DEPARTMENT OF MINES
SOUTH AUSTRALIA

Geophysical Investigations in E.L. 185

Cummins area - Lower Eyre Peninsula

Client: Uranerz (Aust.) Pty. Ltd.

by

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Rept.Bk.No. 75/69
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ABSTRACT

Seismic refraction appears to have been successful in delineating the irregular floor of the Tertiary basin which underlies Cummins on Eyre Peninsula. Velocities of the Tertiary sands, silts, clays, peats and lignites are predominated by that of the water which saturates them (c. 1670 m/s), since the water table is very shallow. The floor of the basin consists of metasediments of the Flinders and Hutchison Groups whose velocities vary from 4200 m/s to 6500 m/s.

Several deep channels have been delineated. One is a major feature, stretching from Cummins to possibly as far south as Avoid Bay and out to sea. This channel has links, most likely through rock type and tectonic structure, to a major gravity high on the LINCOLN 1:250 000 gravity map.

Two traverses indicate that the gravity method may be an efficient and economical way of outlining basement relief, provided stations are close enough together, and that there is adequate information on basement depths at intervals sufficiently close to define the regional effect.

INTRODUCTION

E.L. 185 is situated in southern Eyre Peninsula where it covers part of a shallow Tertiary basin bounded on the east and west by Proterozoic basement outcrops. The northern and southern limits of this basin are as yet ill-defined. The basin is considered to be prospective for sedimentary uranium deposits because it contains lignites, sands and peat beds within the Tertiary sequence, and because the basement rocks surrounding it may have served as good sources for the uranium.

Uranerz (Aust.) Pty. Ltd. who are the lessees, asked the Geophysical Services Section of the South Australian Mines Department to carry out a programme of geophysical investigations to outline the basement paleo-surface in order to detect sub-surface channels prospective for uranium. Originally an experimental traverse was to have been made to test three methods, which were seismic refraction, gravity and seismic reflection (using a Bison 1570B signal enhancement seismograph). However, in view of the tight schedule imposed by drilling rig availability it was decided to concentrate mainly on seismic refraction because useable results could be computed more quickly.

GEOLOGY

The general geology of the area is shown in Plan No. S11494. The table below gives an outline of the regional geology: a detailed description may be found in Johns (1961). For more detailed descriptions of the local geology refer to the reports (on open file) for S.M.L.s 483 and 642 (Nixon, 1971; Carrie, 1971) for Endeavour Minerals N.L.

Period	System	Formation	Lithology
Quaternary	Recent Pleistocene	Undifferentiated	Sand dunes, aeolianite, calcrete, laterite.
Tertiary	Eocene to Pliocene	Undifferentiated	Clays, sands, lignites, gravels, peats.
Proterozoic		Hutchison Group	Mica schists, Amphibolites, haematite quartzites, dolomites, gneisses, graphitic rocks.
		Flinders Group	Gneisses, quartzites, dolomites, schists, amphibolites.

Basement in the area consists of rocks of the Flinders and Hutchison Groups (Johns, ibid.). These are sediments which have undergone different grades of metamorphism. The Flinders Group contains a higher proportion of gneissic rocks and granulites, while in the Hutchison Group schistose rocks tend to predominate. Both contain quartzites and dolomites. The type section on the LINCOLN 1:253,440 geological sheet (Commonwealth Geological Map Series - Sheet 1, 53/11) shows a broad synclinorium of Hutchison Group rocks underlain by Flinders Group rocks forming the floor of the Cummins Basin. The rocks are tightly folded with north-south trends, and the pattern of basement ridges controls the present relief of the basin floor. Basement rocks are weathered to depths of at least 15 metres (Nixon, 1971).

The Tertiary sequence consists of horizontally bedded clays and sand and gravel beds with occasional peat and lignite beds extending to depths of at least 150 metres.

Palynological studies have revealed an Eocene flora which indicates a paralic depositional environment (interbedded marine and fresh water sediments).

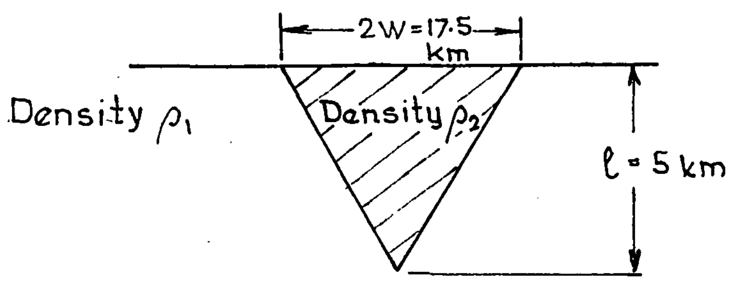
Quaternary sediments are represented by Pleistocene aeolianite deposits in the south and west of the leased area and by Recent sands, clays and alluvial and swamp deposits elsewhere.

Previous Geophysical Work

Seedsman and Harris (1956) report on an airborne scintillometer survey made in 1954 over eastern Eyre Peninsula which revealed a collection of minor anomalies two or four times background west and east of Cummins. An anomaly greater than four times background over Marble Range was found after field checks to be in gneissic rocks with no evidence of mineralization.

In 1955 Adastra Hunting Geophysics Pty. Ltd., on behalf of the South Australian Department of Mines, conducted an aeromagnetic survey on a regional basis over this part of Eyre Peninsula. Flying height was 500 metres above M.S.L. with a nominal flight line spacing of 800 metres. The results are available on a series of maps published by the Department of Mines at scales of 1:63 360 and 1:253 440. See also Plan No. 75-504. An interpretation of these data was made by Webb (1971) in an attempt to obtain basement subsurface contours but he concluded that the high level of flying combined with low sensitivity made it difficult to produce reliable results. Certain basement trends are however discernible on inspection of the maps.

9. A gravity survey conducted in 1971 resulted in the compilation of a Bouguer anomaly map of the LINCOLN 1:250 000 sheet (Ramakrishna, 1972). The average density of stations (1 per 41 km^2) is insufficient to reveal small near-surface features such as buried channels. However the map does provide some insight into the geological structure. Refer to Plan No. 75-505. A gravity high of 30 to 40 milligals, trending north-northeast dominates the lower part of southern Eyre Peninsula. The high has steep flanks, and the eastern flank appear to correspond to the Lincoln fault scarp which extends along the east coast from Port Lincoln to beyond Lipson. The western flank corresponds fairly closely to the western boundary between Flinders Group and Hutchison Group sediments (Johns, ibid, figs. 27 and 42) where the Hutchison Group metasediments form the core of a synclinorium whose axis coincides with the positive gravity anomaly axis. If the situation is approximated by the model shown below then it can be shown that a density contrast of 0.24 gms/cc between the Flinders and Hutchison Group metasediments would be sufficient to produce a maximum gravity anomaly of 30 milligals.



$\Delta\rho = \rho_2 - \rho_1$

$$g\ max. = \frac{4GW\ \Delta\rho\ R}{R^2+1}\left(\frac{\pi}{2} + R\ \ln R\right)$$

where $G = 6.67 \times 10^{-5}$ MKS units

and $R = \ell / w$

This is a plausible explanation because

(a) Johns (ibid., p.17) states that Hutchison Group rocks may attain a maximum thickness of 6 000 metres.

and (b) rocks of the Flinders Group are predominately granitic in character and so may be less dense than the argillite-derived Hutchison metasediments.

Within the area covered by E.L. 185 itself, about 78 kms of seismic reflection traversing was done by L. J. Starkey and Associates for Endeavour Minerals N.L. The instrument used was a single channel Bison 1570B signal enhancement seismograph which sums and stores signals from hammer blows. The method adopted was to sum signals from hammer points between 1.5 metres and 9.2 metres from the geophone at stations 30 metres apart: by doing this, refraction events were cancelled, while reflection events were enhanced. The method proved satisfactory in being able to mark the top of basement to depths of 150 metres. However, a limited seismic refraction programme had also to be carried out in order to measure the velocities of the sediments overlying basement so that reflection times could be converted to depths. The refraction survey showed the following distribution of velocities:

Velocity range	Rock type
c.1830 metres/sec.	Superficial patches of calcrete
940 - 1130 metres/sec.	Tertiary sediments
1740-2820 metres/sec.	Weathered basement
4540-5680 metres/sec.	Unweathered basement

Using a crew of an operator and two field assistants plus a geophysicist to interpret results the survey averaged 2.8 km/day in both reflection and refraction at an average cost of $310 per line km.

METHODS AND EQUIPMENT USED

In this survey the seismic refraction work was done using a 24-channel Texas Instrument Co. 7000B recording seismograph interfaced with a Geospace R1801 electro static camera. Geophones were set out at 61 metre intervals along the spread and the shotpoint was placed at spread centre. After the shot was fired one quarter of the spread (ie. 6 geophones) was moved to the other side of the spread and a shot was then fired at the new spread centre. The survey proceeded in this manner for each traverse. By using this method continuous overlapping forward and reverse refractions from basement were obtained for each geophone station as well as control of upper layer velocities every 366 metres. Where the depth to basement was too great is became necessary to fire shots at the ends of each spread rather than at the centre in order to maintain continuity of reciprocal basement refractions at each station.

Shotholes were drilled using a small Halco rotary percussion rig driven by a Holman compressor. The average charge used consisted of two 1.5 kg sticks of AN60 blasting gelignite at a depth generally of 3 metres.

Each traverse was pegged as the survey proceeded. 1 metre stakes were placed every 366 metres (1 200 feet), and smaller pegs every 122 metres (400 feet). These were numbered from the start of each traverse, increasing with increasing chainage in the direction of traversing.

Some problems were caused by:

(1) Wet weather. In particular electrical cross-feed problems were caused by leakage between wires in the seismic cables due to moisture in them. It was also found that on particularly humid days the charger wire voltage intensity on the electrostatic camera required regular adjustment. Mirrors and lenses in the optical system also tended to fog.

(2) Difficult drilling. Calcrete presented no drilling problems when a downhole hammer was used, but stiff clays often presented severe problems, mostly due to clogging of the air circulation. In some cases it took up to 2 hours to drill a shothole, although on the average the time per shothole was about 35 minutes. This governs the time taken to set up each spread and take a record of the shot: under good conditions this should be about 20 minutes.

For the gravity traverses a Sharpe CG-2 Prospector gravity meter (serial No. 201) was used. The calibration factor for this was 0.0999(7) milligals dial division on 12.2.75.

A sequence of tie stations along each traverse enabled the data to be corrected for intrumental drift and diurnal variations. The data were tied in to isogal station 7116.0404 at Cummins for which the following values have been established:

accepted gravity	=	979687.62 milligals
latitude	=	$34^{\circ}15'48''$
longitude	=	$135^{\circ}43'47''$
elevation	=	66.099 metres

G.T. Galbraith (field assistant) made the gravity readings.

INTERPRETATION OF RESULTS

Seismic

Seismic records were timed for the first arrival of energy at each geophone. For each traverse these travel times were plotted against distance from the shotpoint for every spread to give a composite record of time-distance graphs. The basement refraction events from forward and reverse shots were identified and marked on this record. These data were then subjected to reciprocal analysis (refer to Plan No. S11495) to give a set of time-depths for geophone stations on each traverse.

The time-depth of a refractor as defined in Plan No. S11496 is essentially the everage of the times for a ray travelling from the refractor surface to reach the geophone station as a first event from both forward and reverse shots. If the refractor surface is reasonably plane within the vicinity of the geophone, then this average time can be converted to an actual depth by applying an appropriate conversion factor.

From examination of the time-distance graphs it is apparent that there are at least three refracting horizons of interest in the area.

Layer	Velocity	Thickness	Remarks
0	Vo	Ho	Zone of aeration: soil and sediments above water table.
1	V_1	H_1	Water-saturated sediments.
2	V_2	H_2	Basement refractor: metasediments of great thickness.

It is acknowledged that weathered basement may provide a fourth horizon, but, partly due to its thickness in relation to its depth and velocity, and partly due to the large geophone spacing used, it cannot be identified positively on the time-distance graphs. We can assume a velocity for it and calculate the maximum thickness it may attain before it could influence the graphs, but its true velocity and thickness remain unknown. The assumption therefore must be that its thickness remains relatively constant and that variations in the paleo-surface are reflected in variations in unweathered basement.

For a given geophone station let To be the time-depth for the water table and T_1 be the time-depth for the basement. The total depth to basement neglecting the effect of weathered basement is given by

$$Z = Ho + H_1 \qquad -(1)$$

Now (refer to Plan No. S11497)

$$Ho = ToVo \sec i_{o1} \qquad -(2)$$

and $$H_1 = (T_1 - Ho \cos i_{o2}/Vo)\ (V_1 \sec i_{12}), \qquad -(3)$$

where $$i_{o1} = \arcsin (Vo/V_1)$$

$$i_{o2} = \arcsin (Vo/V_2)$$

and $$i_{12} = \arcsin (V_1/V_2).$$

Since there was insufficient time to do "weathering" spreads to determine Vo accurately we shall assume a constant value of 300 m/s for it. Values of V_1 are derived from the inverse slopes of the initial segments on the time-distance graphs, and values of V_2 were determined from the corrected travel times in the reciprocal analysis.

Taking typical values of 1 530 m/s for Vo and 5 500 m/s for V_2 it can be seen that

$$\cos i_{o1} = 0{,}98 \text{ and } \cos i_{o2} = 0.99$$

so that to a good approximation we can write

$$\sec i_{o1} = \cos i_{o2} = 1.$$

Thus, the formula which gives an estimate of the total depth is

$$Z = 0.3T + (T_1 - To)\ (V_1 \sec i_{12}), \quad -(4)$$

where Z is in metres

TO, T_1 are in milliseconds

and V_1, V_2 are in km/s.

To values are measured from reciprocal analysis (where applicable) or by interpolating the half-intercept times from shotpoint to shotpoint.

Sources of error

(1) Errors in measuring V_2 will not greatly affect depth calculations

eg.

V_2	V_1	To	T_1	Z
5500	1530	5	80	121
4600	1530	5	80	123

ie. a 16% error in basement velocity results only in a 2% error in Z.

(2) Errors in measuring V_1

These may be due to:

(a) anisotropy due to the layering of the sediments, viz. interbedded sands and clays;

(b) velocity inversions, due to, for example, clays overlying thick beds of peat, or calcretes overlying lower velocity sediments.

eg.

V_2	V_1	To	T_1	Z
5500	1530	5	80	121
5500	1285	5	80	101

ie. a 16% error in V_1 results in a 17% error in Z.

(3) Errors in measuring Vo and To

These could have been measured more accurately, had time permitted, if "weathering" spreads had been done. Nevertheless, because the depth to the water table can be assumed to be constant over relatively wide areas where surface topography is gentle, only absolute values of Z should be affected: relative values will depend more on changes in V_1 and T_1.

(4) Errors in timing

All times are measured to the nearest millisecond. It is estimated that maximum errors in picking the breaks on the records could be ± 2 milliseconds, while the reciprocal time may be in error by ± 3 milliseconds.

Thus the time-depths may be in error by $\pm (2^2 + 2^2 + 3^2)^{1/2} = \pm 4.1$ milliseconds.

This is very much a function of distance from the shot and of basement depth as both affect the sharpness of the breaks (although amplifier gain settings compensate somewhat for these). The error therefore is likely to be a constant percentage of basement depth and is not likely to exceed 5%.

(5) <u>Errors due to basement irregularities of high relief</u>

These undermine the basic assumption in calculating the time-depths that the refractor is planar immediately below each geophone station over a distance subtended by twice the critical angle of refraction (in this case, say, over $\pm$ 60 m). Included in these are cases where the refractor slopes at an angle to the horizontal greater than the critical angle, for then no rays can be returned to the surface from this zone. Such errors are intrinsic to the process and cannot be estimated; smoothing of the data is probably the best treatment.

<u>Gravity</u>

After correcting the data for intrumental drift and tidal effects, they were converted to gravity differences (in milligals) with respect to the isogal station at Cummins (7116.0404). Latitude, elevation and Bouguer (assuming a surface density of 2.67 gms/cc) corrections were then applied to give the Bouguer gravity in milligals for each station.

To compute the gravity effect due to variations in basement topography alone, it is necessary to remove from the Bouguer gravity profile the gravity effects from all other sources. Effects from density changes in materials at the ground surface are likely to be sharp and of small magnitude, and these are best removed by smoothing the Bouguer gravity profile to remove very small wavelength variations. On the other band, intra-basement effects (the so-called regional gravity effect) may be of large magnitude but with very long wavelengths (if the profiles are regarded as being represented by a Fourier series expansion), and removal of these depends on a knowlege of bedrock depths at intervals along the profile. At these points the residual gravity due to depth of burial of basement may be estimated and hence a point on the regional gravity profile can be established. A smooth curve passing through all such points is taken as the regional gravity profile. Depth estimates at points in between the control stations can then be derived from the residual gravity (smoothed Bouguer gravity minus regional gravity). Obviously the better the regional gravity profile can be estimated, the better the depth estimates will be. The regional gravity for Line 1 is derived from the seismic depth estimates alone. On Line 9, depth estimates from drillholes which intersected basement have been used, together with seismic depths from Line 10 on the eastern end and Line 1 on the western end (see Plan No. 75-503).

RESULTS

(1) Line 1

Seismic (see Plan No. 75-490)

This traverse extended over a distance of 21.5 km. Values of V_1 (water-saturated sediments) were fairly uniform and ranged from 1 400 m/s to 1 680 m/s, except over basement highs where they tended to be slightly lower.

Note in particular major channels indicated

(a) between 5 and 6 km from 00;

(b) between 7 and 11 km from 00;

(c) between 14 and 17 km from 00;

and (d) between 18.5 and 21 km from 00;

Note also major basement topographic highs at 1.2 km from 00 and between 11 and 14 km from 00. (These correspond to surface topographic highs).

Gravity (see Plan No. S11492)

The regional gravity for the short gravity traverse made on line 1 is estimated from seismic depths at three points, one at each end and one at the middle. The residual gravity agrees well with the detailed seismic profile, indicating a basement high along this section. Of necessity the gravity profile gives a smoothed picture of the basement profile and this is further compounded by using the Bouguer slab formula to estimate basement depths. Thus, the minor sharp depressions which appear at 0.8 km and 1.8 km respectively on the seismic profile are represented only by inflections on the profile derived from the gravity. (By using an iterative scheme such as Qreshi and Mula (1971), these inflections could probably be resolved into depressions). Nevertheless, it seems that, with proper control, the gravity method is capable of resolving important features (greater than 200 m in width) such as the basement high already noted.

(2) Line 2

Seismic (see Plan No. 75-491)

Upper layer (V_1) velocities measured along this section adjoining Lake Greenly are relatively high (2 000 to 2 800 m/s), higher in fact than one would expect from water-saturated sediments. There are two possible explanations for this:

(a) the section above basement consists entirely of fairly consolidated rock which could even be weathered basement. If this is so then maximum basement depths are at least 100 m below ground surface, ie. there could be up to 100 m of weathering;

(b) a velocity inversion occurs (a high velocity layer overlying a lower velocity layer) due to, for example, a well-developed but thin limestone overlying water-saturated sands. In this case a lower average velocity should be assumed, and calculated depths will be correspondingly lower.

Basement profiles under both these assumptions are shown in Plan No. 75-491, where the average V_1 velocity (1 530 m/s) for Line 1 is used for case (b). The drilling informatinn apparently supports case (b). In any case there seem to be two major depressions, one between 0.4 and 1.7 km from 00, and one between 3.2 and 4.3 km.

(3) Line 3 (see Plan No. 75-492)

Although irregular, the basement profile along this section is fairly shallow, with only one major depression between 6 and 8 km from 00. Velocities in the upper (V_1) layer range from 1600 to 2070 m/s, in keeping with those on Line 1 and, in fact, with most water-saturated sediments.

(4) Line 7 (see Plan No. S11493)

This short traverse was situated at the eastern foot of the Marble Range. Upper layer velocities are of the same order as on Line 2 (Plan No. 75-491), so that a similar situation may occur here. If there is in fact a velocity inversion then the depression centred 1 km from 00 assumes some importance and may be worthy of investigation. Basement at the northern end of the line is, however, too shallow.

(5) Lines 4, 5, 6 and 8 (see Plan Nos. 75-493, 75-494, 75-494 and 75-496)

These lines are noteworthy because they cover the most important feature in the area, a deep channel extending from north of Cummins and possibly reaching the sea through Avoid Bay. This channel is remarkable in that its course almost exactly parallels the contours on the western flank of the gravity high. This association is probably because the channel follows the trace of some easily eroded member of the basement rocks near the contact of the Flinders and Hutchison Groups.

The seismic traverses across this channel tend to show a deep central channel with characteristically steep sides with subsidiary troughs on its western and eastern edges. There are indications that the sides of the main channel may slope at angles to the horizontal greater than the critical angle of refraction (greater than say 20°); in fact the western edge may be fault-controlled.

Line 8 is the seismic line furthest south, along the Flinders Highway. However, an extension of the channel to the sea through Avoid Bay may be inferred from the aeromagnetic map. At its deepest part the channel is almost certainly well below sea level. If it does extend out to sea the fresh water springs which should resultsat sea from such a situation may be a possible explanation for the coastal bitumen strandings so often reported in this area (Sprigg, 1961).

(6) Line 9 (see Plan No. 75-497)

Gravity only was measured on Line 9, which ran through Cummins. The regional gravity was obtained from the sparse drillhole and seismic information available. Better control is desirable in order to obtain a more accurate representation of basement depths, particularly on the eastern end, where the seismic depths from Line 10 are very doubtful.

Nevertheless, the typical picture of an irregular basement floor does emerge from the residual gravity profile. Two points are worth noting:

(a) the trough underneath Cummins itself which the school bore penetrated seems to contain two channels separated by a minor basement high;

(b) at the western end there is a pronounced basement high which corresponds to a surface topographic high.

(7) Line 10

Seismic records on Line 10 were extremely poor due to the very windy conditions encountered on the last day of shooting and more particularly to a steel pipeline along the edge of the track which gave apparently an echeloning effect to the records. Because of this, no profile has been calculated for this line, and only one doubtful depth estimate was made in order to fix the regional gravity for Line 9.

CONCLUSIONS

The basement floor within the area of E.L. 185 is irregular and contains many channels. The use of the seismic refraction method appears to have been successful in delineating most of these channels. In particular a deep channel which passes under Cummins has been charted nearly to the sea.

This channel has an indirect association with contours defining a gravity high on the LINCOLN 1:250 000 gravity sheet: but is of insufficient depth and width to produce a direct effect on this map because of the wide gravity station spacing. Its association lies rather in that the course of the channel may follow an easily eroded member of a metamorphic basement structure which itself gives rise to the gravity high.

Nevertheless, traverses employing closely spaced (122 m) gravity stations have shown that if adequate control of the regional gravity effect can be obtained from knowledge of basement depths at intervals along each traverse, a reasonably good estimate of the finer basement profile should results. The basement depths for control purposes could come from either seismic or drilling data and should preferably be at intervals of 3-4 km. Surface levelling is necessary, but only one operator is required for the gravity measurements.

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21st May, 1975

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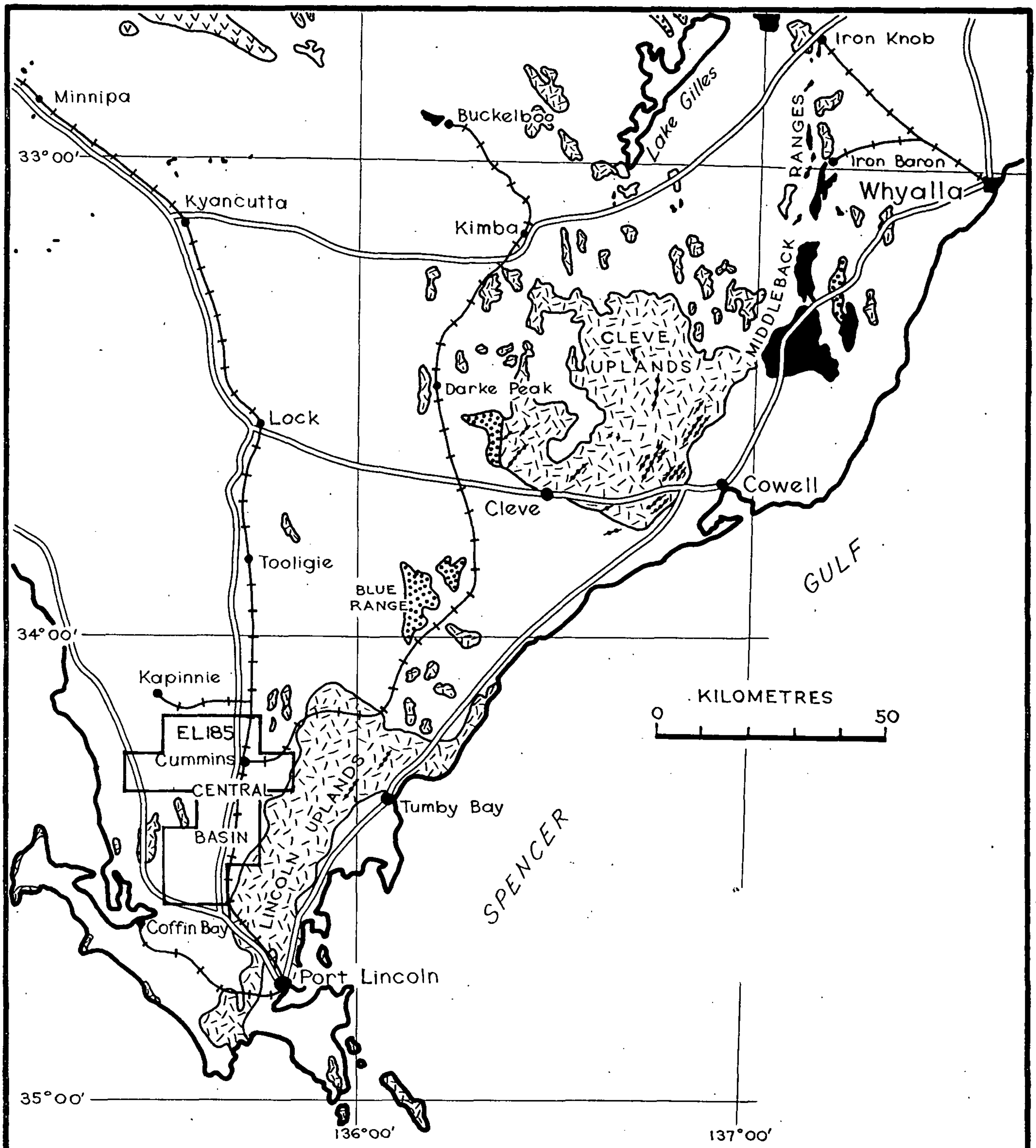

LEGEND

CAINOZOIC		Mainly silica and carbonate sand and aeolianite overlying Tertiary sediments.
PRECAMBRIAN		GAWLER RANGE VOLCANICS: Pink quartz feldspar porphyry.
		BLUE RANGE SANDSTONE: Conglomerate, sandstone, siltstone, dolomite.
		BURKITT GRANITE, CHARLESTON GRANITE, MOONABIE PORPHYRY and other massive coarse grained granites.
		CLEVE METAMORPHICS: Schist, gneiss, quartzite, iron formation. Dolomite.

Modified from a plan prepared by Hiern (1972).

DEPARTMENT OF MINES — SOUTH AUSTRALIA

Douglas Nichol GEOLOGIST	**Drn.** D.N. **Tcd.** A.F. **Ckd.** A.F. **Exd.**	SOUTHERN EYRE PENINSULA SHOWING EL 185 REGIONAL GEOLOGY	**SCALE:** 1:1250 000 S11494 **DATE:** AUGUST 1974

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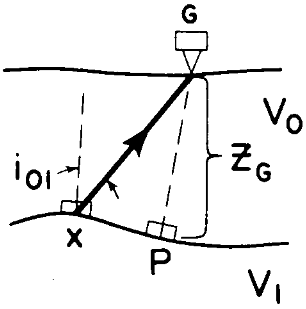
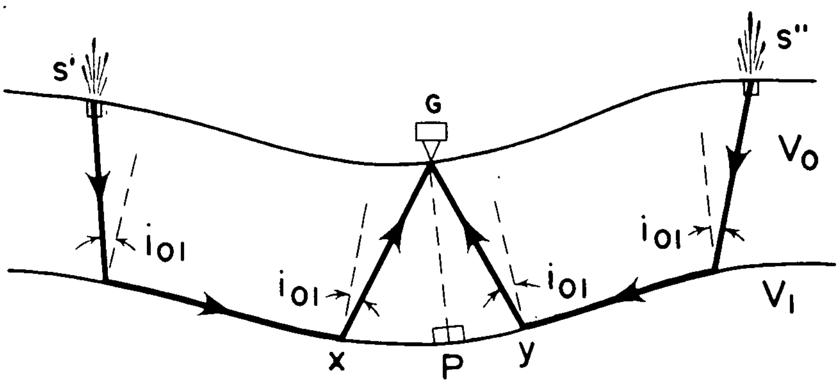


TIME DEPTH

T_G = time delay in travelling between refractor and surface

$$= \frac{Gx}{V_0} - \frac{Px}{V_1}$$

$$= \frac{Z_G \cos i_{01}}{V_0}$$



$$T_G = \tfrac{1}{2}\left(T_{s'G} + T_{s''G} - T_{s's''}\right)$$

(1) Determine reciprocal time $T_{s's''}$

(2) Add recorded travel times from shooting each way

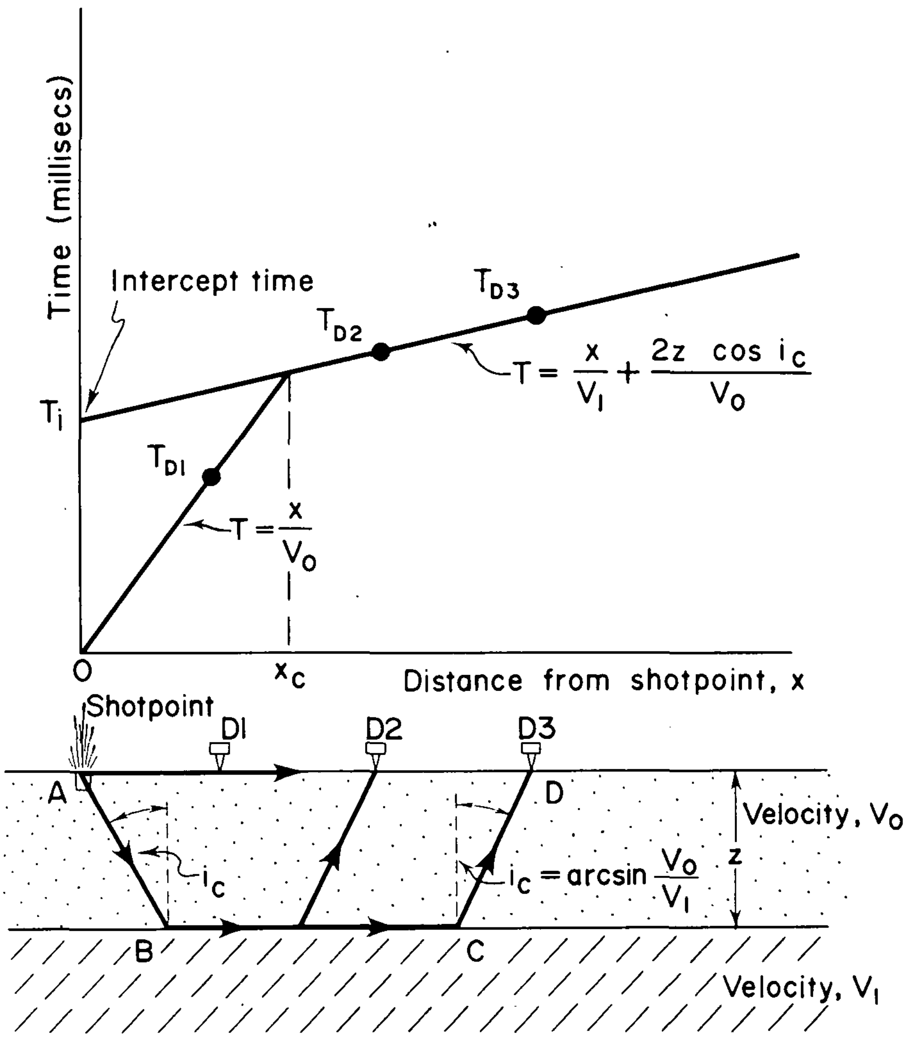
(3) Subtract $T_{s's''}$ and divide by 2

(4) Calculate depth Z_G

DEPARTMENT OF MINES — SOUTH AUSTRALIA

GEOPHYSICAL SERVICES SECTION	Drn. RN Tcd. AF Ckd. Exd.	SEISMIC REFRACTION METHOD OF RECIPROCAL ANALYSIS	SCALE: S11495 DATE: April 1975

500-2.69 665



Travel times

(a) Direct wave: $T = \frac{x}{V_0}$

(b) Refracted wave: $T = T_{AB} + T_{BC} + T_{CD}$

$$T_{AB} = T_{CD} = \frac{z}{V_0 \cos i_c}$$

$$T_{BC} = \frac{x - 2z \tan i_c}{V_1}$$

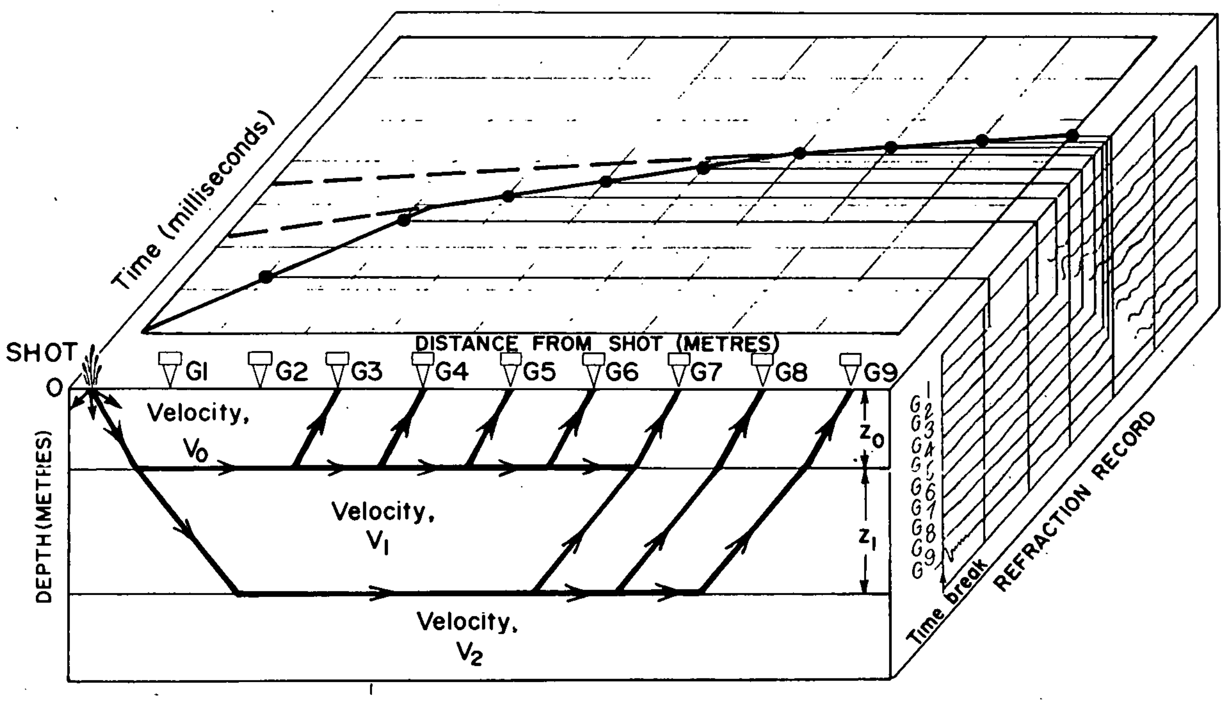
DEPARTMENT OF MINES — SOUTH AUSTRALIA

GEOPHYSICAL SERVICES SECTION	**Drn.** R.N.	SEISMIC REFRACTION TWO LAYER CASE	**SCALE:**
	Tcd. A.F.		S11496
	Ckd.		
	Exd.		**DATE:** April 1975

SEISMIC REFRACTION — 3-layer case

Thickness of m^{th} layer underlain by n^{th} layer, intercept time t_n is

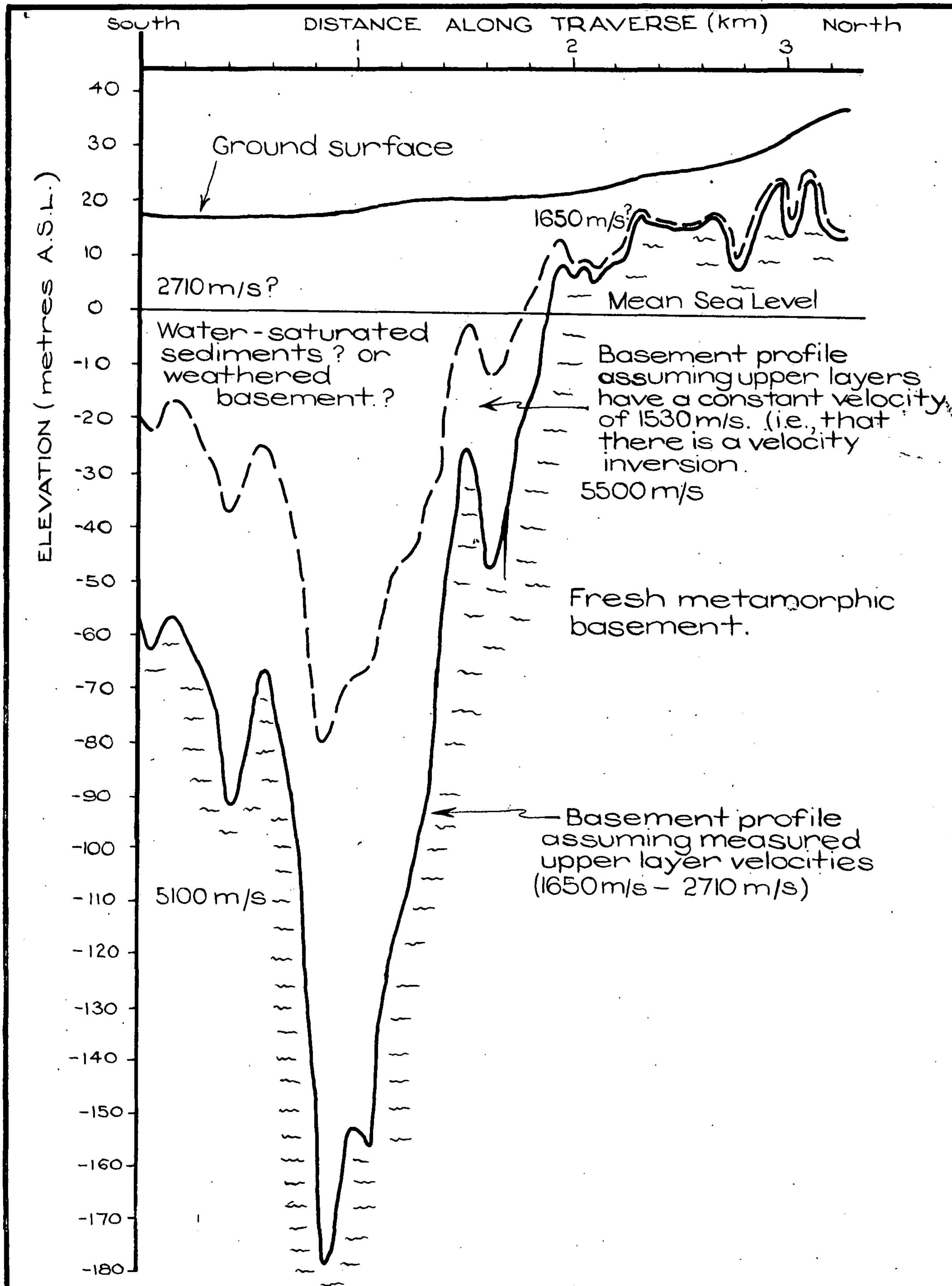
$$z_m = \left(t_n - \sum_{j=0}^{m-1} z_j \frac{\cos i_{jn}}{V_j}\right) \cdot \frac{V_m}{\cos i_{mn}}$$



DEPARTMENT OF MINES — SOUTH AUSTRALIA

GEOPHYSICAL SERVICES SECTION	**Drn.** R.N.	SEISMIC REFRACTION MULTILAYER CASE	**SCALE:**
	Tcd. A.F.		S11497
	Ckd.		
	Exd.		**DATE:** April 1975

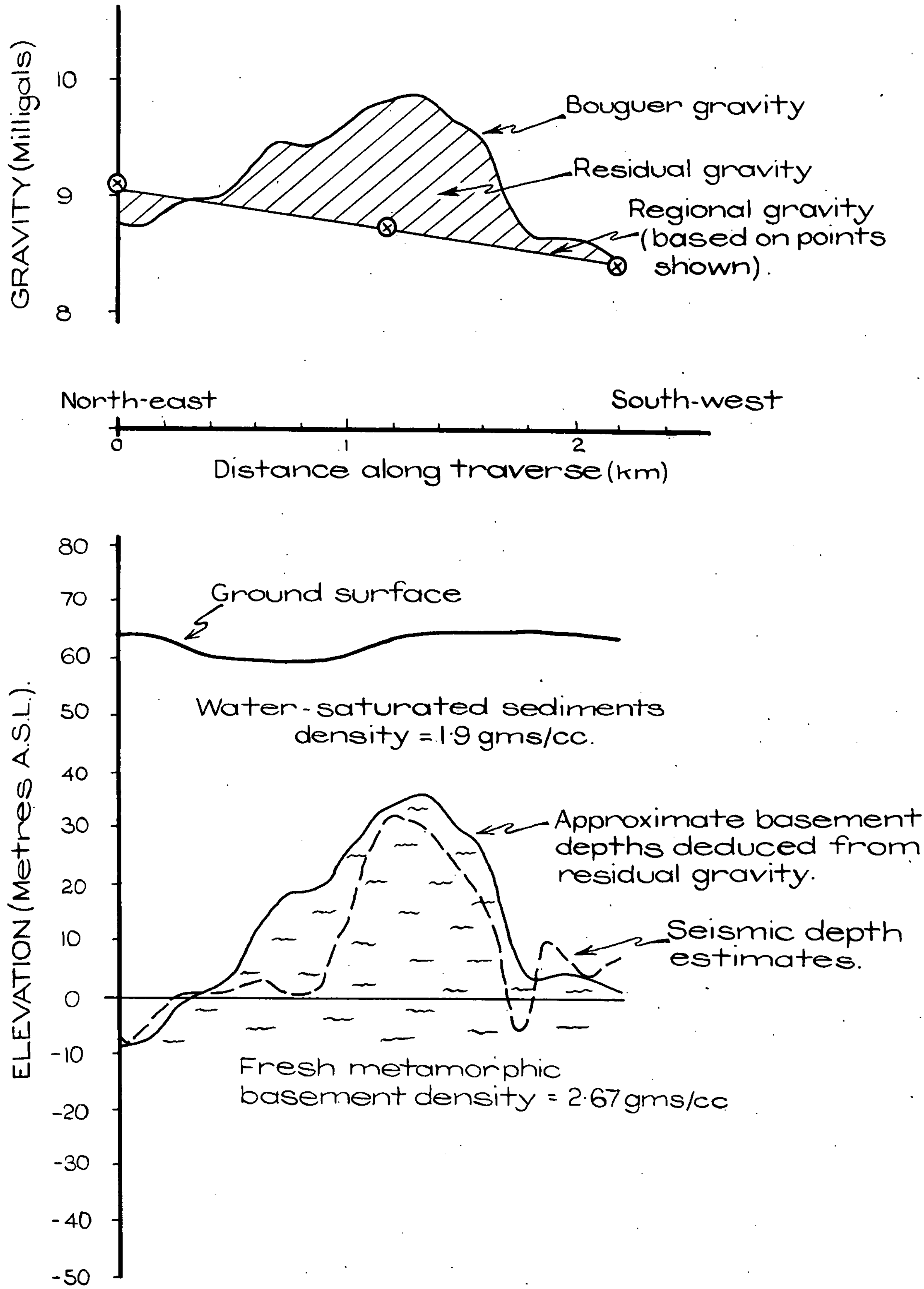
500—2.69 665



DEPARTMENT OF MINES — SOUTH AUSTRALIA

GEOPHYSICAL SERVICES SECTION	**Drn.** R.N	EL 185 SOUTHERN EYRE PENINSULA	**SCALE:** 1 : 25,000
	Tcd. J.W	URANERZ (AUST) PTY. LTD.	S11493
R.G. Nelson	**Ckd.** AF	SEISMIC TRAVERSE LINE - 7	
GEOPHYSICIST	**Exd.**		**DATE:** 12 - 5 - 75

500-2.69 665



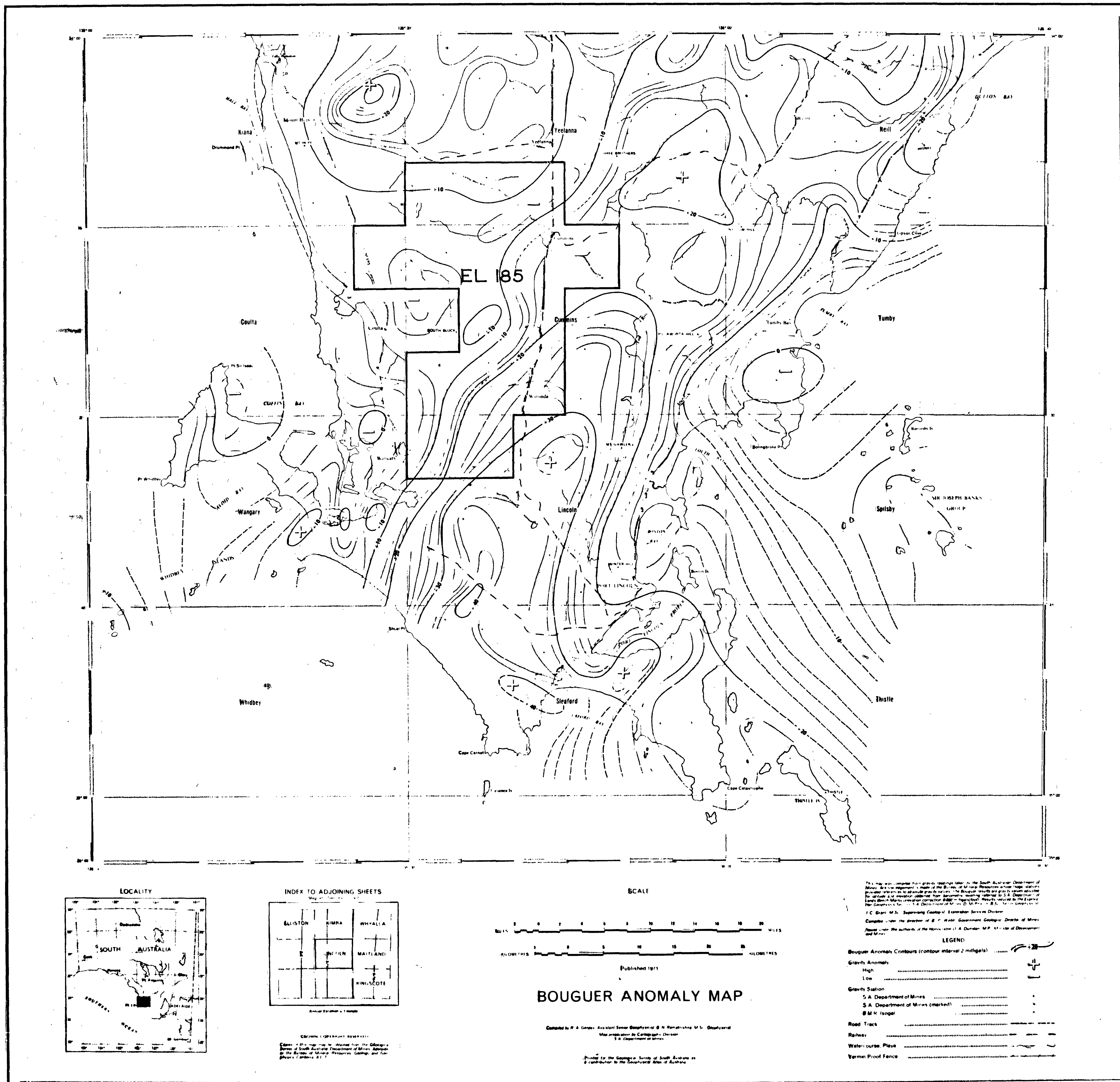
DEPARTMENT OF MINES — SOUTH AUSTRALIA

GEOPHYSICAL SERVICES SECTION	Drn. R.N.	E.L.185 SOUTHERN EYRE PENINSULA	SCALE: 1 : 25,000
	Tcd. J.W.	URANERZ (AUST.) PTY. LTD.	S11492
R. Nelson GEOPHYSICIST	Ckd.	GRAVITY TRAVERSE LINE 1	
	Exd.		DATE: 12-5-75

500-2.69 665

LINCOLN

GEOLOGICAL SURVEY OF SOUTH AUSTRALIA
DEPARTMENT OF MINES ADELAIDE



LINCOLN

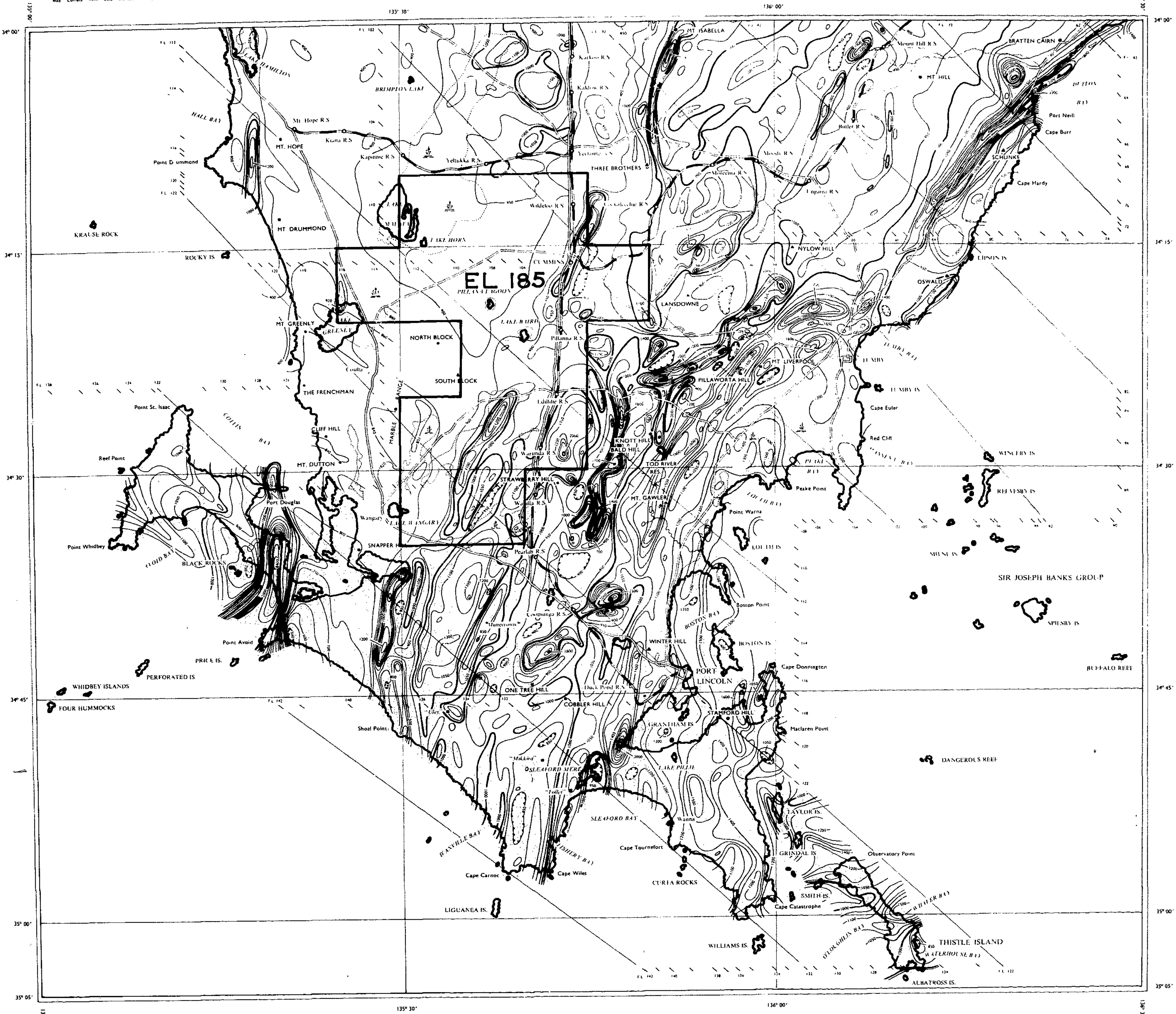
75-505

LINCOLN

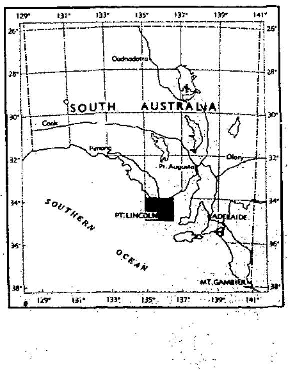
AUSTRALIA 1:253,440
Map Corners from data available at publication

GEOLOGICAL SURVEY OF SOUTH AUSTRALIA
DEPARTMENT OF MINES, ADELAIDE

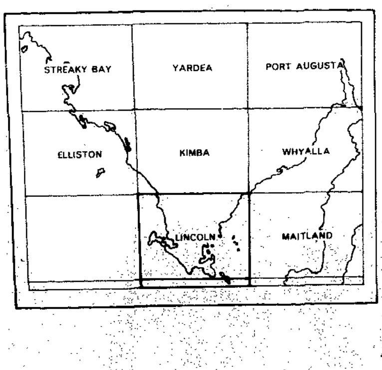
4 MILE GEOPHYSICAL SERIES SHEET I 53-11 ZONE 5



LOCALITY



INDEX TO ADJOINING SHEETS



SCALE

MILES 2 1 0 2 4 6 8 10 12 14 16 18 20 MILES

KILOMETRES 5 0 5 10 15 20 25 KILOMETRES

AEROMAGNETIC MAP OF TOTAL INTENSITY

Published 1963

NOTE

This map is compiled from air-borne magnetometer surveys conducted by Adastra Hunting Geophysics Ltd., on behalf of The S.A. Department of Mines.
The total magnetic intensity at 1,500 feet above ground level was recorded continuously. The contours are corrected for normal regional gradient. Uncontrolled photo-mosaic assemblies were used to navigate flight lines at a spacing of one mile and controlled base maps indicate the aircrafts actual flight course as recorded on overlapping photographs taken with a 35mm. Vinten camera during flight.
Results reduced by Geophysical Section, S.A. Dept. of Mines. J. E. Webb, B.Sc., A.S.A.S.M., Senior Geophysicist.
Compiled under the direction of T. A. Barnes, M.Sc., Government Geologist.
Issued under the Authority of the Honourable Sir A. Lyell McEwin, M.L.C.

LEGEND

Magnetic Contours (values in gammas) ....

Flight line ....

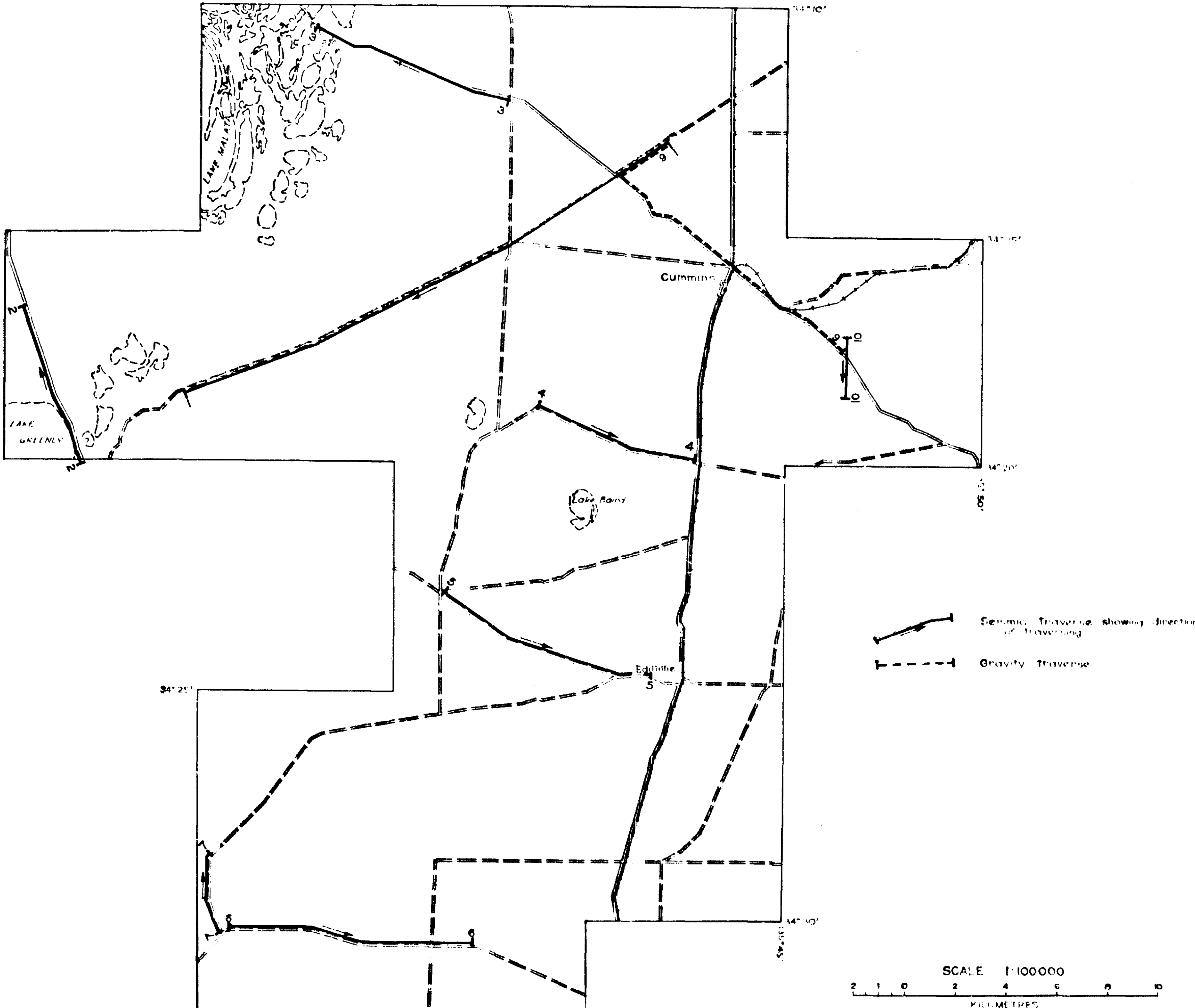
Magnetic low ....

Railways ....

Roads shown thus ....

This 4 mile map reduced by S.A. Dept. of Mines from published 1 mile maps.

LINCOLN 75-504

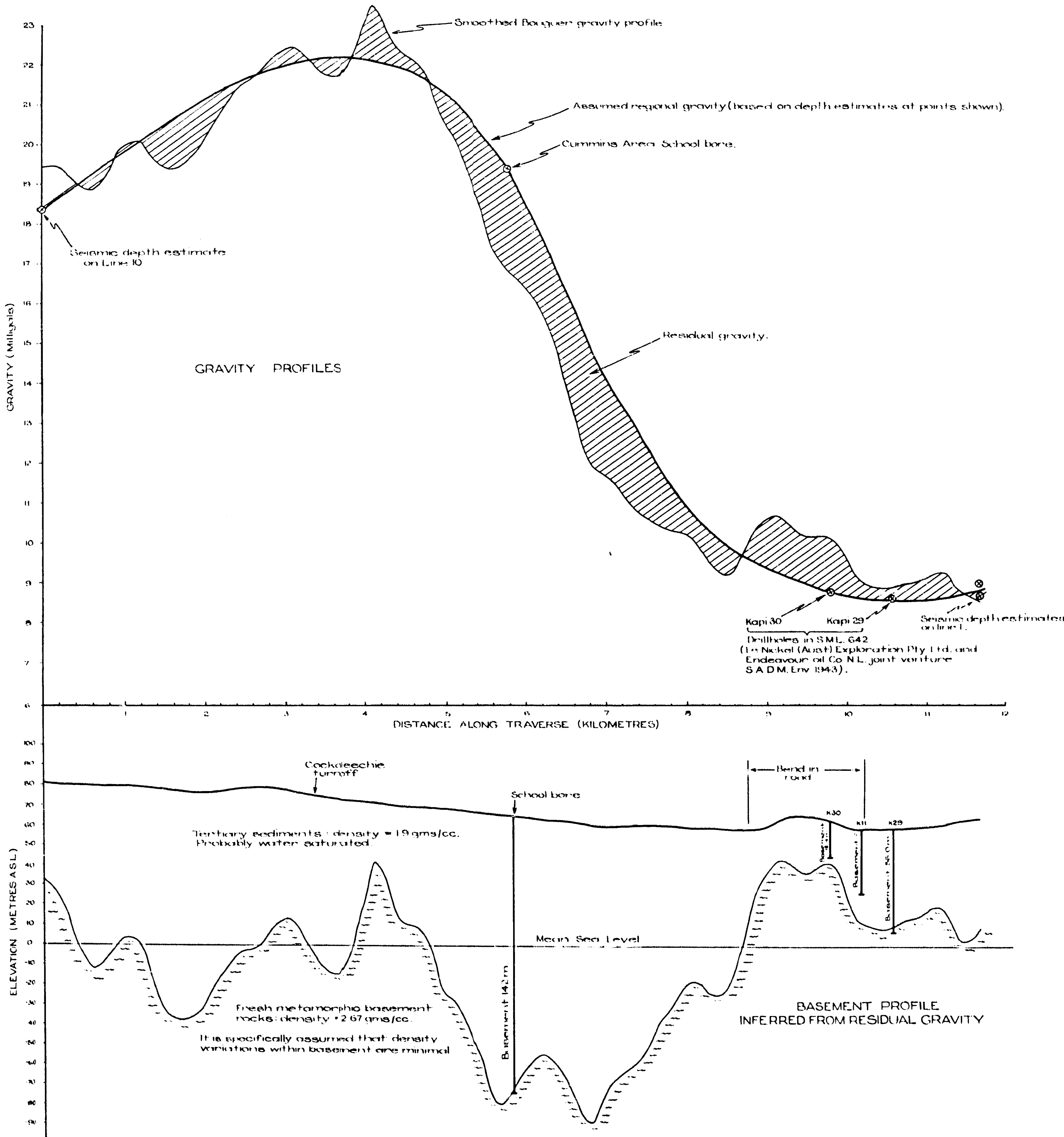


DEPARTMENT OF MINES – SOUTH AUSTRALIA

EL 185 SOUTHERN EYRE PENINSULA
(URANERZ AUST. PTY. LTD.)

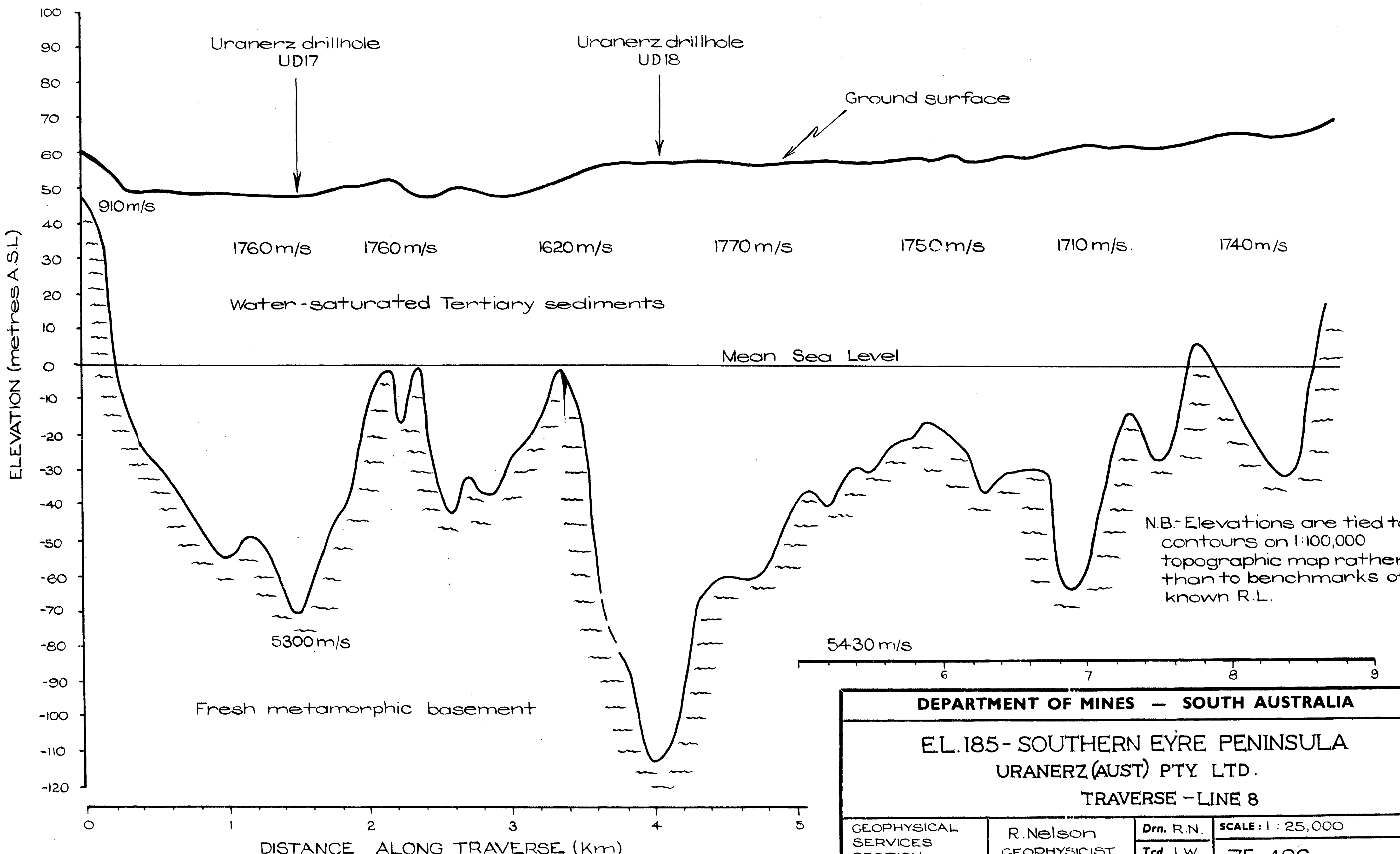
LOCATION OF TRAVERSES

SERVICES SECTION		Compiled R	Scale :
			Date :
		Drn. 4F	Drg No 75-503
Director of Mines		Ckd	



DEPARTMENT OF MINES — SOUTH AUSTRALIA			
E.L. 185 - SOUTHERN EYRE PENINSULA URANERZ (AUST) PTY. LTD. GRAVITY TRAVERSE - LINE 9			
GEOPHYSICAL SERVICES SECTION	R Nelson GEOPHYSICIST	Compiled R.N.	Scale: HORIZONTAL 1:25,000 VERTICAL 1:1000
			Date: 12-5-75
Director of Mines		Drn. J.W. Chd.	Drg. No. 75-497

5029, 6029, 6028



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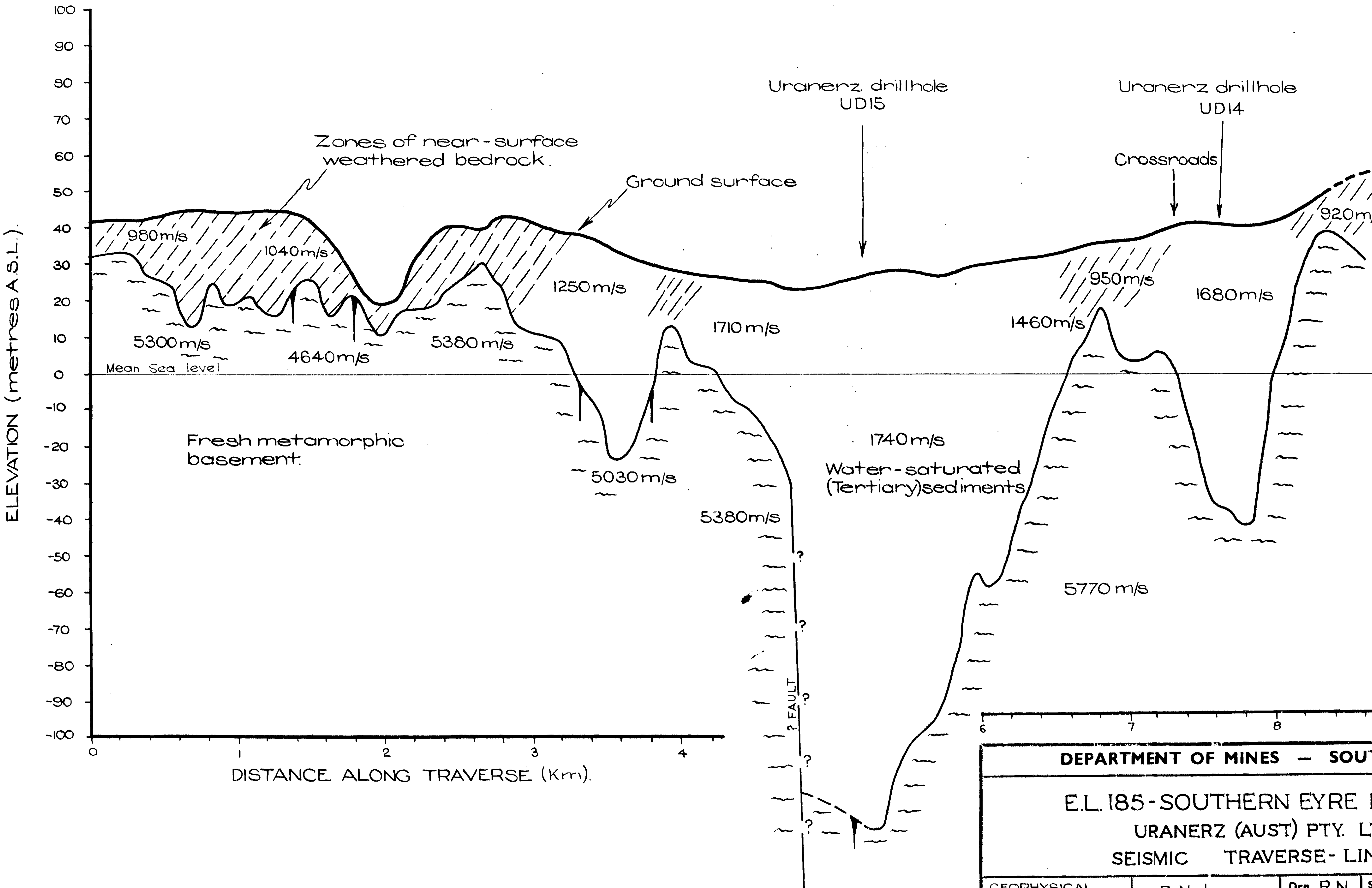
E.L. 185 - SOUTHERN EYRE PENINSULA

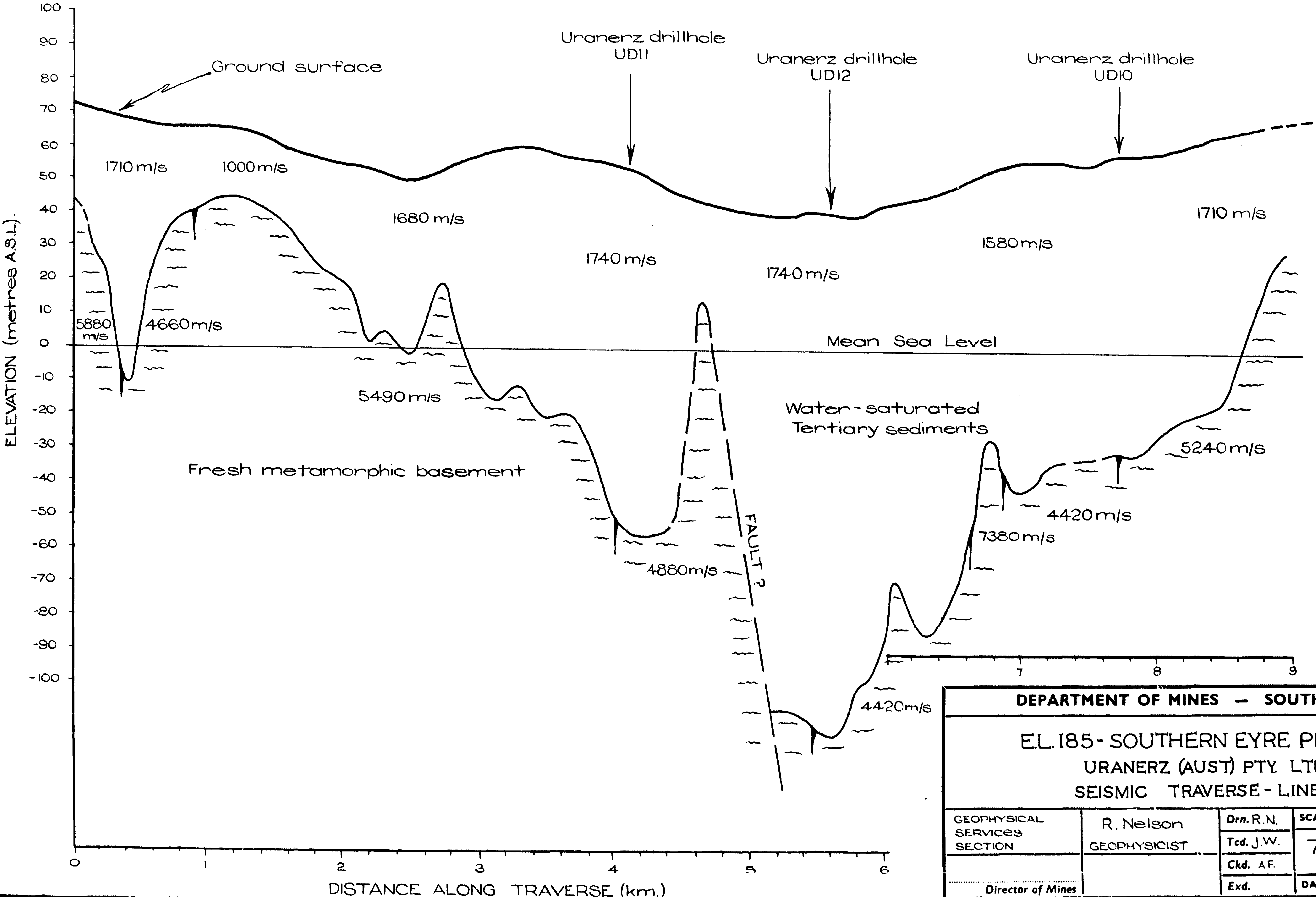
URANERZ (AUST) PTY. LTD.

TRAVERSE - LINE 8

GEOPHYSICAL SERVICES SECTION	R. Nelson GEOPHYSICIST	Drn. R.N.	SCALE: 1 : 25,000
		Tcd. J.W.	75-496
		Ckd. A.F.	
Director of Mines		Exd.	DATE: 12-5-75



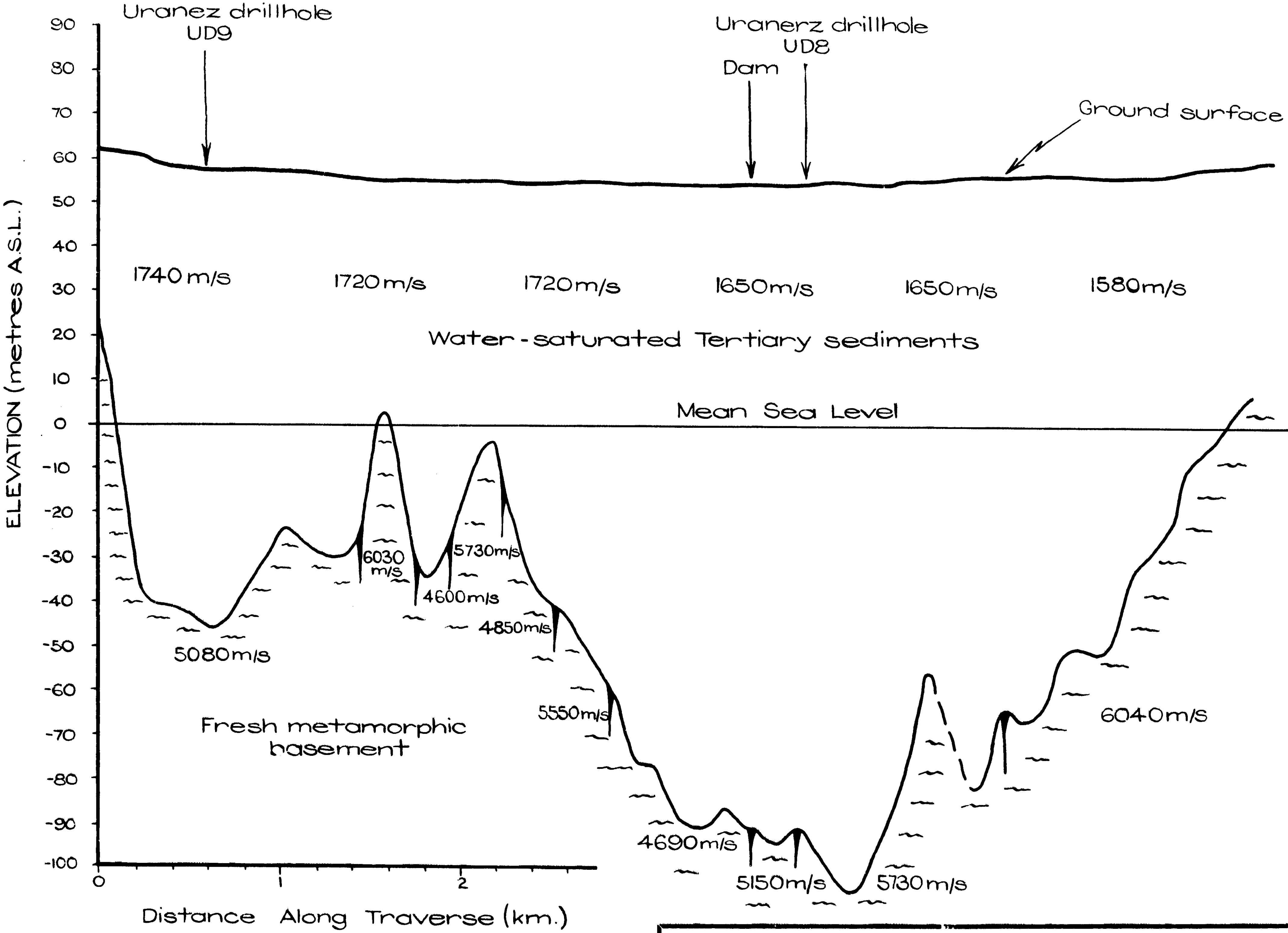
DEPARTMENT OF MINES — SOUTH AUSTRALIA			
E.L. 185 - SOUTHERN EYRE PENINSULA URANERZ (AUST) PTY. LTD. SEISMIC TRAVERSE - LINE 6			
GEOPHYSICAL SERVICES SECTION	R. Nelson GEOPHYSICIST	Drn. R.N	SCALE: 1 : 25,000
		Tcd. J.W.	75-495
		Ckd. A.F.	
Director of Mines		Exd.	DATE: 15-5-75



DEPARTMENT OF MINES — SOUTH AUSTRALIA

E.L. 185 - SOUTHERN EYRE PENINSULA
URANERZ (AUST) PTY. LTD.
SEISMIC TRAVERSE - LINE 5

GEOPHYSICAL SERVICES SECTION	R. Nelson GEOPHYSICIST	Drn. R.N.	SCALE : 1 : 25,000
		Tcd. J.W.	75-494
		Ckd. A.F.	
Director of Mines		Exd.	DATE : 12-5-75



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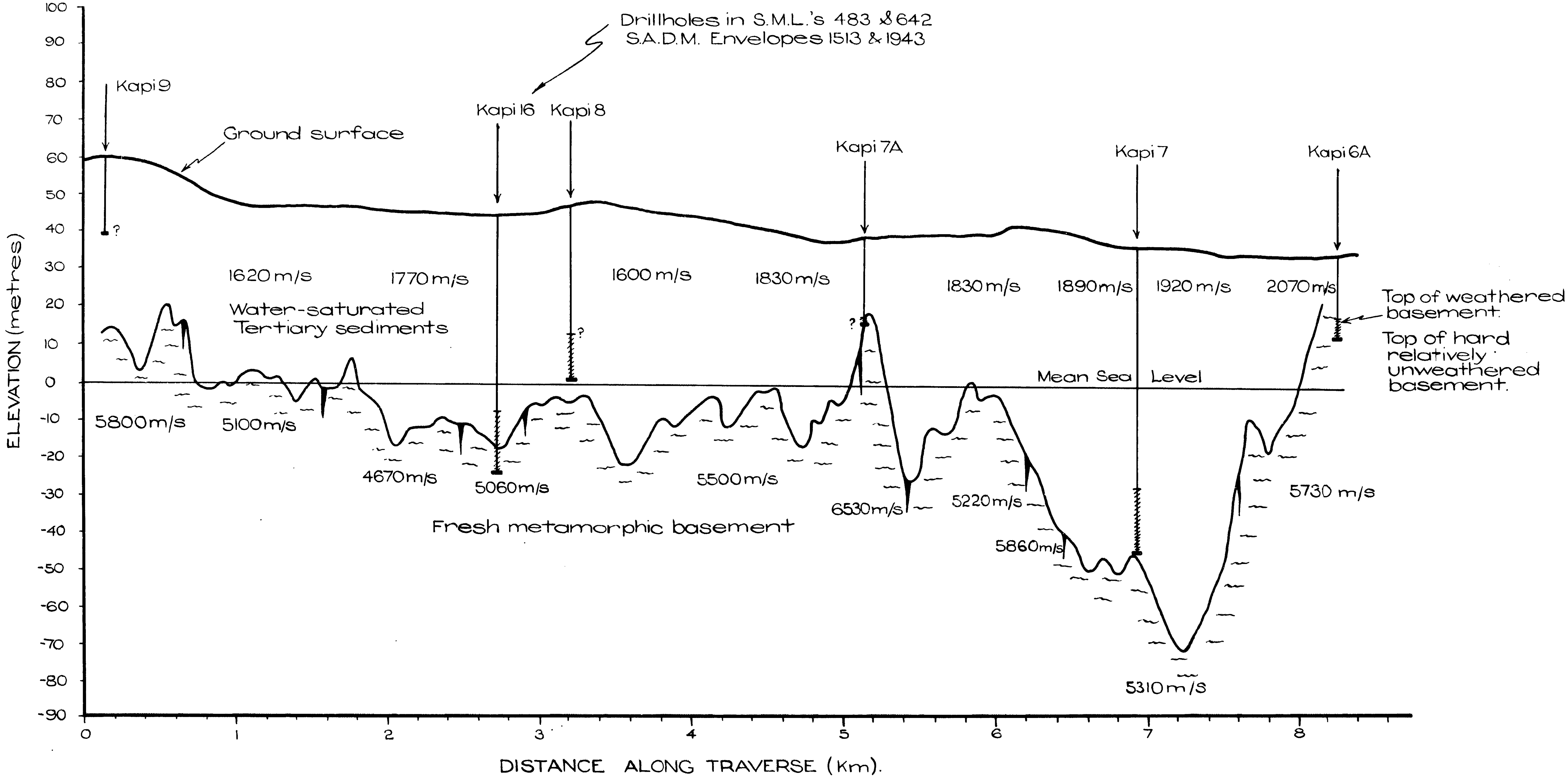
E.L. 185 - SOUTHERN EYRE PENINSULA

URANERZ (AUST) PTY. LTD.

SEISMIC TRAVERSE - LINE 4

GEOPHYSICAL SERVICES SECTION	R. Nelson GEOPHYSICIST	Drn. R.N.	SCALE: 1 : 25,000
		Tcd. J.W.	75-493
		Ckd. A.F.	
Director of Mines		Exd.	DATE: 12-5-75



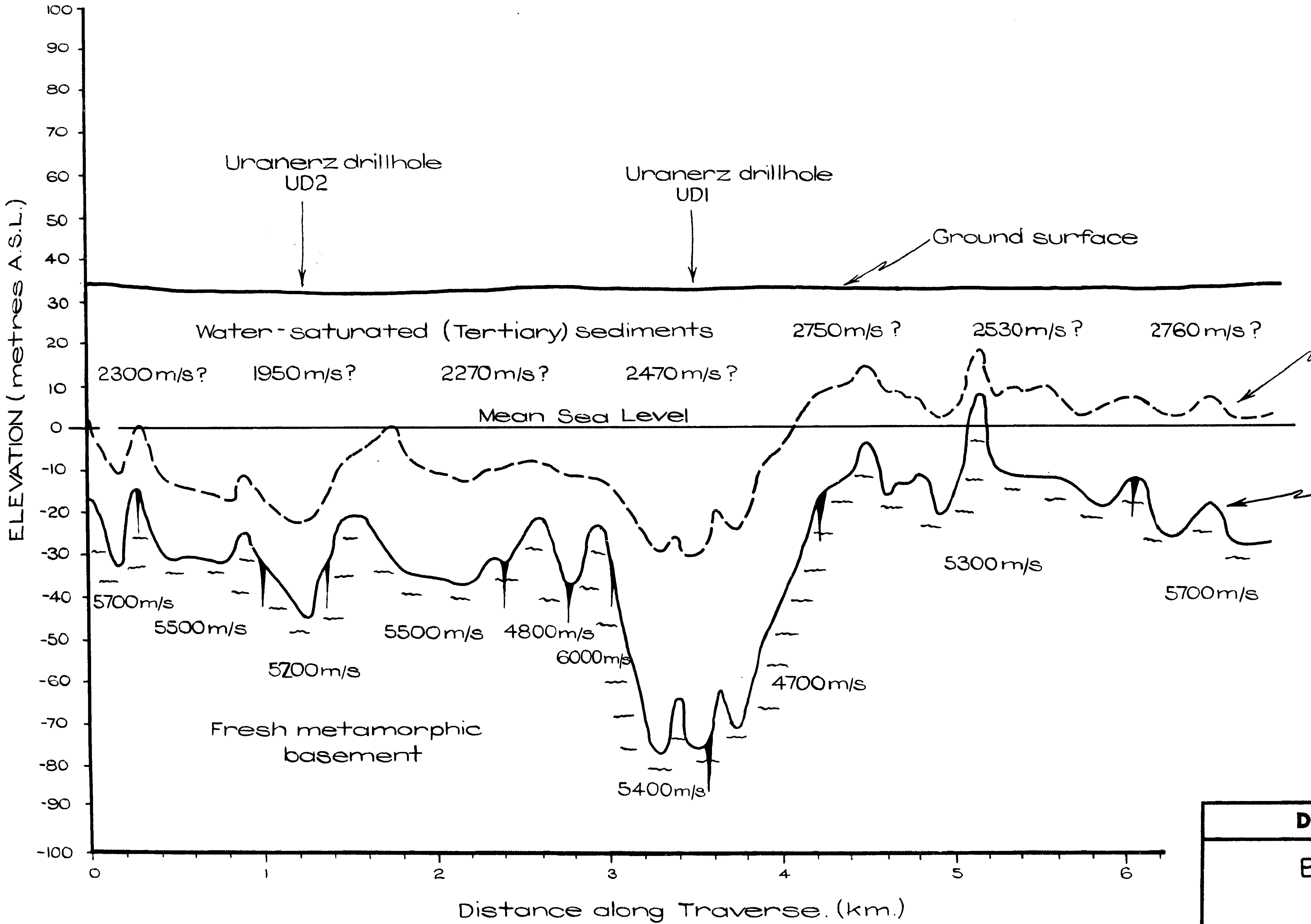
DEPARTMENT OF MINES – SOUTH AUSTRALIA

E.L. 185 - SOUTHERN EYRE PENINSULA

URANERZ (AUST.) PTY. LTD.

SEISMIC TRAVERSE – LINE 3

GEOPHYSICAL SERVICES SECTION	R. Nelson GEOPHYSICIST	Drn. R.N.	SCALE: 1: 25,000
		Tcd. J.W.	75-492
		Ckd. A.F.	
Director of Mines		Exd.	DATE: 12-5-75



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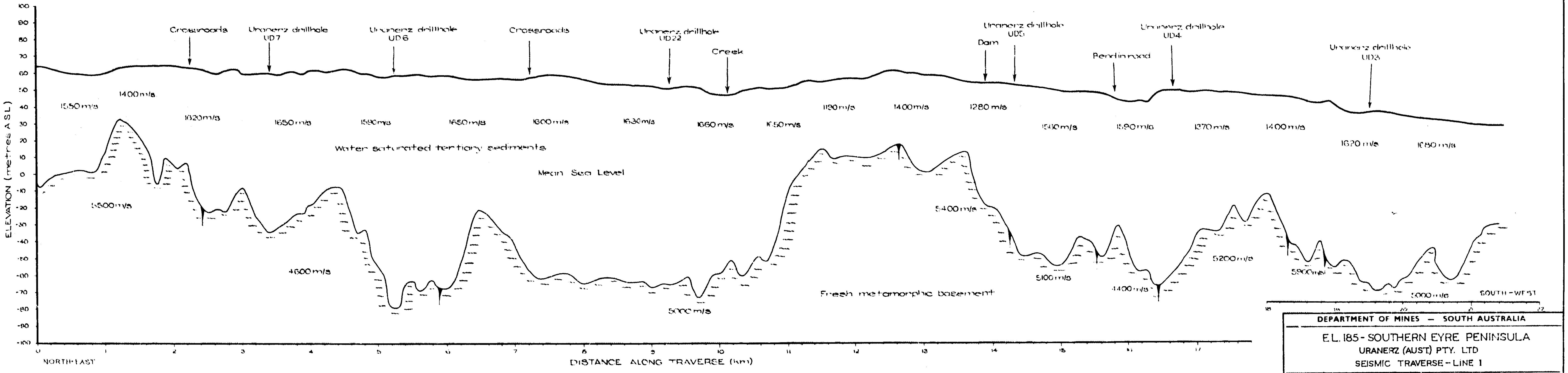
URANERZ (AUST.) PTY. LTD.

SEISMIC TRAVERSE - LINE 2

GEOPHYSICAL SERVICES SECTION	R. Nelson GEOPHYSICIST	**Compiled** R.N.	**Scale:** 1:25,000
			Date: 12-5-75
Director of Mines		**Drn.** J.W.	**Drg. No.** 75-491
		Ckd. A.F.	

1000-9.73 E407



DEPARTMENT OF MINES — SOUTH AUSTRALIA

E.L. 185 - SOUTHERN EYRE PENINSULA

URANERZ (AUST.) PTY. LTD

SEISMIC TRAVERSE - LINE 1

GEOPHYSICAL SERVICES SECTION	R Nelson GEOPHYSICIST	Compiled R N	Scale: 1 : 25,000
			Date: 12-5-75
Director of Mines		Drn. J W	Drg. No. 75-490
		Chd. AF	

5029, 6029, 6028