DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

Rept.Bk.No. 80/123

A GEOPHYSICAL INTERPRETATION OF THE TALLARINGA TROUGH AND KARARI FAULT ZONE

GEOLOGICAL SURVEY

by

N.J. LIMB

GEOPHYSICIST

D.M. No. 400/76

CONTENTS

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

Rept.Bk.No. 80/123
D.M.E. No. 400/76

A GEOPHYSICAL INTERPRETATION OF THE TALLARINGA TROUGH AND KARARI FAULT ZONE

ABSTRACT

Interpretation of new gravity data, in conjunction with aeromagnetic and seismic data from TALLARINGA and gravity and magnetic data from adjoining map sheets of BARTON, COOBER PEDY and TARCOOLA, has increased understanding of the origin of gravity patterns on TALLARINGA. The commonly accepted view that the positive gravity anomaly in the Tallaringa Trough is due to dense dolomitic rocks is discounted. Many problems of interpretation remain and a stratigraphic drill hole is recommended to help resolve them.

The gravitational effect of Tertiary palaeochannels has been recognised as being of the same order as the effect of sediments within the Tallaringa Trough, which causes some interpretational difficulties. It is suggested that the gravity method be applied to map the Tertiary channels.

The Karari Fault Zone magnetic anomaly has been examined briefly and a pervasive northwest trending fracture pattern identified, suggesting the existence of further Mulgathing Trough style features on TALLARINGA. One such feature has been located and further work on this recommended.

1. INTRODUCTION

Following recent stratigraphic drilling results from the Officer and Arckaringa Basin (Pitt et al., 1980), the Geophysics Section of S.A. Department of Mines and Energy undertook a major helicopter gravity survey on the TALLARINGA 1:250 000 map sheet to improve knowledge of the Karari Fault Zone and the Tallaringa Trough. Accordingly, the survey with station spacing of 2.5 km covered most of the Tallaringa Trough as it is currently known and the Karari Fault Zone on TALLARINGA. Appendix "A" contains details of survey specifications and statistics from this survey. Figure 1 outlines the survey area.

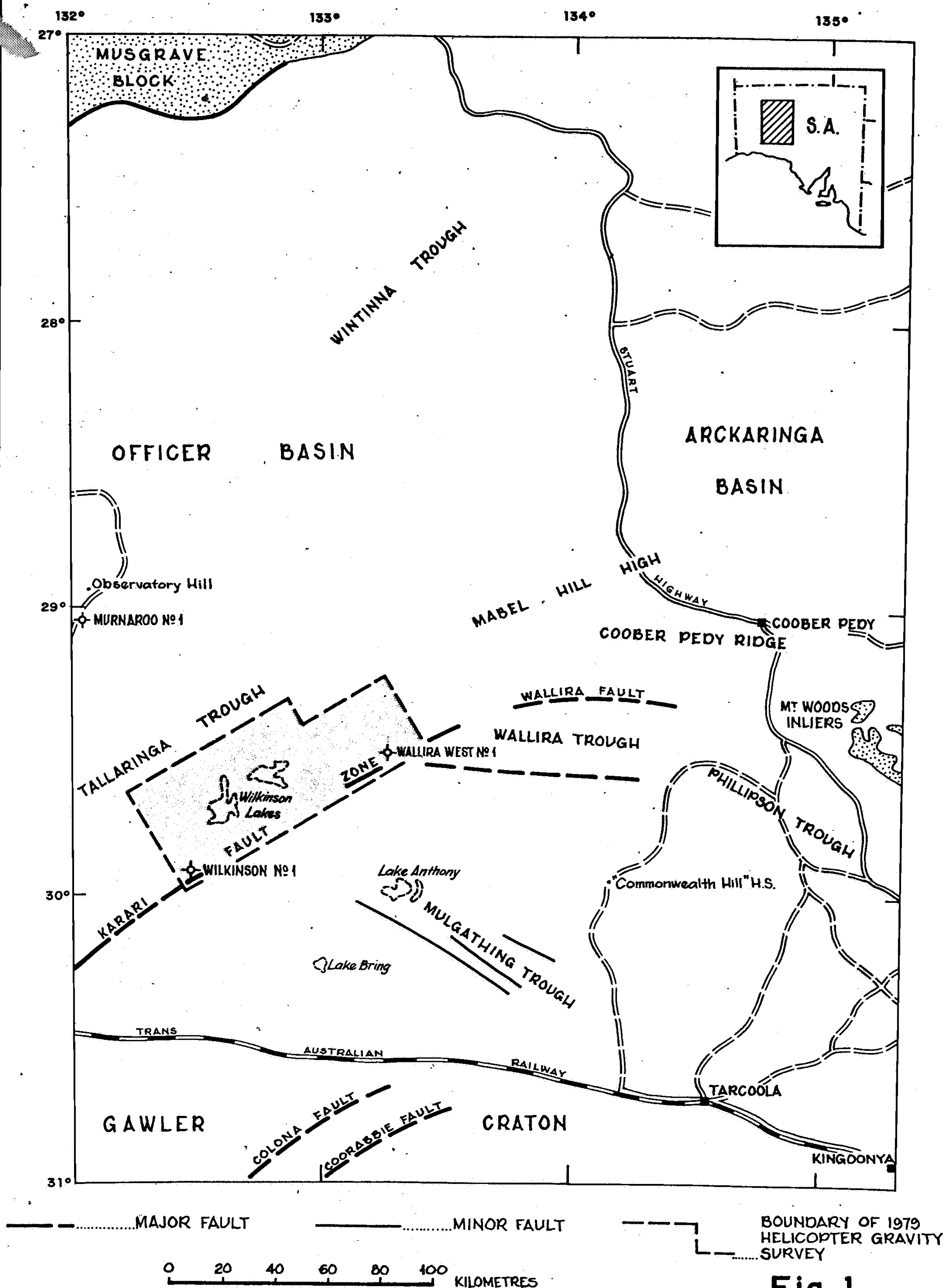
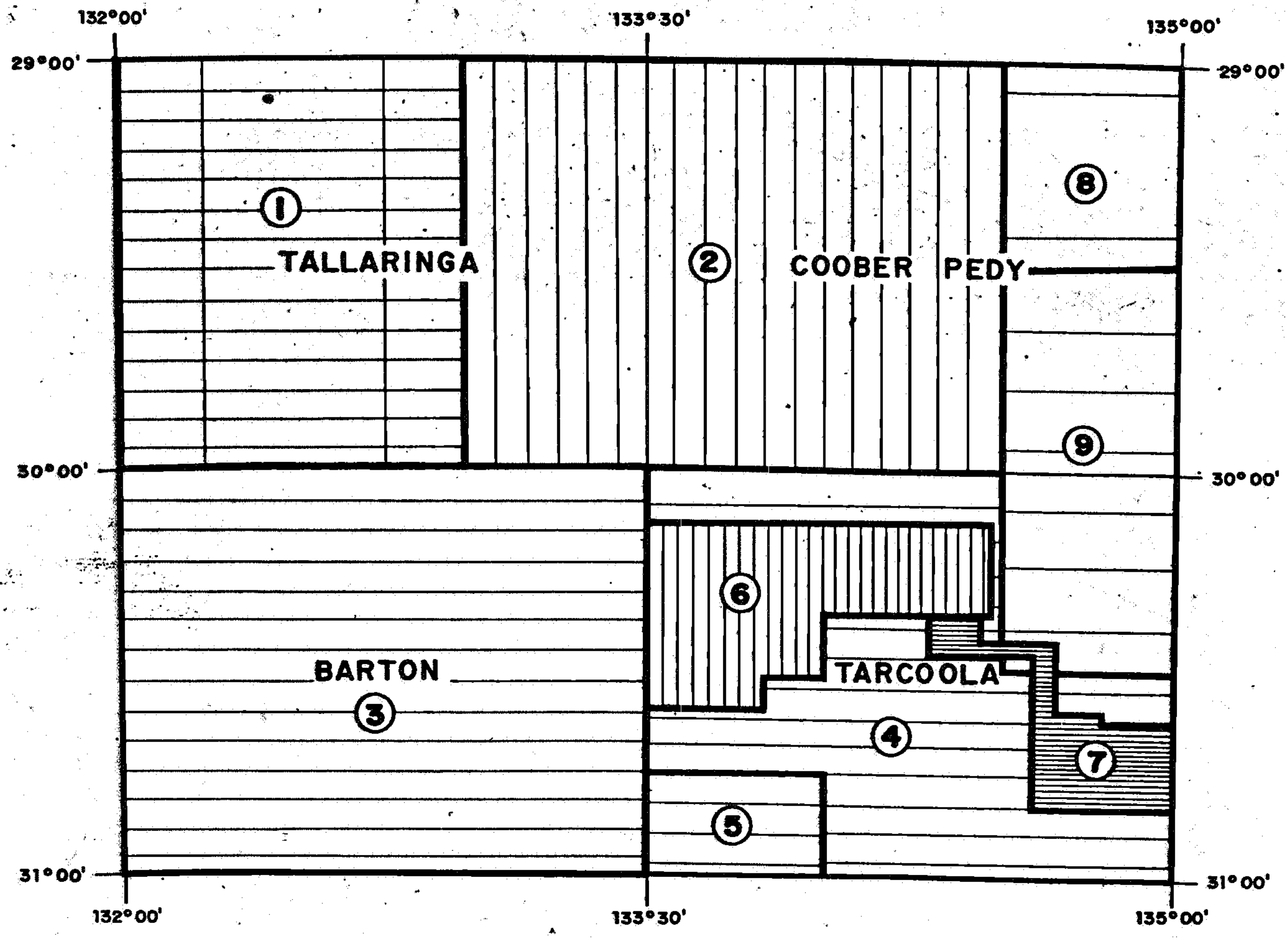


Fig. 1

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED B. E. M.	12-11-80 C D O	DATE
TALLARINGA TROUGH AND KARARI FAULT ZONE	DRAWN N. R. S.	SCALE 1:2 000 000	
LOCALITY PLAN	DATE 4-7-80	PLAN NUMBER S14950	
	CHECKED		

2018



NOTE: Lines represent flight lines (not to scale but relative densities and directions are correct).

0 20 40 60 80 100 KILOMETRES

AREA Nº	LINE SPACING (km)	SURVEY HT. (m)	BY	FOR	DATE	TYPE SENSITIVITY & CONTOUR INTERVAL	COMMENTS
1	1·6 EW, 10 NS	200 AGL	Geometrics	S.A.D.M.E.	1977	DIGITAL < 0·1 N.T. 10 N.T.	COMPUTER CONTOURING (DOPPLER NAV) IGRF RES.
2	1·6 EW	150 AGL	B.M.R.	S.A.D.M.E.	1957	ANALOG. 50 N.T.	POOR FLIGHT LINE CONT.
3	1·6 EW	150 AGL	B.M.R.	S.A.D.M.E.	1970	E. DIGITAL 100 N.T./in. 50 N.T.	POOR FLIGHT LINE CONT. (CONTOURED AT 5 N.T.)
4	1·6 EW	150 AGL	Adastra	S.A.D.M.E.	1958	ANALOG. 50 N.T./in. 100 N.T.	
5	1·6 EW	150 AGL	B.M.R.	S.A.D.M.E.	1961	ANALOG. 200 N.T./in. 50 N.T.	
6	0·8 NS	135 ATC	Geosearch	Kennecott	1970	DIGITAL < 0·1 N.T. 20 N.T.	I.G.R.F. RESIDUAL
7	0·4 EW.	90 AGL	Geometrics	Getty	1975	DIGITAL 0·05 N.T. 20 N.T.	COMPILED S.A.D.M.E. I.G.R.F. RESIDUAL
8	8 EW	460 Baro.	Aero Services	DELHI	1961	ANALOG. LOW 10 N.T.	
9	3·2 EW	150 AGL	B.M.R.	S.A.D.M.E.	1966	ANALOG. 50 N.T./in. 50 N.T.	

REFERENCE: S.A.D.M.E. Atlas of Technical Data

Fig. 2

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

TALLARINGA TROUGH AND KARARI FAULT ZONE

AEROMAGNETIC SURVEY SPECIFICATIONS

COMPILED B. E. M.	C.D.O. 12-11-80 DATE
DRAWN N. R. S.	SCALE 1 : 2 000 000
DATE 4-7-80	PLAN NUMBER S14951
CHECKED	

2018

This report is intended primarily to present an interpretation of these new gravity data and in doing so draws upon gravity, aeromagnetic, seismic and geological data from TALLARINGA (see sections 3 and 4) and adjacent map sheets, viz. BARTON, COOBER PEDY and TARCOOLA (Fig. 2).

A section of the area under examination is currently held under Exploration Licences 413 and 514 by BP Mining Development Aust. Pty. Ltd. and the remaining segment has several Exploration Licence Applications awaiting processing.

The area is considered important because the Departmental stratigraphic wells, Wilkinson No. 1 (Gatehouse, 1979) and Wallira West No. 1 (Townsend, 1972), both drilled within the Tallaringa Trough (Fig. 1), have indicated zones of petroleum source rock potential (Pitt et al., 1980).

Further, finely disseminated pyrite from the carbonates of the Wilkinson and Wallira West core and anomalous base metal values from the carbonates of Wilkinson No. 1 (Lydyard, 1979) have revealed the possibility of "Mississippi Valley" style mineralisation within them.

In addition, Pitt et al (1978) in their report on the Tallaringa Paleodrainage system, considered the potential for sedimentary uranium and gold deposits to be high in this system. They also noted lignite bearing material within the Tertiary and suggested further investigation of possible basins containing this material.

Finally, the Precambrian basement in the area warrants investigation for base metal and uranium mineralisation, if for no other reason than that these possibilities are largely untested in this region.

The interpretation is principally based upon a new Bouguer gravity contour map produced by the author for TALLARINGA

(Enclosure A), an elevation map produced by the author from all available elevation data on TALLARINGA (Enclosure B), a re-interpretation of the 1970 seismic work in the area and the aeromagnetic data.

2. LOCATION AND ACCESS

Finlayson (1979) has summarised location and access thus: "The area is reached from Tarcoola or Coober Pedy via Commonwealth Hill station along station tracks or from Watson via Maralinga. It lies within the Woomera restricted area and permission for entry must be obtained from the Defence Support Centre. About 90% of the area lies outside of pastoral leases west and north of Commonwealth Hill station. The topographical relief is mainly low with large shallow dry lake depressions and east-west trending sand dunes up to 20 m high. Tracts of mulga and casuarina scrub make access difficult to some areas. The climate is arid, with an annual rainfall average of 165 mm at Commonwealth Hill, and high evaporation rates. Day temperatures in excess of 40^{o} are not uncommon during the summer months. Known water resources are confined to bores on Commonwealth Hill station".

3. PREVIOUS WORK

Geology

1970 SADM: Reconnaissance of part of TALLARINGA (Williams, 1970).

1975 Shell Development (Aust.) Pty. Ltd.: Sedimentary Uranium and Permian Coal - Open file Env. 2663. (Barclay, 1975).

1976 CRA Exploration Pty. Ltd.: Permian Coal - Open File Env. 2666. (Whitby, 1976).

1977 Nobelex NL: Base metals in Basement - Open file Env. 3057. (Dreverman, 1977).

1978 SADME: Garford-Tallaringa Palaeodrainage System (Pitt, et al, 1978).

1979 SADME: Stratigraphic Wells - Wallira West No. 1 and Wilkinson No. 1 (Townsend, 1972 and Gatehouse, 1979).

1980 SADME: Preliminary map of TALLARINGA 1:250 000 scale based on photointerpretation and ground reconnaissance - currently under revision (Benbow pers. comm. 1980).

1978-80 BP Mining Development Aust. Pty. Ltd.: Sedimentary Uranium in Palaeochannels - Closed file. (Envs. 3339 & 3570).

Geophysics

Aeromagnetic Surveys:

1958 BMR for SADM: 1.6 km line spacing north-south lines from 133°00' to eastern margin of TALLARINGA (poor data).

1965 Adastra Hunting Geophysics for Exoil - small amount of widely spaced data on TALLARINGA (Steenland, 1965).

1977 Geometrics International Corporation for SADME: all of TALLARINGA west of 133°00' - good digital data. Radiometric data also recorded.

Gravity Surveys:

1969 SADM: Helicopter gravity survey 4 mile station spacing (Gerdes & Taylor, 1969).

1970 SADM: Seismic shot point gravity survey (Appendix A).

1974 SADM: Seismic shot point gravity survey (Appendix A).

1979 SADME: Helicopter gravity survey 2.5 km station spacing (Appendix A).

Seismic Surveys: SADM:

1970 Reconnaissance seismic refraction surveys (Milton, 1972 & 1973).

1974 Seismic reflection and refraction survey (Milton, 1975).

Interpretation of Geophysics: SADME:

1972, 73, 75. Interpretation of seismic data related to Tallaringa Trough (Milton, 1972, 73, 75).

1979 Interpretation of magnetic, gravity and radiometric data of TALLARINGA (Finlayson, 1979).

4. REGIONAL GEOLOGY

4.1 Basement Geology

On TALLARINGA, the oldest structural unit is the Gawler Platform which comprises Precambrian basement rocks. These were described by Williams (1970) as "a sequence of quartz feldspar gneisses, pegmatite and quartz veins with a few chloritic schists. Dolerite dykes intrude parallel to the metamorphic foliation which is generally north trending and vertical". Outcrop of this basement is particularly poor (Webber, 1980; pers. comm.) and deep weathering common (Williams, 1970).

Nobelex drilled two diamond drill holes 16 km north-northwest of Dingo Fault gate (Dreverman, 1977) which intersected pyroxene granulite. Geochronology of samples of the core have yielded an Archean to Early Proterozoic age of 2442 $\pm$ 54 Ma (Webb, 1978). The susceptibility of the core was measured at regular intervals along its length and these results are reproduced in Appendix B. In addition Dreverman (1977) noted numerous outcropping amphibolites and a small banded iron formation. The strike of the metamorphic foliation in the area is variable between 010° and 070°.

In summary, very little is known of the Precambrian basement on TALLARINGA. This is the result of poor outcrop and the limited amount of work undertaken on the problem. The mapping of TALLARINGA by Benbow during 1980 should help a great deal. The structural inter-relationships and age relationships of these basement rocks are largely unknown at this time.

4.2 Phanerozoic Geology

The Phanerozoic section in TALLARINGA is better known than the basement. To the north of the Karari Fault lies the Officer Basin and part of the Arckaringa Basin. The Arckaringa Basin is a broad depression upon the northern Gawler Block, encompassing several graben-like troughs and containing Permian sediments laid down in both terrestrial and marine environments (Wopfner, 1970). The Tallaringa Trough is one such "graben-like" feature (Milton, 1975) and it is into this trough that Wallira West No. 1 and Wilkinson No. 1 have been drilled.

Both holes intersected sediments of assumed Cambrian age, which have been tentatively correlated with the Observatory Hill Beds (Gatehouse, 1979). In Wallira West No. 1 these were overlain by Early Permian, Late Jurassic, Early Cretaceous and Tertiary sediments of the Arckaringa and Great Artesian Basins. In Wilkinson No. 1, the Observatory Hill Beds are overlain by Tertiary sediments, the Permian being absent, thereby implying a limit to the Arckaringa Basin somewhere between the two wells (Fig. 1); (Pitt et al, 1980).

Permian and Mesozoic sediments outcrop in a few isolated areas within the study area and have been encountered in numerous company drill holes (Enclosure C).

During early Tertiary times a drainage system developed and within this system of the Tallaringa and Garford Palaeochannels (Pitt et al, 1976) a sequence of clays, sands and lignites were deposited. Up to 200 m of Tertiary sediments have been encountered in some of the paleochannels (Webber; pers. comm., 1980). This drainage system can now be recognised as a number of broad topographic depressions (Enclosure B). Outside the drainage system thinner Tertiary sequences cover older outcrop. Dune sands also mask much of the older outcrop in the area.

4.3 Comments

It is timely to examine some important and relevant points which arise from the geology as it is known.

The nature of the Observatory Hill Beds in Wallira West No. 1 and Wilkinson No. 1 requires close examination. Most of the sediments which make up these beds are classified as limestone or dolomite because either the calcium carbonate or calcium-magnesium carbonate content is more than 50% (Gatehouse, pers. comm., 1980). However, visually these beds appear to be calcareous siltstones (Gatehouse, pers. comm., 1980) and their specific gravities have values more characteristic of siltstones than limestones and dolomites. Appendix "B" contains the available density information in the study area. It will be seen that the density of the Observatory Hill Beds is variable between approximately 2.4 t/m^3 in Wilkinson No. 1 and 2.6 in Wallira West No. 1. Also, significant halite intervals occur in Wilkinson No. 1 (Gatehouse, 1979) and the halite density is very close to 2.2 t/m^3, regardless of depth of burial.

It would appear that the gravity expression of the Observatory Hill Beds in the Tallaringa Trough is not likely to be as pronounced as the large positive effects of the massive dolomites of the Boorthanna and Wintinna Troughs with densities between 2.7 and 2.85 t/m^3.

An additional observation about the known geology relates to the presence of Proterozoic sediments within the trough. Wilkinson No. 1 is now thought to have bottomed in Punkerri Beds or their equivalents (Pitt et al., 1980) which are Late Proterozoic in age. They appear conformable with the overlying carbonates (Gatehouse, 1979). This is the only evidence relating to Proterozoic sediments in the trough and it is therefore worth considering if geophysical data contain information on this matter.

A common density used for Adelaidean material is 2.67 t/m^3 and if this density is assumed, it is unlikely that there would be enough contrast between crystalline basement at between 2.6 and 2.7 t/m^3 and Adelaidean sediments, or even between the carbonate and Adelaidean rocks, to produce a significant gravity anomaly. Much greater densities within the Adelaide System sequence are common, but, as a number of exploration companies working on the Stuart Shelf have discovered, such density variations are impossible to distinguish from density variations within basement.

The tillites within the Adelaide System often have iron rich beds, such as the Benda Siltstone and the Braemar Ironstone, which give a strong magnetic response and if these or similar beds are present in the Tallaringa Trough some magnetic expression should result. One way of explaining the Karari Fault magnetic anomaly is by such material being "exposed" along the fault. Magnetic effects from such a situation would be difficult to interpret unambiguously, nevertheless the possibility of magnetic source rocks existing within the Adelaidean sequence must be kept in mind.

Note: Excellent examples of the magnetic response due to iron rich beds can be seen on the OLARY aeromagnetic map.

5. GEOPHYSICAL DATA

5.1 Magnetic Data

Aeromagnetic data from TALLARINGA, COOBER PEDY, BARTON and TARCOOLA have been used to compile this report and to gain an overview of important magnetic features which occur on TALLARINGA.

The first step in examining data on this scale is to establish which surveys make up the published map sheets and check their specifications. Details of the surveys and their specifications are shown in figure 2. Figure 3 contains an example from TARCOOLA of two different surveys of the same area and demonstrates how much information is missing from the regional aeromagnetic survey data on these four 1:250 000 map sheets.

It is obvious that data quality on the eastern third of TALLARINGA (Fig. 2, area 2) will restrict interpretation. In surveys such as this, flight line path control is poor and interpreters should examine contours in conjunction with plotted flight lines before attempting to interpret dislocations, etc. The western two thirds of TALLARINGA (Fig. 1, area 1) is covered by a survey of high standard, but the data are computer contoured and in areas of shallow basement caution should be exercised when interpreting foliation directions and linear features.

5.2 Gravity Data

Data from TALLARINGA, COOBER PEDY, BARTON and TARCOOLA have been used to obtain an overview of the gravity patterns on TALLARINGA.

The data used to compile the TALLARINGA sheet are set out in Section 3 (Appendix A deals with the production of this map). For the other sheets, the SADME standard published 1:250 000 Bouguer anomaly maps were used. These were all compiled principally from 4 mile station separation helicopter gravity surveys and limited groundwork in areas of special interest, e.g. Mulgathing Trough (refer SADME Atlas of Technical Data for details).

A Bouguer density of 1.9 t/m^3 was chosen for data reduction on TALLARINGA and COOBER PEDY. However, BARTON and TARCOOLA were reduced with 2.67 t/m^3. This results in some mismatching of contours (see Enclosure D) but does not seriously affect the interpretation.

On TALLARINGA a number of seismic lines have been surveyed along the fences and one (FR) along the Dingo Flat gate to Nowra Tower track (Enclosure C). Gravity readings have been taken at each shot point on these lines giving a series of long lines with gravity stations 366 m (1 200 feet) apart. These stations were optically levelled (cf. barometric levelling for helicopter surveys) and station to station accuracy is therefore $\pm$ 0.05 milligals or better.

These lines are presented as profiles in Figures 4, 5 and 6. They have proved to be extremely useful in the interpretation because the high accuracy has enabled identification of important features which are normally within the error envelope of the barometric gravity data. This is discussed further in section 6.2.

5.3 Seismic Data

The Arckaringa Basin has been the target for intermittent seismic work since the late 1960's. The Boorthanna, Wintinna, Phillipson, Wallira and Tallaringa Troughs have been investigated to various degrees. This work, in association with drilling located on geophysical targets, has been very successful in the case of the Boorthanna, Phillipson, Wallira and Wintinna Troughs in determining the basic structural configuration and depth of sediments.

Investigation of the Mulgathing Trough south of the Karari Fault zone (Fig. 1) is a more recent project and a report is currently in preparation (Hall; pers. comm., 1980).

Milton (1972, 1973, 1975) presents an interpretation for most of the seismic work. In general, extrapolation from trough to trough of formation/seismic velocity relationships has been successful, although the Tallaringa Trough has presented problems. The 1970 refraction seismic work in the central eastern part of TALLARINGA (Enclosure C, Section E-F) indicates two seimsic velocity changes, the upper one of which has not been correlated with any change in sediment type in Wallira West No. 1, despite the presence of Permian sediments, and a lower one which has been correlated with the Observatory Hill Beds (Milton, 1973). It is unlikely that this boundary corresponds with the Permian/Cambrian contact but is due rather to a density change within the Cambian, although this cannot be confirmed at present because the well velocity survey of Wallira West No. 1 failed to obtain results for the carbonates (Townsend, 1971).

Milton (1975) presents an interpretation for the FR seismic reflection/refraction line (Enclosure C). Wilkinson No. 1 was drilled near shot point FR 65 as a stratigraphic well, on the basis of this interpretation. The interpretation was based on the assumption, which Milton noted may not be valid, that the geological section would be similar to other Arckaringa Basin sections and he postulated the presence of Mesozoic and Permian material, using typical seismic velocities from other Arckaringa Basin troughs.

Wilkinson No. 1 showed that Mesozoic and Permian sediments are absent in this area and the well velocity survey by Finlayson (in Gatehouse, 1979) demonstrated the highly variable velocities from different sections of the Cambrian.

This variability of seimsic velocity has important implications for future seismic work in the Tallaringa Trough and this is discussed further in section 7.

Further, Milton (op. cit.) states "The track is at an angle of less than 40^{o} to the major axis of the trough....... This is a considerable departure from the ideal orientation...... and has probably led to some distortion of interpreted depths due to three dimensional effects".

This fact combined with the more recent velocity information must throw some doubt upon the depth to crystalline basement commonly accepted for the area.

6. INTERPRETATION

6.1 Introduction

The structural configuration of the Tallaringa Trough is poorly understood. Milton (1975) has suggested a half graben model and Finlayson (1979) has expanded on this idea and has demonstrated that the trough is much more complex than previously thought, with the possibility of many up-and down-thrown blocks within it. The average depth of sediment is considered to be between 1 km and 1.5 km but this is based on limited evidence. Interpretation is severely limited by poor data quality and lack of data. Accordingly, many outstanding problems must await the collection of further data, including those from stratigraphic drilling, before they can be solved.

6.2 Gravity and Seismic Exploration

A composite contour map of Bouguer gravity for TALLARINGA, COOBER PEDY, BARTON and TARCOOLA is presented in Enclosure A. It can be seen from the diagram that the Phillipson, Wallira and Mulgathing Troughs coincide well with negative gravity anomalies and similarly the Coober Pedy and Mabel Creek basement highs correspond well with large positive gravity anomalies. On TALLARINGA, three other major gravity features are apparent, viz.:

(1) A large elongate positive anomaly; the "Munjena gravity high".

(2) A large negative anomaly which joins the Wallira Trough negative; the "Winwar gravity low".

(3) Another positive anomaly which extends onto BARTON, which will be called the "Woldra gravity positive".

These gravity features do not have such an obvious relationship to the known geology as those quoted above.

The cause of the positive gravity anomaly over the Tallaringa Trough is perhaps the most fundamental question to be answered. As discussed in section 4.3, it is unlikely that it is due to massive dolomites within the trough and it seems that it is the result of a complex interaction of a number of features (Finlayson 1979). Before examining the problem in detail, refer to Enclosure

A, the composite gravity map at a scale of 1:500 000. Note that the Munjena gravity high and the Mabel Creek gravity high appear to first glance to be related. Some confusion may arise because of this similarity, so it should be remembered that these anomalies represent different features.

The Munjena gravity high, the Winwar gravity low and the Woldra gravity high are inter-related and will be examined together. A knowledge of the regional gravity field is fundamental to the understanding of these features, a regional in this sense being the gravitational effect arising from deep crustal features and intra-basement density variations. The profiles presented in Figures 4, 5 and 6 have been compiled to aid in the definition of the regional. They contain profiles of Bouguer gravity from seismic lines WAA, WAI, WAM and WAJ with some interpolated values from the contours and a compilation of all other geophysical and geological data from the area. The location of the lines is shown on Enclosure C. The two presented as Figures 4 and 5 are the most useful because, although they are not ideally positioned relative to the Karari Fault Zone anomaly, i.e. at right angles to it, they are at a relatively high angle to it.

Profiles shown on Figures 4 and 5 are similar in outline in that they contain a broad negative (referred to by Milton (1973) as the "Wallira West gravity low") in the centre with similar magnitude highs on either side. The high on the south side is the Woldra gravity high and on the north side the Mungena gravity high. The drill hole and outcrop geological data presented on Enclosure C indicates that the basement is either outcropping or near surface over most of the Woldra high, which implies a lateral increase in density of the crystalline basement to the south. This explanation has also been suggested by Milton (1973).

Moving along the profiles towards the north, the seismic and drilling information helps to define the regional (refer Fig. 4). The seismic data have enabled the accurate positioning of the "Karari Fault" at shot point WAA 154, although the increase in depth to crystalline basement between shot points 141 and 154 suggests some additional step faulting may be present.

On the south side of the fault the seismic profile indicates an undulating crystalline basement. This is almost certainly an expression of the Tertiary palaeochannels in the area.

It is a relatively easy matter to calculate the gravitational effect of the Tertiary sediments (assuming a density of 1.9 to 2.1 t/m^3) and plot the regional or, where the depth is not accurately known, to sketch in a regional and calculate the depth of Tertiary sediments.

Tertiary palaeochannels such as these have significant potential for sedimentary uranium and gold mineralisation (section 1). The above example illustrates that, given a knowledge of the regional gravity field, the palaeochannels can be accurately mapped by surveying gravity profiles across them with station spacings of 100 to 500 m, depending on the detail required. Some limited support drilling may be required, but systematic drilling should not be necessary.

The seismic data on Figure 4 show that the major fault in the Karari Fault Zone occurs on the northern side of the gravity negative. Clearly the Tallaringa gravity negative arises from deeper crustal features and has very little relationship to the Tallaringa Trough as such. This idea was also suggested by Finlayson (1979) who attributed it to granitic intrusions at depth, but exactly what is causing the mass deficiency at depth is uncertain. However, the gravity negative suggests that the major tectonic events responsible for the fault zone may have also introduced some lighter crustal material at depth into the stressed region.

The nature of the regional field on the northern side of the fault is difficult to resolve. To aid this resolution a knowledge of the gravitational effect of the sediments in the trough is necessary.

Referring to Figure 5, the main fault occurs at shot point WAI 154 on the seismic cross section. This is coincident with a significant inflection on the gravity profile and it is proposed that the difference (approximately 4 milligals) between the observed Bouguer gravity at points A and B (Fig. 5) is approximately equal to the residual gravitational effect of the sediments in the trough. This hypothesis is reasonable in view of the known thickness and density of sediments in the trough. For example, Wallira West No. 1 has 12.5 m of Tertiary, 8.8 m of Cretaceous, 23.5 m of Jurassic and 270 m of Permian sediments which have densities in the range 1.9 to 2.3 t/m^3. The carbonate sequence below has an average density of 2.6 t/m^3 (Appendix B) and the basement density is between 2.6 and 2.7 t/m^3.

As discussed in section 4.3, the carbonate and any Proterozoic sediments in the trough are unlikely to produce a significant gravity anomaly and therefore the residual anomaly probably arises from the 305 m of sediments above the carbonates. Assuming an average density contrast between these sediments and the Observatory Hill Beds + basement of -0.4 t/m^3 and a thickness of 300 m and by using the infinite horizontal slab approximation, viz. $g = 2\pi\rho Gh = 0.04187\rho$ milligals/m, these sediments would produce an anomaly of about 5 milligals. This is the same order as the observed effect. Note that this gravity anomaly produced by the sediments in the trough is about the same as anomalies resulting from the sediments in some of the Tertiary palaeochannels. Some interpretation difficulties result from this equivalence of effect of the trough and channel sediments.

A suggested regional is marked on Figure 5 but it must remain speculative since no data are available to constrain it on the northern side. This part of the curve has been constructed by assuming that the gravitational effect of the caustive body is approximately symmetrical. If this is the case, then a substantial positive gravity anomaly still occurs over the trough as indicated by Finlayson (1979). Finlayson has further suggested that a number of basement highs (horsts?) exist within the trough and these could contribute a significant proportion of the anomaly. Alternative explanations invoke the presence of dense Proterozoic sediments (Finlayson, op cit) or a thick volcanic sequence within the sedimentary pile. However, assymetry of the regional's causative body may render unnecessary the postulate of excess mass as an explanation. Summarising, until a deep hole is drilled in the centre of the Tallaringa Trough to enable the regional to be effectively established, it will be impossible to distinguish between the options set out above.

Figure 6 is included mainly for the sake of completeness. Because of the angle of the WAM/WAJ line to the major axis of the Tallaringa Trough and its proximity to the Wallira Trough, the seismic and gravity data are more complex and correspondingly more difficult to interpret than those on Figures 4 and 5. Note that the seismic profile implies a degree of step faulting rather than a discrete "Karari Fault".

6.3 Aeromagnetic Interpretation

Finlayson (1979) has examined the aeromagnetic data from TALLARINGA and produced an "aeromagnetic province" map and a "depth to magnetic basement" map. The interpretation presented in this report is intended to supplement and add to Finlayson's work and to examine the magnetic data in relationship to the new gravity data.

Aeromagnetic data from TALLARINGA, COOBER PEDY, TARCOOLA and BARTON have been examined to gain an overview of the important magnetic features on TALLARINGA. Enclosure D is a composite map at 1:500 000 of the magnetic contours of the above map sheets. Section 5.1 sets out details of survey specifications and quality over the area.

The Karari Fault Zone magnetic anomaly (Enclosure E) is one of the most prominent features on the total magnetic intensity map of South Australia and yet it is still very poorly understood. The nature of the causative body of the anomaly is not known. Possible causes are:

(1) A more magnetic block being faulted against a less magnetic block;

(2) A basic intrusion along a fault plane;

(3) Adelaidean tillites in the basin (Section 4.3);

(4) A basic lava flow within the basin;

(5) A shear (mylonite?) zone in the basement; or

(6) Any combination of these.

Consider the Bouguer anomaly map of TALLARINGA (Enclosure E). The shaded zones A-B and C-D represent the area between the top of the positive and the bottom of the negative of the Karari Fault Zone magnetic anomaly. The centre of the causative body should lie somewhere within this zone. The short lines marked "F" and "F_1" or "F_2" indicate the position of the top of the main faults ("F_1" and "F_2" indicating step faulting) determined from seismic and drilling evidence.

The magnetic and gravity negative anomalies are not coincident over their full length and the magnetic anomaly diverges markedly from the top of the fault in the northeast. The dislocation of the anomaly (A-B and C-D, Enclosure E) is discussed below.

The intensity of the anomaly varies along its length

(Figs. 4, 5 and 6 and Enclosure E) but generally it maintains a constant shape. An infinite dyke model (induced field) is relatively easily fitted to the anomaly and the simplest model is a body with a depth to the top of about 500 m, a width of 500 to 700 m, a steep (60^o-85^o) dip towards the south dimensionless and a relatively high magnetic susceptibility (0.01). These figures are the result of preliminary modelling only and a much more systematic modelling programme is required. However, they do suggest, along with the information from Enclosure E, that a basic intrusion along a fault plane or a shear zone along one of the fault planes is a likely explanation. The displacement is easily explained if the body is along a lower step fault which is displaced from the ones above.

Enclosure D is a composite plan at 1:500 000 of the aeromagnetic data from TALLARINGA, COOBER PEDY, BARTON and TARCOOLA and it has marked on it a number of interpreted features. Some will be examined here; the others are marked on for comparison with magnetic anomalies on TALLARINGA.

Provinces A and B (Enclosure D) are recognised solely on the basis of their respective magnetic response. Apart from the section of province A on TALLARINGA, the boundaries of each are uncertain because data quality is poor. They are not recognised in the gravity data (Enclosure A), probably because the gravity effect of deeper crustal features overwhelms the gravity effect of the different surface rock types. Another possibility is that, although they may represent different basement rock types, they may not have significantly different densities from each other or the surrounding rocks. It is suggested, on the basis of the similarity of magnetic patterns, that the provinces represent blocks of similar basement. It is thought that many of the larger amplitude anomalies in these provinces arise from banded iron formations.

The Colona Fault and the Coorabbie Fault are subparallel to the Karari Fault Zone magnetic anomaly and this suggests that all three may have originated from the same tectonic stresses.

Enclosure D has some northwest trending dykes marked on it and it is thought that many more exist but are not seen because data quality is too poor. Figure 3 demonstrates this point.

The origin of these dykes and their age relationships is uncertain, but it is suggested that they intrude fractures which are associated with a major northwest trending fracture system. This system is pervasive across a large area of the State and it is suggested that it is associated with the "Gairdner Dyke Swarm". This idea does not imply that the dykes were intruded at the same time, simply that they have been intruded along the same fracture system which has probably been active over a long period. It is suggested that in places the intruded dyke may be the only evidence of the fracture and in other places there may be a fracture without any associated intrusion.

The Mulgathing Trough and its extension (Enclosure A) appears to be a small graben whose bounding faults are part of this fracture system and it is the author's contention that a number of other similar features occur in the area. One possible site is to the southeast of Wallira West No. 1, where Permian sediments have been encountered in drillholes (Enclosure A). The gravity data in the area appear to form an elongate negative anomaly. However, the station density is very low and more detailed traverses across the feature would be required to confirm this.

The apparent dislocation of the Karari Fault Zone magnetic anomaly just to the northeast of Wallira West No. 1 is probably also the result of movement along this northwest trending fracture system.

Further, at the northeastern end of the Munjena gravity high (Enclosure A) is an area of much lower gravity values; the Karari gravity low, which suggests that the basement may be significantly deeper in this area due to block faulting along the northwest trending fracture system. It has been suggested by Finlayson (1979), that the thickest section of Permian sediments in the Tallaringa Trough occurs in this region.

7. CONCLUSIONS AND RECOMMENDATIONS

The new gravity data and subsequent interpretation in this report have clarified a number of problems related to the Tallaringa Trough. The expected gravity response of the sediments in the trough has been calculated and it has been shown that the gravitational effect of sediments within Tertiary palaeochannels is of a similar magnitude. The recognition of these features should make subsequent interpretation of gravity profiles in the region more precise. In addition, it has been shown that these thicker Tertiary sequences can be effectively mapped with a limited amount of gravity work. It is recommended that exploration of the palaeochannels, should it be conceived, be undertaken in the first instance by gravity investigations to locate drilling sites.

It has been demonstrated that the gravitational effects of deeper crustal features dominate the gravity patterns on TALLARINGA. The large negative anomaly arises because of lighter crustal material at depth and its intimate association with the Karari Fault Zone suggests that this may be an important tectonic zone. Some literature research is recommended to compare similar gravity features from known tectonic zones.

It has not been possible to define the regional gravity field on the north side of the Karari Fault Zone and until this can be done further resolution of the structural configuration of the

Tallaringa Trough will not be possible with the gravity method. Seismic reflection work within the trough is unlikely to be of full value at this stage because the highly variable densities and hence seismic velocities from within the carbonates and the lack of knowledge of Proterozoic sediments within the trough would make interpretation inconclusive. Similarly, without more control magnetic data are unlikely to provide significant interpretative data.

In summary, it is considered that a stratigraphic drill hole in the centre of the Tallaringa Trough is very desirable. In view of the logistical problems in the region, shot point WAA 190 on the Dingo Flat gate to IGY corner dog fence is recommended as a possible site for such a hole, although anywhere along the Tallaringa gravity positive should achieve the same goals. Because of the uncertainties mentioned above (Sec. 6.1) a depth to crystalline basement at this site cannot be given. However, a hole of similar depth to Wilkinson No. 1, i.e. 750 m is envisaged. If basement highs do occur within the trough, crystalline basement may be intersected before this depth, but even if this is not the case geological and petrophysical data gathered from the hole would be invaluable. A well velocity survey of such a hole is strongly recommended, since any future seismic work in the area would require as much velocity information as possible.

The number of and depth to magnetic sources in the trough is uncertain. Since digital computer tapes of the 1977 Geometrics International Corporation survey data are available, it is recommended that a limited amount of "Compudepth"[1] processing be undertaken on a number of the north-south tie lines of this

---

1. "Compudepth" is a computerised algorithm developed by Geometrics International Corporation to determine the edges of and depths to two-dimensional magnetised prismatic bodies.

survey. This system gives poor resolution for anomalies arising from multiple sources, hence poor or meaningless results would be anticipated over shallow and outcrop basement terrain. Within the Tallaringa Trough, however, meaningful results would be anticipated. Because of the complexity of the method the solutions, while appearing straightforward, are in themselves complex and interpretation of them should only be undertaken by someone with a clear understanding of the mathematical concepts involved.

The Karari Fault Zone magnetic anomaly is still poorly understood and it is recommended that a thorough examination of the anomaly along its length, making use of extensive computer modelling, be undertaken. Some limited ground magnetic traverses of the anomaly at right angles to it would aid this work.

The existence of a northwest trending fracture system across the region has been discussed along with the possiblity of additional Mulgathing Trough style features. It is suggested that the region immediately to the southeast of Wallira West No. 1 is a very likely site for such a feature. It is a complex zone with the south bounding fault of the Wallira Trough adding to the complexity. The gravity stations in the area are widely spaced and it is therefore recommended that the station density be increased and that a limited number of high accuracy gravity lines oriented approximately northeast-southwest be established.

Aeromagnetic data from the eastern third of TALLARINGA are poor and any attempt to identify further northwest trending on the basis of its magnetic response, is not possible. A detailed survey is recommended with a flight line spacing of 500 m and flight direction of east-west, although the specifications may be varied according to particular aims.

NJL:ZV

N.J. LIMB

REFERENCES

Barclay, C.J., 1975. Relinquishment report on E.L. 175 and 214 for Shell Development (Australia) Pty. Ltd. S. Aust. Dept. Mines and Energy Open file Env. (unpublished).

Benbow, M.C. and Pitt, G.M., 1978. The Garford Formation. Q. geol. Notes, geol. Surv. S. Aust., 68:8-15.

Dreverman, P.C., 1977. Completion Exploration report on E.L. 288, Indooropilly, S.A. Nobelex N.L. rept. S. Aust. Dept. Mines and Energy, Open file env. 3057 - (unpublished).

Finlayson, B., 1979. A Geophysical Interpretation with Depths to Magnetic Basement - TALLARINGA, GILES, MURLOOCOPPIE, 1:250 000 sheets. S. Aust. Dept. Mines and Energy Rept. Bk. 79/90 (unpublished).

Gatehouse, C.G., 1979. Well Completion Report Wilkinson No. 1. S. Aust. Dept. Mines and Energy. Rept. Bk. 79/88 (unpublished).

Jago, J.B., 1980. Writ. Comm. Report on Trilobite fossils from Marla No. 1 Stratigraphic Well - in S. Aust. Dept. Mines Docket No. 1035/74 (unpublished).

Lydyard, A.J., 1979. A Petrographic Study of the Sediments in Seven Officer Basin Stratigraphic wells. S. Aust. Dept. Mines and Energy Rept. Bk. 79/55.

Milton, B.E., 1972. Seismic Survey - Western and Central Arckaringa Basin - 1970. Mineral Resour. Rev., S. Aust. 132:65-74.

Milton, B.E., 1973. Geophysical Exploration of the Arckaringa Basin - 1970. Mineral Resour. Rev., S. Aust., 134:62-76.

Milton, B.E., 1975. Reconnaissance seismic exploration, southwest Arckaringa Basin, S.A., 1974. Q. geol. Notes. geol. Surv. S. Aust., 53:3-9.

Pitt, G.M., Benbow, M.C., Youngs, B.C., 1980. A Review of Record Geological Work in the Officer Basin, S.A., A.P.E.A. Journ. V. 20, 1980.

Pitt, G.M., Benbow, M.C., Barnes, L.C., Harris, W.K. and Lindsay, J.M., 1978. Report on drilling in the Tallaringa Palaeodrainage system, 1976. S. Aust. Dept. Mines and Energy report 78/38 (unpublished).

Steenland, N.C., 1965. Eastern Officer basin Aeromagnetic survey O.E.L. 28, S.A. Rept. by Adastra Hunting Geophysics Pty. Ltd. for Exoil Pty. Ltd. S. Aust. Dept. Mines and Energy, Open file Env. 527 (unpublished).

Townsend, I.J., 1972. Wallira West No. 1 well completion report. S.A. Dept. Mines and Energy, Rept. Bk. 71/170 (unpublished).

Webb, A.W., 1978. The Geochronology of the Ancient Basement Rocks of the Gawler Craton. Progress Report 15 & 16. (unpublished).

Whitby, K.J., 1976. Geology and Coal resources E.L. 213 C.R.A. Rept. S. Aust. Dept. Mines and Energy, Open file Env. 2666 - (unpublished).

Williams, A.F., 1970. A geological reconnaissance on portion of the TALLARINGA 1:250 000 sheet area. S.A. Dept. Mines and Energy, Rept. Bk. 70/75 (unpublished).

Wopfner, H., 1970. Permian Palaeogeography and Depositional Environment of the Arckaringa Basin, South Australia. In: Proceedings and Papers, 2nd Gondwana Symposium, South Africa, 1970 Pt. 1:273-281.

ACKNOWLEDGEMENTS

The author wishes to thank the following people for their time and advice. Bernie Milton, Sue Daly, Mark Benbow, Graham Pitt, Colin Gatehouse, Bridget Youngs, Bruce Finlayson, Graham Webber, Robin Gerdes, Deane McPharlin, Professor Boyd and John Hall who helped prepare Appendix A.

APPENDIX A

1979 Helicopter Gravity Survey (79E3.) - Tallaringa

The survey was carried out using the "cell" method described by Hastie and Walker (1962).

Approximately 750 stations were observed in a square grid pattern with station spacing of 2½ km (one station to 6.25 km^2). The standard cell contained 49 stations each (including ties to adjoining cells and repeat readings for drift control). Cell centres and tie points were marked with wooden pickets and, with the help of flight photographs, should be recoverable for several years.

Repeat readings for instrument drift control were made within two hours except when dense, featureless bush made navigation difficult.

Gravity and elevation ties were made to six permanently marked stations of a regional survey flown in 1969 (Gerdes and Taylor, 1969).

Personnel: two gravity meter operators (J. Hall & N.J. Limb)
one pilot
one driver/mechanic

For further surveys of this type, an extra pilot and gravity meter operator is recommended.

Equipment: Sharpe geodetic gravity meter
Wallace and Tierman altimeters (two0
Recording microbarograph
Bell 206B (jet Ranger) helicopter
Bedford 5 tonnes 4 x 4 flat-top
Chevrolet 1.5 tonne 4 x 4 tray-top
Two-berth caravan (two)

Loop closure errors:

	Maximum	Average
Gravity	.22 mgals	.07 mgals
Elevation	9.4 m	2.4 m

Operating statistics:

Flying days	22 (June 20 to July 13)
Days lost	2
Total flying hours	133.9
Approximate Cost	$85/station

Enclosure A is a preliminary version of the new Bouguer Anomaly map for TALLARINGA at a scale of 1: 500 000. It incorporates the data from the 1969 4 mile station spacing helicopter gravity survey, and the new helicopter gravity work. In addition the gravity data from the 1970 and 1974 seismic work has been processed and incorporated.

These data are contoured at a 1 milligal interval. This is within the error envelope of barometrically levelled gravity data (i.e. helicopter surveys). However, it was felt that too much information, relative to the aims of the interpretation presented in this report, would be lost if a 2 milligal interval was used.

A Bouguer density at $1.9t/m^3$ was chosen for data reduction because it was thought that this figure best represented the surface material density. Checks of Bouguer gravity versus elevation were made and no serious problems were evident.

The gravity data used to compile this map have been incorporated in the S.A.D.M.E. State gravity computer file and computer plots at a specified scale and Bouguer density are available upon request.

References:

Gerdes, R.A. and Taylor, B.J., 1969. First six monthly report on the helicopter gravity survey, 1969. S. Aust. Dept. Mines report 69/39 (unpublished).

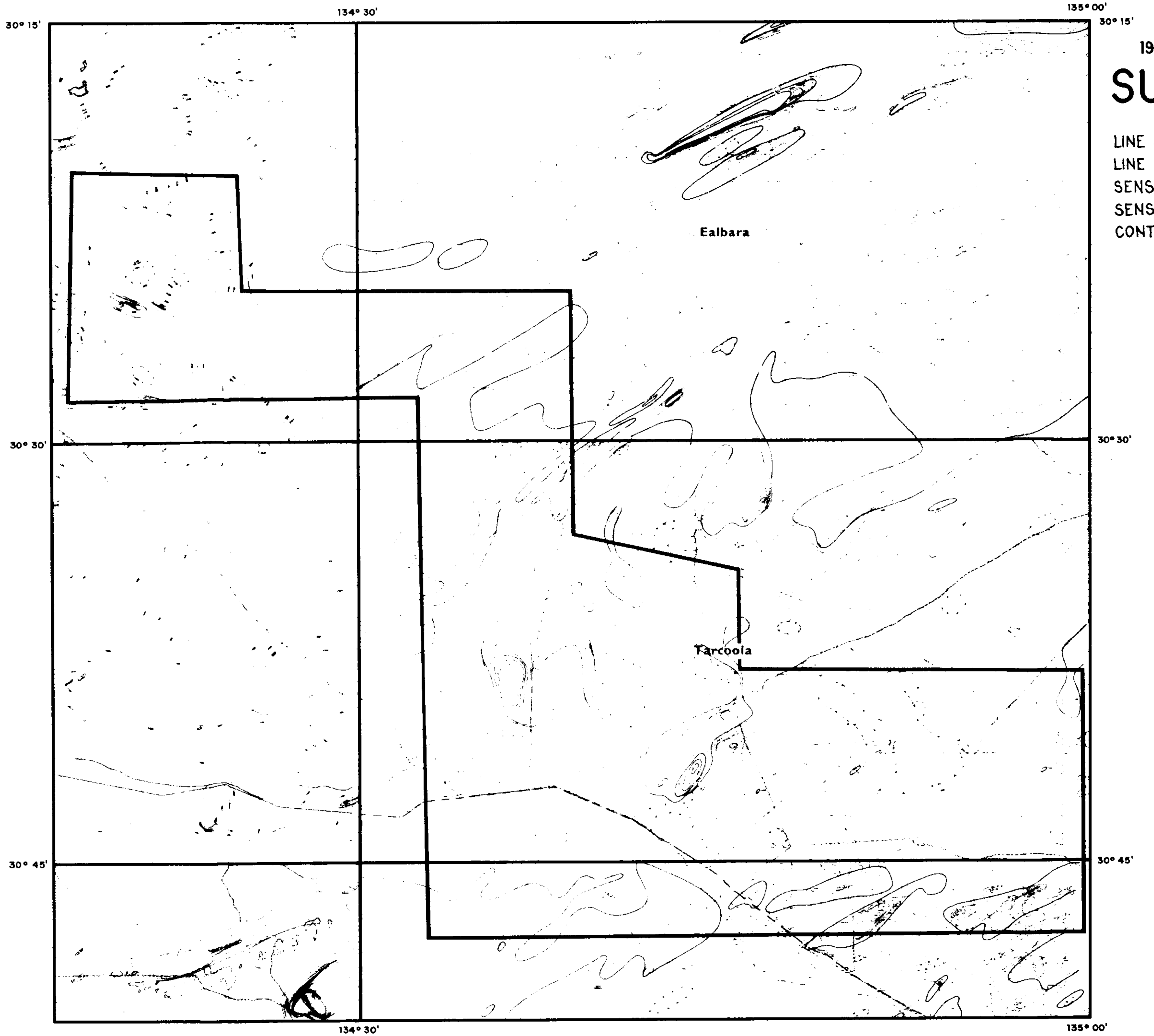
Hastie, L.M. and Walker, D.G. 1962. Two methods of gravity traversing using helicopters. Rec. Bur. Miner. Resources Geol. Geophys. Aust., 1962/134 (unpublished).

APPENDIX B

This appendix contains details of all available specific gravity and magnetic susceptibility measurements of rocks from within the study area.

Sample depth (m)	Formation/Lithology	No. Samples	Specific Gravity t/m^3	Magnetic Susceptibility x 10^{-6}
Wallira West No. 1 Core	(S.G. values Gerdes; pers. comm., 1980)			
46.9 - 90.5	L. Permian Stuart R claystone	8	1.97	
131.1 - 283.5	L. Permian Boorthanna Fmn. sandstone	8	2.14	
329.8 - 358.8	Cambrian(?) limestone/ dolomite	18	2.61	
Wilkinson No. 1	(Gerdes in Gatehouse, 1979)			
211 - 574	Cambrian carbonate sequence	Samples at	2.41	
230 - 289	"	metre		70
290 - 574	"	intervals		30
575 - 710	Cambrian evaporite sequence (exclusive of halite)			150
Nobelex Drill Holes	(Dreverman, 1977)			
DDH 1				
91 - 160	Pyroxene granulite	"		10 000
DDH 2				
70 - 211	Pyroxene granulite	"		3 000

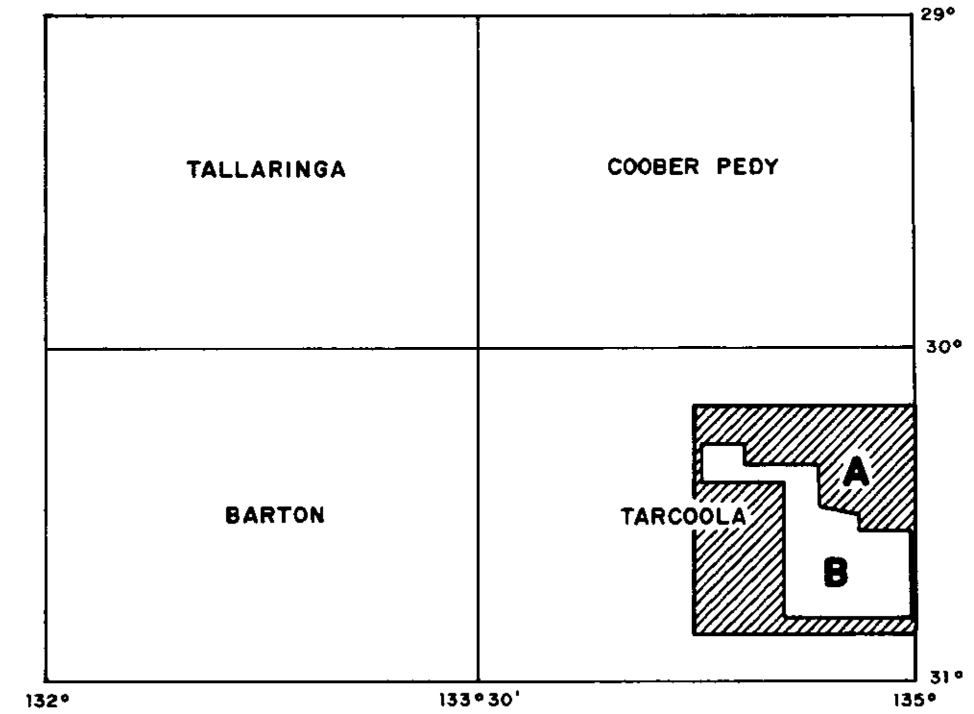
These holes were drilled on magnetic anomalies (Dreverman, 1977) and it was concluded that there is a sufficient amount of magnetite in the core to account for the anomalies.

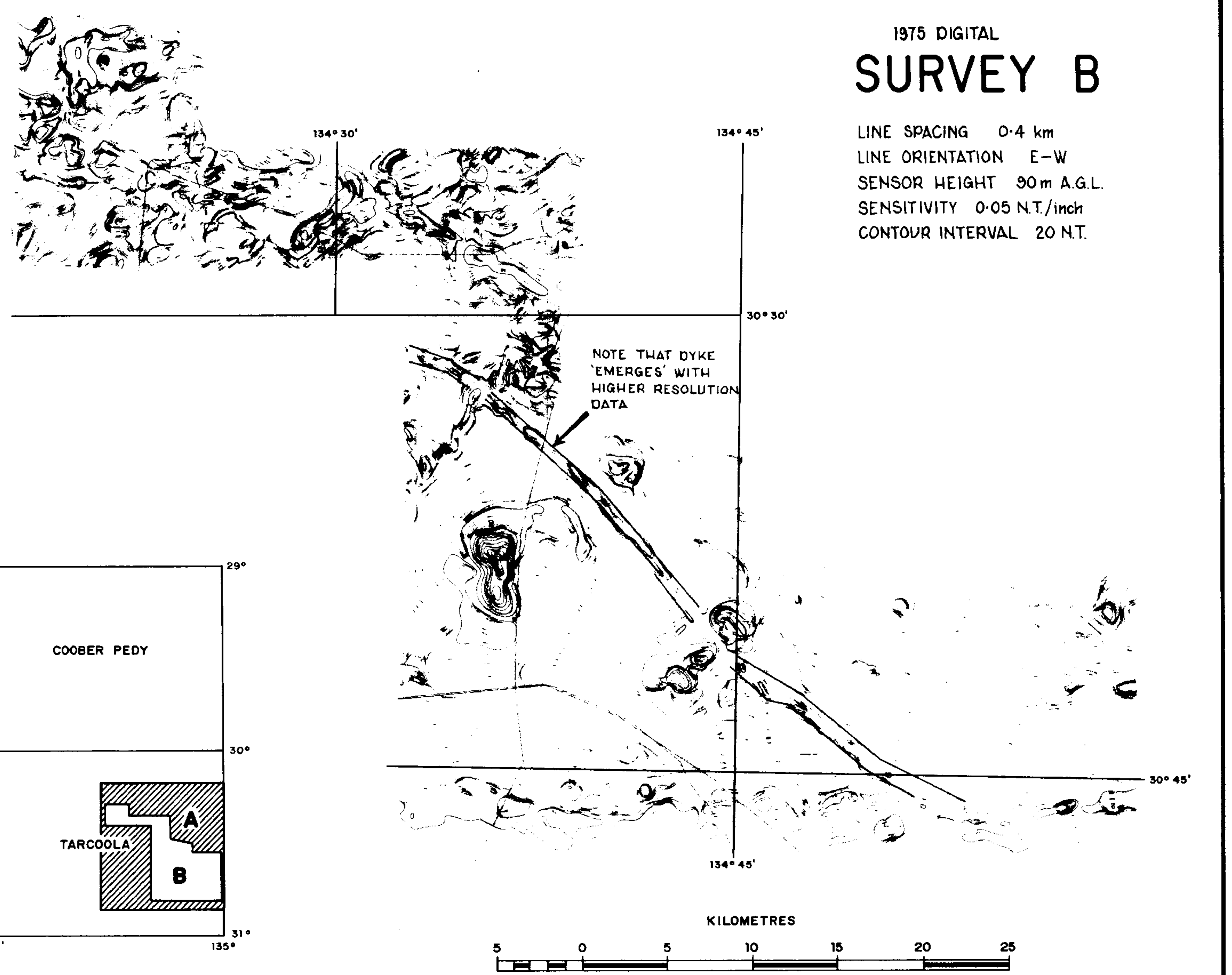


1958 ANALOG.

SURVEY A

LINE SPACING 1·6 km
LINE ORIENTATION E-W
SENSOR HEIGHT 150 m. A.G.L.
SENSITIVITY 50 N.T./inch
CONTOUR INTERVAL 100 N.T.





1975 DIGITAL

SURVEY B

LINE SPACING 0·4 km
LINE ORIENTATION E-W
SENSOR HEIGHT 90 m A.G.L.
SENSITIVITY 0·05 N.T./inch
CONTOUR INTERVAL 20 N.T.

Fig. 3

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED B.E.M.	12.11.80 C.D.O. DATE
TALLARINGA TROUGH AND KARARI FAULT ZONE	DRAWN N.R.S.	SCALE 1:250 000
AEROMAGNETIC SURVEY QUALITY COMPARISON	DATE 4-7-80 CHECKED	PLAN NUMBER 80-497

2018

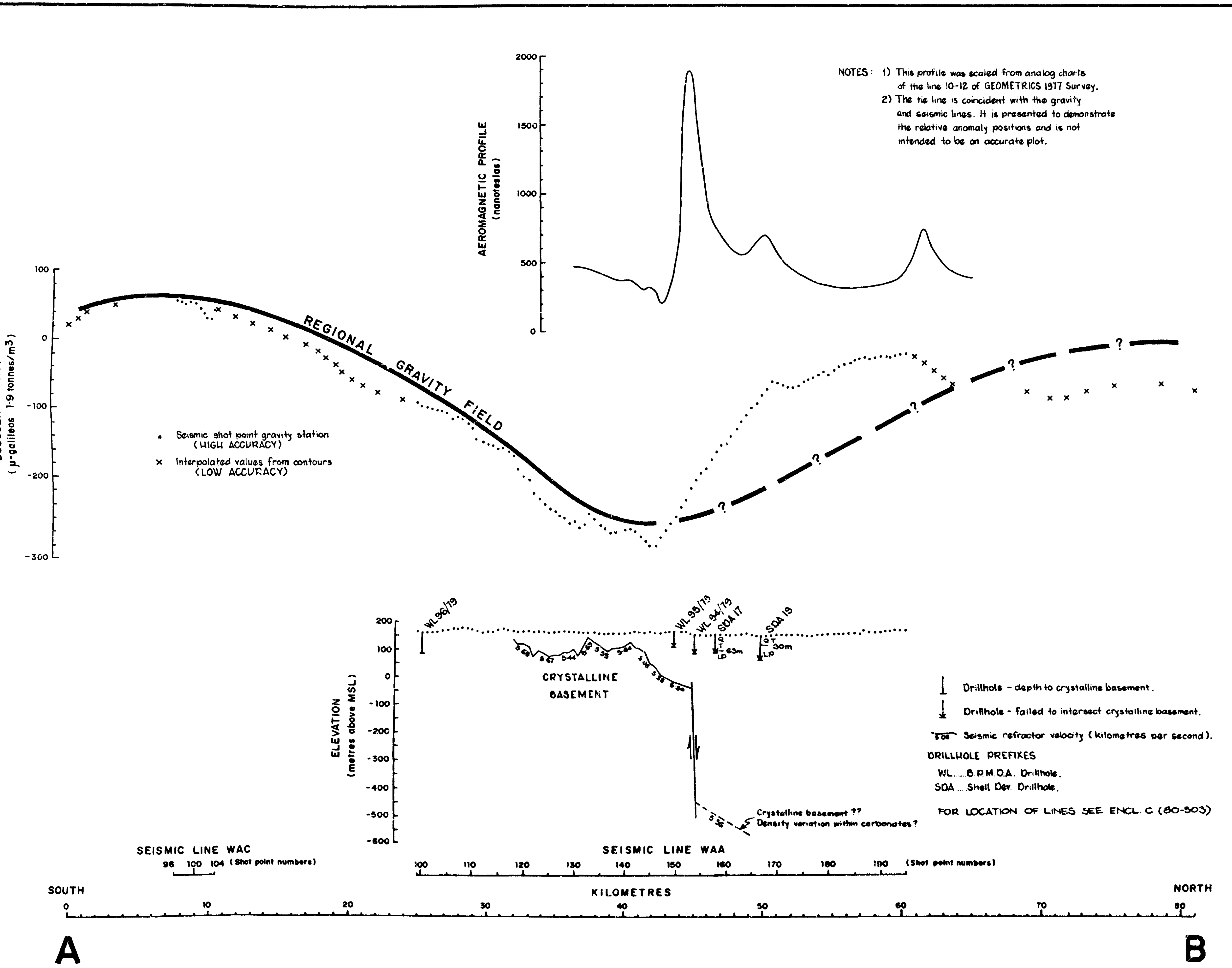


Fig. 4

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

TALLARINGA TROUGH AND KARARI FAULT ZONE

PROFILE COMPARISON
LINES WAC & WAA

COMPILED	B.E.M.
DRAWN	N.R.S.
DATE	4-7-80
CHECKED	12-11-80
SCALE	1: 250 000
PLAN NUMBER	80-498

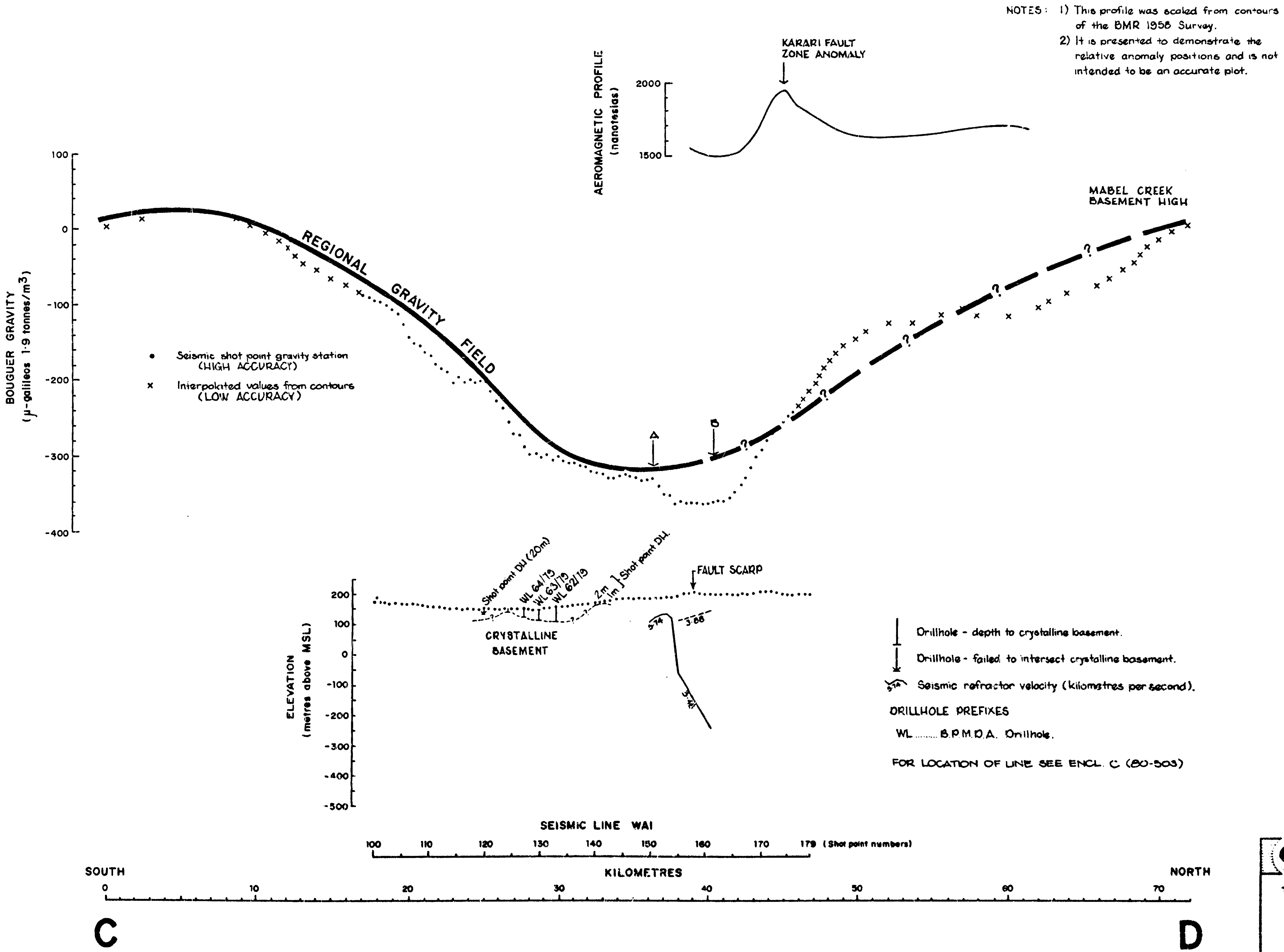


Fig. 5

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA

TALLARINGA TROUGH AND KARARI FAULT ZONE

PROFILE COMPARISON LINE WAI

B.E.M.
DRAWN N. R. S.
DATE 4-7-80
12-11-80
SCALE 1:250 000

80-499

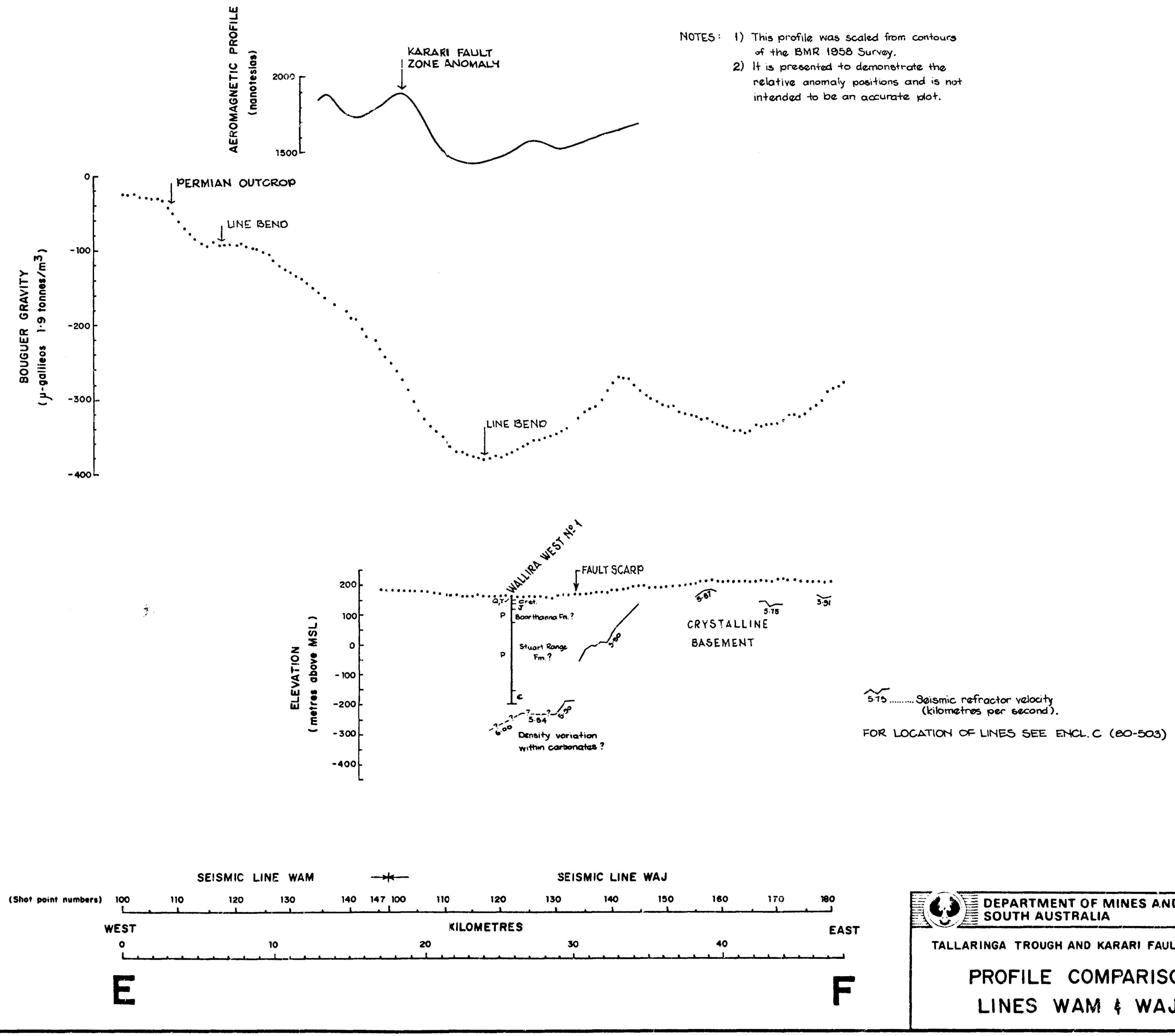


Fig. 6

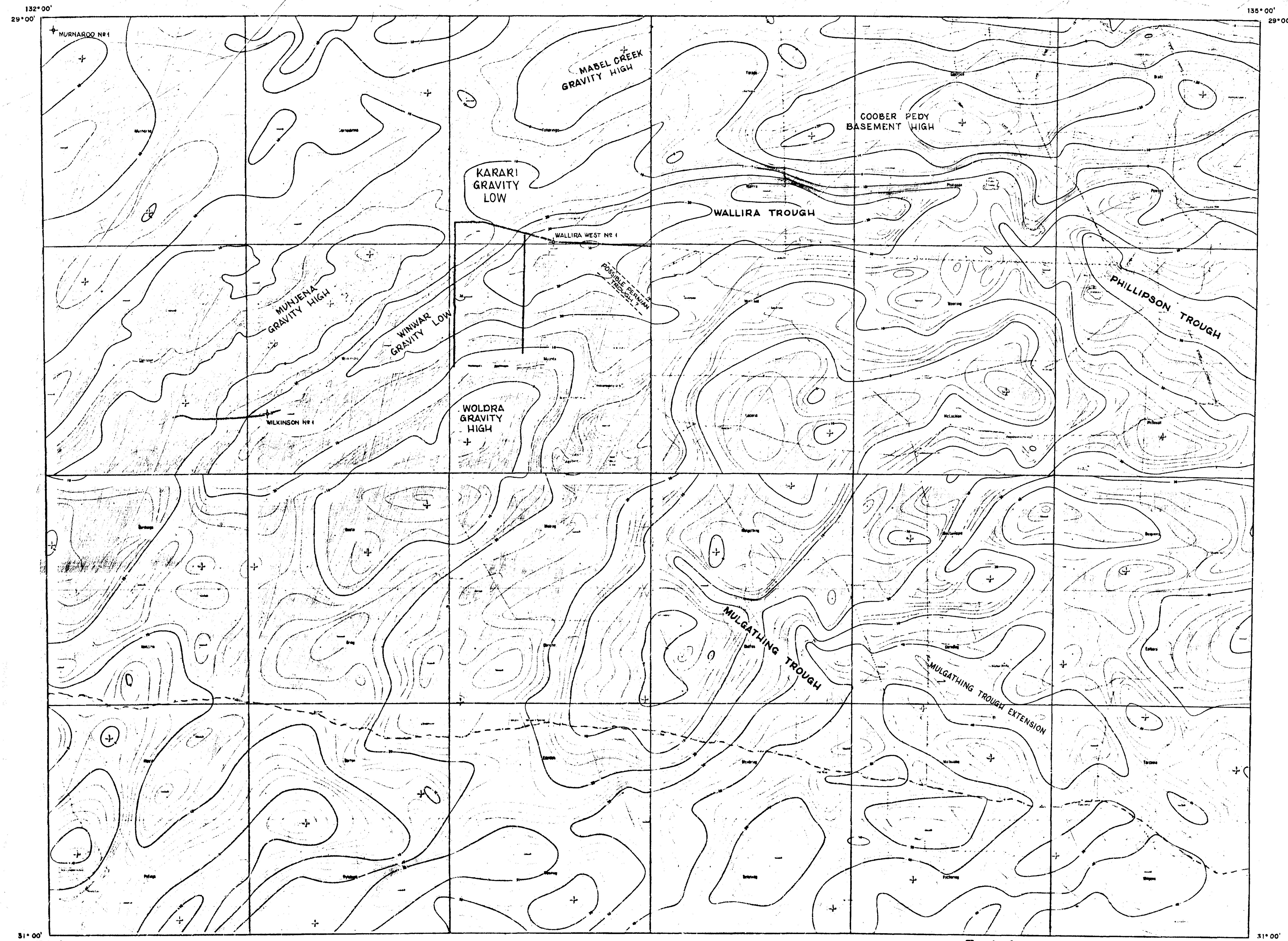
DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA

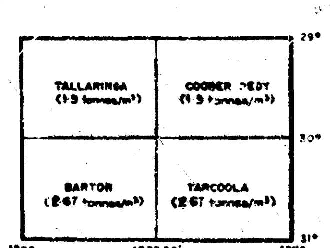
TALLARINGA TROUGH AND KARARI FAULT ZONE

PROFILE COMPARISON LINES WAM & WAJ

B.E.M.
N.R.S.
4-7-80
12.11.80
1:250 000
80-500

2018





CONTOUR INTERVALS

10 μ-GALILEOS (1 mgal) — TALLARINGA

20 μ-GALILEOS (2 mgals) — COOBER PEDY, BARTON, TARCOOLA

KILOMETRES

10 0 10 20 30 40 50

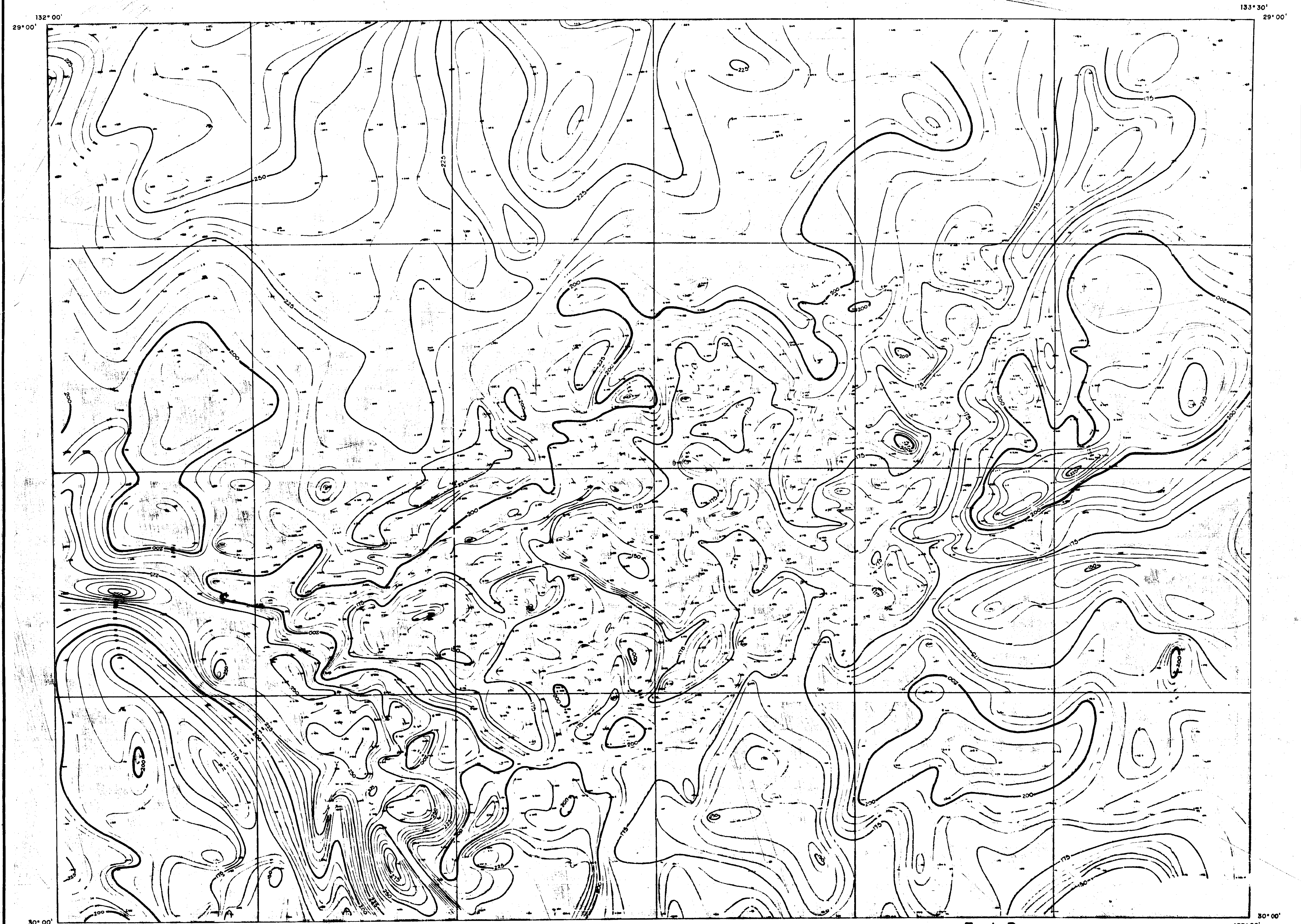
Encl. A

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA

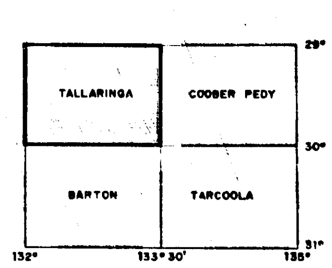
TALLARINGA TROUGH AND KARARI FAULT ZONE

COMPOSITE BOUGUER GRAVITY PLAN

COMPILED	B.E.M.
DRAWN	N.R.S.
DATE	4-7-80
CHECKED	
CDO	12-11-80
SCALE	1:500 000
PLAN NUMBER	80-501



Encl. B



CONTOUR INTERVAL - 5 m
DATUM - Mean Sea Level
COMPILED - N. Limb (Jan. 1980)

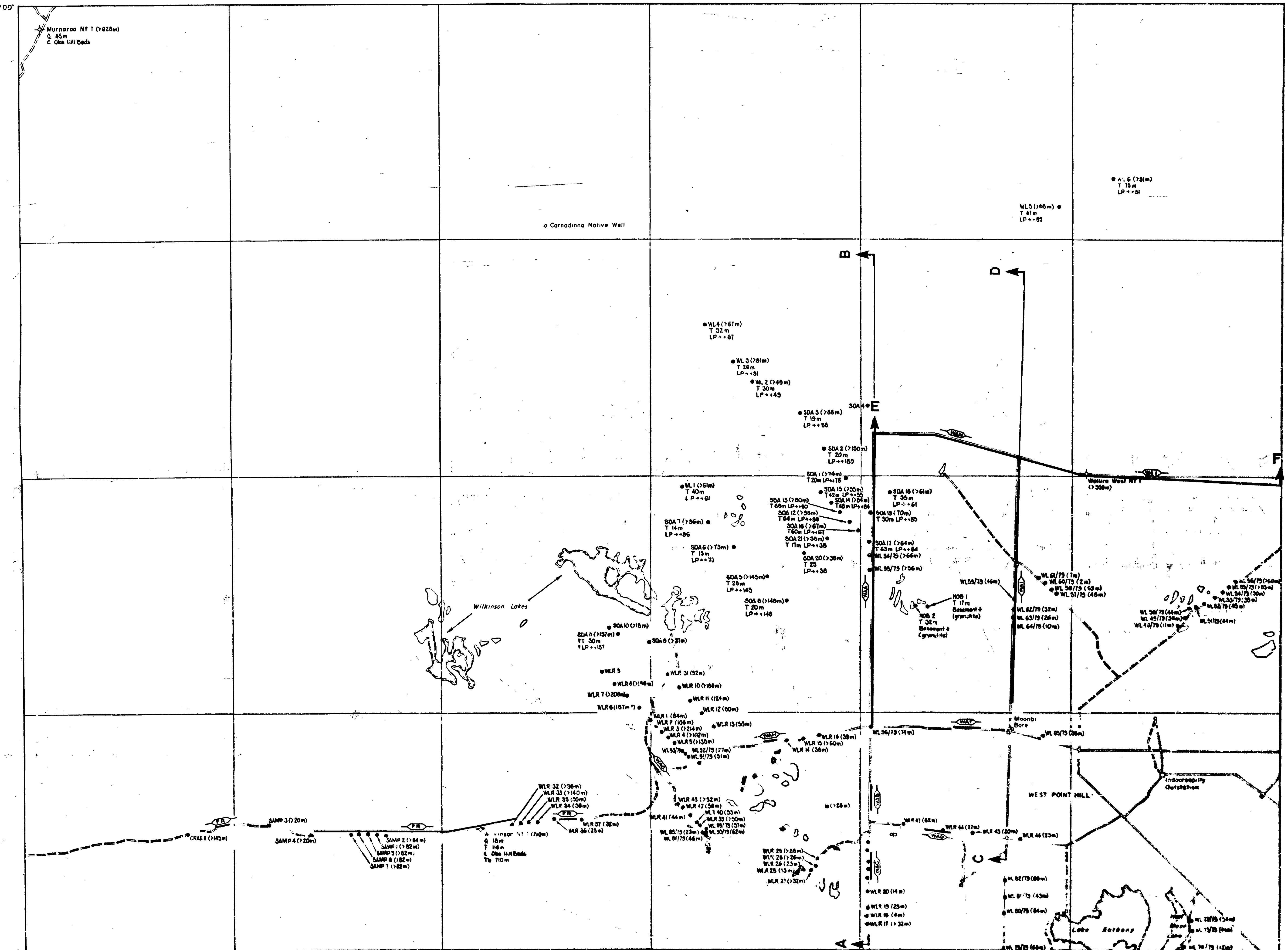
KILOMETRES
5 0 5 10 15 20 25

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA

TALLARINGA TROUGH AND KARARI FAULT ZONE

TOPOGRAPHIC CONTOUR PLAN

COMPILED	B E M
DRAWN	N.R.S.
DATE	4-7-80
CHECKED	
C G O	DATE 12.11.80
SCALE	1 : 250 000
PLAN NUMBER	80-502



Encl. C

- Company drillhole with number and depths to Tertiary and Lower Permian
- (>80m) indicates total depth (basement not intersected).
- (80m) indicates basement intersected at this depth.
- Basement outcrop.
- Stratigraphic well.
- Seismic line
- Profile line.

REFER TO FIGURES 4, 5 & 6. (80-498, 80-499, 80-500)

KILOMETRES

5 0 5 10 15 20 25

TALLARINGA	COOBER PEDY
BARTON	TARCOOLA

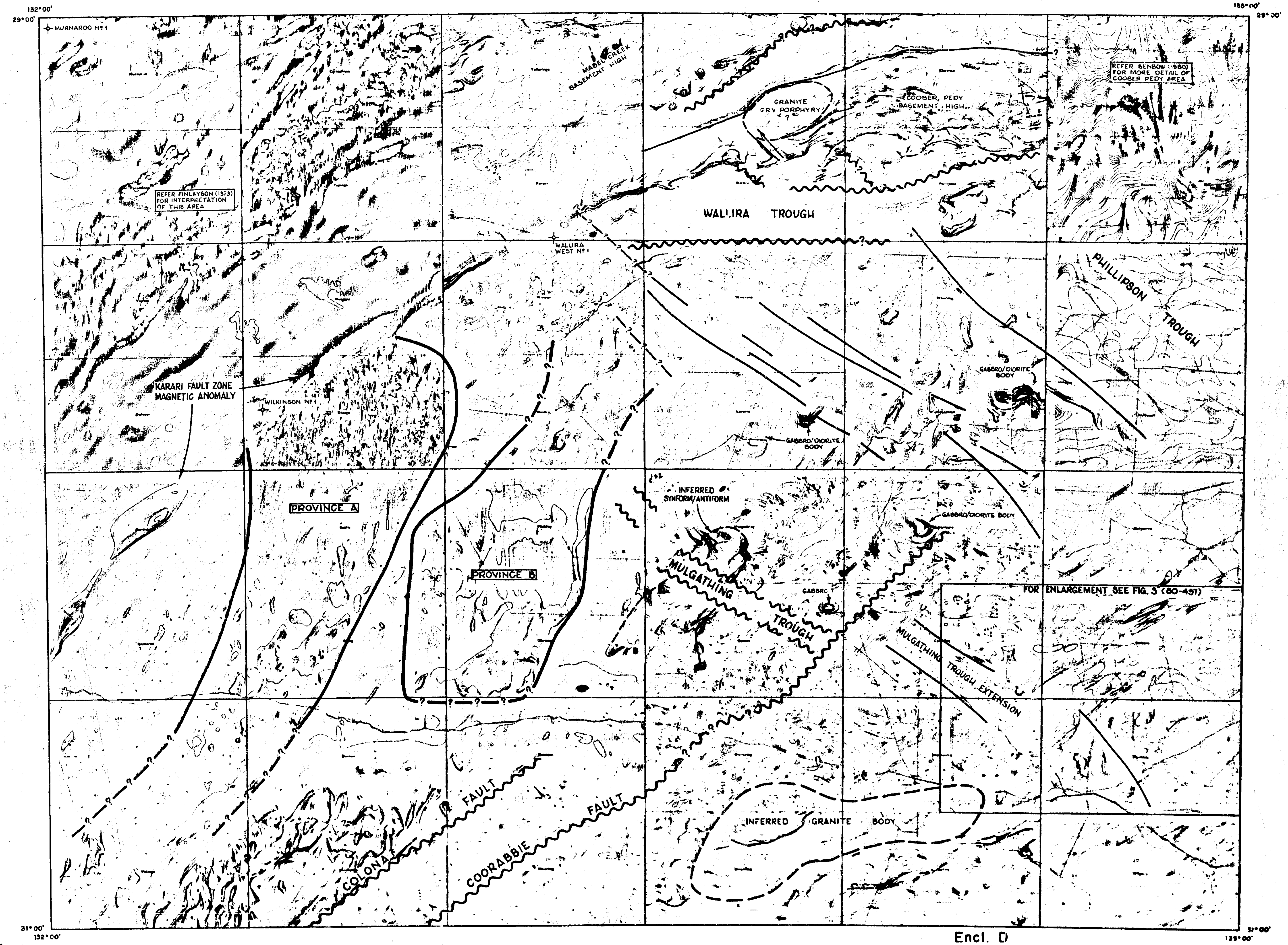
DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA

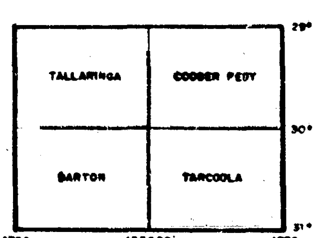
TALLARINGA TROUGH AND KARARI FAULT ZONE

SEISMIC AND DRILLHOLE DATA

80-503

Encl. D





...Dislocation (fault ?).

Basic dyke trend

...Stratigraphic well.

NOTES:
- FEATURES SHOWN ARE CONFIRMED BY MAPPING OR DRILLING.
- FEATURES LABELLED WITH ? ARE INFERRED FROM MAGNETIC AND GRAVITY DATA.
- REFER TO FIG. 2 FOR SURVEY SPECIFICATIONS. (S14851)
- AREAS 6 & 7 OF FIG. 2 ARE NOT INCLUDED ON THIS PLAN.

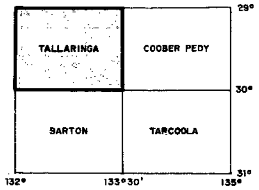
KILOMETRES
10 0 10 20 30 40 50

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

TALLARINGA TROUGH AND KARARI FAULT ZONE

COMPOSITE AEROMAGNETIC INTENSITY PLAN

B F M
R R S
4-7-80
CHECKED
12-11-80
SCALE 1 500 000
80-504



Magnetic anomaly fault plane.

F ....Fault.

............Stratigraphic well.

BOUGUER GRAVITY CONTOURS: Interval 10 μ-galileos (1 mgal)
Density 1·9 tonnes/m³

KILOMETRES
5 0 5 10 15 20 25

Encl. E

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA

TALLARINGA TROUGH AND KARARI FAULT ZONE

KARARI FAULT ZONE MAGNETIC ANOMALY FAULT PLANE and BOUGUER GRAVITY COMPARISON

COMPILED	B.E.M.
DRAWN	N.R.S.
DATE	4-7-80
CHECKED	
C.D.O.	DATE 12-11-80
SCALE	1:250 000
PLAN NUMBER	80-505