DEPARTMENT OF MINES

SOUTH AUSTRALIA

GEOPHYSICS IN THE SEARCH FOR GROUNDWATER
MIMILI STATION (FORMERLY EVERARD PARK)

by

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Rept.Bk. No. 74/74
G.S. No. 5393
D.M. No. 924/73

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ABSTRACT

The results of tests using seismic refraction and electrical resistivity methods in the area around Mimili Station in the far north-west of South Australia indicate that such methods, especially when they are used in conjunction with each other, may give valuable information on the subsurface, particularly as regards depth to bedrock in alluvial-covered areas.

The presence of groundwater may be inferred from an association of seismic velocities and electrical resistivities,

viz. velocities of 1500-2000 m/sec in association with resistivities of 10-60 ohm/metres could be considered diagnostic of water-saturated alluvium.

Although the area has a high "noise" content from near-surface effects, the magnetic method seems to be useful for locating basic dykes which may act as groundwater traps.

A number of drillholes have been recommended to test the conclusions of this report.

INTRODUCTION

Mimili Station (formerly Everard Park Station) is located in the far north-west interior of South Australia, 115 kilometres south of the S.A.-N.T. border and 67 kilometres west of the Stuart Highway. It lies within the Everard Ranges which rise abruptly to heights of 300-400 metres out of the surrounding plains.

Rainfall on the average, amounts to less than 250 mm annually. However, it is quite irregular, so that droughts may continue over a number of years before being relieved by periods of often exceptionally high rainfall (as in 1973).

The alluvial and colluvial plains which surround the Everard Ranges are covered with high protein grasses and spinifex which support a thriving cattle industry. The lack of any viable surface waters means that groundwater is a precious commodity.

GROUNDWATER : MODES OF OCCURRENCE

In this area groundwater occurs predominantly through the downward percolation of surface rainfall and the run-off from the ranges. It collects and is stored in shallow aquifers (sands and gravels) which are found in the alluvia and colluvia of outwash fans or in bedrock depressions in the valleys between the ranges.

The valleys themselves may be controlled by faulting or jointing in the crystalline basement rocks (Miller, 1967) as are the systems of shears and dykes which traverse the area (Krieg, 1972). These shear zones (and possibly jointing in the dykes too) comprise the other principal source of groundwater.

REGIONAL GEOLOGY

Mimili is situated on the Musgrave Block which is an uplifted area of crystalline ?Lower to Middle Adelaidean metasediments and intrusives. Both the metasediments and the intrusives are cut by swarms of mafic dykes whose trend is north-west.

Abutting the Musgrave Block on its eastern margin on a faulted contact is a Middle Adelaidean sequence of strongly folded but unmetamorphosed sediments.

Mildly folded Palaeozoic sediments overly these Adelaidea beds with a marked angular unconformity, achieving thicknesses of greater than 4000 metres in the Officer Basin which lies to the south of the Musgrave Block.

The Great Artesian Basin in this region is represented by thin flatlying Mesozoic sediments east of the area and therefore cannot be considered of much importance when evaluating the groundwater prospects.

Recent aeolian and alluvial sediments blanket most of the area.

For a more detailed description of the regional geology refer to Krieg (1972), on whose work the above résumé is based.

LOCAL GEOLOGY

Refer to Plan No. S10652 which shows the area concerned, its geology, and the locations of geophysical traverses.

The dominant rocks are biotite hornblende gneisses of the Musgrave Block, intruded by gabbro and microgabbro dykes. South and west of Robb's Well massive inselbergs of the Ilbillie Adamellite are exposed.

The intermontane valleys and alluvial plains are formed from ?Recent shallow red clays and sandy soils.

There are small isolated patches of Tertiary quartzose silcrete.

GEOPHYSICAL TECHNIQUES

Seismic refraction, resistivity and magnetic methods were used. Their various attributes are described below.

1. Seismic refraction

The velocities measured in conventional seismic surveys refer to the velocities of compressional waves travelling through the media concerned. They are thus related to the elastic properties (bulk moduli) of the media. Some representative values are tabled overleaf.

TABLE 1

SEISMIC VELOCITIES OF VARIOUS MATERIALS

Material	Compressional velocity (m/sec)	Reference
Air	330	Parasnis, 1966 (p. 120)
Dry sand	150-700	Emerson, 1968
Water	1450	Parasnis, 1966 (p. 120)
Wet sand	1500-2000	Emerson, 1968
Crystalline rocks of Musgrave Block (Mt. Cavanagh, N.T.)	5320-5490	Nelson, 1973

Note that because of its high incompressibility water has a fairly high velocity.

Theoretical considerations (Gassman, 1951; White and Sengbush, 1953) of compressional waves travelling through a simple packing of quartz spheres show that the velocity should range from 220 m.sec to 520 m/sec when the pore filler is air and from 1580 m/sec to 1850 m/sec when the pore filler is water.

Investigations by Wyllie et al. (1956) on sandstone specimens indicate that for water saturations of up to 70% the velocity remains sensibly constant and of the same order as the dry velocity. From 70% to 100% of full saturation the velocity increases rapidly.

Emerson (1968) refers to this and other investigations, concluding that "dry and partially water-saturated sands may be distinguished from fully-saturated sands by compressional wave velocity".

Where unconsolidated sediments are suspected to overly bedrock, therefore, the seismic refraction technique can be used to determine if groundwater is present and also to determine the depth of the water table and the thickness of the sediments. It should be noted, however, that velocities in the range 1500-2000m/sec are not of themselves diagnistic of water-saturated sediments : in fact many of the softer sedimentary rocks as well as some weathered crystalline rocks may have velocities of this order when dry.

2. Resistivity

The minerals which form rocks are, with the exception of the metallic and semi-metallic minerals, very poor conductors of electricity. However, the rocks themselves have either pores or minute fissures or joints along crystal grain boundaries in which water can collect, and this water, more often than not will contain dissolved salts. Therefore rocks, depending on their porosity, their degree of water saturation, and the salinity of the water, will conduct electricity ionically to a greater or lesser degree.

Sediments containing large amounts of clay will generally act as excellent conductors of electricity since clays are capable of ion adsorption. The mechanism of conduction therefore consists of ion exchange on the grain boundaries rather than through diffusion of ions in interstitial waters.

The resistivities of rocks vary widely, but it is possible to make some generalizations, as in Table II.

TABLE II

RESISTIVITIES AND ROCK TYPES

Resistivity (ohm-metres)	Rock type
3-4 (or less)	Clays or highly saline groundwaters (10 000 mg/l)
4-10	Saline groundwaters (4 000-10 000 mg/l)
10-15	Brackish groundwaters (2 000-4 000 mg/l)
15-60	Fresh groundwaters (2 000 mg/l)
100-10 000	Consolidated rock (resistivity increasing with increasing consolidation)

These generalizations hold true, of course, only in the appropriate geological context.

3. Magnetic methods

Most rocks possess a ferromagnetic susceptibility particularly those containing magnetite, so that when they are placed in a magnetic field such as the earth's they acquire a magnetization of their own. The secondary magnetic field thus induced will lead to distortions in the otherwise smoothly varying field of the earth. The amplitude and shape of these distortions will depend on the geometrical shape of the causative body, its size, susceptibility and depth of burial and also on the inclination of the earth's magnetic field at that point.

Basic rocks have in general higher susceptibilities than the more acidic rocks, e.g.,

K (diabase) = 0.000078 to 0.0042

K (gabbro) = 0.00044 to 0.0041

K (granite = 0.00003 to 0.0027

K (porphyry) = 0.000023 to 0.0005

K (gneiss) = 0.00001 to 0.0020

(see Jakosky, 1950, p.165). Therefore, in the geological setting of Mimili it may be possible to use the results of magnetic measurements in detecting basic dykes, their depth, thickness and their attitude.

FIELD TECHNIQUES AND INTERPRETATION

1. Seismic refraction

A Texas Instrument Co. 7000B recording seismograph was used to obtain a record of geophone response to explosions detonated electrically by means of a capacitance blaster. Twenty-four geophones were arranged in in-line spreads at each location with a distance between each geophone of 9.14 m (30 ft). After timing the records for the first onset of energy the results were plotted as time-distance graphs which were then analysed for velocities and depths of the various layers.

2. Resistivity

Resistivity depth probes were made at each of the sites MDP1 to MDP4, shown in Plan No. S10652. These employed the Schlumberger array. Current was introduced into the ground as a 0.3 hz square wave through steel stakes at two points, A & B (see Plan No. 74-126). Between two other points, M & N, in line with A & B and placed so that the entire array was symmetrical about the centre point the potential difference was measured using a McPhar P660 Induced Polarization receiver. Note that the distance MN is very much less than the distance AB so that effectively the voltage gradient dv/dx is measured.

The voltage/current ratio was muliplied by a factor depending on the geometry of the array to give the so-called apparent resistivity. Electrodes A & B were expanded progressively so that when the apparent resistivity for a given electrode configuration was plotted against AB/2 a sounding curve was derived. Each such curve was then analysed using master curves (Orellana and Mooney, 1966) to give the distribution of resistivity with depth.

In the case of the horizontal traverse MCST1 (see Plan No. S10652) a fixed electrode array was used with AB = 175 m and MN = 25 m. This array was then translated over the ground surface to give a set of apparent resistivity values for each position of the array centre. It can be shown that where low resistivity sediments overly an insulating basement material then the depth of the sediment section is given by (for AB/2 large enough)

$$z = (x)(rav/rx),$$

where $x = AB/2$,

rav = average resistivity of sedimentary section,

rx = apparent resistivity for $x = AB/2$.

Hence, if it can be assumed that the average resistivity of the sediments is uniform throughout a traverse then the depth of section can be derived from apparent resistivity values along the traverse.

3. Magnetic

Values of the total magnetic intensity of the earth's field were read at 25 m intervals along traverse MCST1 using an Elsec proton precession magnetometer. The proton pulse count was set at 1024 cycles. With this setting the total magnetic field intensity in gammas is given by

$$H = \frac{2405.1}{C} \times 100\ 000$$

where C = count time in seconds.

The results are shown plotted in Plan No. 74-126.

RESULTS

1. Depth probe MDP1

These investigations were made near the site of the household supply bore. A driller's log is available for this bore, indicating that weathered granite lies 15.3 m below clay. The bore is 23.01 m deep and the supply comes probably from the weathered granite. Salinity is 1385 mg/l.

The resistivity depth probe yields the following interpretation:

Layer	Resistivity (ohm metres)	Thickness(m)	Depth(m)
1	280	1.5	0
2	20	0.9	1.5
3	50	7.9	2.4
4	3.1	4.2	10.3
5	Infinite	-	14.5

The seismic section is shown in Plan No. 74-140. It reveals a high speed bedrock refractor (3770 m/sec) dipping steeply to the north-east at an angle of 8^{o}.

Its depth near the bore is 15.0 m, indicating that this may be the weathered granite, although the high velocity indicates that the weathering may not be extensive but rather that the rock is well-jointed. The depth is in agreement with the resistivity interpretation which shows bedrock at 14.5 m.

A 3.1 ohm metre layer overlying the bedrock layer in the resistivity interpretation could be interpreted as highly kaolinised granite.

The 50 ohm metre layer which corresponds in terms of thickness and depth to a 1920 m/sec seismic layer could be taken to represent sediments saturated with reasonably fresh water. In view of the conditions of exceptionally high rainfall which the area was then experiencing it is possible that this may be a valid interpretation.

The presence of an 8° dip in the bedrock refractor to the north-east augurs well for further investigations in this direction.

2. Depth probe MDP2 (Robb's Well)

Refer to Plan No. 74-124.

The existing well at this site is 14.0 m deep apparently in alluvial gravels and silt. Water salinity is 1115 mg/l.

The interpretation of the resistivity results gives:

Layer	Resistivity (ohm metres)	Thickness (m)	Depth (m)
1	285	0.7	0
2	57	1.6	0.7
3	12.8	52.8	2.3
4	529	-	55.1

The 12.8 ohm metre layer, which appears to have a seismic velocity of 2020 m/sec is considered to consist of water-saturated sediments. Bedrock is probably represented by a 529 ohm-metre layer of velocity 3750 m/sec whose depth, according to the seismic results is about 42 m. The depth to bedrock according to resistivity measurements is 55.1 m : this is probably unreliable since thin sequences of sands and clays in the sedimentary beds can lead to anisotropic effects. The result of similar work done in the Curnamona area near Lake Frome has shown that such conditions can lead to overestimates in depth to bedrock by up to 20% of the actual depth. Applying a correction of 20% in this

case yields a resistivity depth estimate of 44 m which agrees with the probably more accurate seismic estimate.

The yield of Robb's Well could therefore be increased by making the well deeper than its present 14 m.

3. Depth probe DP3

Seismic and resistivity results here show that under a few metres of soil lies what is probably weathered bedrock with a resistivity of 290 ohm-metres and seismic velocities of the order of 2830-3140 m/sec. This extends to a depth of 20-30 m where it is succeeded by ?fresh unweathered basement rock (600 ohm-metres and 5600 m/sec).

Groundwater prospects here are considered to be small because both the resistivity and the velocity of the ?weathered bedrock indicate that it is compact and relatively free from jointing.

4. Constant separation traverse MCST4

This traverse was made in an intermontane valley west of the homestead. Inselbergs of the crystalline basement crop out at each end of the traverse.

A resistivity traverse using the configuration described earlier was made to determine the deepest part of the buried valley section (as represented by the lowest value of apparent resistivity). Resistivity depth probe MDP4, oriented at right angles to the traverse line, was made at this point. The following interpretation derives from this:-

Layer	Resistivity (ohm-metres)	Thickness(m)	Depth(m)
1	265	1.1	0
2	25	3.4	1.1
3	11.2	3.8	4.5
4	40	52.0	8.3
5	Infinite	-	60.3

An average resistivity value for the sediments overlying bedrock was calculated from this interpretation. This, together with the horizontal traverse results, was used to give depth estimates along the traverse.

Following this, three seismic depth probes were made at the points along the traverse shown on Plan No. 74-126. The results from these were used to plot a seismic cross-section of the valley floor.

See Plan No. 74-125 which compares the seismic and resistivity results at the deepest point. A combination of a seismic velocity of 2020 m/sec and a resistivity of 40 ohm-metres for the thickest layer is a good indication that this part of the section may consist of water-saturated sediments.

The depth at this point is estimated from the seismic results to be 56 m. The resistivity results given an estimate of 60.3 m, but applying a 20% anisotropy correction to this gives a figure of 48.2 m.

A drillhole at this point to test these conclusions is highly recommended.

The results of the magnetic traverse on MCST1 are shown plotted in Plan No. 74-126. Of particular interest is the anomaly which appears 1 kilometre from the western end, and which could be due to dyke-like bodies. This anomaly is shown in Plan No. S10726 after removal of large-scale regional effects. It was analysed using horizontal derivative methods to separate anomalies and the methods of Koulomzine et al. (1970) for deriving the dyke parameters. The results show that the anomaly could be caused by two dykes at depths of 30 to 40 m both dipping in substantially the same direction (60-70^{o} to the north-east). The geometry of this interpretation is shown in Plan No. S10726. Drilling is recommended to test this hypothesis as dykes could act as water traps.

CONCLUSIONS AND RECOMMENDATIONS

1. In view of the possibility that the basement dips at 8^{o} towards the north-east at the household supply bore, further investigations in this direction are warranted.

2. Although Robb's Well is only 14 m deep, it seems likely that basement lies at a depth of 42 m. Therefore the water supply could be increased by deepening this well.

3. The site of depth probe MDP3 is not considered worthy of further investigation as the seismic velocities and resistivities are too high.

4. A drillhole is recommended at the point where the bedrock section seems deepest on traverse MCST1. This could be to a depth of 50 or 60 m.

5. The cause of the magnetic anomaly discovered on traverse MCST1 is considered to be worth investigating. A rotary drill hole to a depth of 30 m situated 975 m from the western end of the traverse is recommended.

11th March, 1974
RGN:IA

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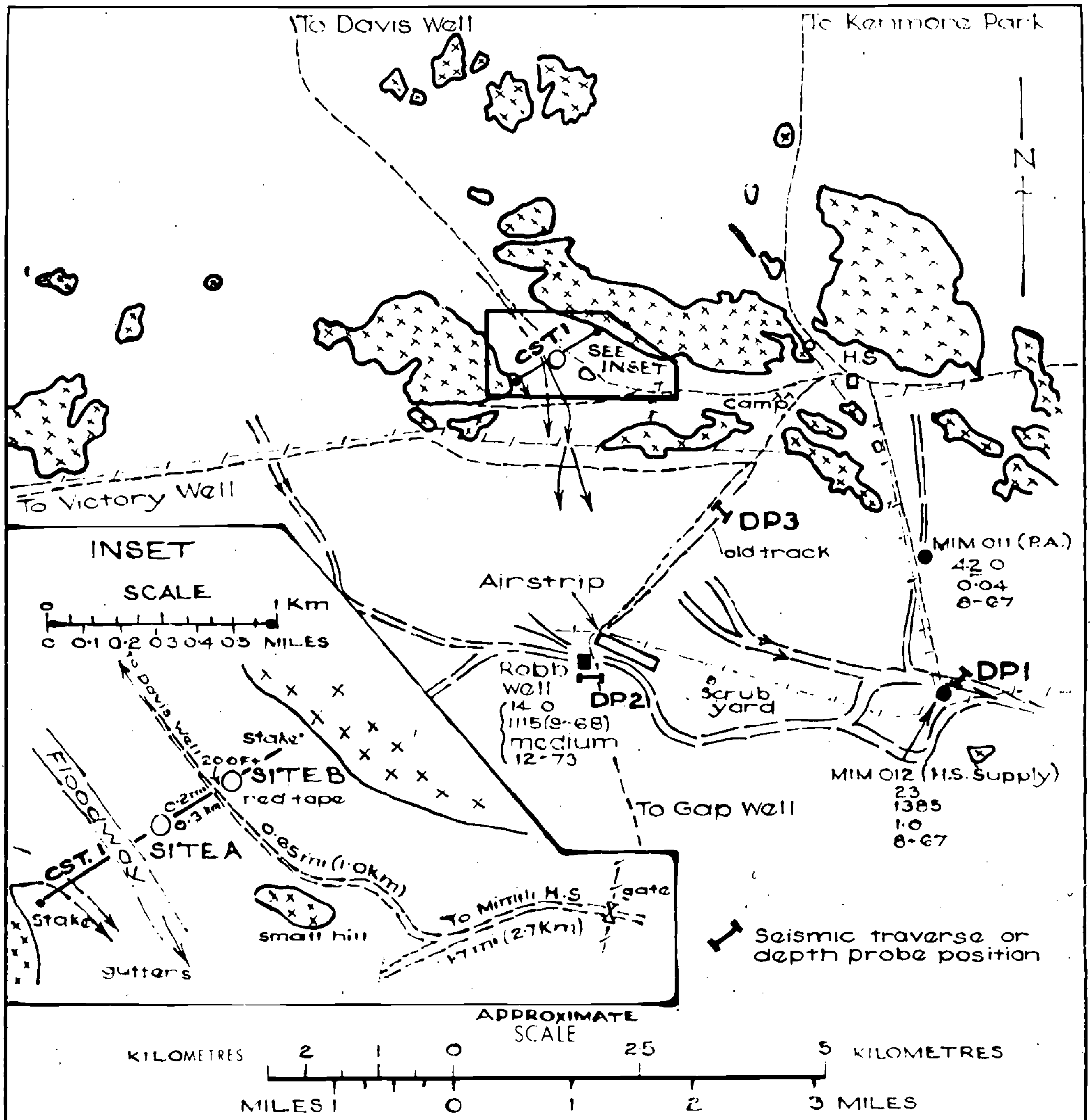


LEGEND

Compiled by direct tracing of airphoto "Illbillie" Svy.736 Run 1 Photo No 025 with reference to EVERARD 1:250000 Geological Sheet

- Red clayey sand soil covered with medium-dense mulga
- Granite gneiss and biotite hornblende gneiss

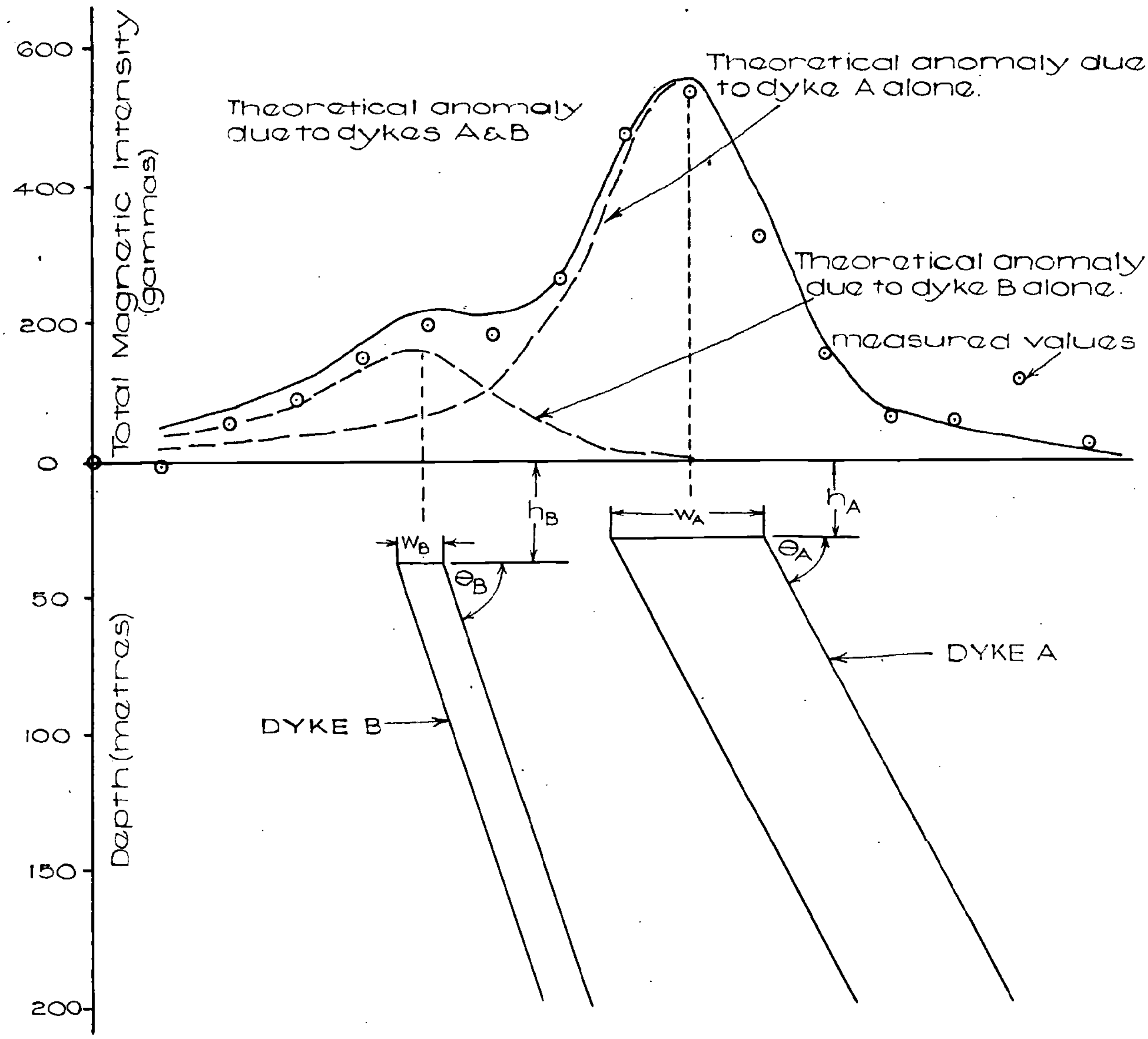
Strike and dip of bedding
Strike and dip of jointing
Strike and dip of foliation
Strike and dip of cleavage
Geological boundary
Fault line
Drainage lines
Surface storage
Track
Fence

Existing bore hole — Depth in metres; Salinity ...; ... per sec; Month year
Well
Spring
Abandoned borehole
Proposed borehole

SITE A (pegged) 0.3km (0.2mi) S.W. of intersection of track & seismic line
SITE B (not pegged) 60m (200ft) N.E. of intersection

DEPARTMENT OF MINES - SOUTH AUSTRALIA		
HYDROGEOLOGY SECTION	GROUNDWATER SURVEY	Date 3 Jan 1974
Compiled H. Dixon	MIMILI STATION LOCATIONS OF GEOPHYSICAL TRAVERSES	Drg No S10652
Drn R.B. Ckd A.F.		Aa

RE No. 12??A MP
A4



DYKE PARAMETERS

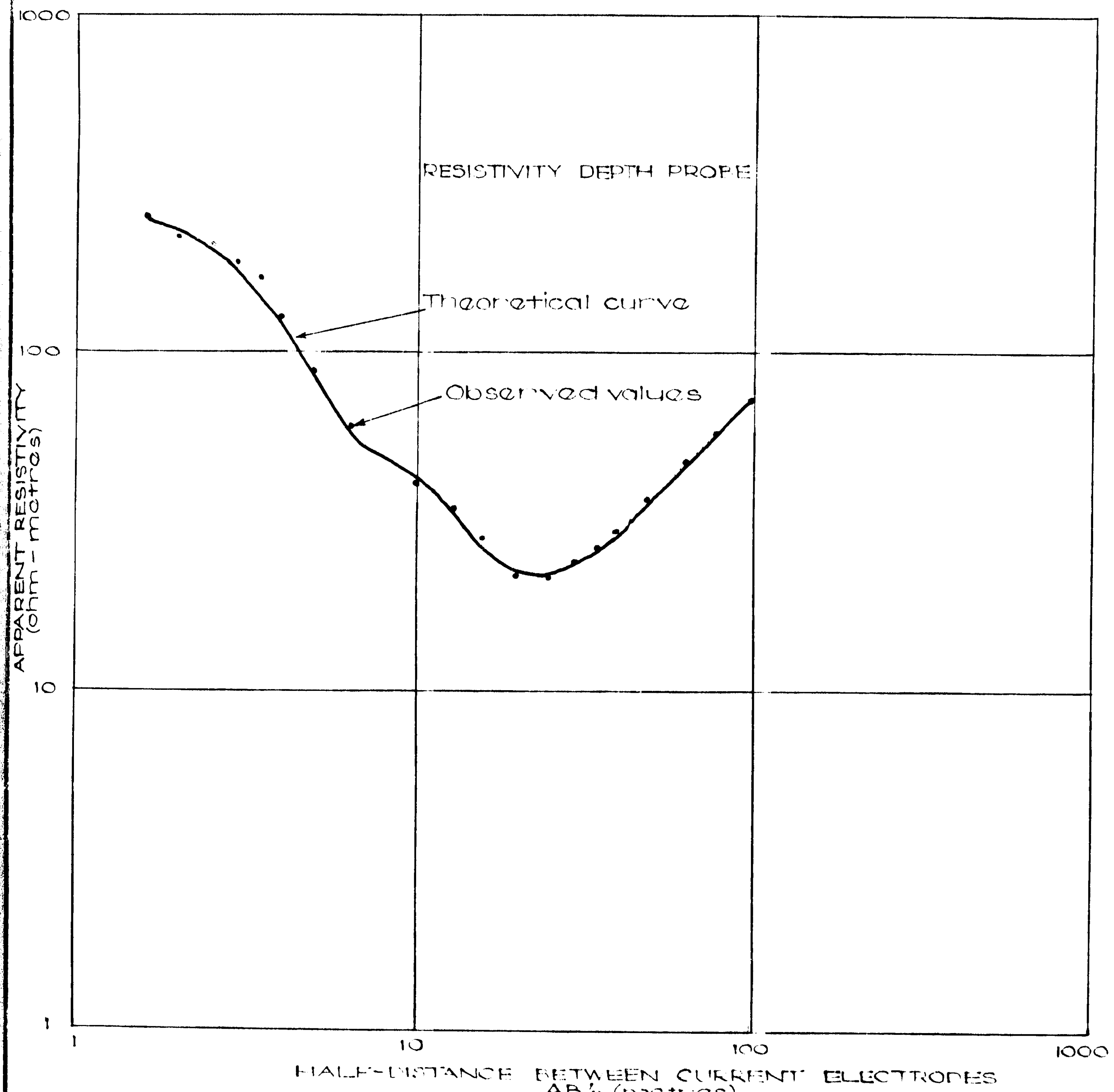
Magnetic susceptibility contrast, AK_e = 0.004389
Magnetic inclination, I = −59°
Total ambient magnetic field, T = 55600 gammas
Assumed strike of dykes with respect to magnetic north,
A_T = 119°

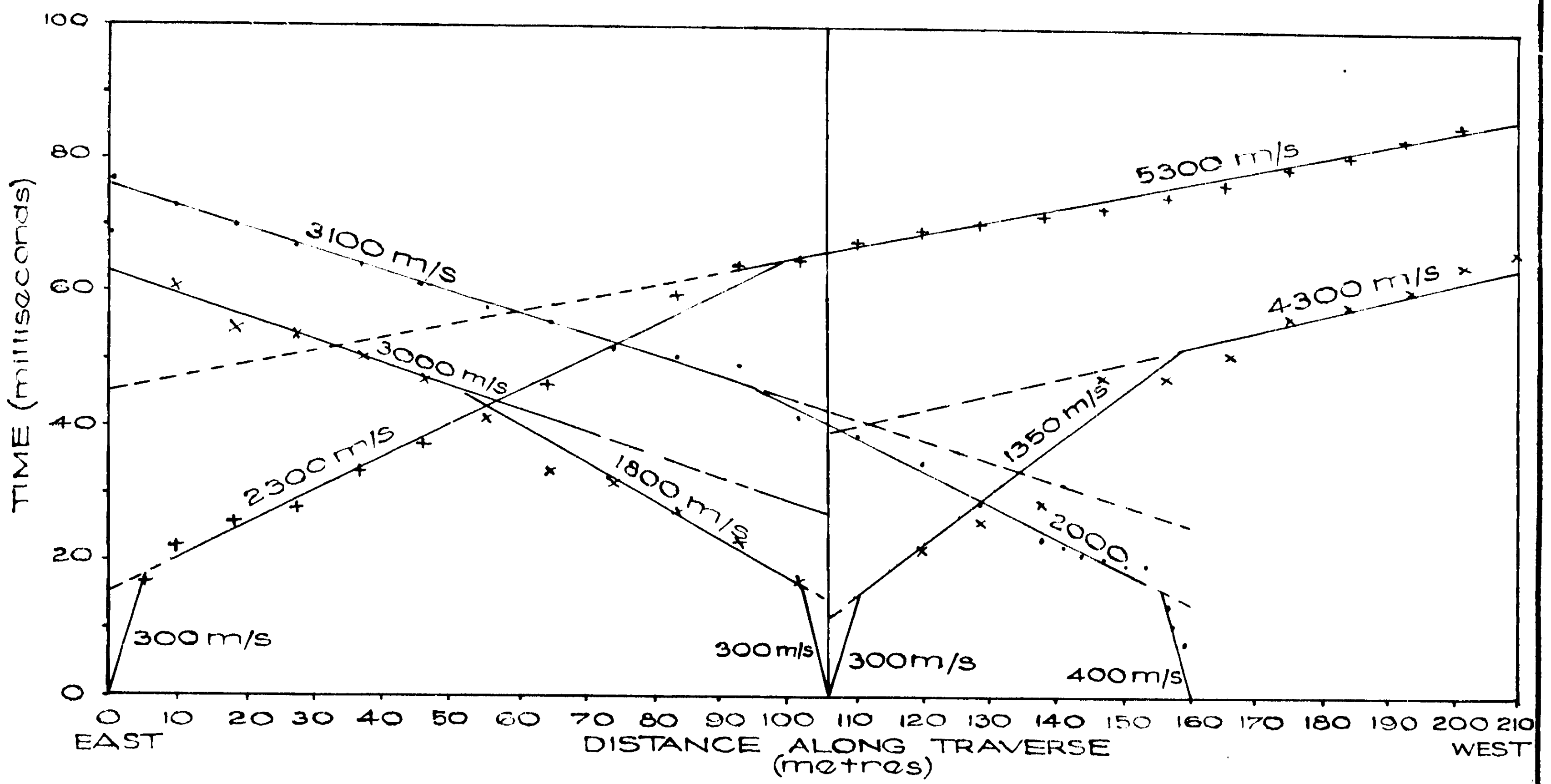
For Dyke A: W_A = 57.8 m; h_A = 27.2 m; θ_A = 61.2°
For Dyke B: W_B = 16.8 m; h_B = 37.9 m; θ_B = 71.0°

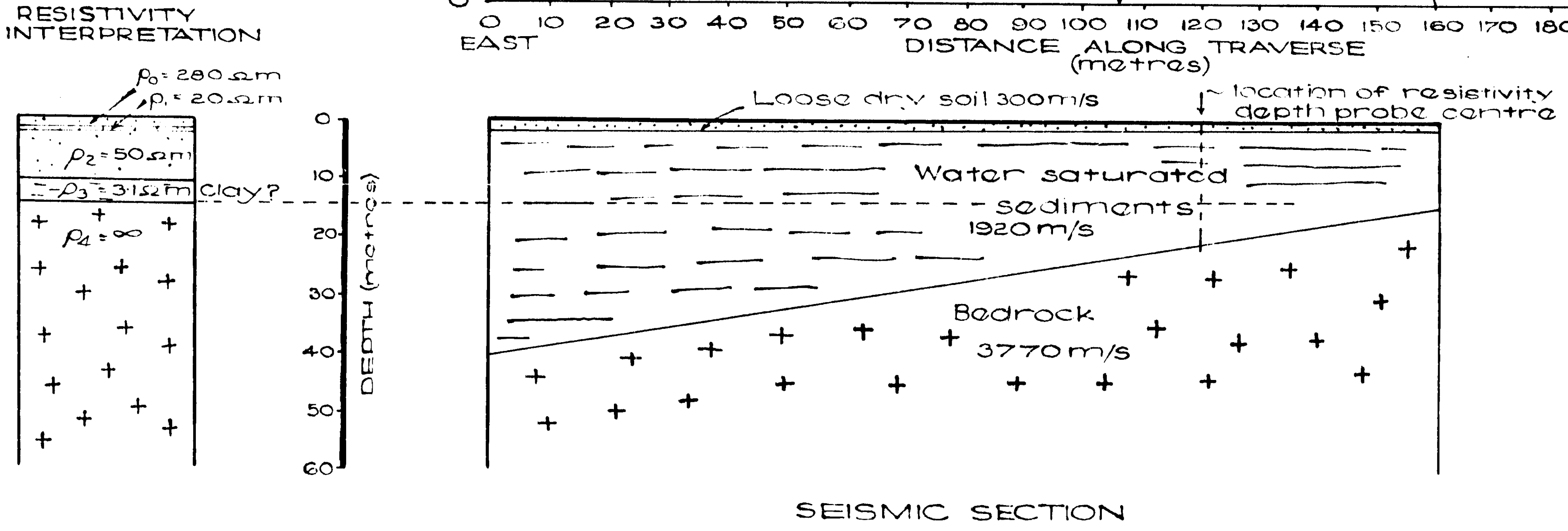
DEPARTMENT OF MINES — SOUTH AUSTRALIA

EXPLORATION GEOPHYSICAL SECTION	**Drn.** RGN	GROUNDWATER SURVEY	**SCALE:** 1:2500
	Tcd. R.B.	MIMILI	S10726 Aa
	Ckd. A.F.	TRAVERSE CST. 1	
	Exd.	INTERPRETATION OF MAGNETIC ANOMALY	**DATE:** 14 FEB 1974

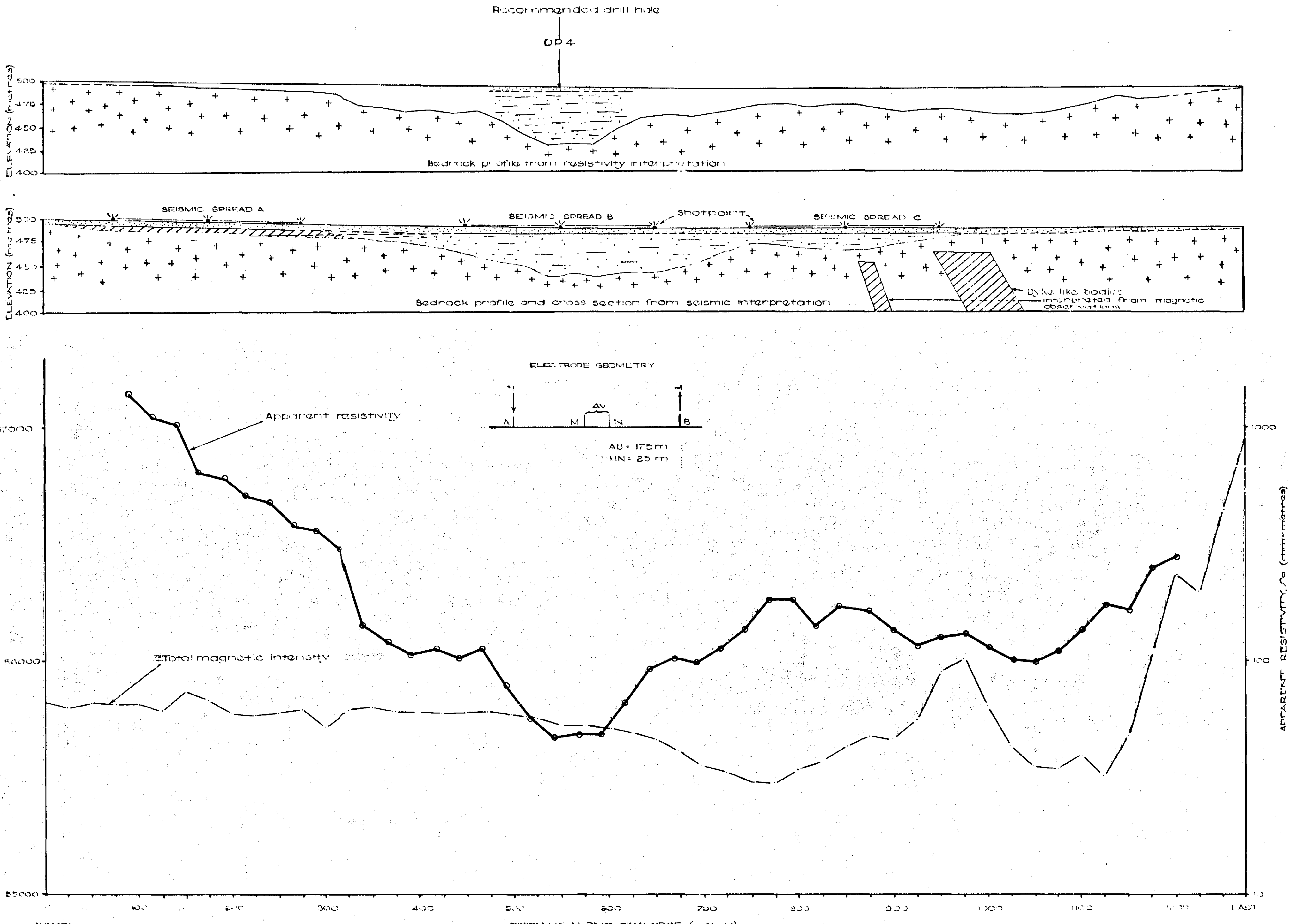
500–2.69 665



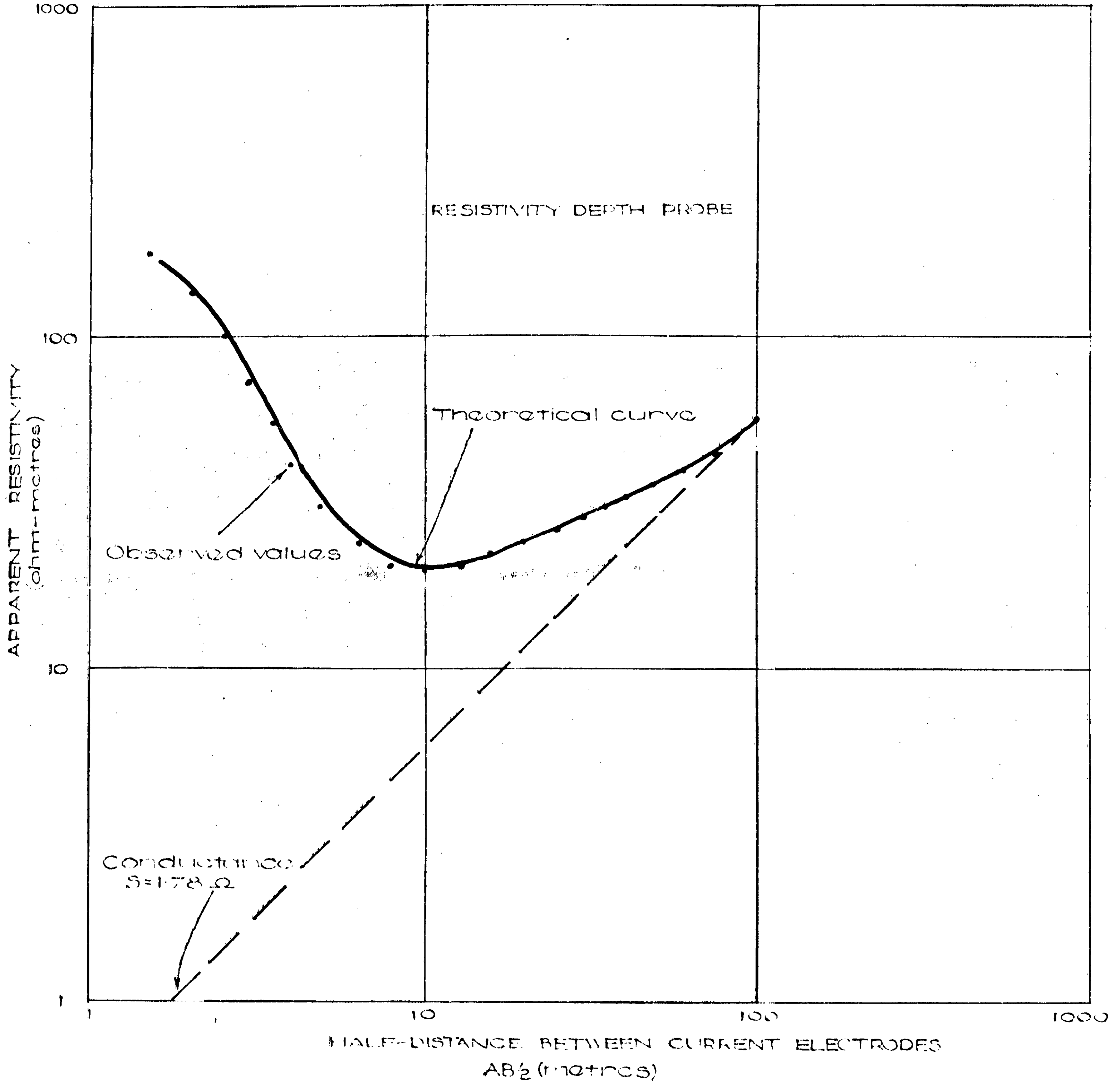


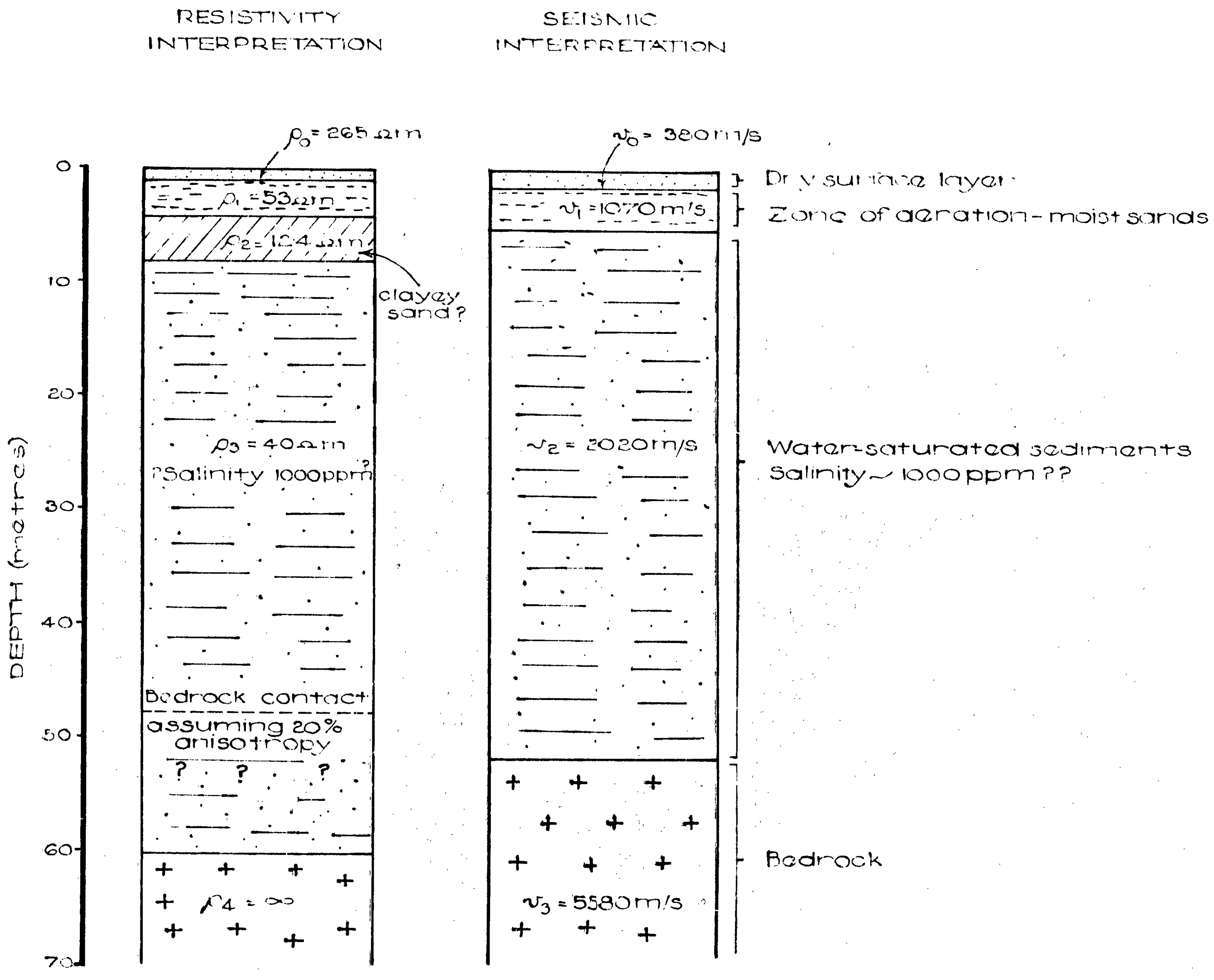


	DEPARTMENT OF MINES – SOUTH AUSTRALIA	Scale: 1:1000
Compiled: RGN	GROUNDWATER SURVEY MIMILI	Date: 22ND FEB 1974
Drn. RB / Ckd A.F.	RESISTIVITY DEPTH PROBE DP1 SEISMIC AND RESISTIVITY INTERPRETATIONS	Drg. No. 74-140 Aa



DEPARTMENT OF MINES — SOUTH AUSTRALIA			
GROUNDWATER SURVEY–MIMILI TRAVERSE			
GEOPHYSICAL OBSERVATIONS AND INTERPRETED BEDROCK PROFILE			
EXPLORATION GEOPHYSICAL SECTION	GEOLOGIST	Compiled RGN	: 1/000
			: 21 FEB 1974
Director of Mines		Drn. RB	Drg No. 74-126 A3
		Ckd. AF	



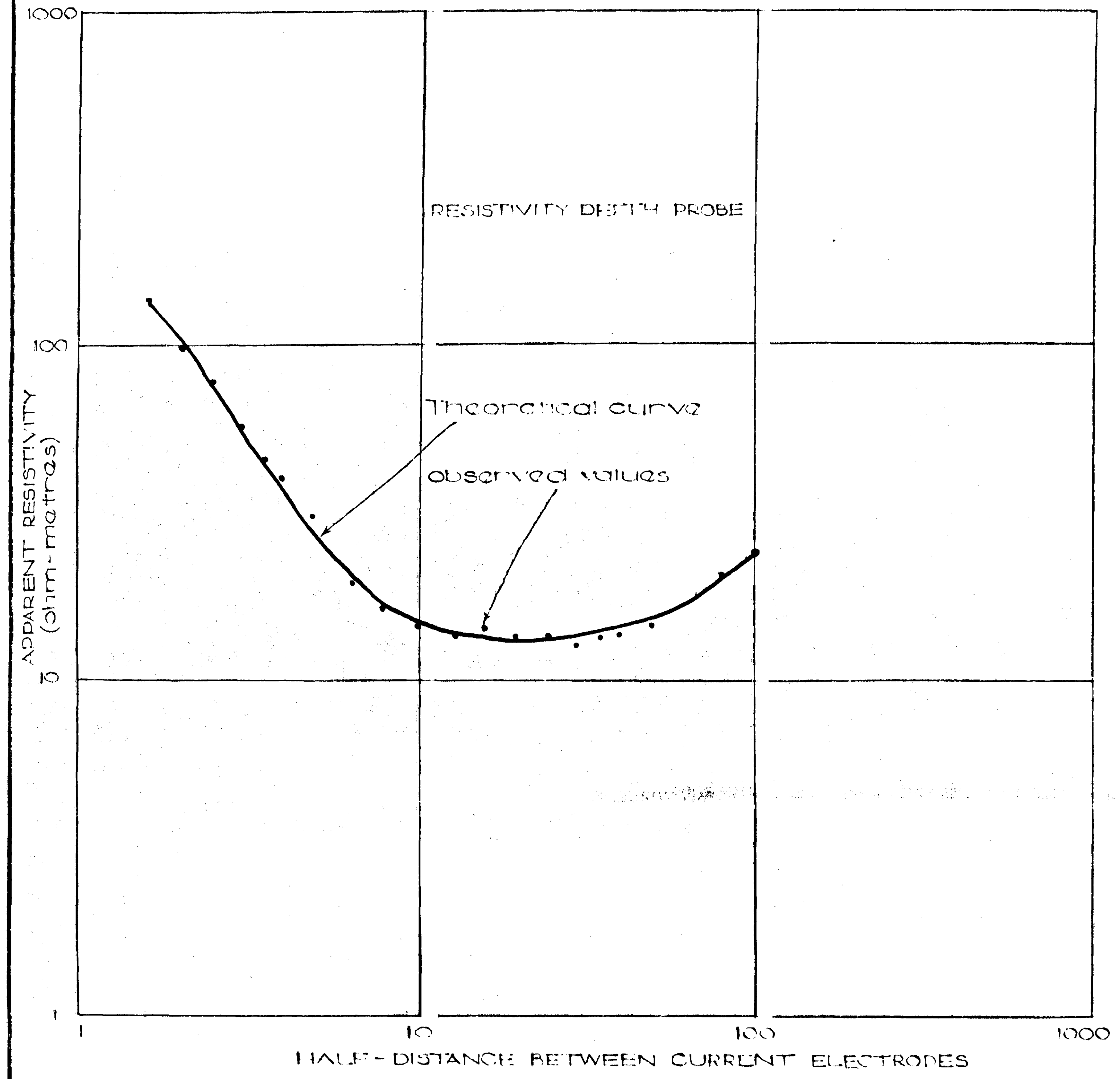


DEPARTMENT OF MINES – SOUTH AUSTRALIA

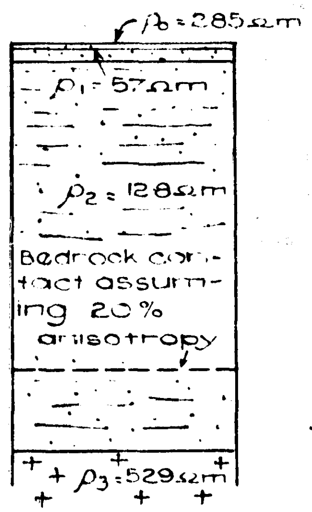
GROUNDWATER SURVEY-MIMILI
RESISTIVITY DEPTH PROBE DP4
(TRAVERSE CST 1)
SEISMIC AND RESISTIVITY INTERPRETATIONS

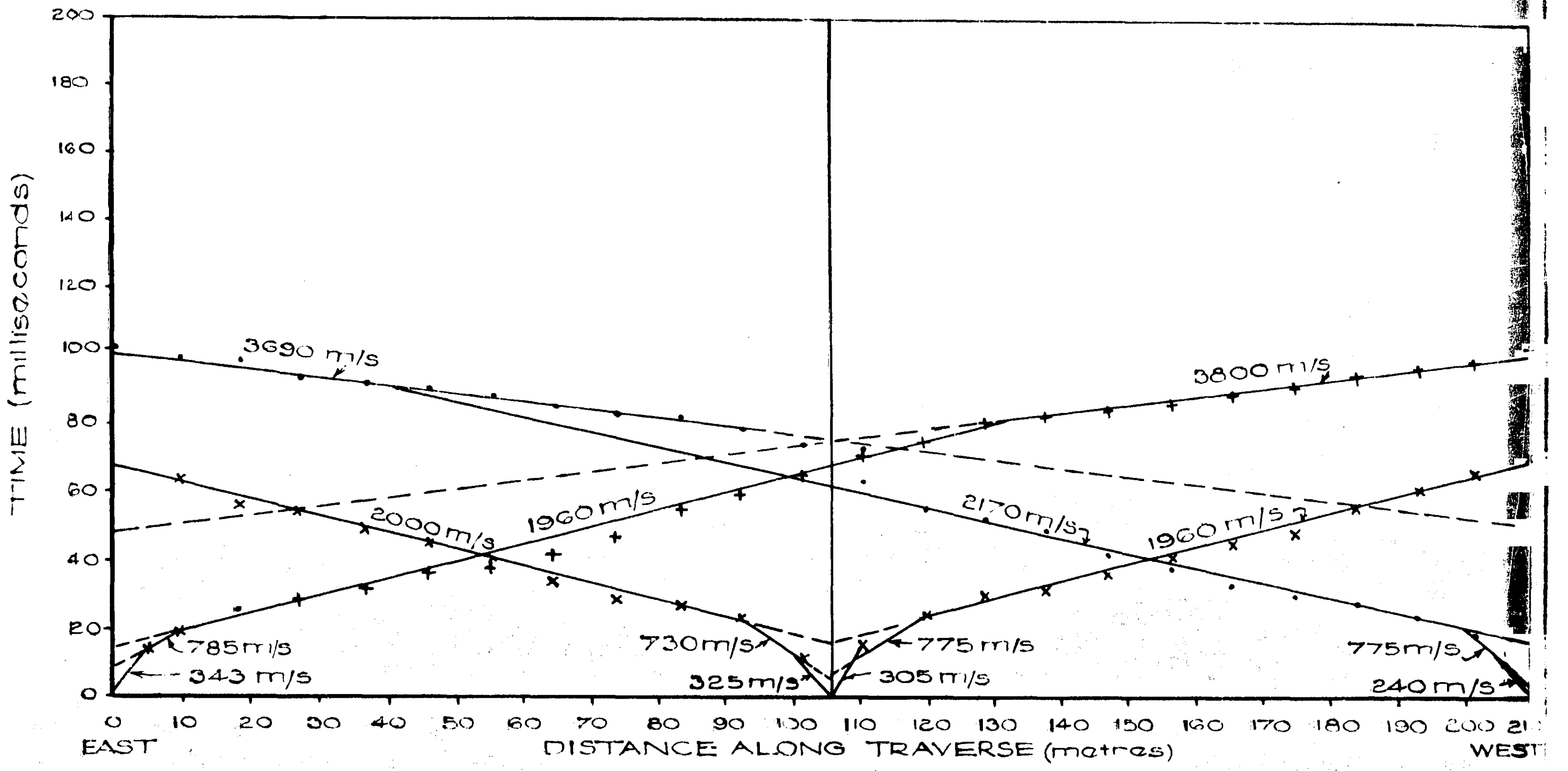
Compiled: R G N.
Drn. R B Ckd. A F

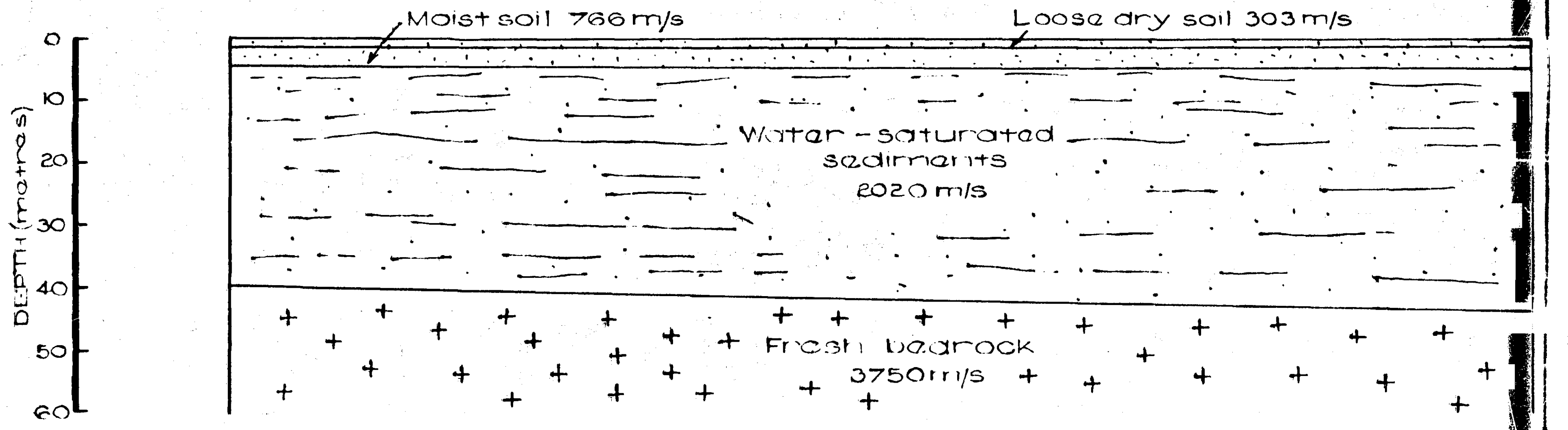
Scale: 1:500
Date: 18 FEB 1974
Drg. No. 74–125 Aa



RESISTIVITY INTERPRETATION



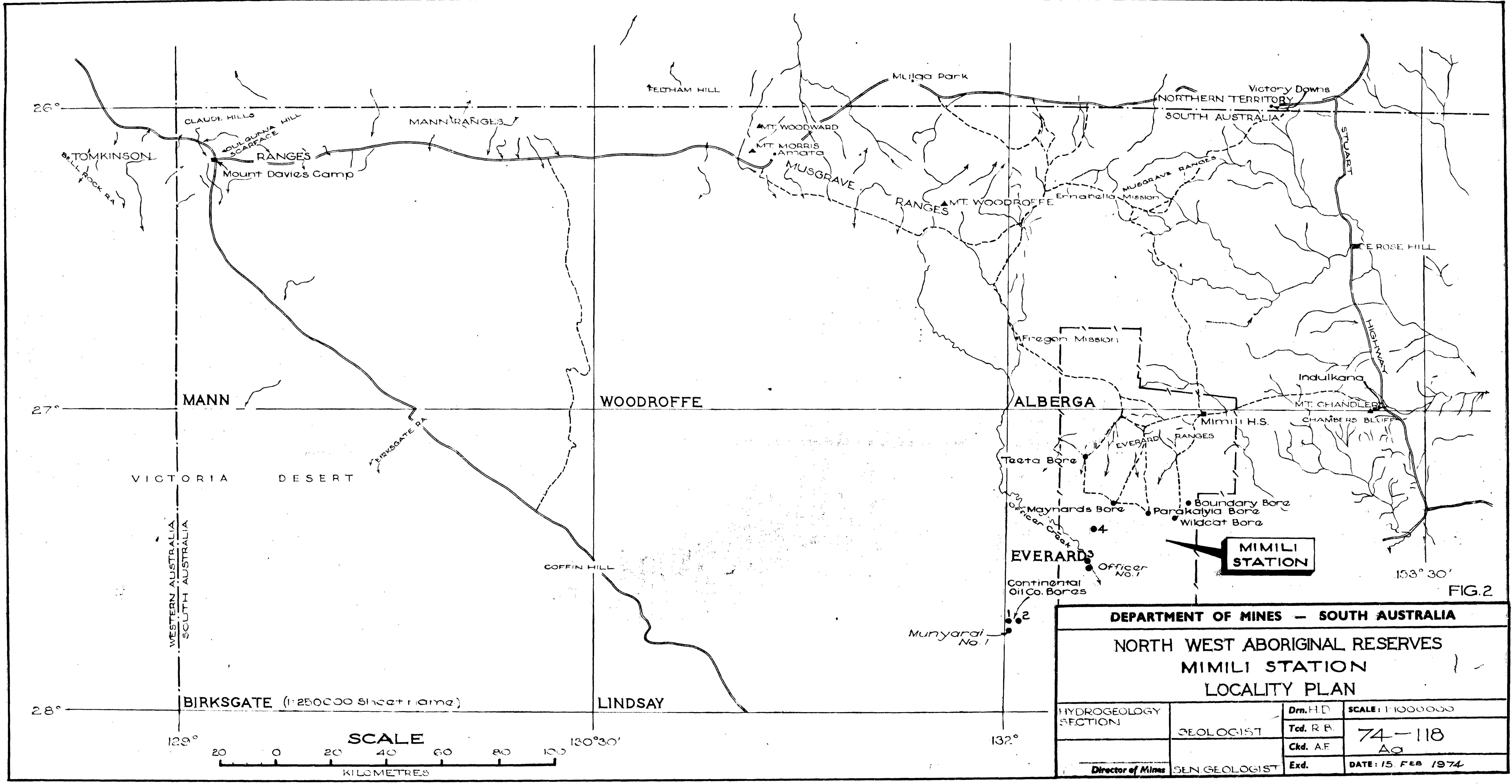




SEISMIC SECTION

Compiled: R.G.N.	**DEPARTMENT OF MINES – SOUTH AUSTRALIA**	Scale: 1/1000
Drn. R.B. Ckd. A.F.	GROUNDWATER SURVEY MIMILI RESISTIVITY DEPTH PROBE DP2 ROBB'S WELL SEISMIC AND RESISTIVITY INTERPRETATIONS	Date: 20 FEB 1974
		Drg. No. 74–124 Aa

FIG. 2



DEPARTMENT OF MINES — SOUTH AUSTRALIA

NORTH WEST ABORIGINAL RESERVES
MIMILI STATION
LOCALITY PLAN

HYDROGEOLOGY SECTION		Drn. H.D	SCALE: 1:1000000
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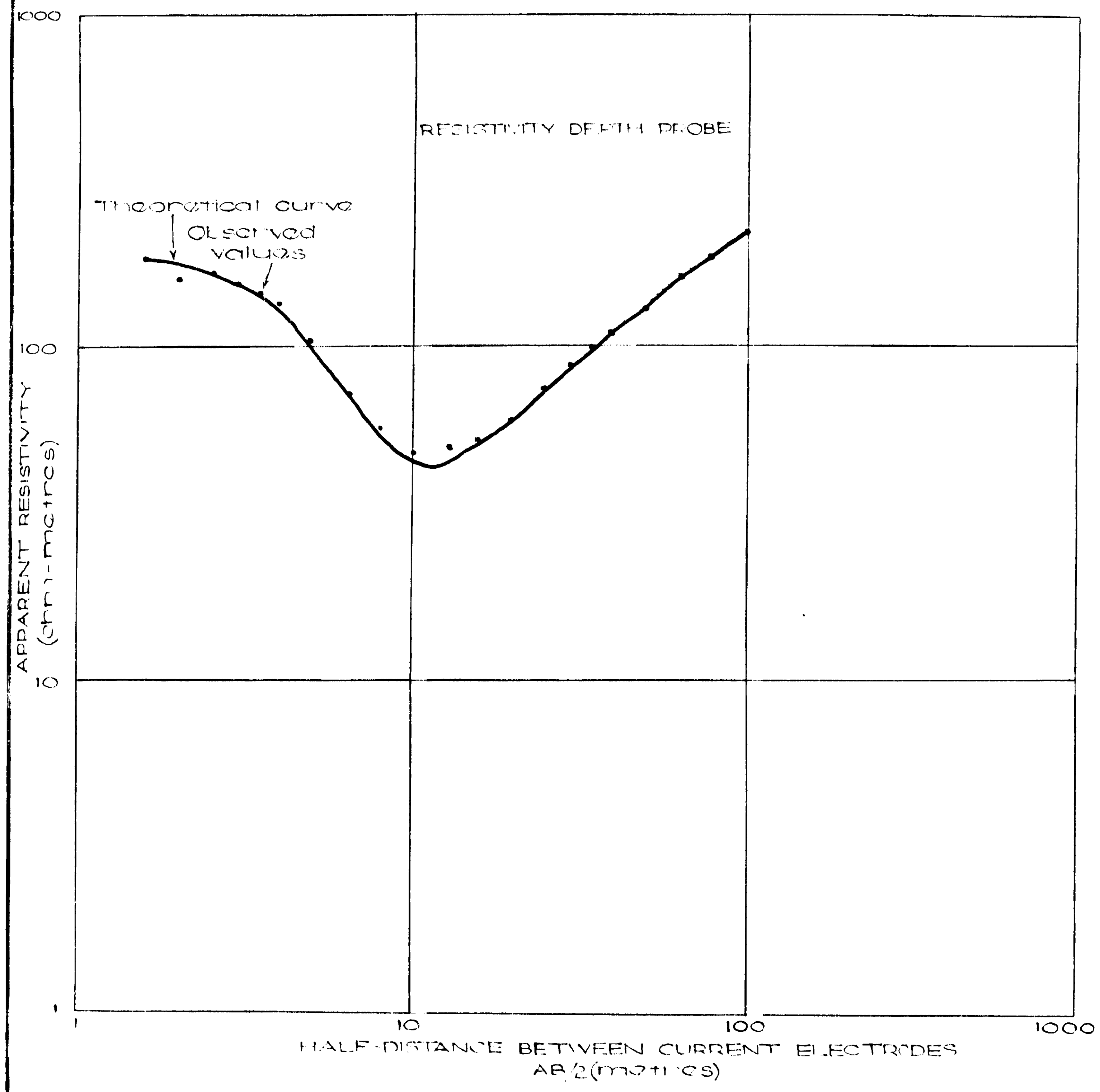
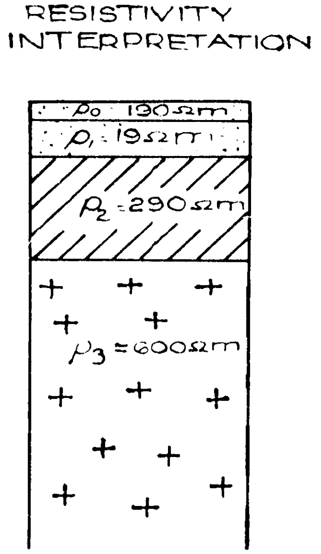
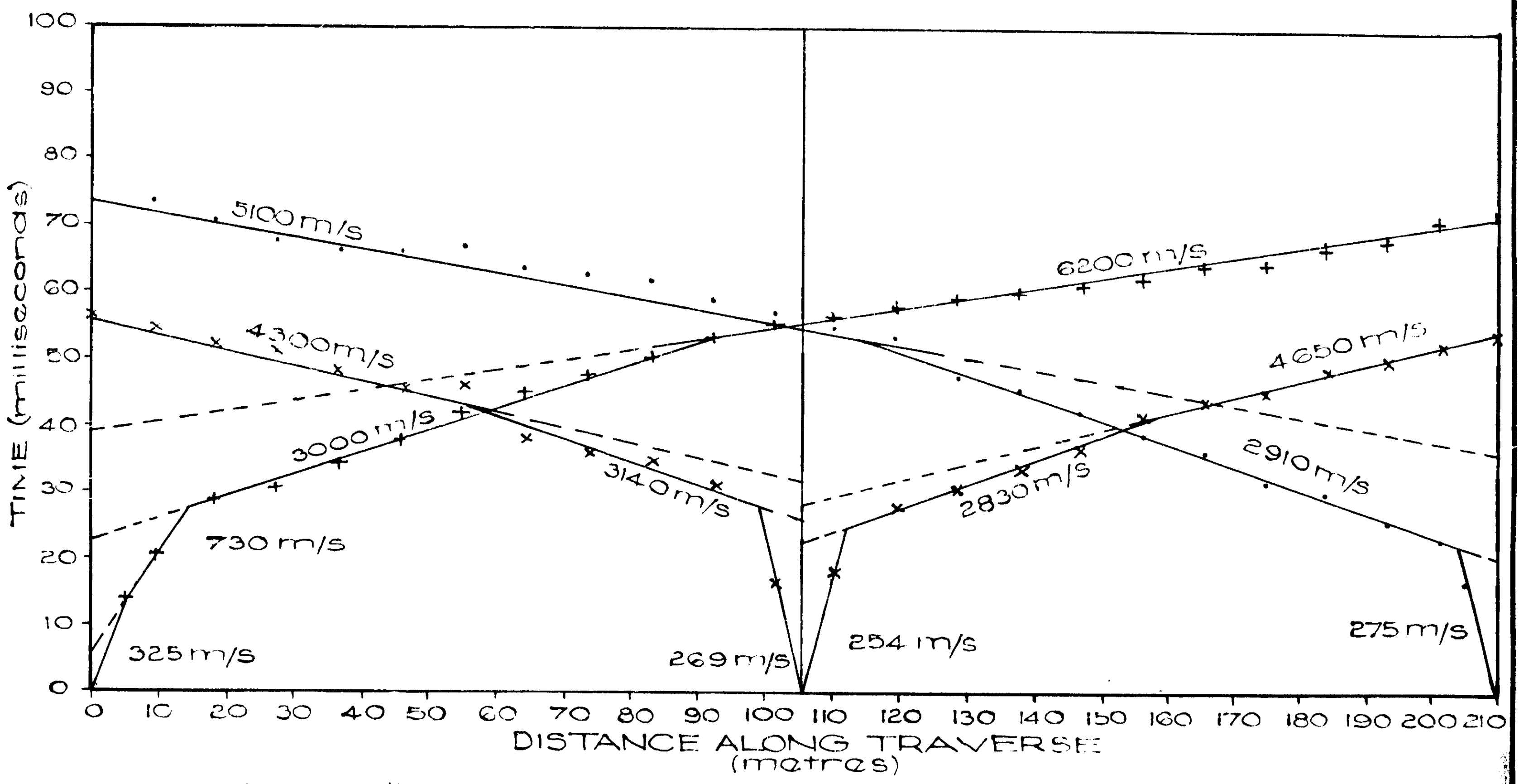
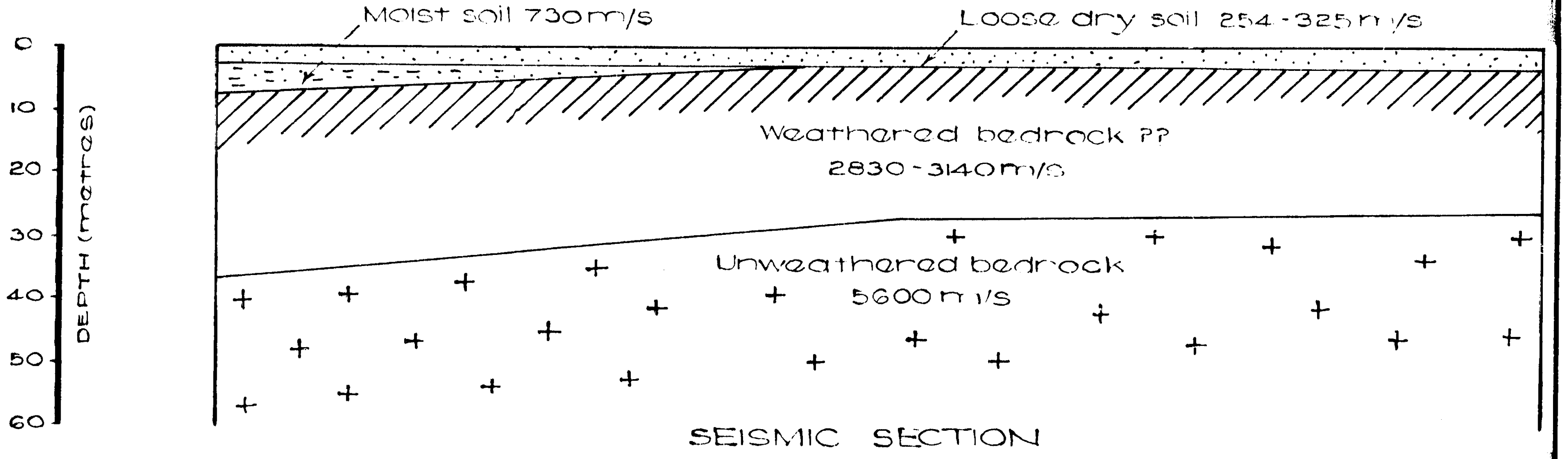
		Ckd. A.F.	
Director of Mines	SEN. GEOLOGIST	Exd.	DATE: 15 FEB 1974









	DEPARTMENT OF MINES – SOUTH AUSTRALIA	Scale: 1:1000
Compiled: R G N	GROUNDWATER SURVEY-MIMILI	Date: 28 FEB 1974
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