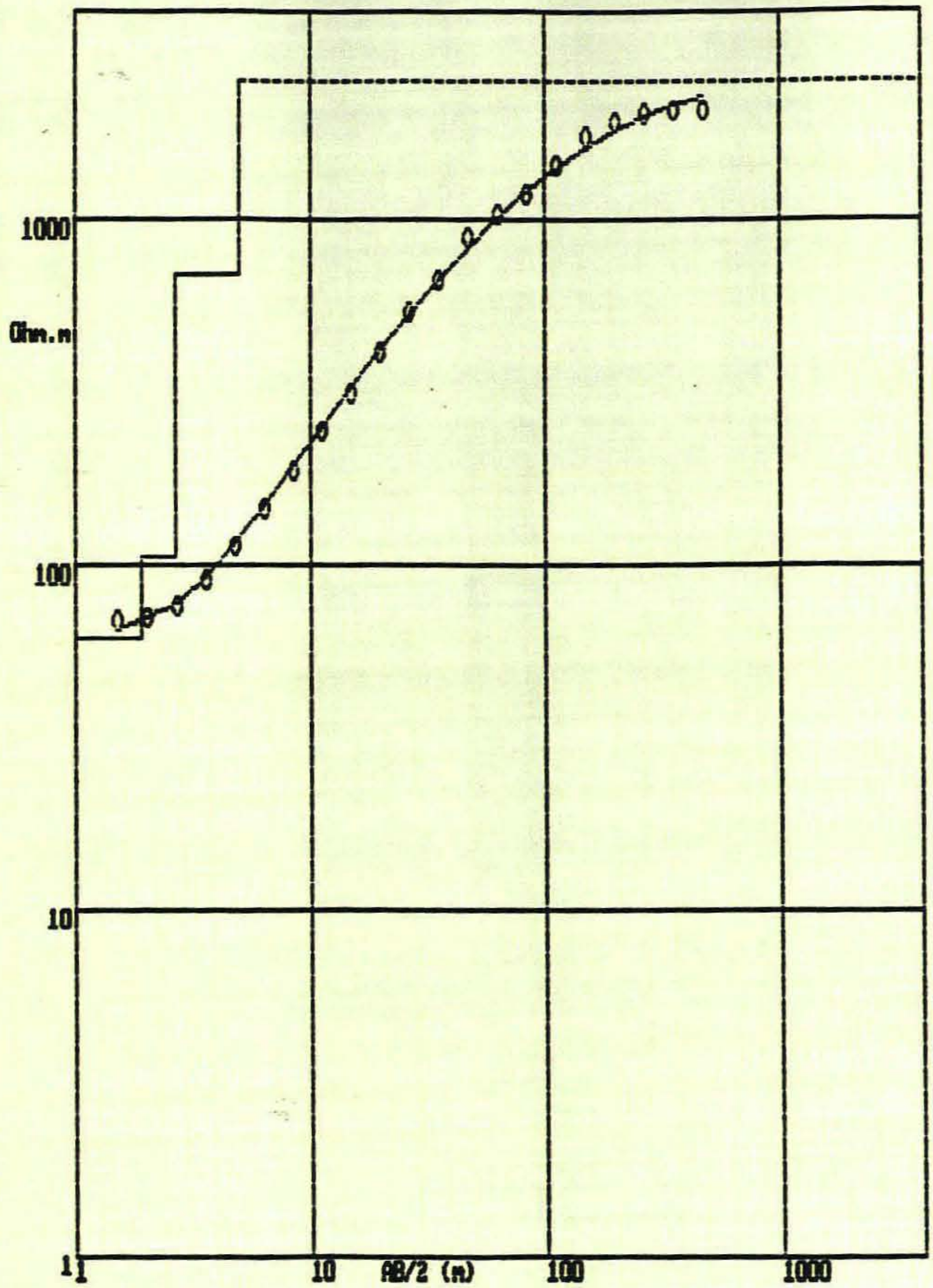
Date of the measurement	:	FEB 91
Location	:	W.CLARA
Map nr.	:	GRID G14.4
Measuring station nr.	:	CLSVES15
Curve Fitting RMS Error	:	3.0 %



Model parameters :

Layer	Thickness	Resistivity	Interpretation
1	0.5	80.7	
2	3.0	160.3	
3	12.5	46.7	
4	INF.	1166.3	

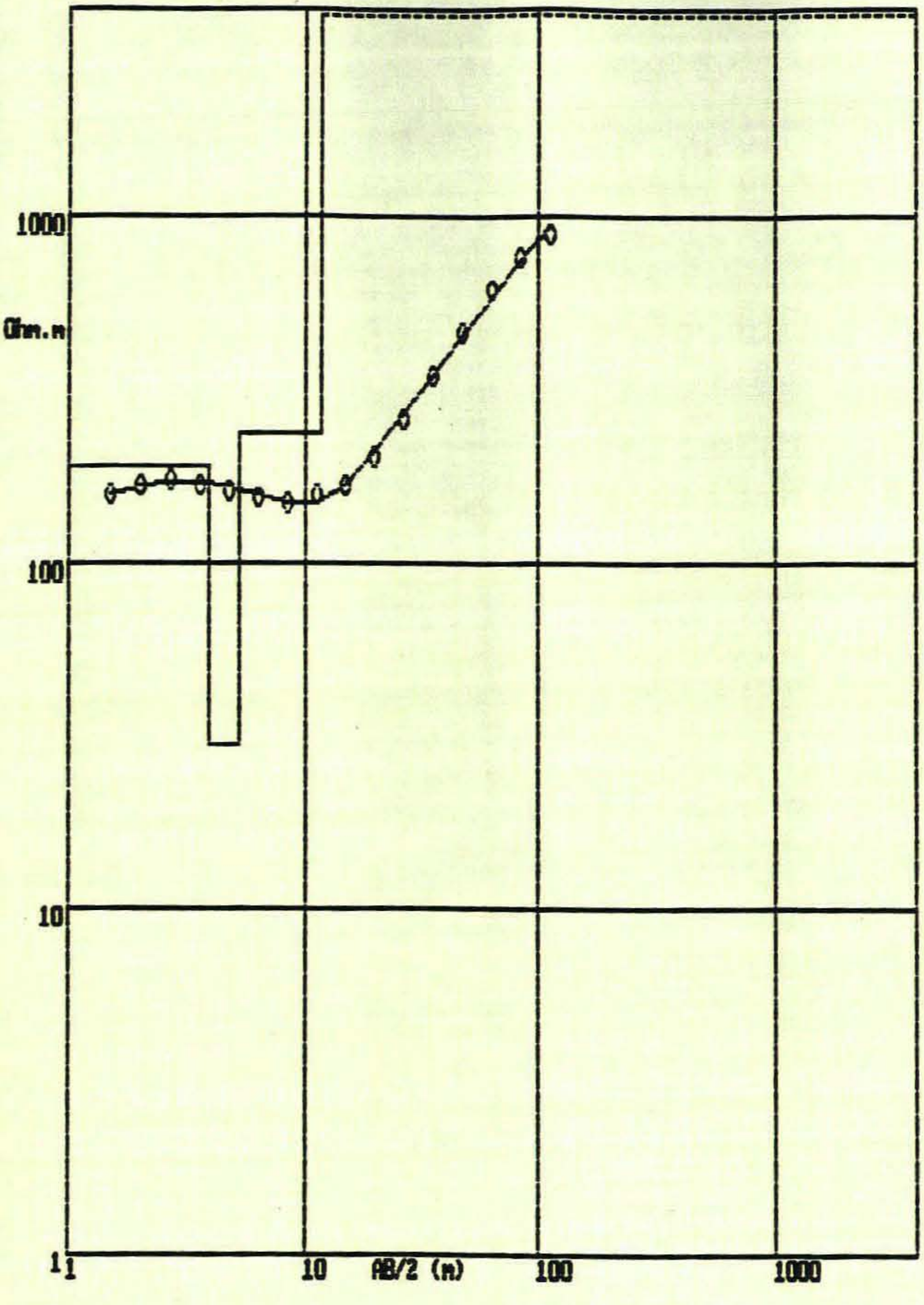
Date of the measurement	:	FEB 91
Location	:	W.CLARA
Map nr.	:	GRID g-h 15.5
Measuring station nr.	:	CLSVES16
Curve Fitting RMS Error	:	3.9 %



Model parameters :

Layer	Thickness	Resistivity	Interpretation
1	1.9	61.8	
2	0.7	104.4	
3	2.3	688.0	
4	INF.	2500.7	

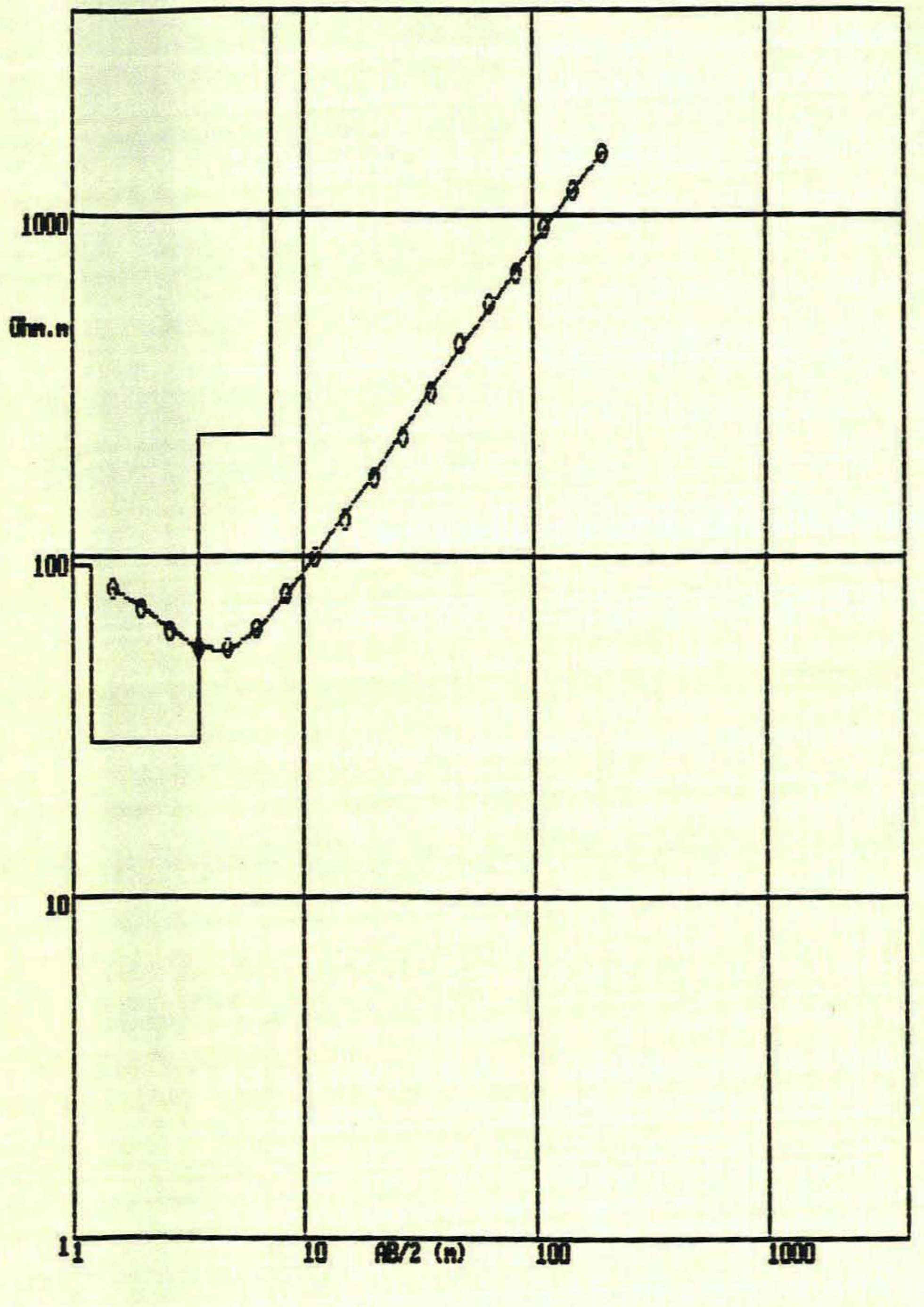
Date of the measurement	:	FEB 91
Location	:	W.CLARA
Map nr.	:	GRID J16
Measuring station nr.	:	CLSVES17
Curve Fitting RMS Error	:	2.8 %



Model parameters :

Layer	Thickness	Resistivity	Interpretation
1	0.5	124.2	
2	3.4	193.0	
3	1.3	29.9	
4	6.5	236.6	
5	INF.	3847.8	

Date of the measurement :	FEB 91
Location :	W.CLARA
Map nr. :	DALY FIELD
Measuring station nr. :	CLSVES18
Curve Fitting RMS Error :	2.0 %



Model parameters :

Layer	Thickness	Resistivity	Interpretation
1	1.2	93.2	
2	2.4	28.6	
3	3.7	226.2	
4	INF.	8920.0	