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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1964/48

BERRY SPRINGS / DARWIN RIVER TEST GEOPHYSICAL SURVEY, N T 1963

by

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SUMMARY

A geophysical test survey in the Berry Springs/Darwin River area Northern Territory was made in November and December 1963 at the request of the Commonwealth Department of Works.

The Berry Springs, about 20 miles south-east of the Darwin River, are a possible but limited supplement to the Darwin city water supply. It was suggested by the Department of Works that by damming the lower Darwin River the flow of water from the Berry Springs may be increased. The existence of a continuous aquifer between the Darwin River and Berry Springs is an essential requirement of this theory. The geophysical survey was made to ascertain whether geophysical methods could detect such an aquifer.

Resistivity, electromagnetic, and bore-logging methods were used. The resistivity results indicate that a buried high-resistivity layer exists between the springs and the river. The depth of this layer is 50 - 90 ft at the springs; it decreases to 10 - 20 ft midway between the springs and the river, and increases to at least 150 ft near the river. The electromagnetic and bore-logging method yielded little or no useful information.

Resistivity values suggest that the high-resistivity layer may be impermeable and that the zone above it could contain an aquifer. If these conclusions are correct then it is considered that movement of water from the Darwin River to Berry Springs would be restricted or prevented by the impermeable layer midway between the river and Berry Springs.

Recommendations are made for diamond drilling to test the validity of the geophysical conclusions before further investigations are contemplated.

1. INTRODUCTION

The Berry Springs/Darwin River area is about 20 miles south-south-east of Darwin; its position is shown in Plate 1.

The Berry Springs are a potential supplement to the Darwin city water supply and would be of great value if the water flow could be increased. The Commonwealth Department of Works has suggested that, by damming the Darwin River at the Upper Pondage site (Plate 1), a large quantity of water could be stored underground between the river and Berry Springs and could flow to the surface at the springs. The Resident Geological Staff, Bureau of Mineral Resources, Darwin and the Water Resources Branch, Northern Territory Administration, have made some investigations in the area but could not reach a definite conclusion on the possibility of the proposed scheme. The Geophysical Branch of the Bureau of Mineral Resources was approached by the Commonwealth Department of Works to conduct a test survey to see if geophysical methods could detect an aquifer between Berry Springs and the Darwin River.

This survey was made between 18th November and 4th December 1963 by J. Ashley (geophysicist) and R.W. Eastick (geophysical assistant) of the Darwin Uranium Group, Bureau of Mineral Resources. Five field assistants were provided by the Department of Works.

Resistivity, electromagnetic, and bore-logging methods were used. Twenty resistivity depth-probes were measured, 14,850 ft of traverse was investigated using the electromagnetic method, and Water Resources Branch boreholes No. 2, 7, 8, 9, and 10 were electrically logged. The positions of depth probes, traverses, and boreholes are shown in Plate 1.

2. GEOLOGY

The regional geology is described by Malone (1962). Detailed geology from Crohn and Barclay (1963) and Rix (1963) is shown in Plate 1.

South and south-west of Berry Springs the ground rises and reaches its highest point, approximately 50 ft higher than the springs, at about one mile north of the Darwin River.

An extensive cover of alluvium and soil makes geological mapping difficult and only a limited knowledge has been gained. On geological grounds the area can be divided into two parts by a line from the vicinity of Berry Springs to about the Lower Pondage site on the Darwin River. North of this line are outcrops of Lower Proterozoic? shale, slate, siltstone, and limestone. The slates dip steeply; immediately north of Berry Springs the slates show evidence of folding. To the south of Lower Proterozoic? rocks are overlain unconformably by Upper Proterozoic? sandstone. Ferricrete crops out in places on the banks of the creeks.

Quartz breccia outcrops are common throughout the area. Some are considered to be tectonic and some to be depositional; Rix (1963) regards those immediately south of Berry Springs as tectonic and he has positioned two faults on this basis.

3. HYDROLOGY

Water analyses and temperature measurements in boreholes have been made by the Water Resources Branch, Northern Territory Administration. The temperature of water from the springs is 3° F higher than the mean temperature of water in boreholes No. 2, 4, 6, and 8. This fact indicates that the springs water comes from considerable depth. Water analyses has led to the conclusion that the water also passes through a limestone or dolomite. Rix (1963) has concluded that the fault just south of the Springs provides an outlet for water from a deep dolomite? aquifer and that the contribution of water from the overlying sandstone is quite small.

4. GEOPHYSICAL METHODS AND SURVEYING

The resistivity, electromagnetic, and bore-logging techniques are described in detail by Heiland (1951) and Jakosky (1950). A summary of each method is given below.

Resistivity

Electrical current is supplied to the ground at two points and the potential is measured between two other points whose spacing or distance from the current electrodes is varied. The ratio of voltage to current multiplied by a factor determined by the geometry of the electrode arrangement gives a value of apparent resistivity, ρ_a, which depends on electrode separation and hence on depth penetration of the currents. The apparent resistivity is the 'average' resistivity of the ground traversed by the current.

The electrode arrangement used was the Wenner system in which four electrodes are equally spaced along a straight line. Current was supplied to the two outer electrodes and potential measured measured between the two inner electrodes. By increasing the electrode spacing, but keeping the mid-point of the electrode array at a fixed position, ρ_a was measured for different depth penetrations at the fixed position. Such a series of measurements is known as a resistivity depth-probe.

The instrument used was a Megger Earth Tester manufactured by Evershed & Vignoles; the electrodes were 3-ft long steel spikes spaced at distances ranging from 5 ft to 600 ft.

Electromagnetic

Two small horizontal coils of fixed separation were employed. A low-frequency electromagnetic signal was induced in the ground by passing an alternating current through one coil (the transmitting coil). This signal in turn induced a current in the other coil (the receiver coil). The coils were moved along the traverse lines and where the conductivity of the ground was uniform the signal in the receiver coil was constant. If a change in conductivity was encountered secondary electromagnetic signals were induced and the received signal altered.

The received signal was measured in two components; one component represented the percentage of the received signal that was in phase with a small reference signal fed directly by cable from the transmitting coil to the receiving coil, the other component was the percentage of received signal which was 90 degrees out of phase with the reference signal. Measurements were made at intervals of 50 ft along the traverse lines and referred to a point midway between the coils.

The depth penetration was dependent on and approximately equal to 0.8 of the coil separation. In this survey the coil separation was 200 ft. The frequency of the transmitted signal was 1760 c/s.

A set of Slingram equipment, manufactured by ABEM, was used.

Electrical bore-logging

Resistivity measurements were made in boreholes by using a two-electrode system. One electrode was at the ground surface while the other was lowered down the borehole. An electrical current was passed between the electrodes and values of resistivity were automatically recorded as the borehole electrode was lowered. The electrical circuit between the electrodes was not closed until the borehole electrode entered water.

A Widco 1000-ft logger was used.

Surveying

All traverses and depth-probe positions were linked to survey pegs located by the Water Resources Branch, Northern Territory Administration.

5. PRESENTATION OF RESULTS

Standard resistivity curves of the variation of apparent resistivity with electrode spacing have been calculated for two and three semi-infinite horizontal layers (La Compagnie Générale de Géophysique, 1955). The standard curves, plotted on log-log scale, are available for a wide range of resistivities and thicknesses of the layers.

The depth-probe results have been plotted on the same scale as, and compared with, the standard curves (Plate 2). In most cases several curves could be fitted to the observed results.

The depth-probe interpretations have also been presented on the map of Plate 3. Layer resistivities have been classed as low, intermediate, or high according to the ranges indicated in Plate 3. The range of layer thicknesses throughout the area can be appreciated quickly from this map.

In Plate 4 a cross-section has been drawn from the resistivity depth-probe results along a line through J_j 19N, hole No. 2, and CB21.

Plate 5 shows the electromagnetic profiles along Traverses J_j and OO.

From the electrical bore-logging the only information gained was the depth to water in the boreholes. These depths are given in the appendix where the resistivity results are compared with geological logs of boreholes No. 2, 7, 8, 9, and 10. The geological logs were made by the Resident Geological Staff, Bureau of Mineral Resources, Darwin.

6. DISCUSSION OF RESULTS

The electromagnetic results do not indicate any large changes in conductivity. At about 00/32E and Jj8S there are changes in the character of the electromagnetic results. East of 00/32E and south of Jj8S conductivity is very uniform whereas to the west and north respectively there are numerous small variations of conductivity. A formation boundary is postulated at about 00/32E and Jj8S and it may be the northern edge of the sandstone which was tentatively placed somewhat farther north on geological evidence. There is no confirmation from the electromagnetic results of the fault postulated by Rix (1963).

The bore-logging results were of little value because the boreholes were lined with steel casing. Electrical current between the electrodes was confined to the steel casing and the only information gained was the depth to water.

The resistivity results, with the exception of the depth-probe at CBP4/10S, agree well with the standard resistivity curves for a series of horizontal layers. The depth-probe solutions indicate either two or three such layers. By comparing the drill logs of boreholes No. 2, 7, 8, 9, and 10 with the corresponding interpretations of depth-probes the following correlations between resistivities and rock types have been made.

Resistivity (ohm - cm)	Rock type
0 - 3000	wet sand or clay
20,000 - 75,000	dolomite or sandstone containing water
40,000 - 270,000	ferricrete
200,000 - ∞	dolomite or sandstone.

Despite the variety of possible solutions available for each depth-probe, the thickness of the surface layer ranges over only a few feet. Where the surface layer is of high resistivity it is presumed to be ferricrete, dry soil, sand, or sandstone. The second layer, of low or intermediate resistivity is probably water-bearing; south of Berry Springs, this layer could be sandstone. The third layer, of high resistivity, either contains little water or contains water in discrete cavities and is correlated with dry sandstone, limestone, or shale and slate. The depth to the third layer is generally ill-defined by the resistivity results. In the cross-section in Plate 4 the boundary of the surface layer and the maximum and minimum limits of the lower layer are shown. The lower layer is close to ground surface at CB11 and borehole No. 7 and 8. To the south and north its depth increases and it appears to form two basins, one enclosing the Darwin River and the other enclosing Berry Springs.

The seismic results from the Upper Pondage site (Andrew, 1963) have been included in the cross-section. If the layer in which the velocity is 8000 ft/sec (sandstone) is correlated with the layer of intermediate resistivity then the depth indications from both methods are not incompatible.

If the lower layer is impermeable, as suggested by its resistivity, then it is unlikely that large quantities of water could flow from the vicinity of the Darwin River to Berry Springs. The water flow would be restricted if not prevented by the lower layer in the region CB11 to boreholes No. 7 and 8. Whether the layers above the lower layer constitute an aquifer is not known; however the Berry Springs appear to be an outlet for deep water, not for water from a near-surface sandstone aquifer.

7. CONCLUSIONS AND RECOMMENDATIONS

The resistivity results have indicated that a layer of low to intermediate resistivity extends from the Darwin River to Berry Springs. The layer varies in thickness and depth but is thinnest and nearest to ground surface about midway between the river and Berry Springs. This layer may be an aquifer. Before further resistivity work is contemplated it is recommended that diamond drilling be done to determine precisely the meaning of the resistivity results. For this purpose a vertical diamond-drill hole at CB14 is recommended; the hole should be continued until the formation beneath the sandstone is identified. The sandstone may be up to 350 ft thick. The drill hole should be cased as little as possible so that it can be electrically logged.

Further electromagnetic work is not recommended.

8. ACKNOWLEDGEMENTS

The co-operation of the Commonwealth Department of Works is gratefully acknowledged. The co-operation of the Water Resources Branch, Northern Territory Administration and Resident Geological Staff, Bureau of Mineral Resources, Darwin in providing and discussing information is much appreciated.

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APPENDIX

Geological logs (from cuttings only) and resistivity depth-probe solutions for boreholes No. 2, 7, 8, 9, and 10.

BORE HOLE NO. 2

Depth (ft)	Rock type	Resistivity interpretation Depth(ft)	Resistivity(ohm-cm)
0 - 10	Ferricrete and soil		
10 - 20	Quartz limonite sand, no clay	(1) 0 - 35	240,000
20 - 35	Vein quartz fragments with white clay	35 - 63	13,000
35 - 45	As above but smaller fragments	63 -	240,000
50 - 70	Large vein quartz fragments	(2) 0 - 32	250,000
		32 - 96	27,800
	Depth to water = 58 ft	96 -	250,000
		(3) 0 - 35	240,000
		35 - 49	6000
		49 -	240,000

BORE HOLE NO. 7

Depth (ft)	Rock type	Resistivity interpretation Depth(ft)	Resistivity(ohm-cm)
0 - 5	Ferricrete		
5 - 15	Quartz - limonite sand, very little clay	(1) 0 - 1.8 18 - 24	90,000 2300
15 - 50	Angular quartz fragments and white clay	24 -	∞
50 - 65	Small fragments of cherty dolomite, no clay	(2) 0 - 2 2 - 20	75,000 1920
65 - 70	Larger fragments of quartz and cherty dolomite	20 -	∞
70 - 78 88 -	Sugary vein quartz)sandstone " " ")in samples		

Depth to water = 21 ft

BORE HOLE NO. 8

Depth (ft)	Rock type		Resistivity interpretation Depth(ft)	Resistivity(ohm-cm)
0 - 10	Ferruginous gravel - ferricrete			
10 - 15	Slightly less ferruginous - more vein quartz pebbles	(1)	0 - 2.5	56,000
15 - 20	White clay and vein quartz - angular fragments		2.5 - 25	1400
			25 -	∞
20 - 25	Sandy clay - few fragments of quartz	(2)	0 - 3	40,000
			3 - 18	1030
25 - 30	Larger vein quartz fragments - iron oxide box work fragments		18 -	∞
30 - 35	Silica box work fragments			
35 - 45	Ferruginous material with fragments of iron and silica boxwork			
45 - 50	Dolomite fragments			
50? - 55?	Silica boxwork fragments - ferruginous			

Bottom on solid dolomite

Depth to water = 21 ft

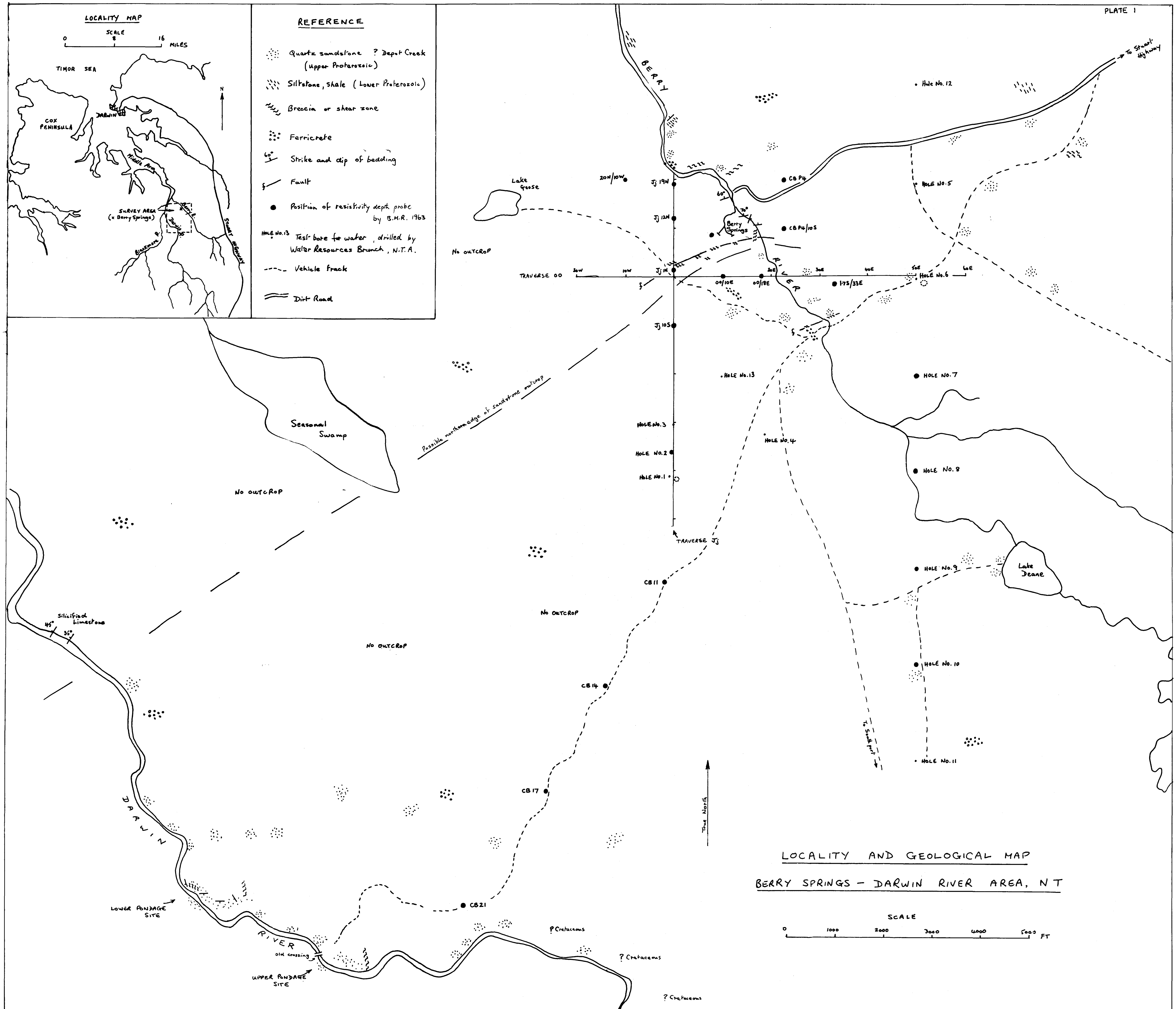
BORE HOLE NO. 9

Depth (ft)	Rock type		Resistivity interpretation Depth(ft)	Resistivity(ohm-cm)
0 - 5	Ferruginous gravel - ferricrete?	(1)	0 - 9	270,000
5 - 15	White sandy clay with some quartz gravel		9 - 117	67,500
			117 -	∞
15 - 20	Vein quartz cuttings			
20 - 25	Vein quartz and ferruginous sandy clay	(2)	0 - 7.5	290,000
			7.5 - 188	72,500
25 - 35	Vein quartz and silica box work fragments		188 -	∞
35 - 40	Limonite, clay, and vein quartz cuttings			
40 - 65	Small vein quartz, cuttings of cherty and siliceous dolomite			

Depth to water = 8 ft

BORE HOLE NO. 10

Depth (ft)	Rock type	Resistivity interpretation Depth(ft)	Resistivity(ohm-cm)
0 - 20	Ferricrete		
20 - 105	Fine-grained quartz sandstone	(1) 0 - 38	200,000
105 - 110	Grades into vein quartz rubble	38 - 228	50,000
		228 -	∞
110 - 155	Vein quartz rubble and fault breccia rubble	(2) 0 - 38	200,000
		38 - 152	50,000
155 -	3" core of silicified fault breccia	152 -	200,000
		(3) 0 - 42	200,000
		42 - 84	22,200
		84 -	200,000
	Depth to water = 46 ft	(4) 0 - 46	200,000
		46 - 55	5000
		55 -	200,000



LOCALITY AND GEOLOGICAL MAP

BERRY SPRINGS - DARWIN RIVER AREA, NT

Bureau of Mineral Resources, Geology and Geophysics, Darwin, N T

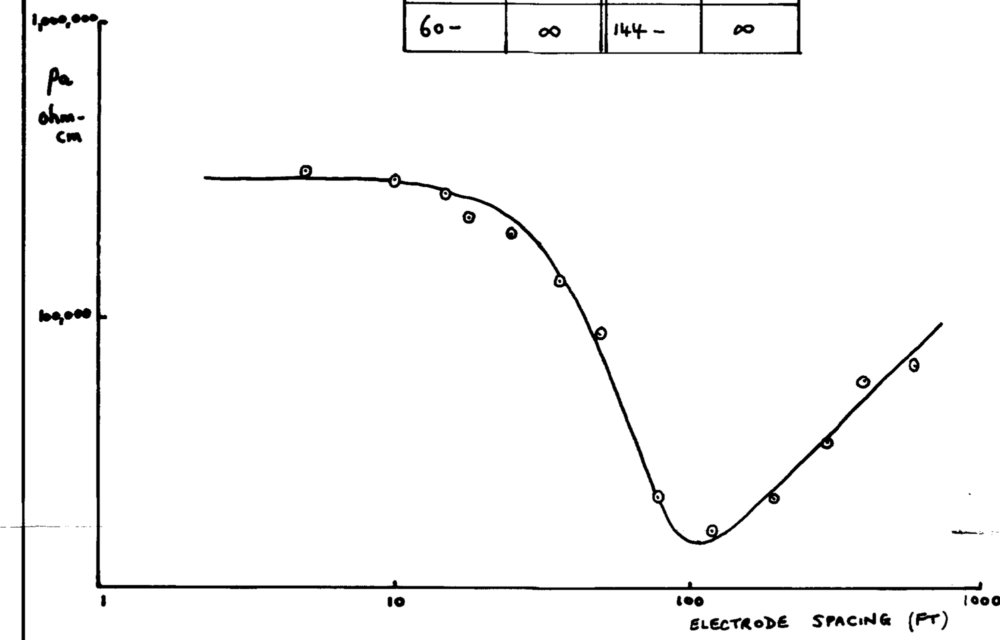
Geology by Resident Geological Staff, B.M.R., Darwin

TO ACCOMPANY RECORD No 1964/48

D52/B7-82

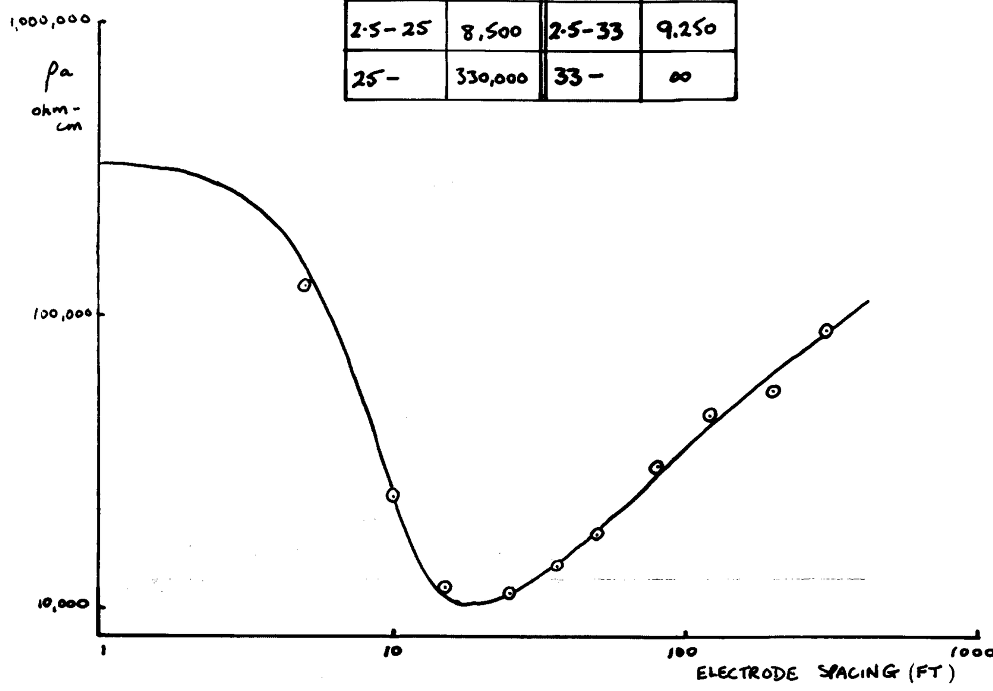
Jj 10S

*D	ρ	D	ρ
0-20	280,000	0-18	280,000
20-60	7,200	18-144	14,750
60-	∞	144-	∞



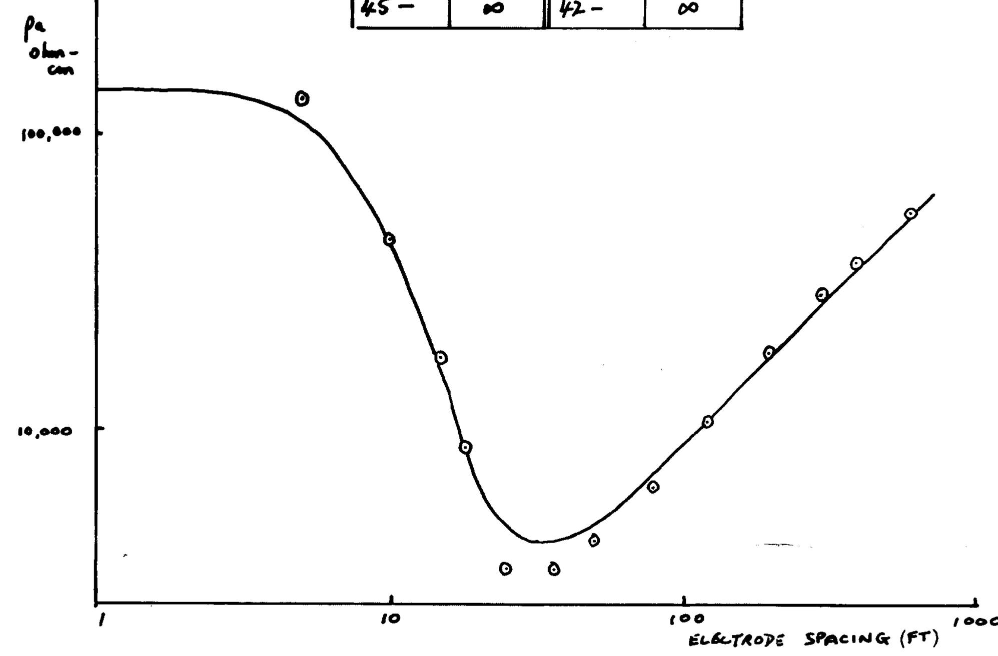
CB P4

*D	ρ	D	ρ
0-2·5	330,000	0-2·5	360,000
2·5-25	8,500	2·5-33	9,250
25-	330,000	33-	∞



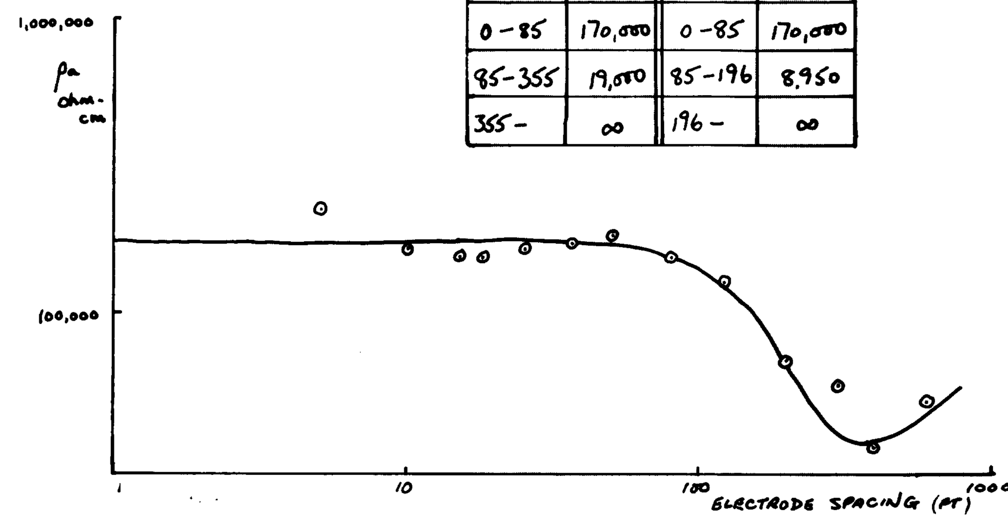
00/10E

*D	ρ	D	ρ
0-4	150,000	0-4	123,000
4-45	3,840	4-42	3,160
45-	∞	42-	∞



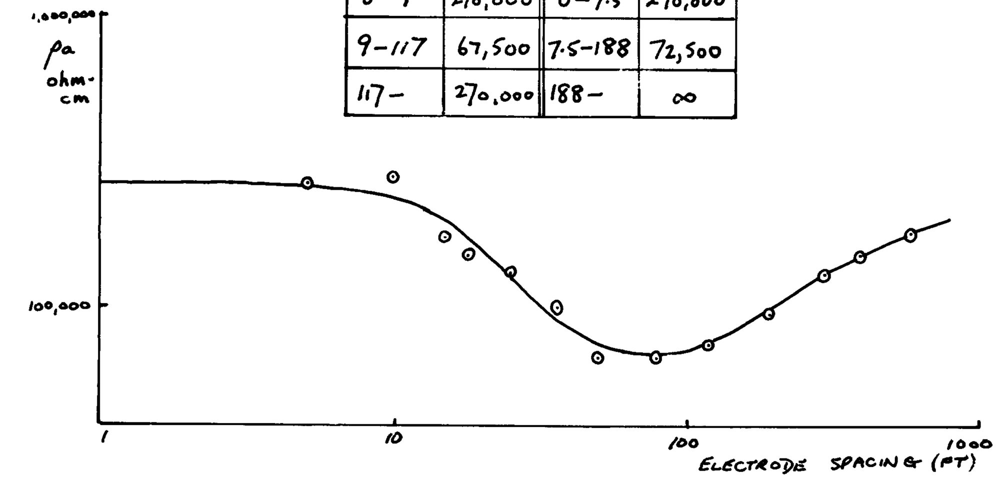
CB 14

*D	ρ	D	ρ	D	ρ
0-85	170,000	0-87	170,000	0-85	170,000
85-128	4,300	87-139	4,300	85-170	8,500
128-	170,000	139-	∞	170-	170,000
		0-85	170,000	0-85	170,000
		85-355	19,000	85-196	8,950
		355-	∞	196-	∞



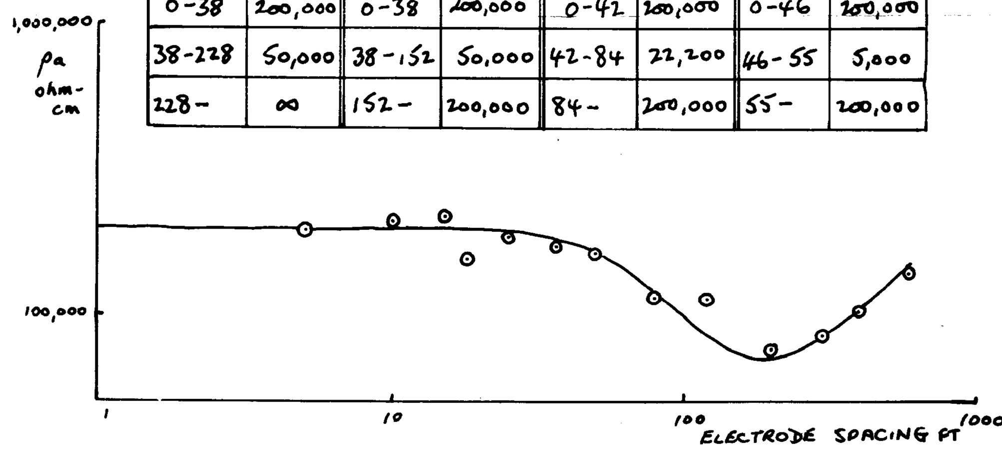
HOLE No. 9

*D	ρ	D	ρ
0-9	270,000	0-7·5	290,000
9-117	67,500	7·5-188	72,500
117-	270,000	188-	∞



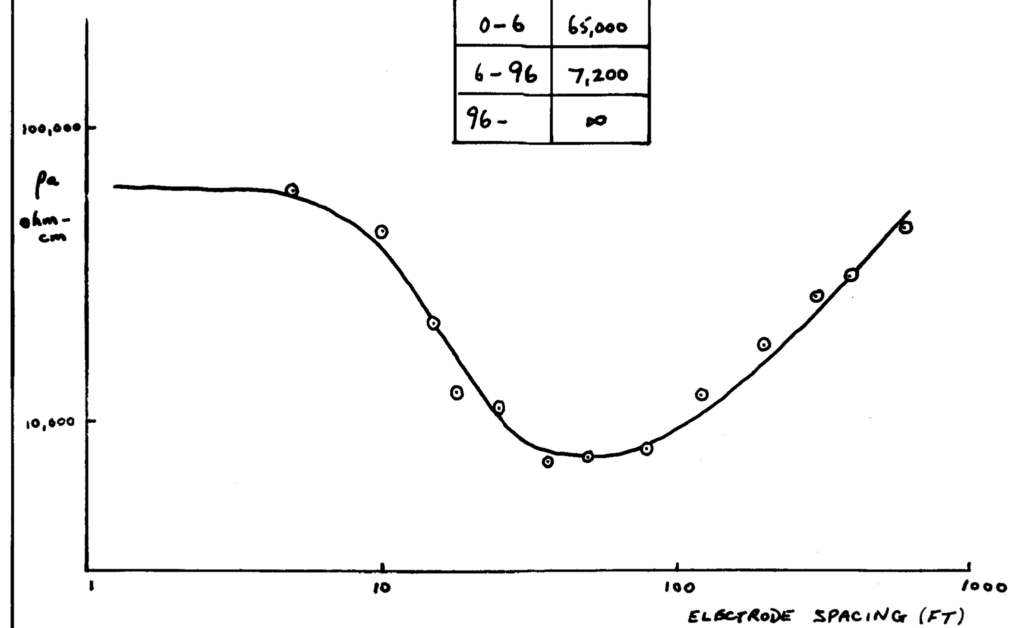
HOLE No. 10

*D	ρ	D	ρ	D	ρ	D	ρ
0-38	200,000	0-38	200,000	0-42	200,000	0-46	200,000
38-228	50,000	38-152	50,000	42-84	22,700	46-55	5,000
228-	∞	152-	200,000	84-	200,000	55-	200,000



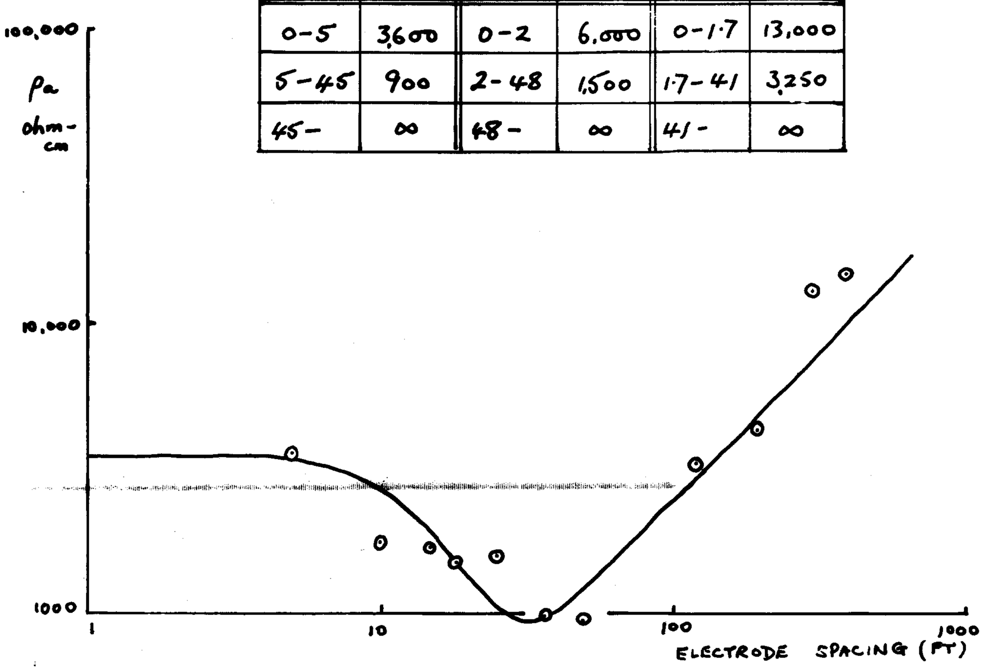
Jj 1N

D	ρ
0-6	65,000
6-96	7,200
96-	∞



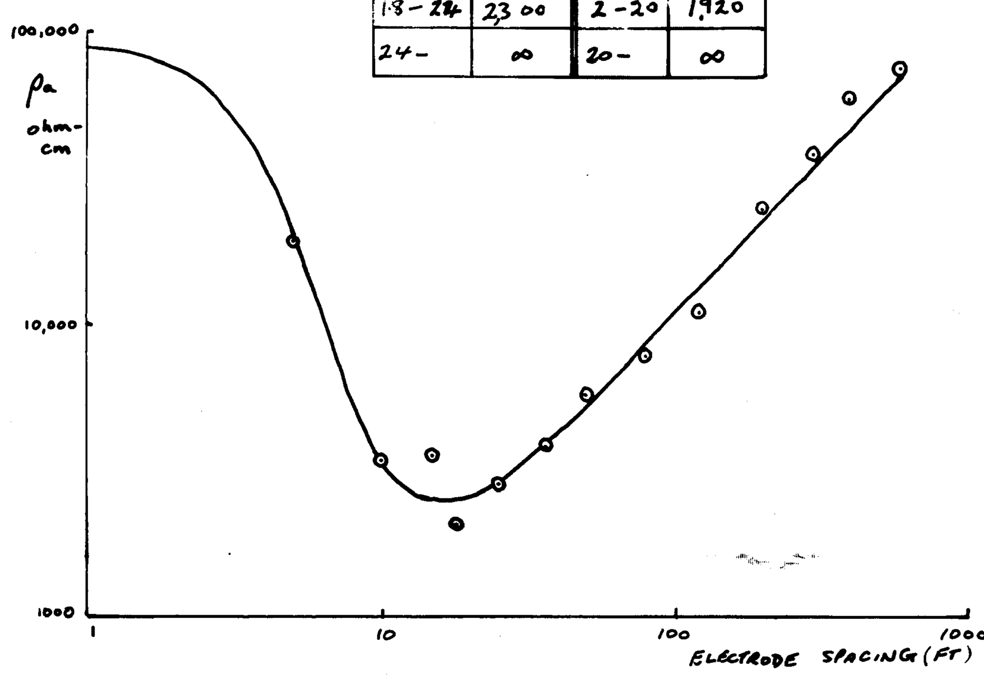
20N/10W

D	ρ	D	ρ	D	ρ
*0-7·5	3,500	0-11	2,200	0-7	3,000
7·5-23	400	11-22	240	7-35	750
23-	∞	22-	∞	35-	∞
0-5	3600	0-2	6,000	0-1·7	13,000
5-45	900	2-48	1,500	1·7-41	3,250
45-	∞	48-	∞	41-	∞



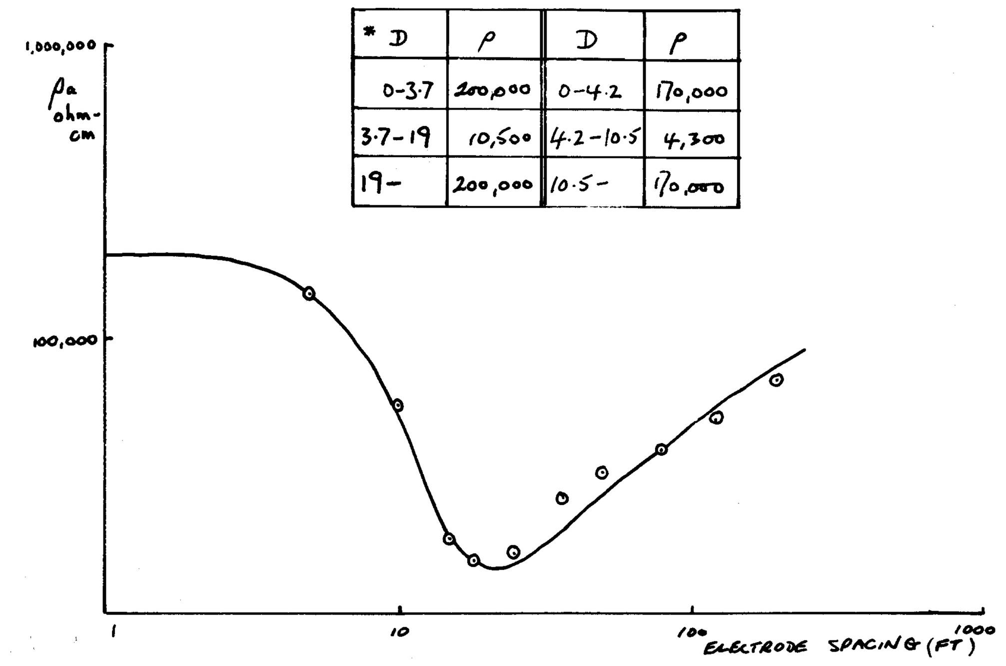
HOLE No. 7

*D	ρ	D	ρ
0-1·8	90,000	0-2	75,000
1·8-24	2300	2-20	1,920
24-	∞	20-	∞



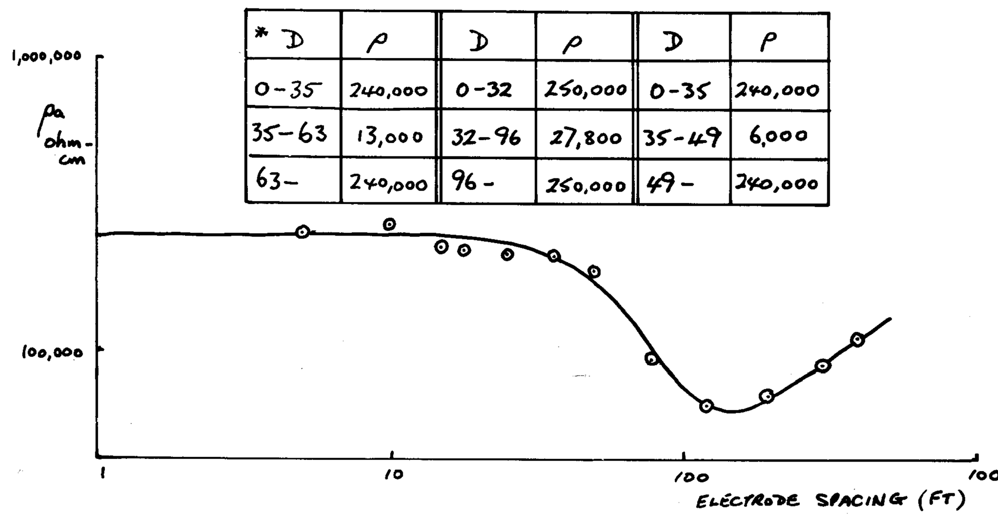
CB 11

*D	ρ	D	ρ
0-3·7	200,000	0-4·2	170,000
3·7-19	10,500	4·2-10·5	4,300
19-	200,000	10·5-	170,000



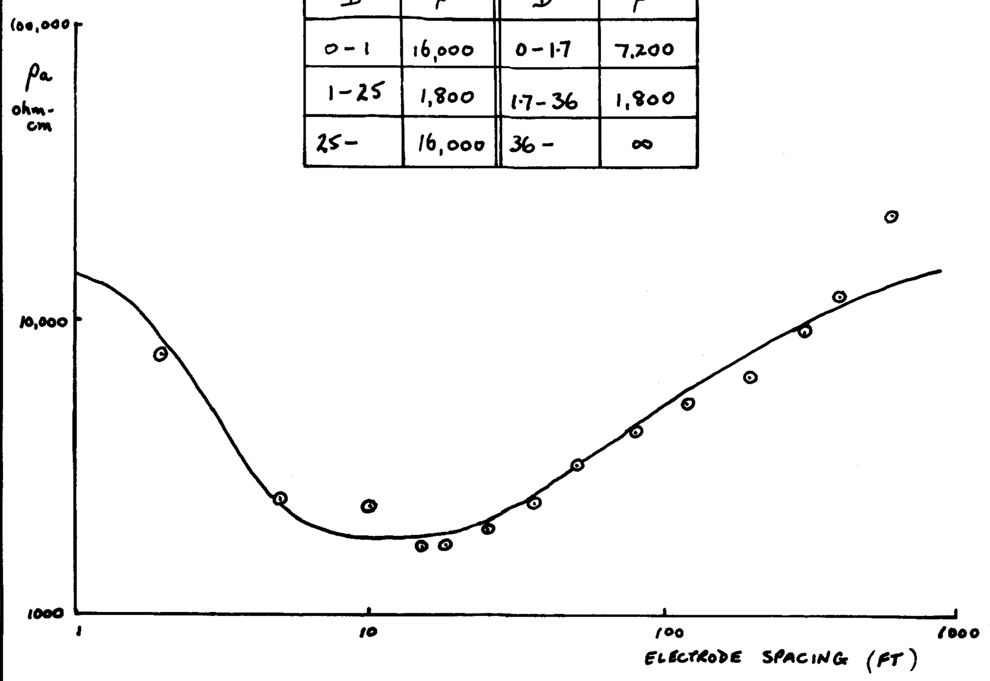
HOLE No. 2

*D	ρ	D	ρ	D	ρ
0-35	240,000	0-32	250,000	0-35	240,000
35-63	13,000	32-96	27,800	35-49	6,000
63-	240,000	96-	250,000	49-	240,000



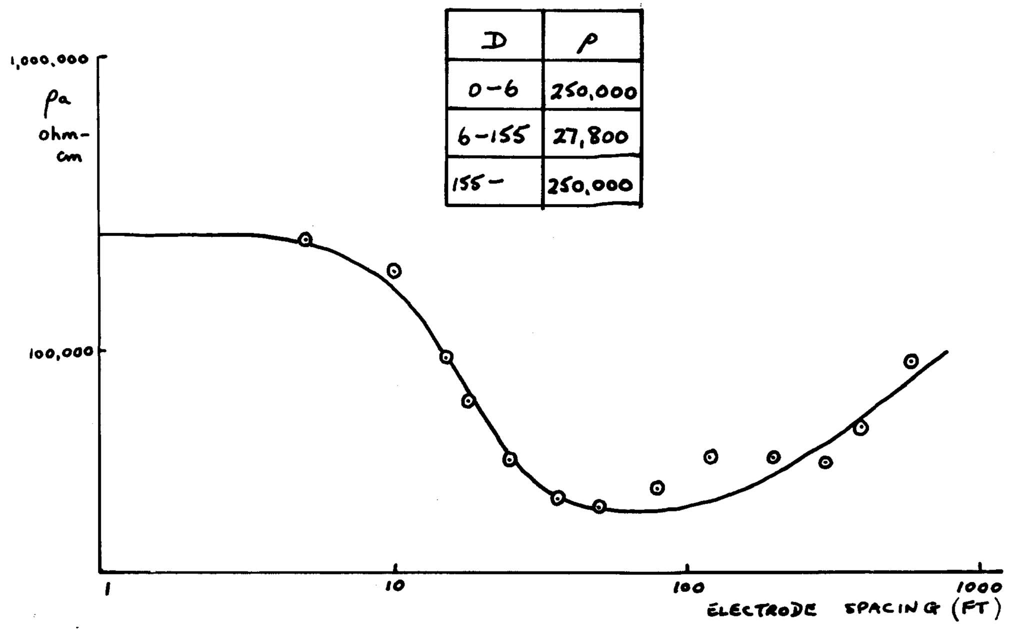
Jj 12N

*D	ρ	D	ρ
0-1	16,000	0-1·7	7,200
1-25	1,800	1·7-36	1,800
25-	16,000	36-	∞



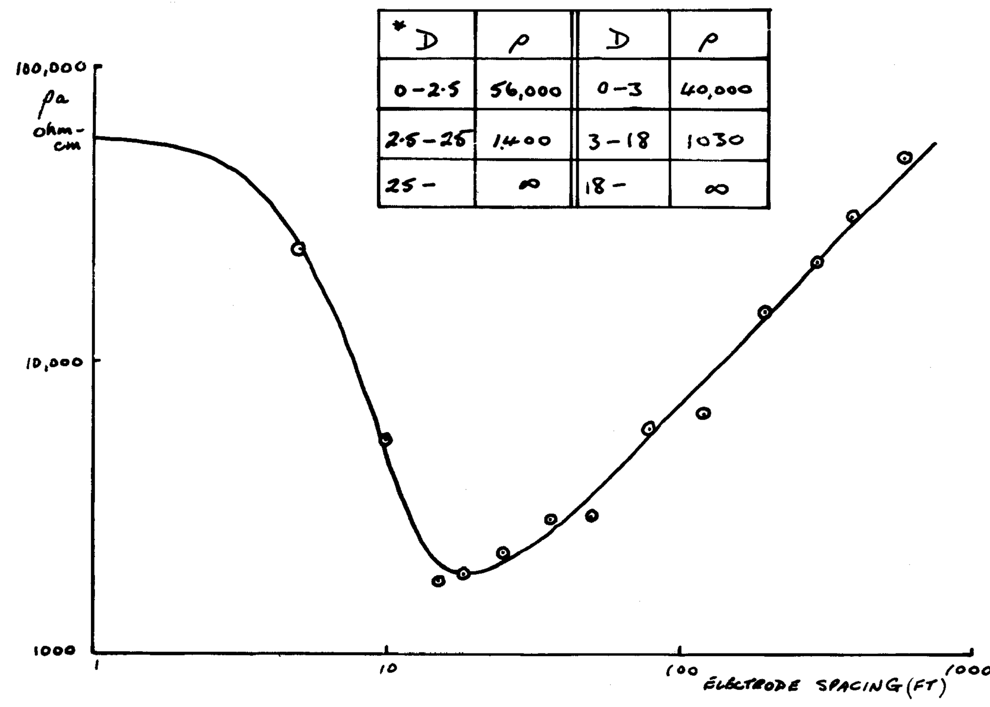
1·7S/33E

D	ρ
0-6	250,000
6-155	27,800
155-	250,000



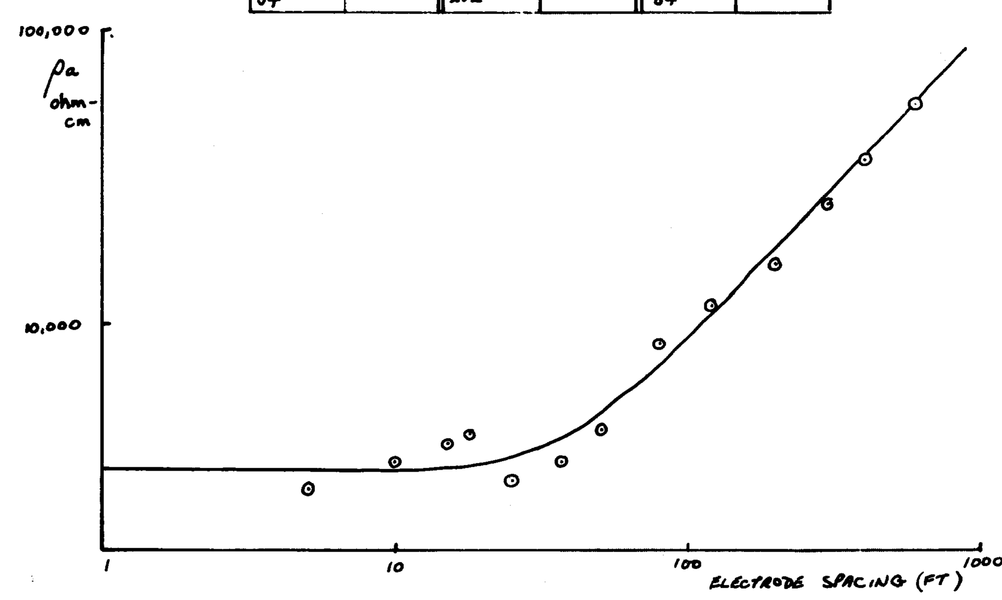
HOLE No. 8

*D	ρ	D	ρ
0-2·5	56,000	0-3	40,000
2·5-25	1400	3-18	1030
25-	∞	18-	∞



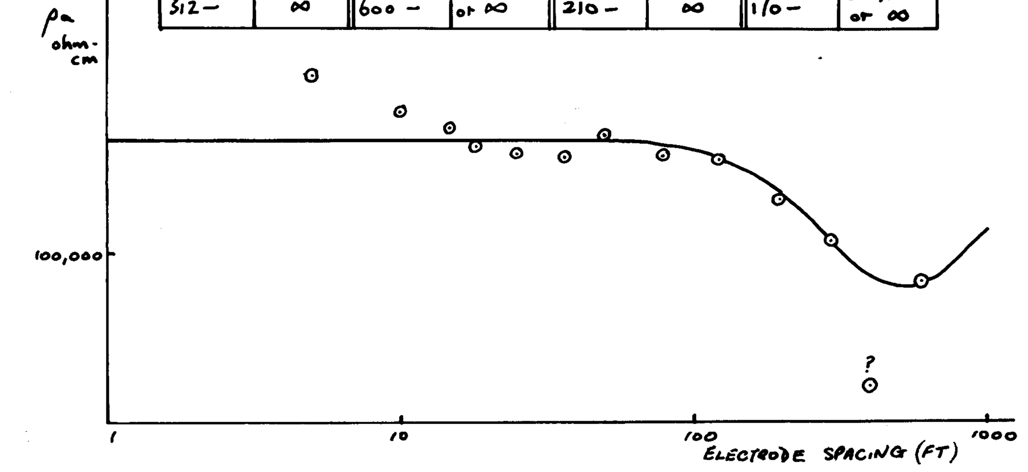
00/18E

*D	ρ	D	ρ	D	ρ
0-32	3,100	0-25	3,100	0-25	3,100
32-	1,120,000 or ∞	25- 50 to 75	12,400	25- 45 to 125	59,000
		50 to 75 -	∞	45 to 125 -	1,120,000
0-9	2,600	0-28	3,100	0-28	3,100
9- 0 to 54	6,050	28- 0 to 252	121,000	28- 0 to 84	27,900
9 to 54 -	∞	28 to 252 -	∞	28 to 84 -	∞



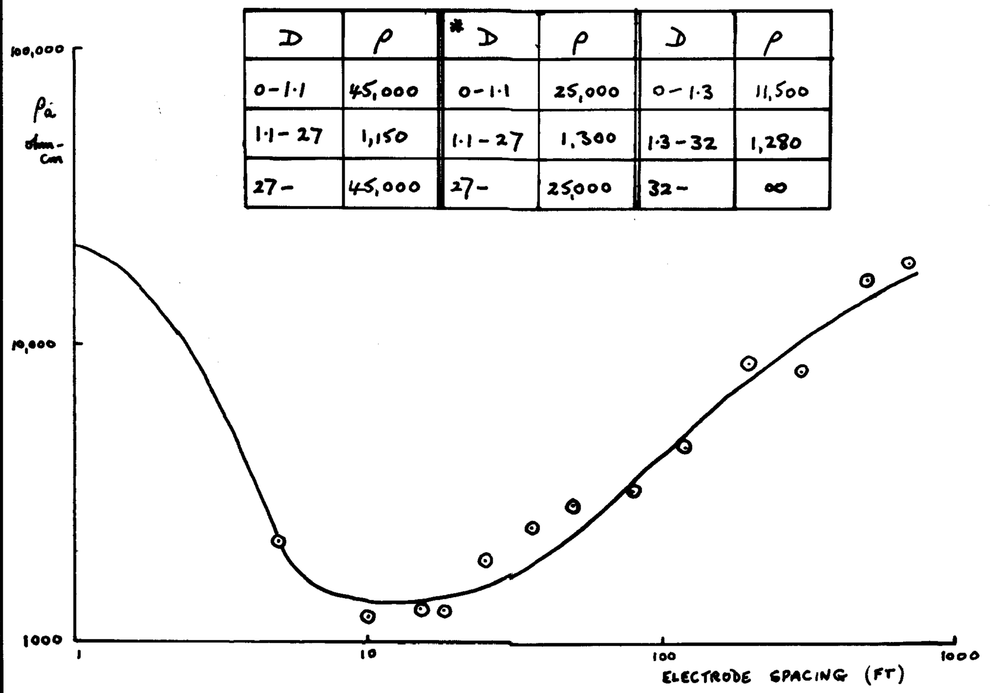
CB 17

*D	ρ	D	ρ	D	ρ	D	ρ
0-120	250,000	0-100	250,000	0-120	250,000	0-130	250,000
120-312	27,800	100-600	62,500	120-210	13,000	130-170	6,800
312-	∞	600-	250,000 or ∞	210-	∞	170-	250,000 or ∞



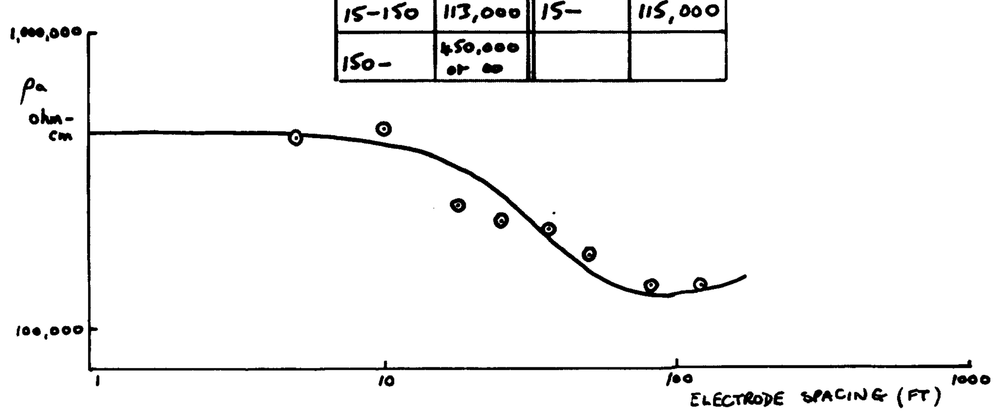
Jj 19N

D	ρ	*D	ρ	D	ρ
0-1·1	45,000	0-1·1	25,000	0-1·3	11,500
1·1-27	1,150	1·1-27	1,300	1·3-32	1,280
27-	45,000	27-	25000	32-	∞



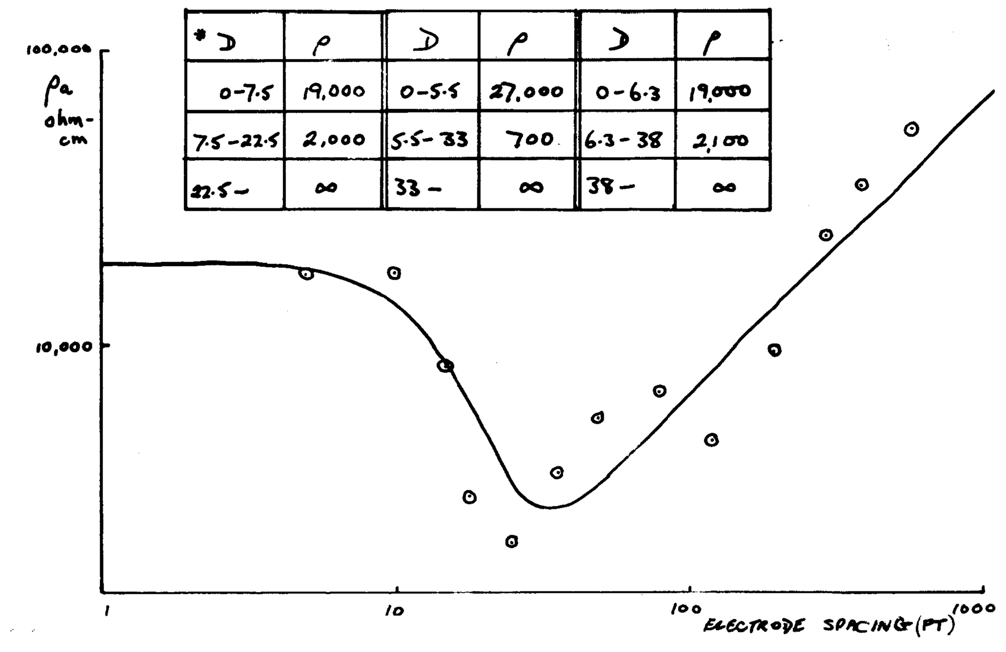
CB 21

*D	ρ	D	ρ
0-15	450,000	0-15	460,000
15-150	113,000	15-	115,000
150-	450,000 or ∞		



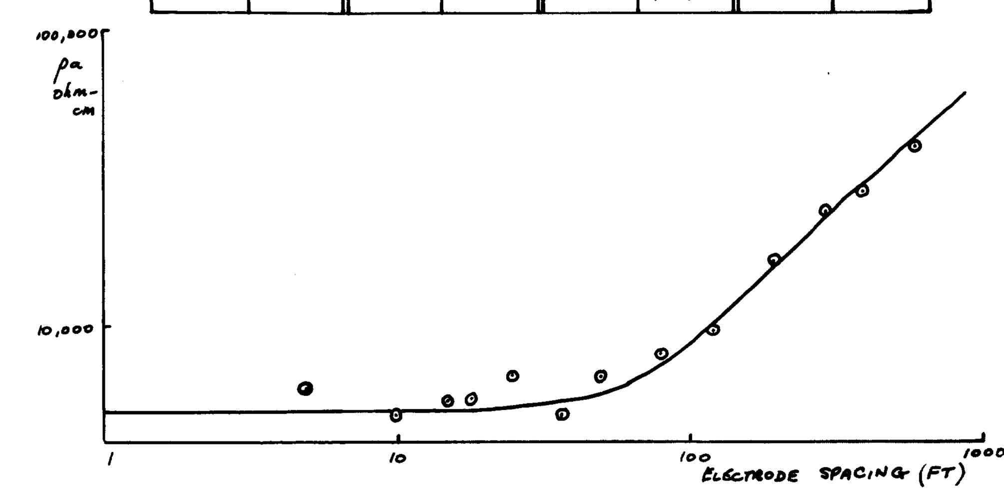
CBP4/10S

*D	ρ	D	ρ	D	ρ
0-7·5	19,000	0-5·5	27,000	0-6·3	19,000
7·5-22·5	2,000	5·5-33	700	6·3-38	2,100
22·5-	∞	33-	∞	38-	∞



BERRY SPRINGS

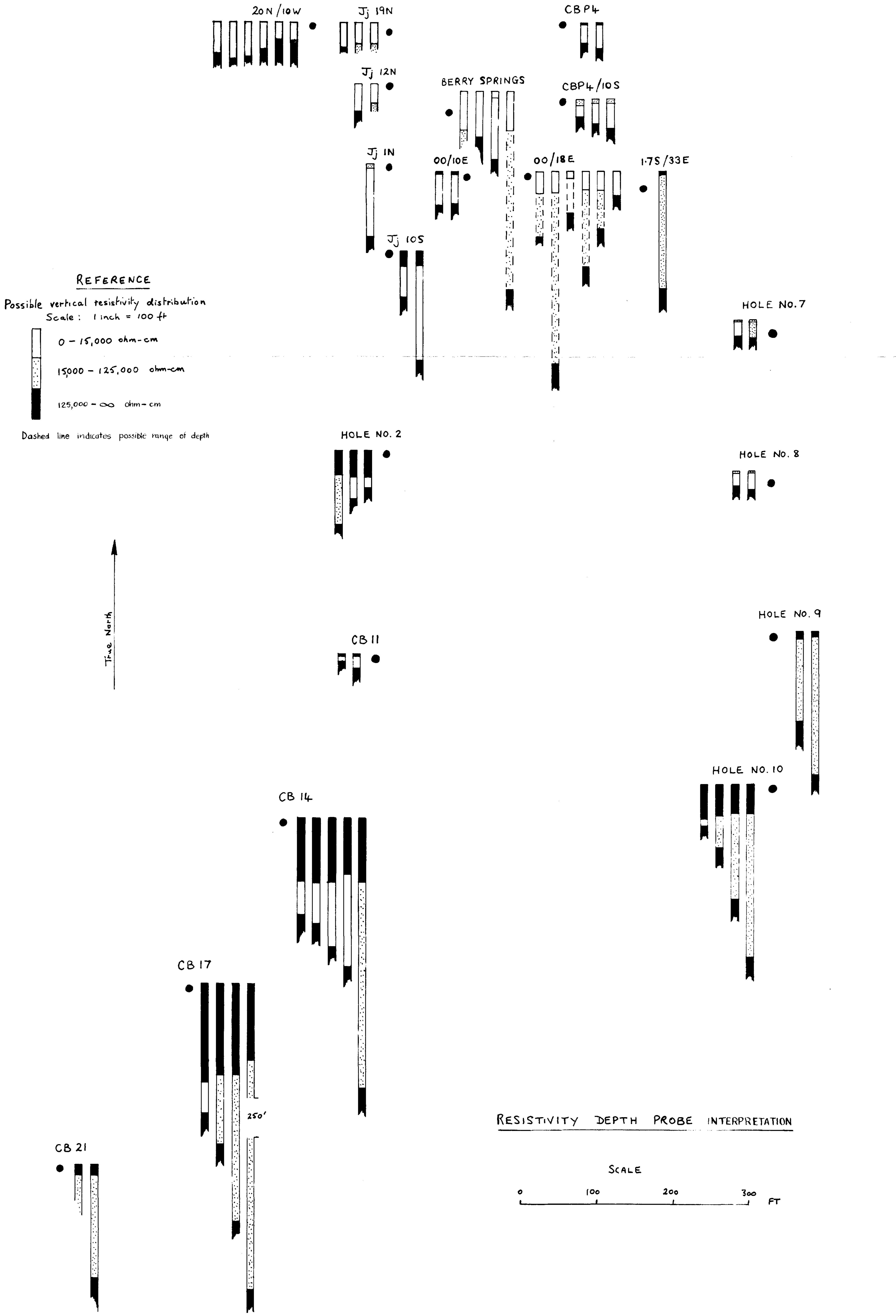
*D	ρ	D	ρ	D	ρ	D	ρ
0-60	5,000	0-52	5,000	0-52	5,000	0-9	5000
60-	200,000	52-	95,000	52- 0 to 260	45,000	9-90	7,500
				52 to 260 -	405,000	90-	∞



RESISTIVITY DEPTH PROBES AND INTERPRETATIONS

REFERENCE

- ρa Apparent Resistivity in ohm-cm
- D Layer thickness (FT) as depth from ground surface for solutions of depth probe
- ρ True resistivity (ohm-cm) of layers
- o Observed values of apparent resistivity
- / Standard resistivity curve for depth probe solution marked *



RESISTIVITY DEPTH PROBE INTERPRETATION

PLATE 4

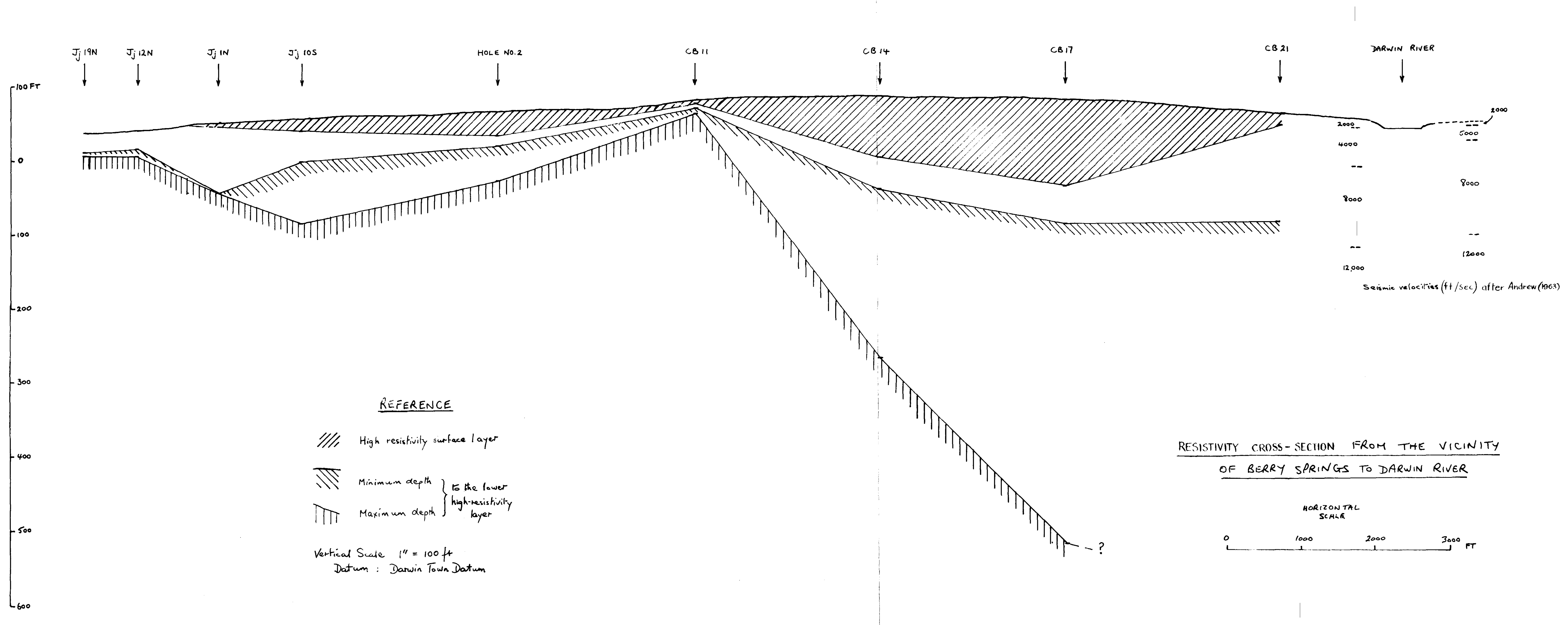
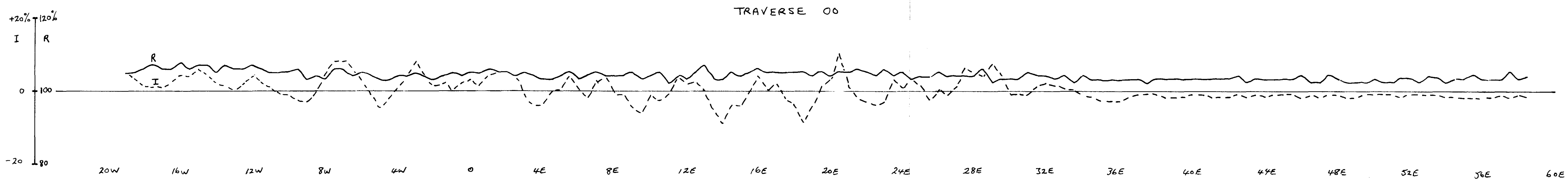
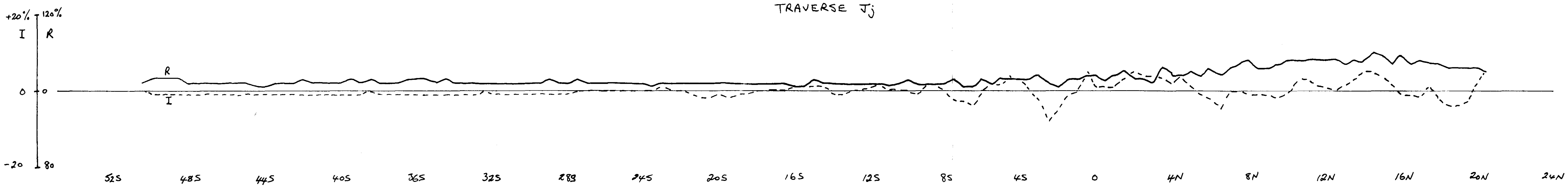

Jj 19N
Jj 12N
Jj 1N
Jj 10S
HOLE No. 2
CB 11
CB 14
CB 17
CB 21
DARWIN RIVER
100 FT
0
100
200
300
400
500
600
2000
4000
8000
12,000
2000
5000
8000
12000
Seismic velocities (ft/sec) after Andrew (1963)
REFERENCE
High resistivity surface layer
Minimum depth
Maximum depth
to the lower high-resistivity layer
Vertical Scale 1" = 100 ft
Datum : Darwin Town Datum
RESISTIVITY CROSS-SECTION FROM THE VICINITY OF BERRY SPRINGS TO DARWIN RIVER
HORIZONTAL SCALE
0
1000
2000
3000
FT

PLATE 5





R = IN-PHASE COMPONENT

I = OUT-OF-PHASE COMPONENT

ELECTROMAGNETIC PROFILES

SCALE

0 400 800 1200 FT