DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

GEOLOGICAL SURVEY
GEOPHYSICS DIVISION

EXPLORATION FOR BURIED TERTIARY CHANNELS NEAR CARALUE BLUFF, EYRE PENINSULA

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CONTENTS PAGE

PLANS

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ABSTRACT

Interpretation of a detailed gravity survey over a Tertiary palaeochannel west of Caralue Bluff, Eyre Peninsula, suggested that the method could not locate the channel because of interference from density contrasts within basement. Re-interpretation of the data reveals that the gravity method does indicate the channel's presence, although obscurely.

A small north-south negative Bouguer anomaly occurring in the vicinity of the broad basement depression was interpreted to be due to a local deepening of the channel. Seismic refraction work across the area subsequently showed the basement to be locally 30-40 m deeper along the axis of this negative anomaly. Gravity modelling of the basement depression, and incorporating density contrasts with-in the basement, gave satisfactory results after many modifications and confirmed a signal-to-noise ratio of approximately 1:2.

The work shows that the detailed gravity method can be applied successfully and should be considered in the early stages of any exploration programme seeking buried palaeochannels.

INTRODUCTION

Many private companies have explored for uranium in the areas of exposed Precambrian basement along the eastern side of Eyre Peninsula, and also in the Tertiary sediments that surround these potential source rocks. Those companies exploring in the Tertiary sediments were mainly discouraged by the expense of exploration drilling. One such company, Mines Administration Pty. Ltd., tried a number of alternative techniques to drilling, including detailed gravity surveying. The gravity survey was conducted over an area west of Caralue Bluff (Figure 1) where drilling had indicated the presence of a basement palaeochannel, but the method was considered to have failed to locate the channel because of interference from large density contrasts within the basement.

Officers of the Geological Survey of South Australia disagreed with some aspects of the interpretation but in order to test their hypotheses a more detailed picture of the basement topography was required. Consequently a small seismic refraction survey was carried out in the area. The field work was carried out in one day in late 1976 by a small crew which had been operating in a nearby area. Two traverses were shot along road sides. Both crossed the suspected palaeochannel and both had gravity data recorded along them (Figure 2).

GEOLOGY

A veneer of Quaternary sediments covers the entire survey area. These sediments are underlain in places by Tertiary sediments, which in turn occupy shallow basins and channels on an irregular palaeosurface eroded in Precambrian rocks.

Basement

The Precambrian basement is probably composed of Lower Proterozoic Cleve Metamorphics. These are well exposed along the eastern side of the peninsula, where they have a dominantly north to northeasterly trend. The metasediments are largely comprised of the Hutchinson Group which is mainly mica schist, but includes a variety of other lithologies (dolomite, pegmatitic gneiss, amphibolite and iron formations). Isolated outcrops of schist are found west of the survey area, and iron formations are present at shallow depths near Warramboo. The sequence also includes the Warrow Quartzite which crops out prominently in the Darke Ranges and Caralue Bluff to the east. Middle Proterozoic basement rocks, equivalents of the Corunna Conglomerate, Gawler Range Volcanics, etc., may or may not be present in the area.

Tertiary

Clays, silts, sands and gravels of probable Eocene age are widely distributed in shallow basins and channels on the irregular Precambrian palaeosurface. Younger sediments of probable Miocene age have also been recognised from the Polda Basin to the south (Harris, 1973). The sediments are commonly carbonaceous, and in some places lignites are well developed. Pyrite is often present. The composition and thickness of the Tertiary section varies widely. Within the survey area it is less than 40 m thick, and was deposited under fluviatile conditions in basement channels (Bryan, 1972). Gravels are locally absent. To the south the sediments have been deposited in basins (e.g. Polda Basin) in a variety of depositional environments (barred basin, paralic, paludal and fluviatile), which explains their variable composition. In places their thickness is greater than 150 m.

Quaternary

The Quaternary section reported by Bryan (1972) consists of 15 m of clay, extending laterally well beyond the Tertiary sand channels, overlain by 18 m of aeolian sands.

PREVIOUS INVESTIGATIONS

The only company to have explored for uranium in the immediate area of interest (see Figure 2) is Mines Administration Pty. Ltd. (Bryan, 1972). Their initial exploration effort involved sampling of groundwaters and an airborne scintillometer reconnaissance. Both techniques yielded only background values, but these results were discounted because of the poor sample coverage in the first case, and the masking effect of the sand and soil cover in the second.

A reconnaissance drilling programme was successful to the extent that a sand channel with associated strong radioactive anomalies was discovered. The uranium content was found to be highly anomalous, but nevertheless absolute values were small. A detailed gravity survey was conducted over the channel to test whether the method could be used elsewhere within the company's lease for locating other Tertiary channels cut into the Precambrian surface.

The contour plan prepared by Wongela Geophysical Pty. Ltd. (Figure 2) shows that the gravity field decreases by about 5 mgal. from west to east, and superimposed on this gradient are positive anomalies with a magnitude of up to 2 mgal. Reporting on the survey, Ingall and Harrison (1971) interpreted the positive anomalies to be due to density contrasts <u>within</u> the relatively shallow basement. Furthermore, they stated that "a gravity anomaly of about 0.2 mgal. can be expected for a channel 200 feet deep", and hence they concluded that such small anomalies due to undulations in basement topography would be masked by the deeper seated affects.

This represents a signal-to-noise ratio of 1:10, and certainly there is no <u>obvious</u> relationship between the gravity and the thickening of sediments as indicated by drilling (refer to the gravity profiles, (Figure 3).

Officers of the Geological Survey of S.A., however, felt that Ingall and Harrison's anticipated anomaly of 0.2 mgal. for a 200 ft. deep channel was in error. The gravity effect of a 60 m thick slab with a density of 0.5 g/cm^3 is 1.3 mgal. The anomaly over a 200 ft. deep channel with a density contrast of 0.5 g/cm^3 would be only slightly less than 1.3 mgal, assuming the channel to be somewhat wider than it is deep, and that it is not deeply buried.

This calculation yields a signal-to-noise ratio of approximately 1:2, and re-examination of the gravity profiles was considered justified. For example, the north-south negative Bouguer anomaly (Figure 2), which in profile appears as only a slight depression on the western flank of the main positive anomaly (Figure 3), could be interpreted as representing a basement depression of some significance - depending on where one locates the background due to regional effects. In fact Ingall and Harrison did recommend drilling along this feature in any future drilling programme, not because they thought it represented a channel, but rather on the assumption that erosional channels on the basement surface might follow less dense and possibly weaker lithological units of the basement.

Although the separation of basement topography and intrabasement effects is obviously difficult, it was felt by officers of the Survey that with a signal-to-noise ratio of 1:2 the method should have a fair chance of achieving its objective, and it was decided to determine the bedrock profile more accurately with seismic refraction and then attempt to relate the gravity information to this.

SEISMIC DATA COLLECTION AND INTERPRETATION

Two traverses were shot across the palaeochannel as shown on Figure 2. These were not surveyed, but spreads were located with reference to bends in fence lines, etc. The seismic equipment consisted of a 24 channel S.I.E. PT100 recording seismograph interfaced with an electrostatic camera. The shothole drill was a large truck-mounted rotary-percussion rig with a kelly length of 6.7 m.

The work was done using 1463 m (4800 ft.) in-line spreads with 61 m (200 ft.) geophone spacings. Shots were fired in the middle of the spread, successive shots being 366 m (1200 ft.) apart. Shotholes were 5 m deep, and 2.6 kg charges of AN60 blasting gelignite were used as a source of energy.

The records were timed, and the data plotted to produce time-distance graphs. These were analysed at each shot position to determine the apparent velocities and intercept times of all refractors that could be identified. In most places three refractors were detected, as shown below.

Layer No.	Velocity (m/s)	Comments
Vo	870	Unsaturated sediments
V_1	1860	Water saturated sediments
V_2	5180	Crystalline basement, probably relatively unweathered.

Conventional seismic refraction equations were then used to determine depths to all refractors. In some places the V_1 layer was not clearly detected, although there was some indication of its presence. At these points it was found that by assuming it to be present the results agreed more closely with drill-hole control. Such 'hidden layer' situations are not uncommon in refraction work.

The method of reciprocal analysis (reviewed by Hawkins, 1961) was also used to yield a 'time-depth' to basement at each geophone position. The method also allows the calculation of 'corrected' velocities, whereby the effects of refractor topography are removed. The basement depths at each shotpoint (as determined by conventional equations) were then used to calculate depth conversion factors (D.C.F.), and by linear extrapolation between adjacent shotpoints a D.C.F. was determined at each geophone position. Using these, time-depths were converted to interpreted depths. Finally all the information was used to prepare seismic velocity cross-sections (Figure 3).

SEISMIC RESULTS AND GRAVITY MODELLING

The cross-sections show fair to good agreement with the drillhole data. The V_1 refractor coincides well with the top of a relatively sandy unit at a depth of c.30 m. The Vo layer, therefore, probably represents the Quaternary clays and aeolian sands reported by Bryan (1972). Had more detailed data been collected, the Vo layer could have been subdivided into two layers representing the sands and clays respectively. This is apparent from the easternmost end of both traverses where the Quaternary clays are absent, and the velocity of the uppermost layer is 535 m/s. Also, two 'weathering' spreads were shot, and for these the velocity of the uppermost unit was 650 m/s. These spreads did not extend quite far enough to measure a separate velocity for the clays, but it is probably slightly greater than 870 m/s. The weathering spreads did indicate that the surface was weakly calcreted, but this was such a weak transmitter of energy as to cause no inversion problems.

The V_1 layer represents the Tertiary channel sands. At the southeastern end of Line 2 this unit changes to predominantly mudstones. The V_2 refractor has velocities characteristic of relatively fresh crystalline basement. This seismic basement correlates well with drill-hole data except at the southeastern end of Line 2. This is most probably explained by a velocity inversion. The mudstones, which are present only along this part of the section, possibly have a lower seismic velocity that the sandy unit at the top of the Tertiary section.

The seismic results show a broad deepening of the basement, just as the drilling had indicated. In the vicinity of the north-south negative Bouguer anomaly the basement is locally 30-40 m deeper, and this indicates that basement topography does, in fact, affect the gravity picture, although the 'signal' is obviously weak relative to the 'noise'.

Some gravity modelling was attempted on Line 1, and although satisfactory results were obtained, the work further illustrated the ambiguities of the method. No local density data were available, so values 'typical' of Tertiary sediments and crystalline basement had to be assumed. The modelling was carried out in two steps.

(a) Using the seismic cross-section and a range of density contrasts, the gravity effect of the sediments was calculated and subtracted from the field data. For a contrast of 0.5 g/cm^3 the resultant curve was quite smooth at those points where the sediments thickened most rapidly, and so this contrast was adopted. This would represent a sediment density of 2.2 g/cm^3 relative to a basement density of 2.7 g/cm^3, which are quite acceptable values.

(b) The gravity effect of intrabasement bodies of various shape with a density contrast of 0.2 g/cm^3 was then calculated, and subtracted from the resultant curve (determined previously). This was tried many times until the anomalies due to local intrabasement effects were cancelled out and the residual was approximately linear. The assumed contrast of 0.2 g/cm^3 was arbitrary, and would represent a density of 2.9 g/cm^3 relative to a basement density of 2.7 g/cm^3.

The model which was finally accepted is shown on Figure 3. The gravity effects of the sediments and the local intrabasement bodies are also shown. The signal-to-noise ratio calculated from these is 1:2.2. It is interesting also to note that the slope of the residual is almost the same as that of a linear regression line through the original field data.

The denser intrabasement bodies occur within zones of relatively higher seismic velocity. There is probably not a strict relationship between these parameters, but it is also noticeable on Line 2, where a particularly high velocity (6980 m/s) was detected at the postulated location of the larger of the denser bodies. Minad's DH24 shows that the basement within this high velocity zone consists of dolomite. Dolomites are typically denser than other lithologies with a similar geological history.

A narrow zone of particularly low seismic velocity (2770 m/s) lies between the two dense bodies on Line 1.

This possibly represents a faulted region, with weathering and erosion of the Precambrian surface being most active along this zone of weakness, giving rise to the observed basement depression. A similarly low seismic velocity was not measured beneath the channel on Line 2, but the data for calculating corrected basement velocities were ambiguous in this region. Alternatively the depression may simply have formed preferentially along a weaker lithological unit.

The small positive Bouguer anomaly just west of the channel becomes more distinct to the south. On Line 2 the basement is locally slightly higher where this anomaly occurs, and also there is a broader zone of relatively higher velocity than on Line 1.

In terms of geology, this simple geometric model suggests that the local basement is probably composed of metasediments of the Cleve Metamorphics, striking north-south, possibly dipping east and with some alternation of lithologies of different densities to give rise to the small positive anomalies. The large regional gradient reflects deeper, larger scale density contrasts.

CONCLUSIONS

The seismic results confirm the presence of a broad basement channel which was initially discovered by drilling. They also indicate that there is a north-south channel where the basement is locally 30-40 m deeper. A detailed gravity survey over the area gives little or no indication of the broad basement depression, but a small negative Bouguer anomaly lies along the axis of the deeper channel.

The gravity effect of a basement depression of the size found here is an easily measurable quantity (>1 mgal.), but in this locality the 'signal' becomes quite obscure in the 'noise' from the local intrabasement sources. Nevertheless the author feels that even here, with a signal-to-noise ratio of 1:2, the signal can be detected and used as a guide to exploration drilling. In other areas the intrabasement effects might be smaller and basement channels larger, with the result that detailed gravity surveying could be applied even more successfully.

In order for the gravity method to detect channels of the size found here the stations would need to be optically levelled and only 100-200 m apart, as for Wongela's survey (Ingall and Harrison, 1971). The cost of this on a large scale in two dimensions would be prohibitive, but it should be economically feasible to make long detailed traverses (one dimension), several kilometres apart, perpendicular to a hypothesized stream direction. Such a programme should enable the detection of any channels that do exist, and as a result enormously reduce the number of drillholes required to explore adequately an area. Naturally, more detailed surveying could be done in areas that prove encouraging.

RECOMMENDATIONS

The economic significance of the deeper depression found by the seismic work is probably very low. The anomalous sands were at the top of the Tertiary sequence, and were relatively thin. There is a possibility that the uranium concentration could be greatest in the centre of the channel, however, and in any future drilling programme in the area this hypothesis should be tested.

It is also recommended that detailed gravity traversing be considered in the early stages of any exploration programme seeking buried channels on a shallow basement surface. Admittedly there are difficulties in interpretation in the initial stages, but as drilling results come in the gravity picture should progressively become clearer, and more useful. Spot seismic work or resistivity depth probes could be used to provide initial depth-to-basement control.

Finally, in any such exploration programme, cores should be cut at several depths in at least some holes to allow density measurements to be made, particularly if a gravity survey has been conducted.

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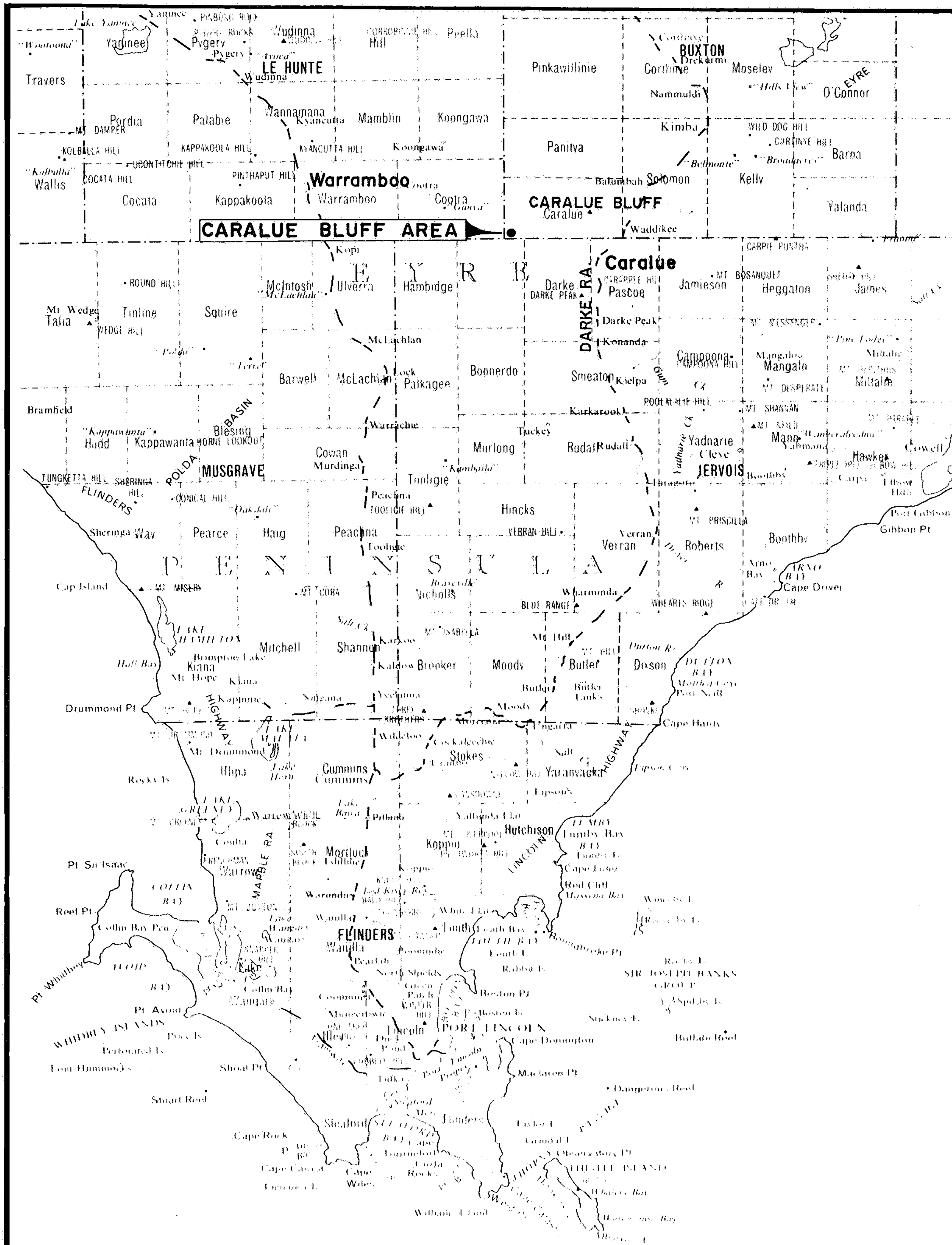
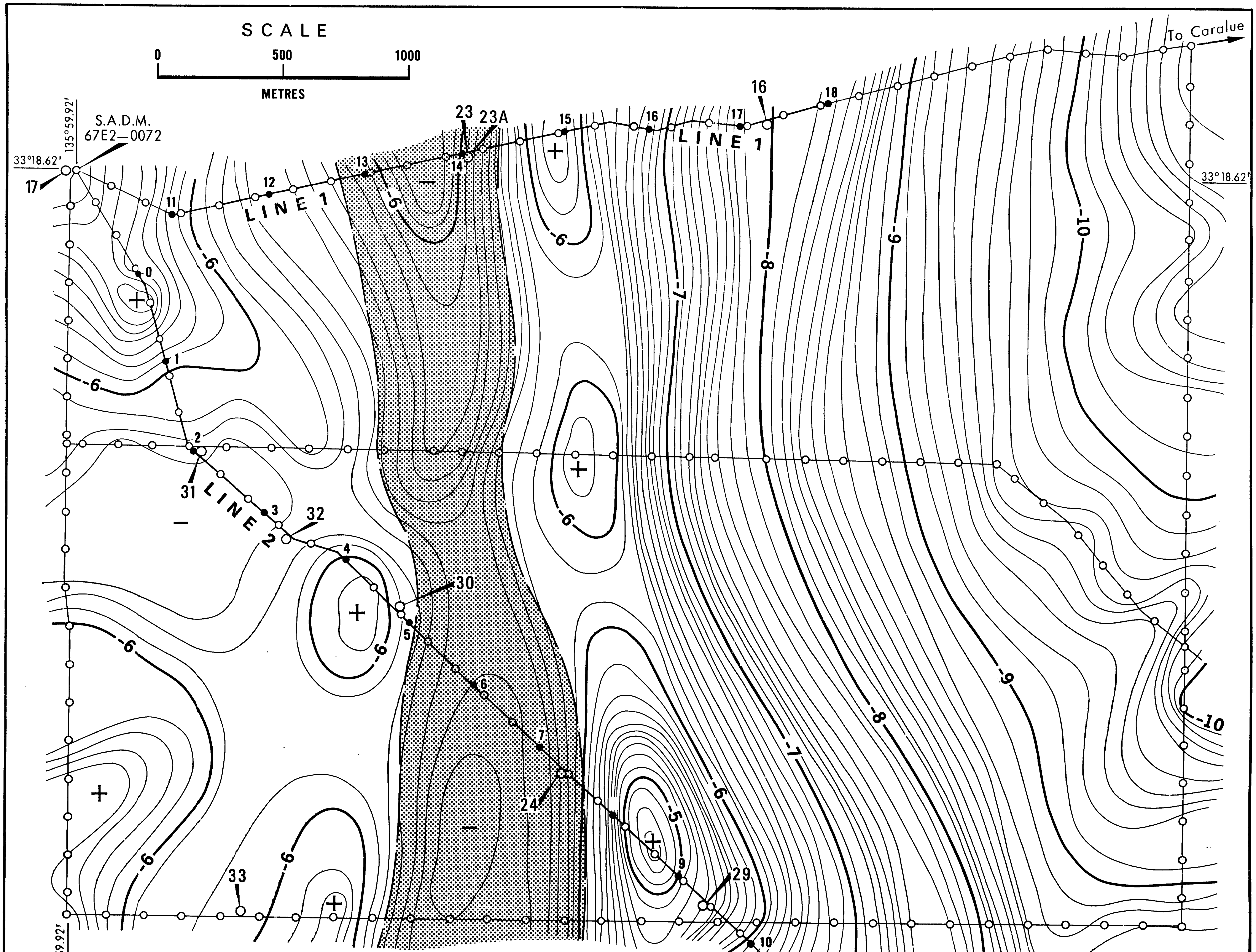


FIG. I

	DEPARTMENT OF MINES—SOUTH AUSTRALIA	SCALE 1:1000000
COMPILED: P. McI.	PALAEO CHANNEL INVESTIGATION—CARALUE BLUFF	DATE 1st Dec. 1977
DRN: T. E. CKD		PLAN NUMBER
	LOCALITY PLAN	S 13151



BOUGUER GRAVITY CONTOURS & SEISMIC LINE LOCATIONS
PALAEO CHANNEL INVESTIGATION—CARALUE BLUFF

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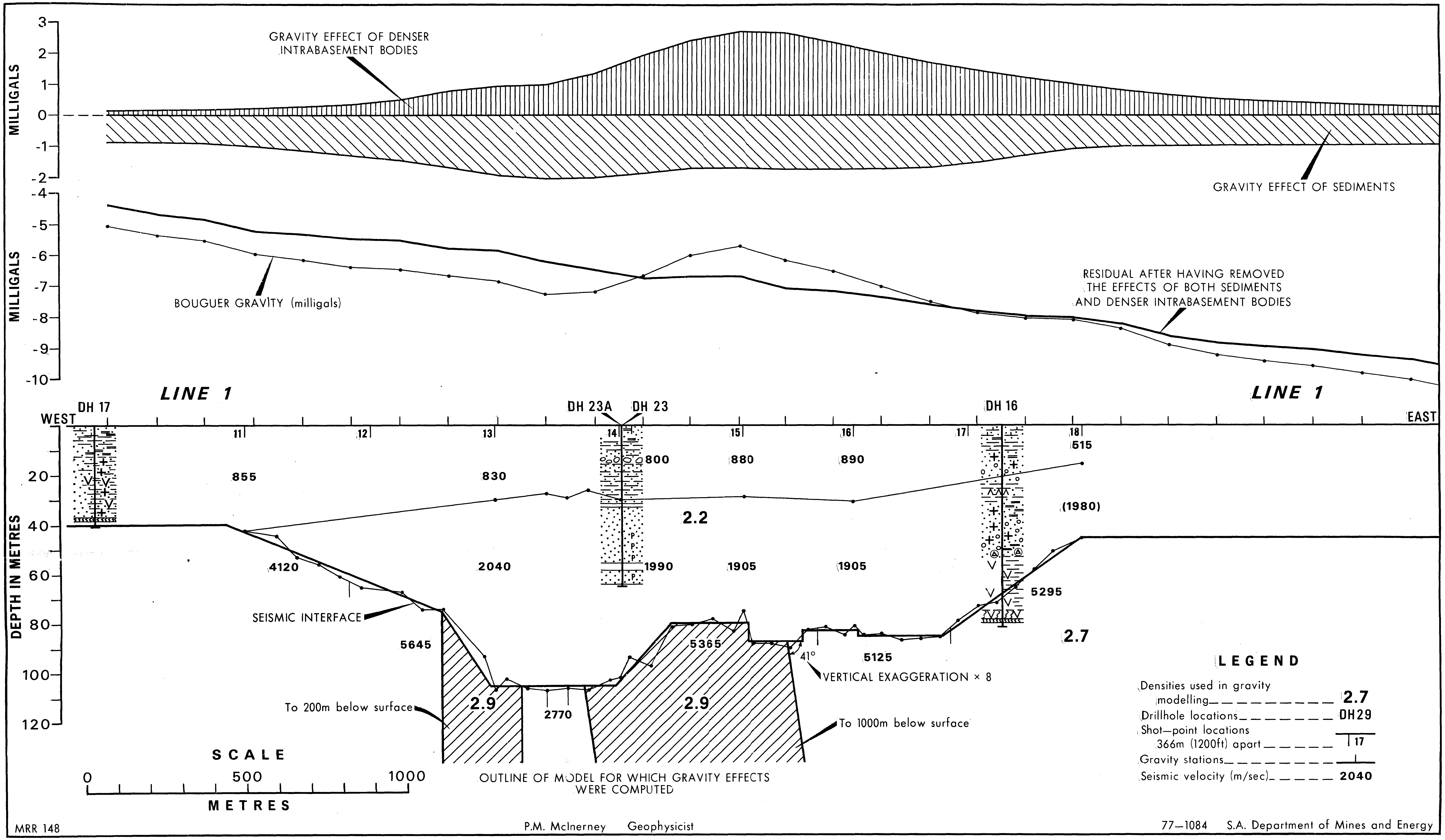
FIG. 2



Reduce to 240 mm 26⅔%

PALAEO CHANNEL INVESTIGATION- CARALUE BLUFF
SEISMIC SECTIONS & GRAVITY PROFILES

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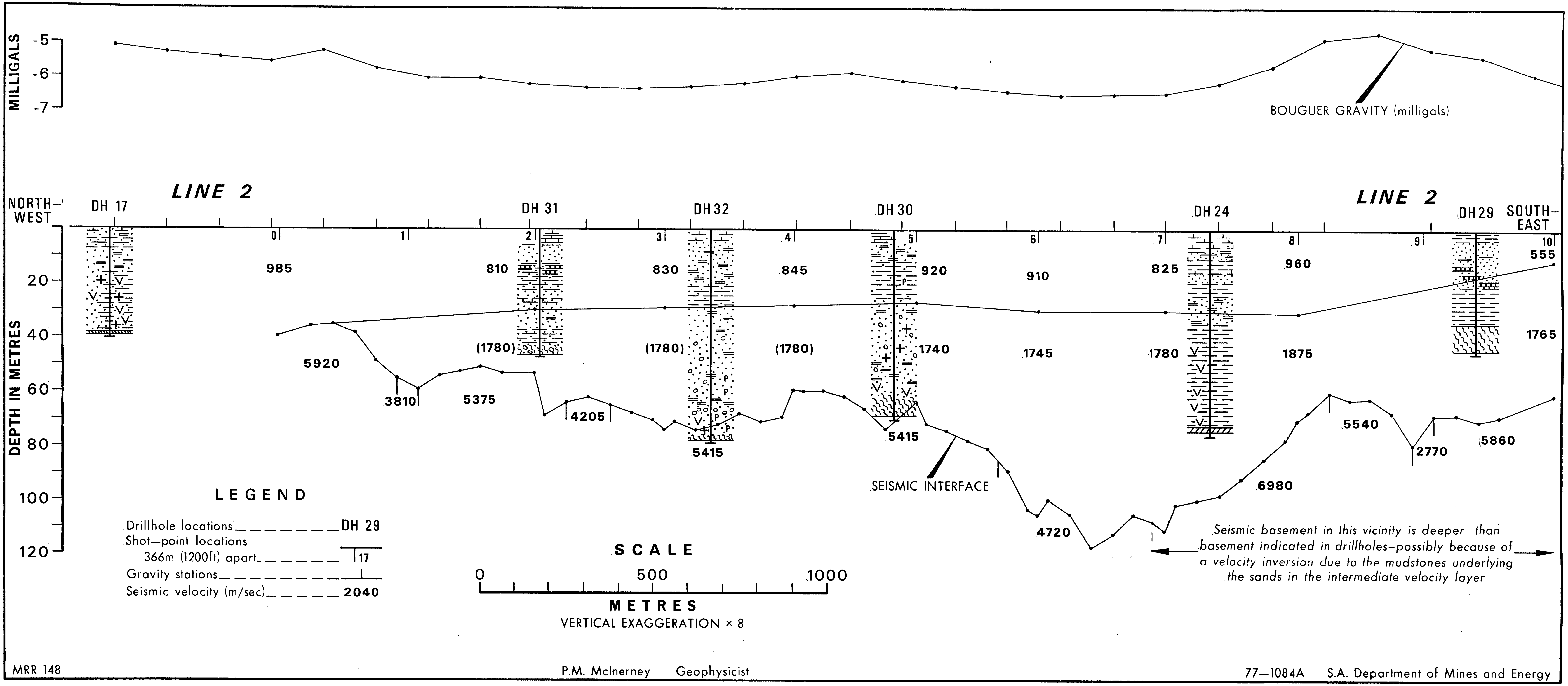
FIG. 3



Reduce to 240 mm
26½ %

PALAEO CHANNEL INVESTIGATION-CARALUE BLUFF
SEISMIC SECTIONS & GRAVITY PROFILES

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Passed
Director-General
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Date: 20.11.78

FIG. 4