DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

REPORT BK NO. 91/1

REPORT ON GEOPHYSICAL STUDIES AT PENRICE QUARRY, ANGASTON, S.A.

GEOLOGICAL SURVEY

by

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GEOPHYSICS

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DEPARTMENT OF MINES AND ENERGY
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Report on Geophysical Studies at Penrice Quarry, Angaston, S.A.

INTRODUCTION

At the instigation of JLC Exploration Services, geological consultants to Penrice Soda Products Ltd., geophysical studies were done to assist in mapping overburden thickness at Penrice's quarry near Angaston, S.A.(Figure 1).

The quarry is located on the eastern verge of the Barossa Valley, where Tertiary cover tapers off and Cambrian basement rocks are exposed. The quarry product, marble, occurs with compacted shales and siltstones (?schists) in the basement rocks.

The quarry is close to the edge of Tertiary and Quaternary sediments filling the Barossa Valley. According to Cobb,(1986), this edge is defined by the Stockwell Fault, but this is questioned by Curtis (pers. comm. 1990). Whether or no the boundary is fault controlled, what is important to this problem is the dip of the interface between crystalline basement rocks and unconsolidated sediments, since this will determine (a) how close the quarry can come to the interface without danger of groundwater leakage from the Barossa aquifers and (b) whether there may be quarriable marble under the sediments.

ROCK PROPERTIES

The basement rocks are expected to be of low permeability generally. However, basement aquifers are reported containing waters of highly varying salinity, but with no figures given. The upper surface of basement is weathered to a thickness of up to 20 metres.

The sediments comprise clays, sands and gravels with some carbonaceous material, and are up to 130 metres thick over the basin. The depositional procedures have resulted in rapid lateral variations in composition. In the area adjacent to Penrice we can expect a full spectrum of sediments and aquifers (Cobb, 1986).

The aquifers comprise the lower aquifer (salinity 1200-1800mg/l) the middle aquifers (salinity 1000-1500mg/l) and the water-table aquifer (salinity around 1000mg/l) in this area. Thus groundwater appears fairly homogeneous.

The water table is expected at a depth of 5 to 20 metres, deepening to the west.

Geophysically, this means that basement rocks should be fairly resistive (over 100 ohm-metres), while saturated sediments will be moderately conductive (5-20 ohm-metres). Dry sediments may be as resistive as basement. Resistivities lower than 5 ohm-metres are not expected with these groundwater salinity levels, but could occur in bound-water strata, such as clays.

SURVEY DETAILS

Vertical Electrical Soundings (VES) were used to determine the depth to basement in the critical area. These soundings use four electrodes in the Schlumberger array, where the electrodes are placed in a line with two current electrodes outside and two potential electrodes within. The current electrodes are moved steadily outwards to give increasing depth penetration. The ratio of the voltage across the potential electrodes to the current, multiplied by a geometrical factor, yields the average resistivity of the ground to a depth determined by the distance between the current electrodes.

Four soundings were attempted on November 28th, 1990, the locations being shown in figure 2. One sounding was done over outcropping marble, to determine the resistivity of this rocktype. The other three were done at various distances from the basement-quaternary contact, in the vicinity of the quarry, out to a maximum distance of 250 metres. The precise locations for the VES sites were chosen so as to minimise the interference from cultural features such as fences, power lines, railway lines, etc.

Considerable difficulties were encountered in getting satisfactory results, primarily because of the dryness of the top half-metre of ground and consequent poor electrode contacts. In order to get sufficient current into the ground to give measurable voltages it was necessary to apply water to the electrodes, a procedure that causes additional complications. Thus, conditions were far from ideal. However, while none of the soundings could be regarded as good data, most of them eventually yielded sufficient acceptable data to allow an interpretation to be done.

The fieldwork was repeated on December 12th, 1990, a few days after soaking rains had fallen on the area. Three of the VES, omitting that over outcropping marble, were redone, with much better results. Good electrode contacts were achieved without recourse to watering, and current transmission into the ground was consistently high. Voltages at the potential electrodes were higher and more noise-free, and the resulting sounding curves were smoother and more easily interpretable.

INTERPRETATION OF RESULTS

The results are presented in Figures 3 to 9, with interpretations. Each plot shows the data values plotted on log-log scales of apparent resistivity in ohm-metres against electrode separation in metres. The resistivity section which gave the best approximation to the field data is shown above the plot, with the calculated model curve shown as a solid line on the plot. The range of model layer parameters which yield an acceptable fit to the repeat data (Figures 7-9) are given in Table 1.

TABLE 1

INVERSIONS

	BEST FIT RESISTIVITY	THICKNESS	MINIMUM RESISTIVITY	THICKNESS	MAXIMUM RESISTIVITY	THICKNESS
SOUNDING 1						
LAYER						
1	1700	0.1	–	–	–	–
2	40	1.5				
3	1.4	0.5	0.4	0.1	4.5	1.7
4	250	0.5	112	1.2	INF	0
5	2	2.6	0.2	0.1	5.5	7.1
6	900					
SOUNDING 2						
1	207	0.9				
2	43	1.7	41	2.6		
3	22	17.8	21	17.5		
4	280	4.2	125	9	1000	1
5	17	30.2	12	21	20	35
6	580		430		INF	
SOUNDING 3						
1	17.8	0.9				
2	5.8	1.4				
3	0.8	0.6	0.04	0.04	1.2	1
4	1069	0.2	58	2.8	INF	0
5	3.2	7	0.05	0.1	4.6	9.9
6	45					

It will be noted that many of the data points in figures 3 to 6 are very scattered, demonstrating the difficulties encountered in gathering usable data during the first survey. In such cases, consistency in the general data pattern was used primarily to determine which points to fit and which to ignore. The second survey gave much more coherent results, and should be regarded as the more reliable of the two.

Sounding 4, (Figure 6), located on the outcropping marble, was done solely to obtain figures for the resistivity of basement rocks of this type. While of limited value, being for dry rock above the water table, they do give an indication of what to expect. The values obtained were 200-1000 ohm-metres. Deeper penetration might have given figures for saturated marble, but this proved impracticable in the dry circumstances.

Sounding 1 (Figures 3 and 7) is located some 40 metres west of the contact. Data from the earlier survey showed severe problems in the mid-range, from 13 to 25 metres spacing so these data are rejected. Beyond 25 metres, the data are fairly consistent.

The inversion of this data shows a half-metre thick resistive layer overlying two moderately conductive layers before resistive basement is detected. The actual thickness and conductivity of these two layers is not precisely known, partly because of noise in the data in this area (between spacings of 2 and 10 metres) and partly because of inherent ambiguities in the method. The depth to basement can be placed at between 10 and 16 metres, but the knowledge gap in the upper layers makes this interpretation suspect.

The repeat of this sounding (Figure 7) is much more coherent, allowing the intermediate layers to be better defined and the depth to basement more accurately assessed. The results are shown in Table 1. The best fit model gives a basement depth of 5.2 metres, but layer 3 and, particularly, layer 5 can be varied somewhat with only a minor degradation in the fit. Sticking to the bounds of probability, neither layer is likely to be more conductive than the optimum model, but both could quite reasonably be more resistive, resulting in a maximum increase in total sediment thickness of 6.4 metres and a maximum depth to basement of 11.6 metres.

The last three points on this curve cannot be fitted so long as the assumption of horizontal layering is maintained. Field inspection indicates that this sounding is located in a basement gully, and that basement is shallower to north and south of the centre point, under the outer electrodes. This would account for the steepening of the curve between 65 and 100 metre electrode locations, where the model curve drops below the field data points. It is therefore anticipated that between 60 and 100 metres north and/or south of the centre of this sounding the depth to basement will reduce to 4.1 metres (optimum fit) to 8 metres (maximum).

Sounding 2 (Figure 4), located some 65 metres west of VES-1, gave considerably noisier results at electrode separations of 8 metres and greater. The inversion shows the same near surface resistive layer, again underlain by resistivities of around 20 ohm-metres. Depth to basement appears to be around 22 metres, but this figure is given with far less confidence than that for VES-1. The basement also appears to be less resistive (116 ohm-metres compared to 921 ohm-metres) but again the data are not conclusive on this point. If true, it could mean that the point is underlain by more porous siltstones, rather than marble.

The repeat of this sounding gave excellent results, as shown in figure 8. All of the layer resistivities are feasible. There is very little flexibility in the model without degrading the quality of fit by an unacceptable amount, so a depth to basement of 54.8 metres is most probable, with upper and lower bounds of 65.3 metres and 42.1 metres. The geological acceptability of this result is discussed below.

Sounding 3 (Figure 5), located in a paddock west of the railway, some 250 metres from the contact, gave much more consistent results, partly because the resistive top layer is absent here, so that electrode contacts were rather more easily obtained. There is still some ambiguity, however, and the depth to basement can vary from 10 to 69 metres, depending on whether the points fitted are between 80 and 130 metres or between 130 and 200 metres, and on the resistivity of layer 5. This layer shows a high degree of equivalence, so that as long as the conductivity-thickness product of the layer is kept constant, the thickness of the layer can vary between 0 and 60 metres without markedly changing the quality of fit of the model curve. Of course, for a zero thickness the layer would have to be infinitely conductive. Putting a realistic lower resistivity bound on the layer of 2 ohm-metres gives a thickness of some 10 metres, and a depth to basement range of 16 to 66 metres.

The repeat of sounding 3 gave a very different interpretation, although the data are not dramatically different. An optimum fit gives reasonable resistivities and a depth to basement of 10.1 metres. The ranges in table 1 are theoretically possible, but it is unlikely that layers 3 and 5 are more conductive than the optimum model. Ignoring these extremes, the range of basement depths is 9.9 to 16 metres. The bottom layer resistivity of 45 ohm-metres is low for marble or, indeed, any compacted rocks, but may indicate weathered basement.

GEOLOGICAL CONSIDERATIONS

The interpretation of Sounding 1 fits with the geological situation very well, with the proviso that the basement gets shallower to the north and south of the centre point of the spread by 2-3 metres.

Sounding 2 does not fit with geological knowledge, which indicates much shallower basement at this point and, moreover, does not match the layering pattern above basement. It is probable that there are lateral variations in basement, possibly a conductive shear or fault zone, running parallel or sub-parellel to the electrode spread. On this theory, layer 4 (table 1) could be basement, layer 5 the conductive shear, and layer 6 basement on the other side of the shear. This would put basement at 20.1 to 22.3 metres depth, with the shear located within about 10 metres east or west of the sounding location and striking generally north. The shear thickness would be of the order of 20 metres. A mylonitic zone in the Stockwell Fault could give this effect.

Sounding 3 detected a shallow (10 metres) low resistivity (45 ohm-metres) bottom layer. This could be weathered basement, with fresh basement undetected by the sounding, or could be a more porous basement rock. If the former, fresh basement would have to be at a depth of some 200 metres, assuming a 200 ohm-metre layer, in order to remain undetected. 40 ohm-metres is certainly low for Cambrian basement, but not impossibly so.

SUMMARY

The quality of data obtained was initially not as high as desired, because of high contact resistances in the dry surface conditions. The repeat survey yielded excellent data, however, and is regarded as definitive.

The marble evidently has a very high resistivity, as shown by sounding 4, but this will decrease when the material is weathered or saturated.

Sounding 1 indicates a depth to basement of 5.2 to 11.6 metres, the former being the more probable figure. To the north and/or south of the sounding point the depth is expected to decrease to 4.1 to 8 metres, the former being again the best fit figure. Basement resistivity is indicative of marble.

Sounding 2 indicates depth to basement as 20.1 to 22.3 metres, as an upper limit. It is probable that there are basement resistivity changes in the vicinity of this sounding, with indications of a north trending shear or fault zone some 20 metres thick located within 10 metres of the sounding location. General basement resistivities are high enough to indicate marble. Because of the deviations from a simple layered model, depth estimates must be less sure, but basement resistivity estimates are unaffected.

Sounding 3 indicates basement at a depth of 9.9 to 16 metres, with the shallower figure giving the better fit. The basement resistivity of 45 ohm-metres is on the low side for Cambrian rocks, but probably is correct, since higher resistivity material would have to be at a depth of some 200 metres in order to be undetected by this sounding. This seems improbably high, since maximum depths to basement within the Barossa Valley are 130 metres (Cobb,1988)

A R DODDS

GEOPHYSICIST

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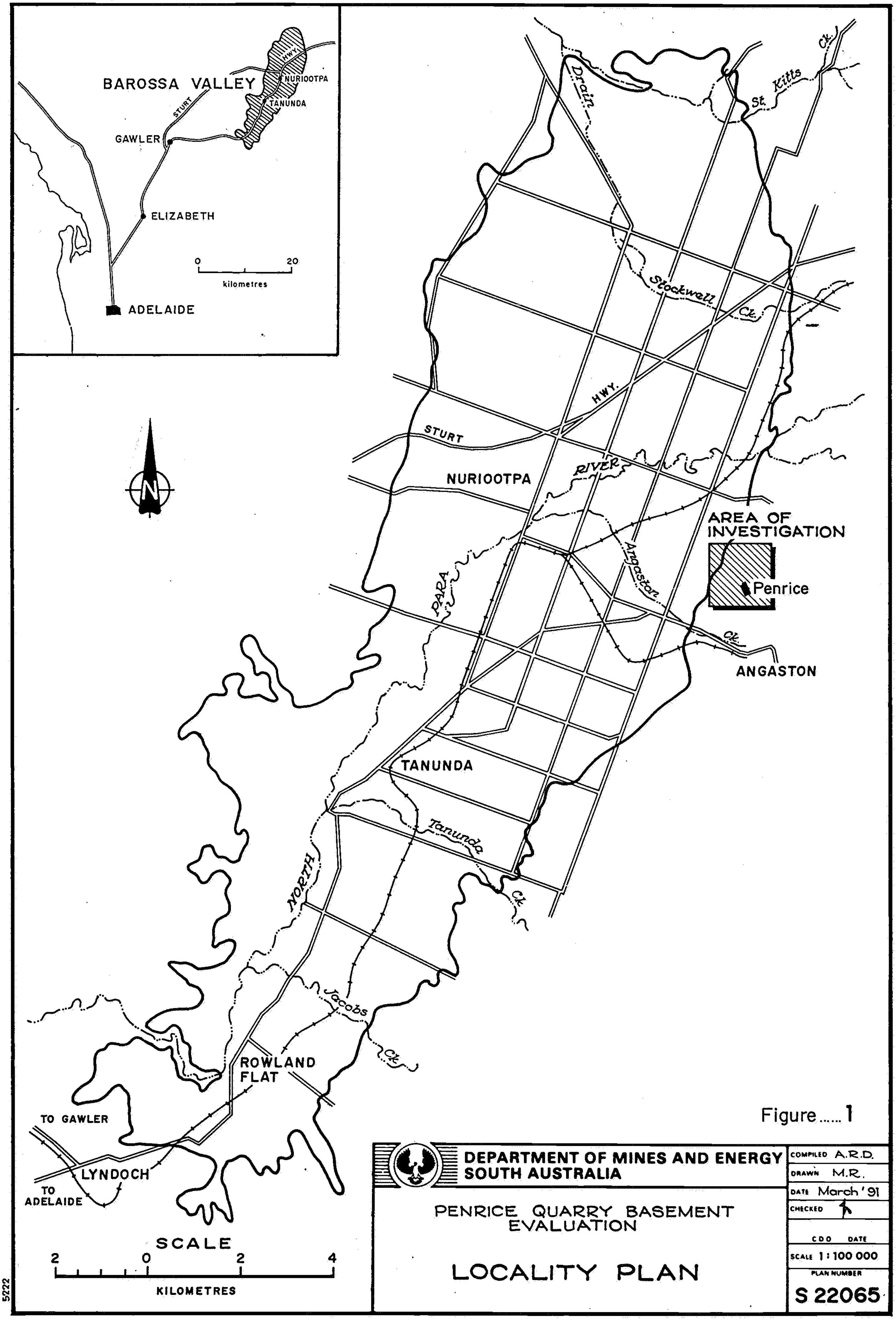

Figure 1

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PENRICE QUARRY BASEMENT EVALUATION

LOCALITY PLAN

COMPILED	A.R.D.
DRAWN	M.R.
DATE	March '91
CHECKED	
CDO DATE	
SCALE	1 : 100 000
PLAN NUMBER	S 22065

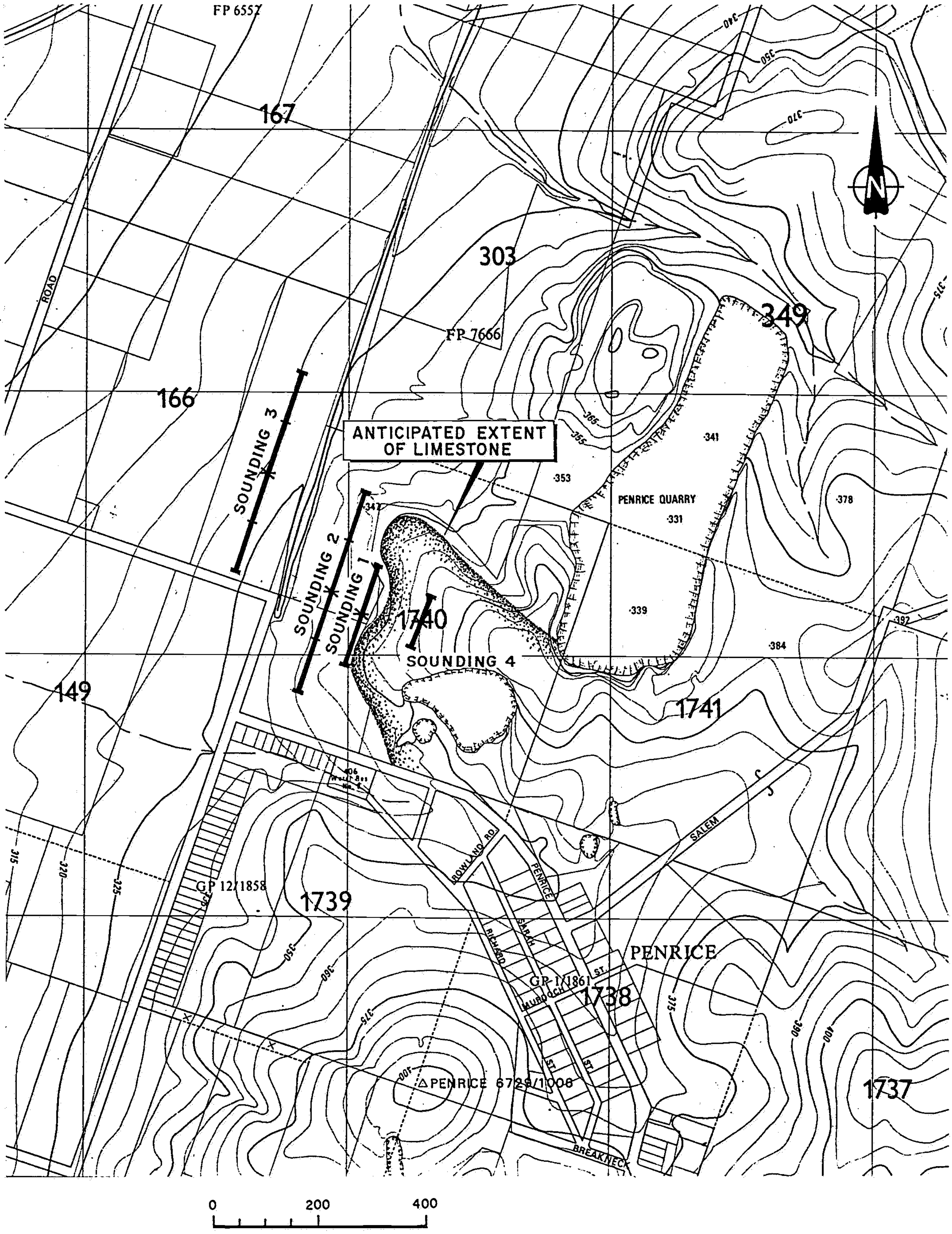


Figure...... 2

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

PENRICE QUARRY BASEMENT EVALUATION
Sections 166 & 1740 – Hundred of Moorooroo

SOUNDING SITE LOCATIONS

COMPILED A.R.D.	C.D.O.	DATE
DRAWN M.R.	SCALE 1: 10000	
DATE March '91	PLAN NUMBER	
CHECKED	S 22066	

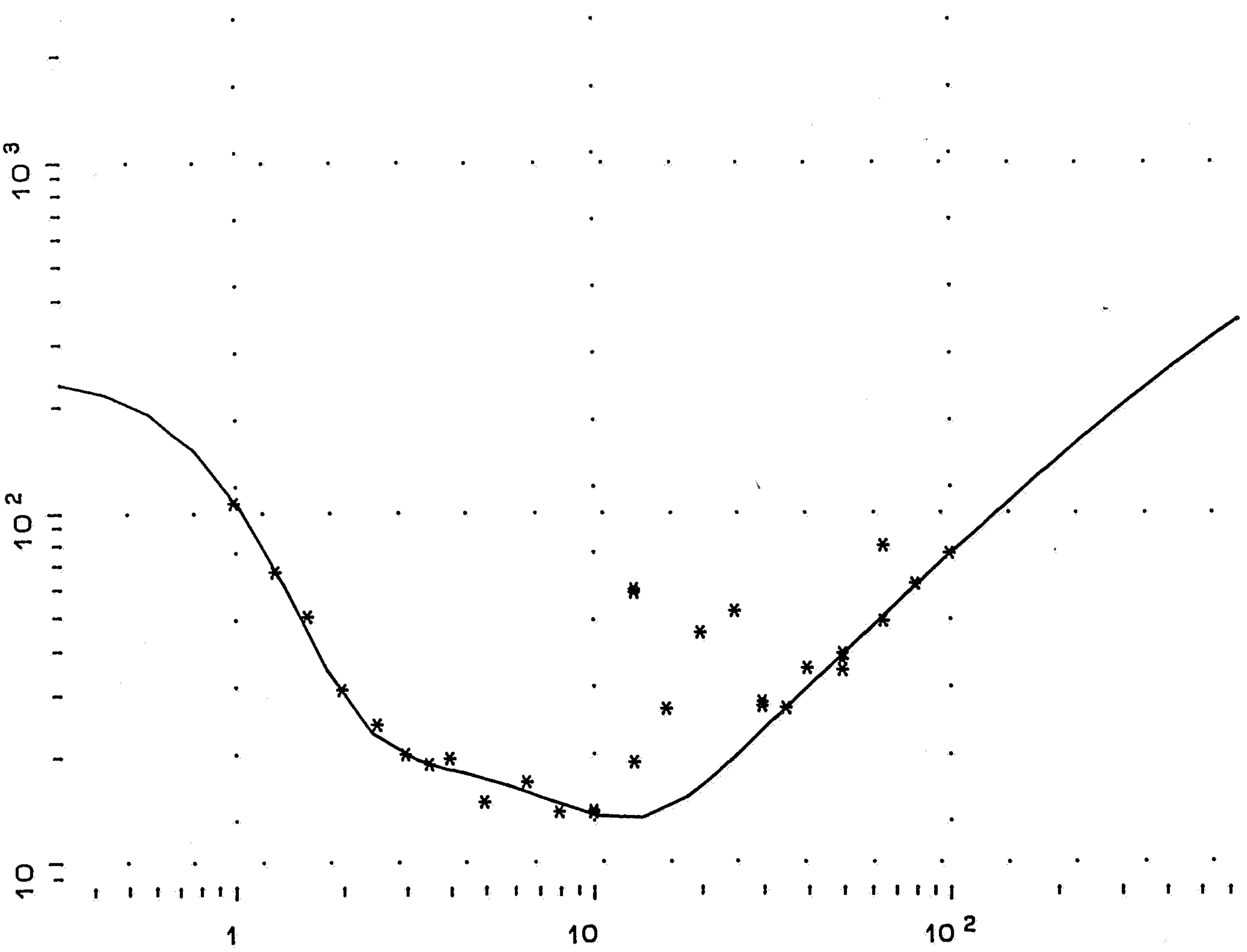
5222

S.A.D.M.E.

PENRICE QUARRY BASEMENT INVESTIGATION

	Resistivity (ohm.m)	depth (m)
	oo	
1		0.000
	246.811	
2		0.460
	18.479	
3		3.310
	8649.756	
4		3.313
	6.551	
5		10.269
	921.457	

SOUNDING 1 1ST SURVEY



* BRGM/GPH * GRIVEL *

Schlumberger

Figure...... 3
S 22067

S.A.D.M.E.

PENRICE QUARRY BASEMENT INVESTIGATION

Resistivity (ohm.m)	depth (m)
oo	
1	0.000
235.058	
2	0.464
35.917	
3	1.065
22.110	
4	21.632
115.566	

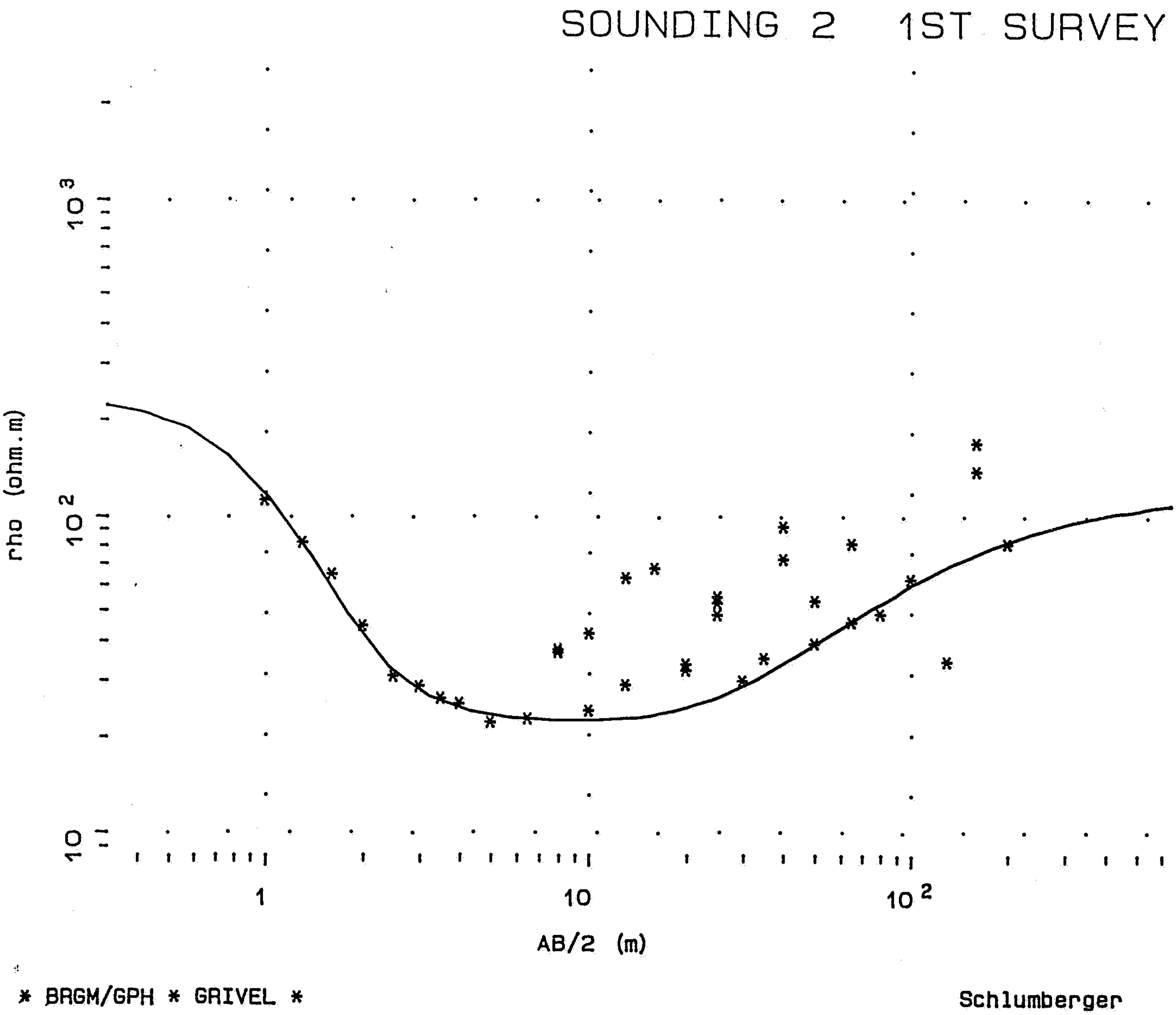


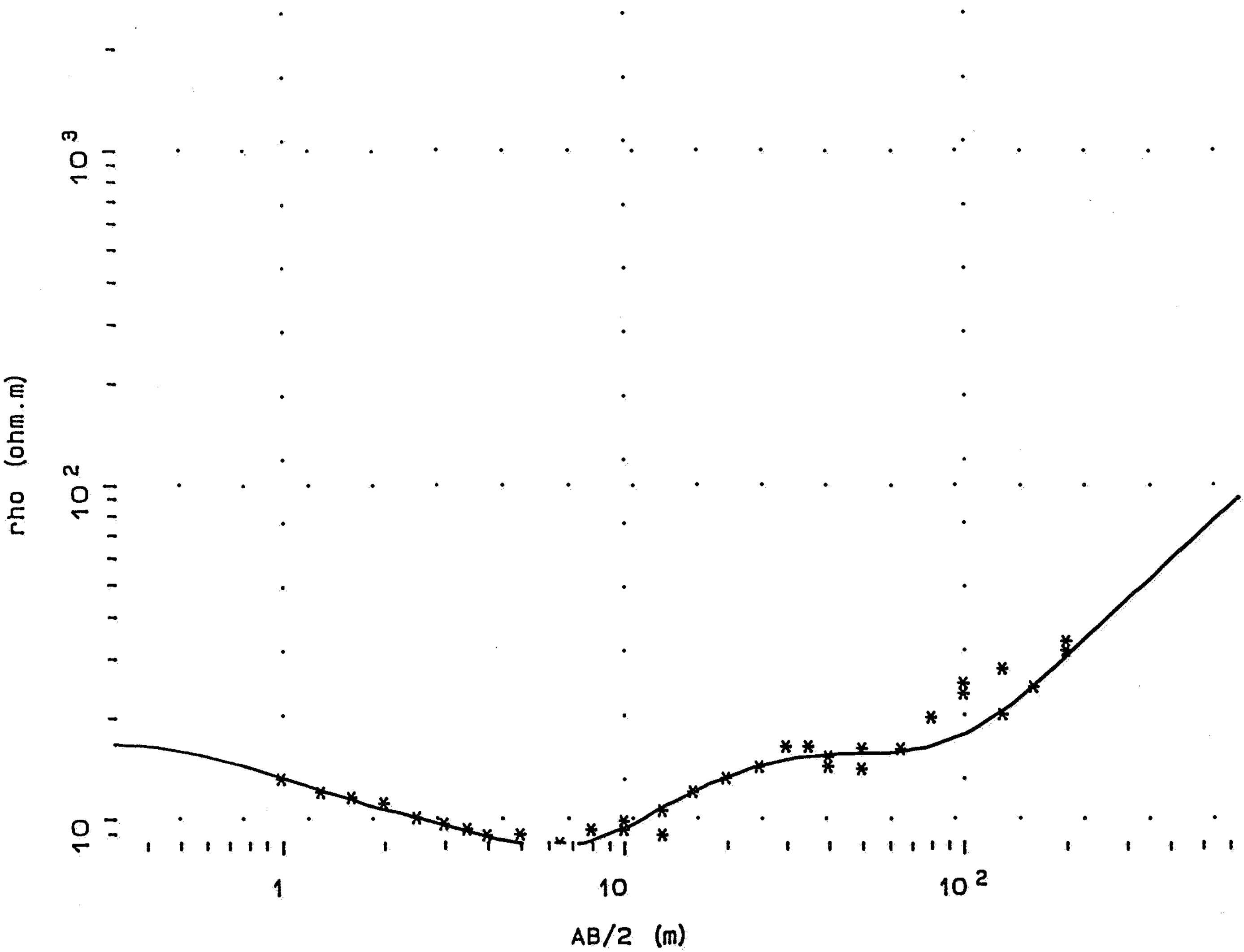
Figure......4
S 22068

S.A.D.M.E.

PENRICE QUARRY BASEMENT INVESTIGATION

	Resistivity (ohm.m)	depth (m)
	oo	
1		0.000
	17.540	
2		0.390
	10.366	
3		2.230
	5.157	
4		5.966
	1069.198	
5		6.198
	11.665	
6		68.818
	774.872	

SOUNDING 3 1ST SURVEY



* BRGM/GPH * GRIVEL *

Schlumberger

Figure 5
S 22069

S.A.D.M.E.

PENRICE QUARRY BASEMENT INVESTIGATION

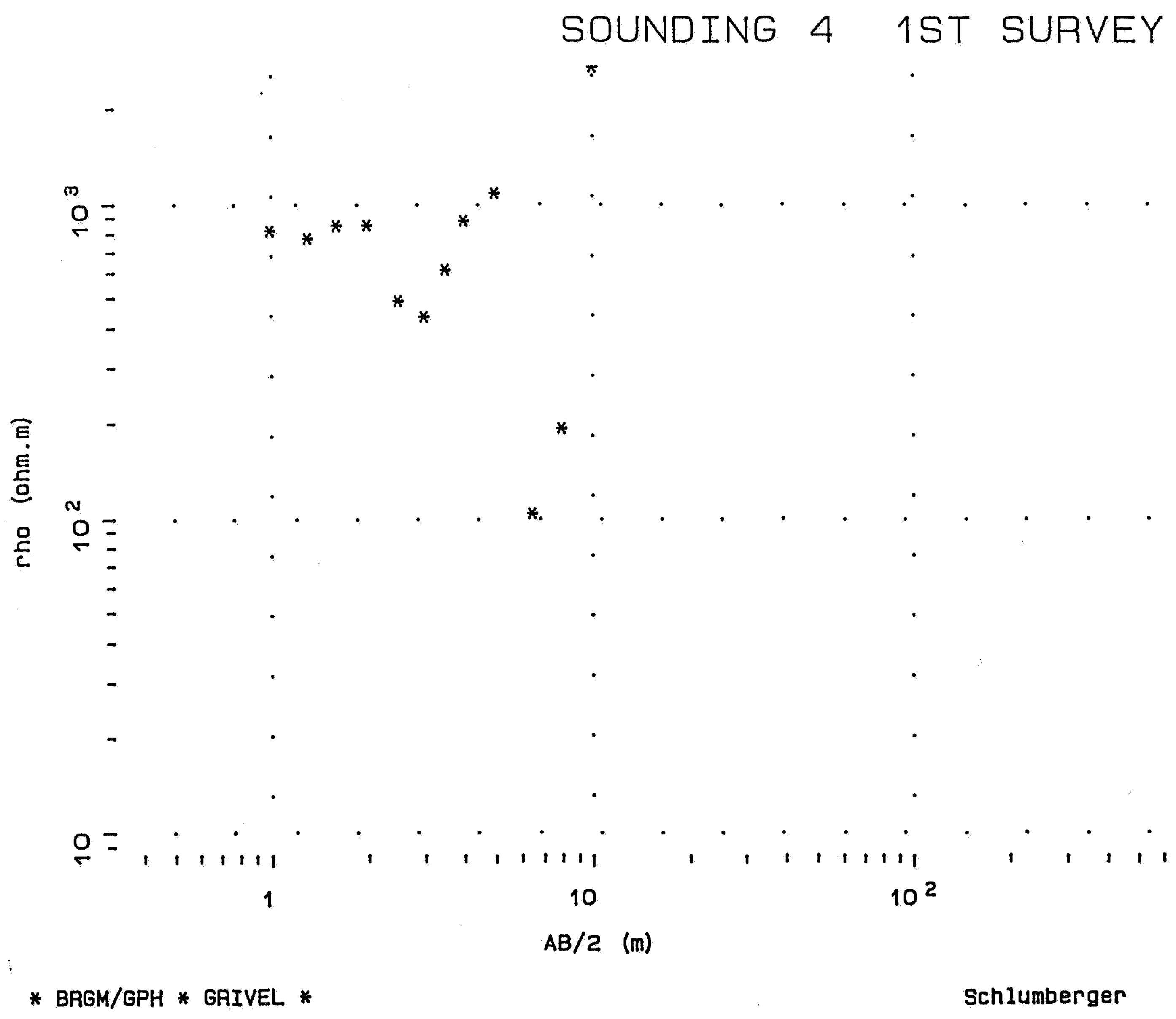
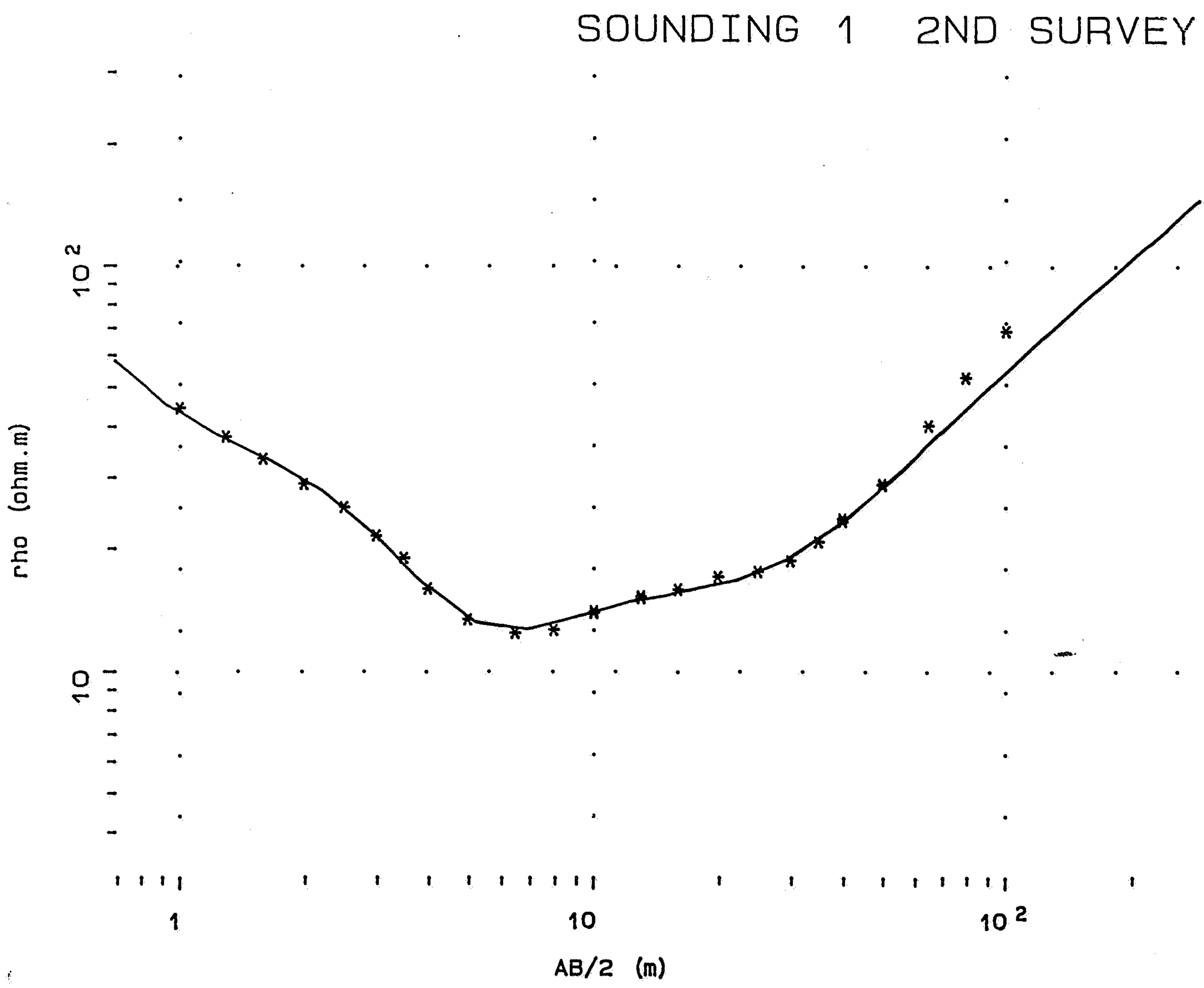


Figure.......6
S 22070

S.A.D.M.E.

PENRICE QUARRY BASEMENT EVALUATION

	Resistivity (ohm.m)	depth (m)
	oo	
1		0.000
	150.110	
2		0.212
	36.770	
3		1.703
	1.409	
4		2.219
	1850.208	
5		2.299
	2.000	
6		4.889
	900.000	



* BRGM/GPH * GRIVEL *

Schlumberger

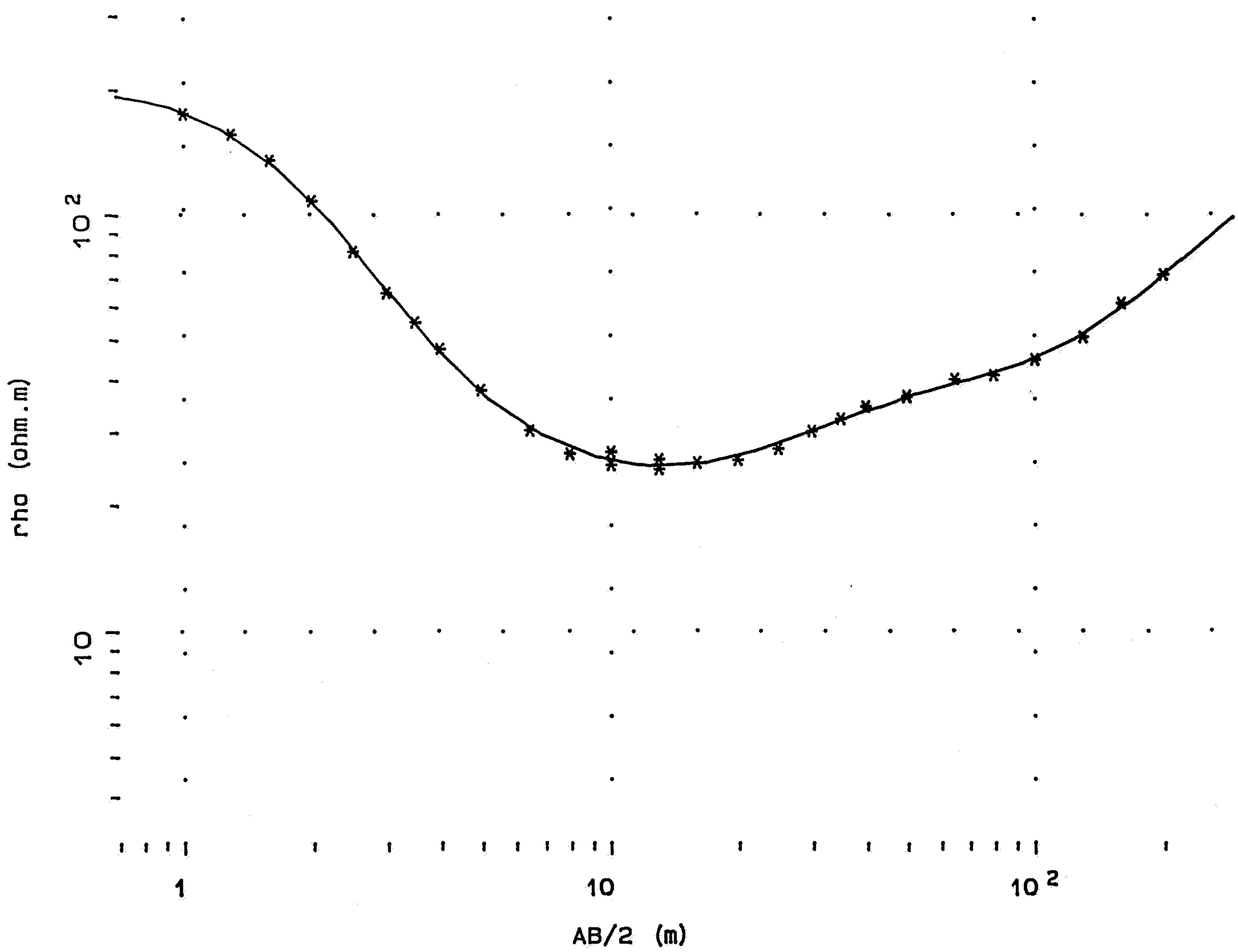
Figure.......7
S 22071

S.A.D.M.E.

PENRICE QUARRY BASEMENT EVALUATION

	Resistivity (ohm.m)	depth (m)
	oo	
1		0.000
	207.504	
2		0.882
	43.427	
3		2.599
	22.187	
4		18.300
	281.283	
5		22.427
	17.245	
6		52.600
	580.148	

SOUNDING 2 2ND SURVEY



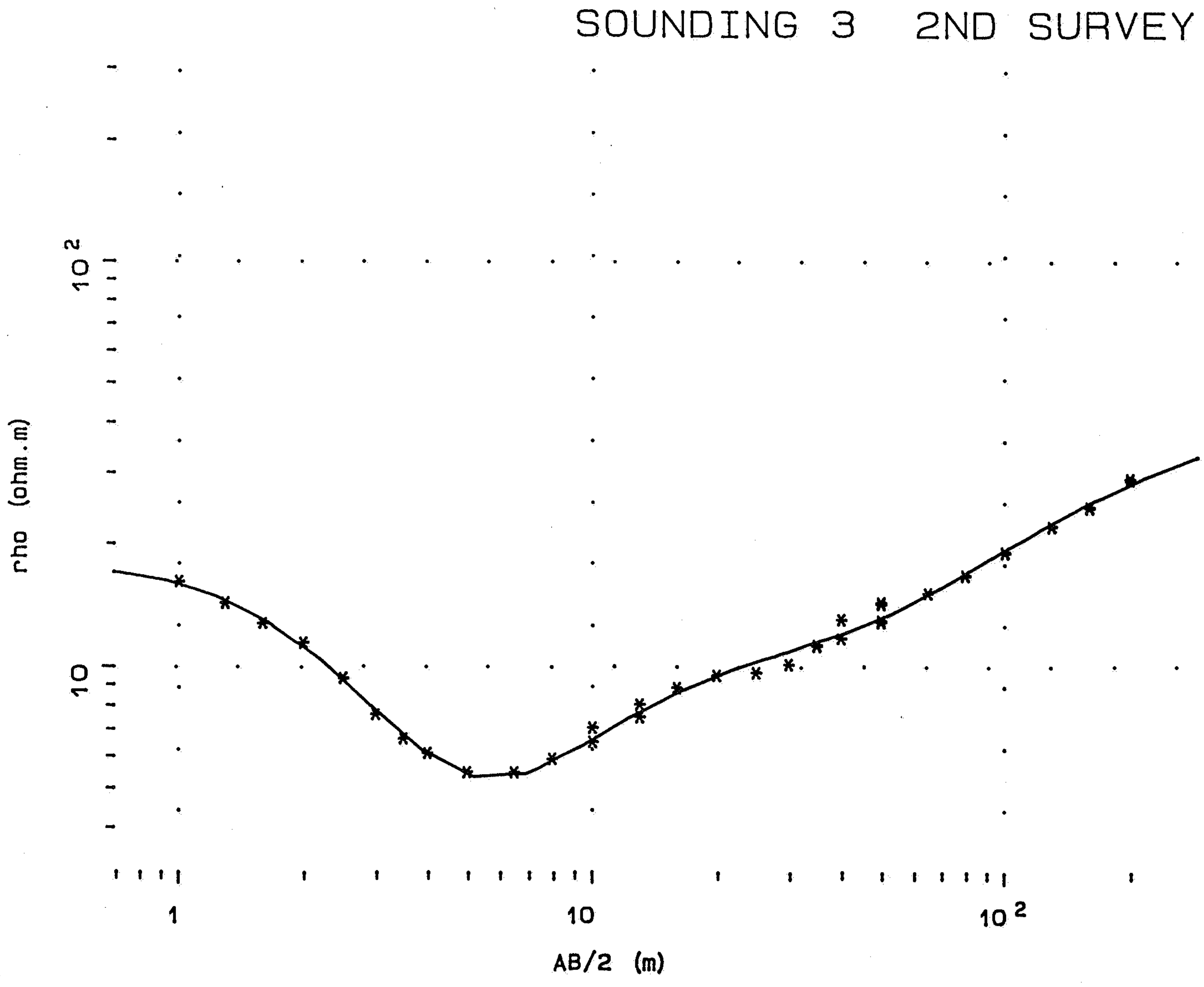
* BRGM/GPH * GRIVEL * Schlumberger

Figure 8
S 22072

S.A.D.M.E.

PENRICE QUARRY BASEMENT EVALUATION

	Resistivity (ohm.m)	depth (m)
	oo	
1		0.000
	17.887	
2		0.933
	5.843	
3		2.523
	0.769	
4		3.194
	1000.000	
5		3.361
	3.255	
6		10.358
	45.145	



* BRGM/GPH * GRIVEL *

Schlumberger

Figure......9
S 22073