DEPARTMENT OF
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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1974/88

RECONNAISSANCE HELICOPTER GRAVITY SURVEY, S.A., 1970

by

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SUMMARY

The Bureau of Mineral Resources Geology and Geophysics conducted a reconnaissance helicopter gravity survey in western South Australia during 1970. The cell method of flying was used to establish about 7800 new gravity stations at a grid spacing of about 7 km over all or parts of twenty-one 1:250 000 Sheet areas.

Six gravity provinces were delineated within the survey area. These correspond broadly to known tectonic units although there are some disparities. Major structural trends within the Precambrian basement and the Phanerozoic cover are generally reflected in the gravity pattern.

In the north of the survey area, an intense gravity ridge extends eastwards along the axis of the Musgrave Block. The ridge cuts across the general northeasterly metamorphic trend but is parallel to major faulting. It is believed to correspond to a zone of relatively shallow crust where dense rocks of the lower crust and upper mantle are anomalously close to the surface. Local Bouguer anomaly highs in the western part of the gravity ridge are correlated with high-level basic intrusions of the Giles Complex.

The deepest part of the Officer Basin roughly coincides with a deep gravity depression bounded by a steep gradient to the north and a gentler gradient to the south. The known thickness of sediments in the Officer Basin cannot entirely account for the depressed Bouguer anomaly values; thus, a regional mass deficiency possibly either a basement density decrease or a thickening of the crust away from the Musgrave Block, or both must exist beneath the basin.

A gravity saddle which coincides in part with a magnetic basement high extends north-northeast across the gravity depression over the Officer Basin. The saddle may be the expression of a basement ridge forming a natural boundary between the eastern lobe of the Officer Basin where Palaeozoic sediments are thick, and the mainly Proterozoic western Officer Basin.

Gravity relief in the southwest of South Australia is attributed in different areas to basement topographic features and to intrabasement density contrasts. A gravity high and a gravity low adjoining the coastline correspond respectively to a basement rise and a Proterozoic/Palaeozoic infrabasin beneath the Mesozoic and Tertiary sediments of the Eucla Basin. Farther north, gravity relief appears to be controlled mainly by basement density variations.

The western part of the Gawler Block is an irregular area of high Bouguer anomaly level. Discrete gravity highs in this area are interpreted

as being due to dense rock bodies within the Gawler Block - probably local concentrations of gneiss and amphibolite in a mainly granitic basement.

A broad gravity depression extends northeastwards across the central Gawler Block. Seismic refraction evidence suggests the depression may be caused by a deep-seated mass deficiency, possibly within the upper mantle.

1. INTRODUCTION

The Bureau of Mineral Resources, Geology and Geophysics (BMR) continued the reconnaissance gravity coverage of Australia by conducting two helicopter gravity surveys in South Australia during 1970. Both were carried out under contract by Wongela Geophysical Pty Ltd using the cell method, described by Hastie and Walker (1962), to establish a grid of gravity stations over the survey areas. This report describes the results from the western survey area, Area A (Fig. 1), in which about 250 000 km^2 were surveyed over all or parts of twenty-one 1:250 000 Sheet areas. The statistics of the survey are given in Appendix 1.

Stations were established at a grid spacing of about 7 km, which is about half a kilometre greater than the spacing for surveys carried out by the South Australian Department of Mines but less than the normal 11-km spacing for BMR reconnaissance helicopter gravity surveys. The smaller grid spacing was chosen by the Department of Mines because of the large proportion of Precambrian shield rocks in South Australia; in addition, the 7-km spacing enables the location of stations at photocentres of RC-9 aerial photographs, thereby facilitating the contouring of topographic maps.

The barometric levelling network established during the survey has been adjusted into a network of third-order bench-marks, placed and levelled in South Australia by the South Australian Department of Lands, and in Western Australia and the Northern Territory by the former Commonwealth Department of Interior. Gravity control was provided by tying some base stations into a network of isogal stations established by BMR (Barlow, 1970). The accuracy of the results is reflected in the values of the standard deviations of the elevation and gravity network adjustments (Appendix 2.).

Ties were made to previous gravity surveys around the periphery of the present survey area. Contours from all previous surveys in South Australia have been included in the map of preliminary Bouguer anomalies (Plate 1) to show the continuation of gravity features into neighbouring areas. Different Bouguer densities have been used in different surveys which partly accounts for slight discontinuities of contour between the present survey and some of the previous surveys tied to. A common density will be used throughout South Australia when all the basic data are incorporated in the BMR collection and recomputed. As the neighbouring area in Western Australia had not then been surveyed, the survey was extended a few kilometres to permit control of contouring up to the state border.

In this report, the results of previous geophysical surveys and known geology, including subsurface data from boreholes, are considered in the preliminary interpretation of gravity results. Only a regional analysis of the gravity results is attempted as the large station spacing filters out short wavelength anomalies, leaving an observed Bouguer anomaly field which reflects only the broad, regional structural elements of the crust.

2. GEOLOGY

The survey area covers parts of four major tectonic units: the Musgrave Block, the Officer Basin, the Gawler Block, and the Eucla Basin. The geology is known mainly from reconnaissance surveys, but more detailed geological mapping of the western part of South Australia is now in progress. Because of the sparseness of outcrop, the geology is largely inferred from scattered borehole data, geophysical data, and by extrapolation from surrounding areas.

The general tectonic framework within and around the survey area is shown in Plate 2. The major geological features have pronounced northwesterly and younger northeasterly trends, which were established in Precambrian times. Subsequent movements and the pattern of Phanerozoic deposition, have followed the earlier Precambrian structural trends.

There is little outcrop throughout the survey area except in the Musgrave Block so only a tentative geological background can be presented here. The following account is largely based on papers by Wopfner (1969, 1970) and Thomson (1969).

Three major geotectonic units were present in South Australia at the close of Precambrian times. Much of southern and central South Australia was dominated by the Gawler Craton*. To the east and northeast was the slightly arcuate Adelaide Geosyncline, while the Musgrave Block dominated the northwest, its southern and eastern extent being uncertain. As previously mentioned, orogenies during the Precambrian established the dominant structural trends, which controlled Phanerozoic events. Four major depositional phases are recognizable in Phanerozoic times (Wopfner, 1969). They are the Cambrian-Devonian, Carboniferous-Permian, Jurassic-Cretaceous, and Palaeocene-Miocene phases.

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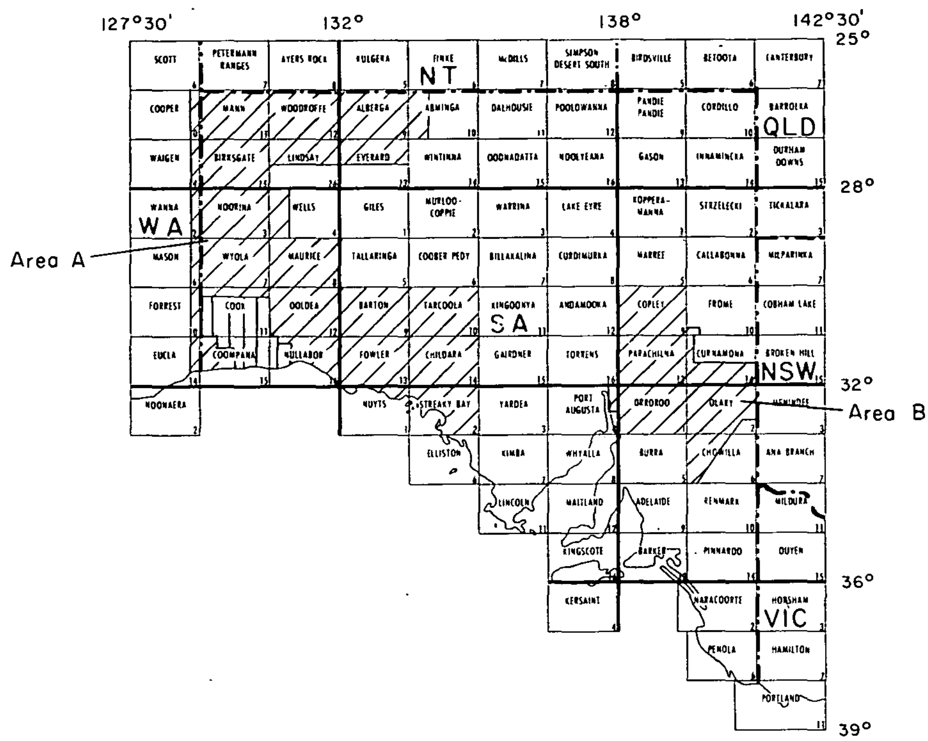
* B.P. Thomson (1969) used the term Gawler Block for only the exposed Precambrian or shield area, and the term Gawler Platform to include both shield and platform areas. In a later paper (1970) he used Gawler Craton instead of Gawler Platform. In this report, Gawler Block is used for the shield area only, and Gawler Craton for the shield and platform areas.



Area surveyed by BMR (1970)

Area surveyed by Outback Oil NL (1965)

FIG. 1

LOCALITY MAP

1970 HELICOPTER GRAVITY SURVEY, SA

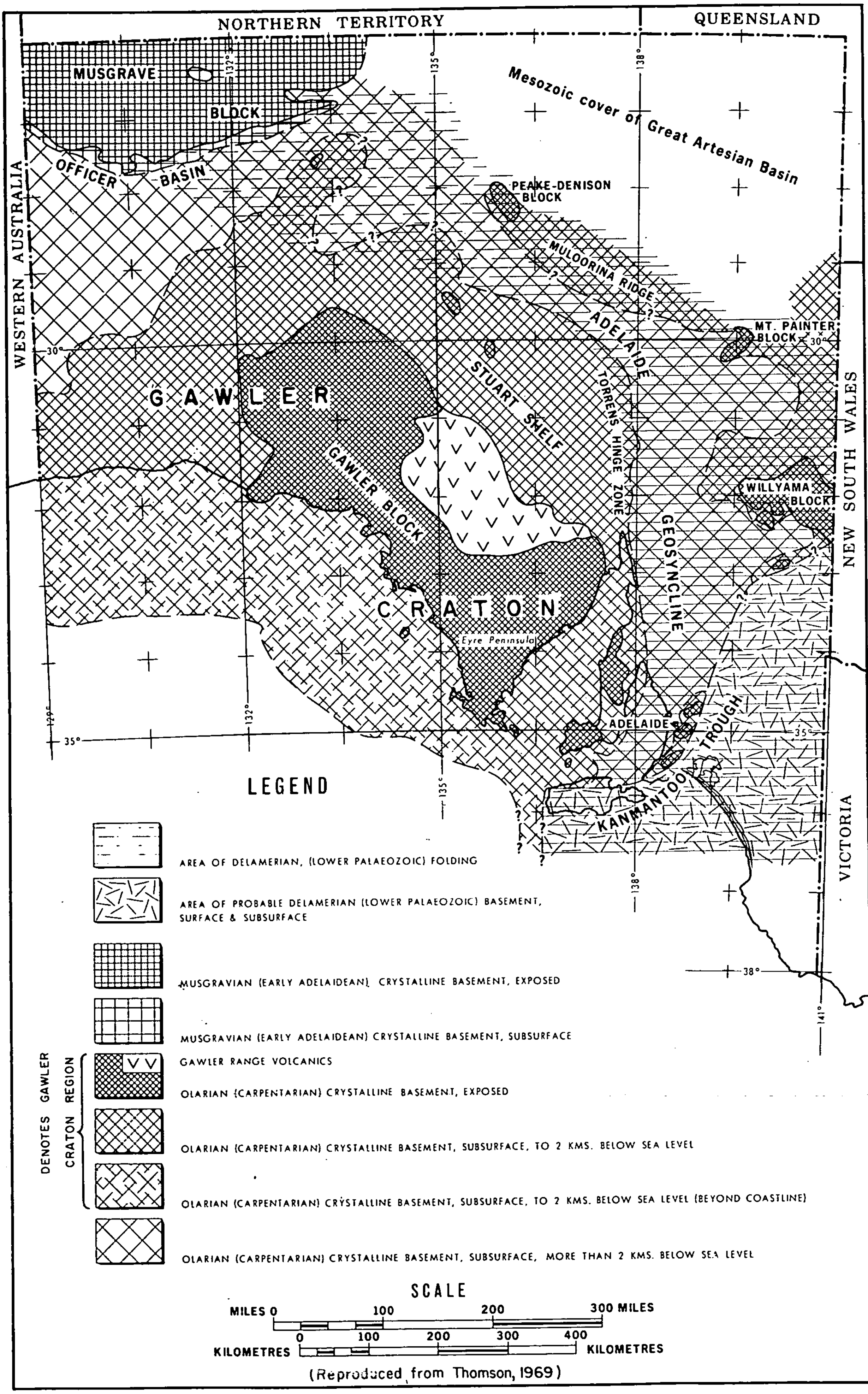
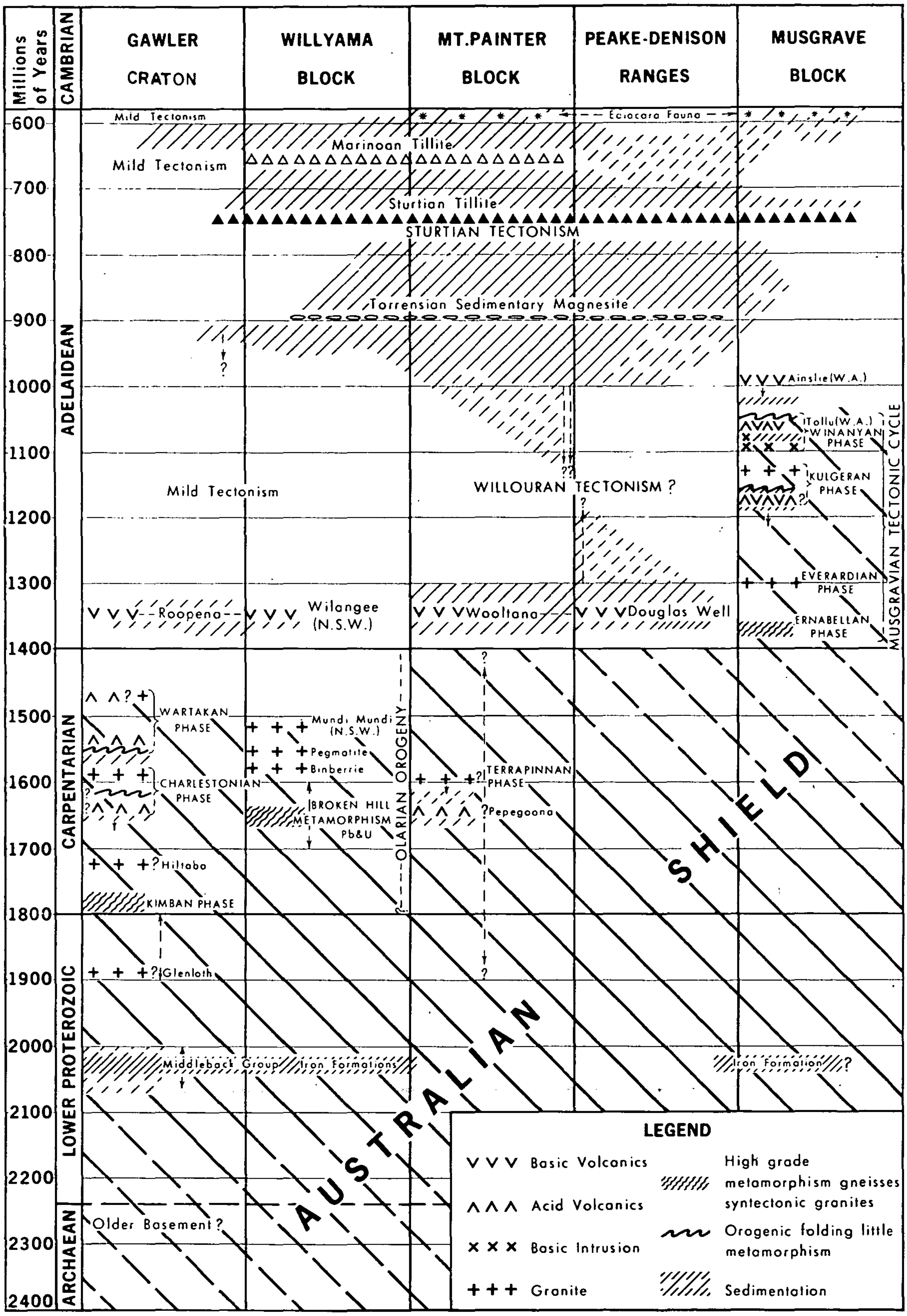


Fig. 2 Major structural units of South Australia.



(Reproduced from Thomson, 1969)

Fig. 3 **Major stratigraphic and tectonic events of the Precambrian.**

Gawler Craton

The Gawler Craton (Fig. 2) is exposed (as the Gawler Block) over a large area of southern-central South Australia, and forms the proterozoic basement of the adjacent parts of the Eucla, Arckaringa, and Officer Basins; its subsurface extent has been inferred from borehole and geophysical evidence.

The tectonic history of the Gawler Craton (Fig. 3) is complex and known in detail only on the eastern Eyre Peninsula. A thick sequence of sediments was deposited on an Archaean basement in Early Proterozoic times, and was deformed in early Carpentarian times (1800 m.y.) during the Kimban Phase, when intense regional metamorphism established strong northeasterly trends (Whitten, 1966) and produced complexly folded gneisses and migmatites. The appearance of acid volcanics marked the beginning of the Charlestonian Phase (1600 m.y.) of folding and plutonism. Gneissic granite whose northern extent is uncertain crops out in the coastal areas of STREAKY BAY* and NUYTS (Walker & Botham, 1969); its age is unknown, but it is older than the Middle Carpentarian gabbros that were intruded around Streaky Bay at the end of the Charlestonian Phase. Sedimentation during Late Carpentarian times resulted in a sequence several hundred metres thick near Tarcoola (Whitten, 1966) and possibly elsewhere. These sediments were deformed and the acid Gawler Range Volcanics were extruded during the Wartaken Phase (about 1500 m.y.).

The western Gawler Craton is a gneissic complex overlain by sediments of the Eucla Basin. Mallabie No. 1 Well (Outback Oil, 1969) encountered gneisses at a depth of 1350 m, and a number of water bores have also encountered a gneissic basement which appears to be dipping gently to the west (Ludbrook, 1957). The northern Gawler Craton is covered by the Late Palaeozoic intracratonic Arckaringa Basin. Stratigraphic drilling and seismic evidence (Milton, 1969) suggest the northern part of the craton consists largely of gneissic and other metamorphic material.

Density data for the Gawler Craton is generally scarce and comes mainly from measurements on borehole and in situ surface samples, and from estimates based on seismic velocities. It is summarized in Appendix 3.

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* Throughout this report the names of 1:250 000 Sheet areas are printed in capital letters to distinguish them from place names.

Musgrave Block

Unlike the Gawler Craton, the Musgrave Block (Fig. 4) is well exposed. It has been extensively explored in the search for minerals, particularly nickel. Thus although the tectonic history of the block is complex (Fig. 3), it is better known than the histories of the other tectonic units within the survey area. The Musgrave Block covers an east-striking elongate area of 80 000 km^2. Gravity evidence suggests that it extends to the northeast under the Great Artesian Basin (Lonsdale & Flavelle, 1963). To the south it is bounded at the surface by the Officer Basin but may extend beneath it. The eastern end of the block may have been the basement of the northern part of the Adelaide Geosyncline (Wopfner, 1969).

The Musgrave-Mann metamorphics are granulites formed by metamorphism of a thick shale sequence. Foliations and relict sedimentary structures in the south of the metamorphic belt show distinct northeasterly trends, but farther north the trends have been obliterated by shearing. The metamorphic events have been dated at 1370 m.y. and form the Ernabellan Phase; this phase may have been preceded by an earlier tectonism equivalent to the Kimban Phase (1800 m.y.) of the Gawler Craton (Fig. 3) and during which the northeasterly trends may have been initiated. A subsequent plutonic phase of the Musgravian Orogenic Cycle (Thomson, 1970), the Everardian Phase (1300 m.y.), included the injection of granites and the commencement of a period of uplift. The degree of metamorphism of the Musgrave-Mann Metamorphics appears to decrease southwards.

Adelaidean sediments to the north of the Woodroffe Thrust and Mann Fault were folded and metamorphosed in the Kulgeran Phase (1130 m.y.). Basement material was locally melted and intruded into the sediments as granitic masses.

The major development of the Mann Fault System proceeded during the Winanyan Phase (1070 m.y.). The southern portion of the block was elevated and the Giles Complex ultramafics were intruded along the faults (Fig. 4, Plate 2). This fault control of the Giles Complex is strongly evident (Sprigg & Wilson, 1958; Nesbitt & Talbot 1966). Basic dyke swarms with northeasterly to easterly trends transecting the Musgrave Block are thought to be related to the Giles Complex. Major vertical movements occurred and deep granulite blocks were pushed from the south along the Woodroffe Thrust. Deep grabens with east-striking trends developed locally and were infilled with up to 6000 m of Adelaidean ? clastics. This event terminated the Musgravian Orogenic Cycle. Sugsequent events show only mild tectonism: deposition of Adelaidean sediments onto the basement and extrusion of the Ainslie Volcanics in Western Australia (1000 m.y.) were followed by comparatively minor folding and uplift in the Cambrian and early Ordovician.

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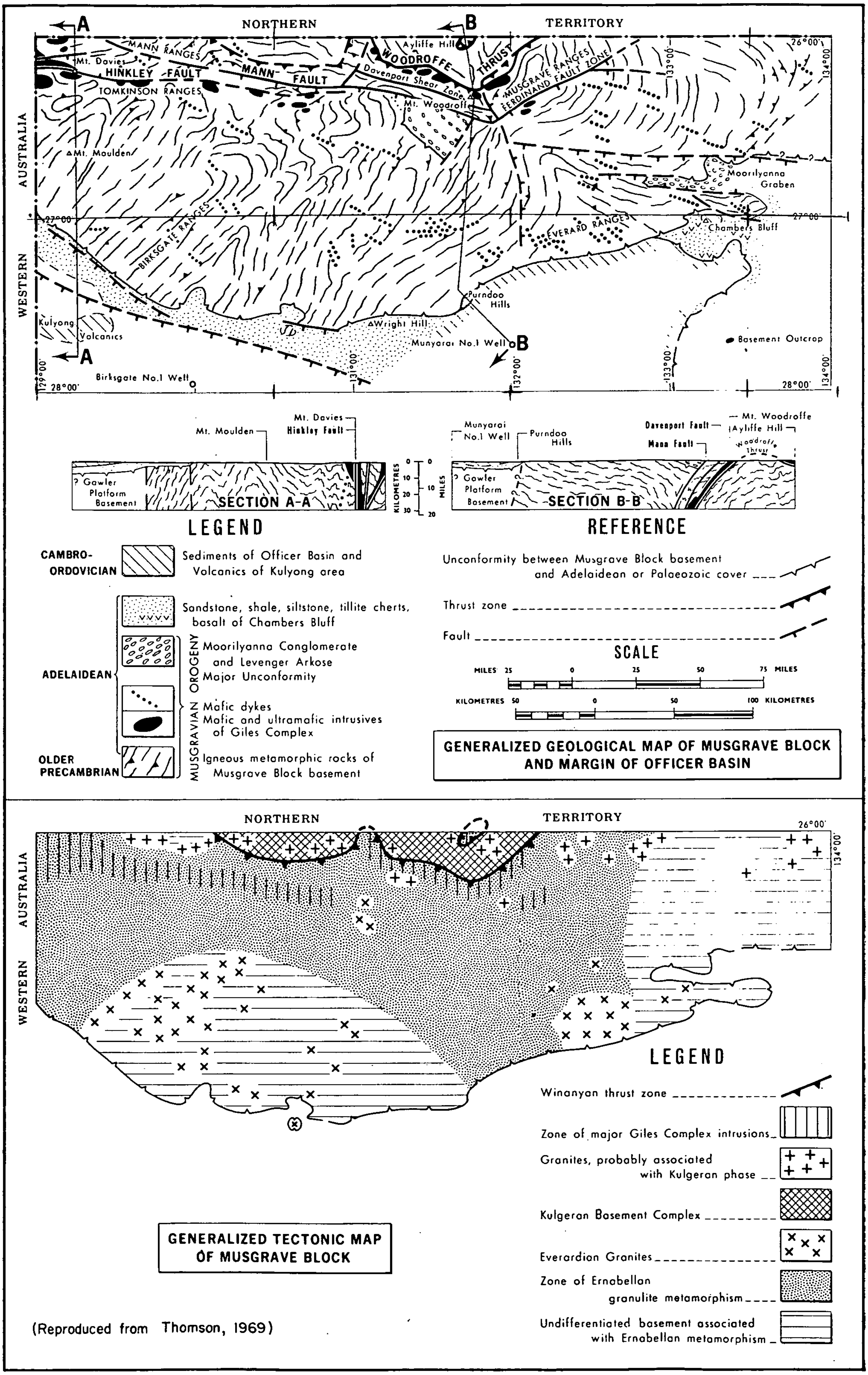

FIG. 4 Generalized tectonic and geological map of the Musgrave Block and margin of the Officer Basin.

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Density information for the Musgrave Block is readily available: data supplied by the South Australian Department of Mines are summarized in Appendix 3.

Officer Basin

The Officer Basin (Plate 2) is an extensive intracratonic basin of Proterozoic and Palaeozoic sediments. Most of the basin lies in Western Australia; only the eastern part, an east-trending asymmetric basement trough south of the Musgrave Block, lies in South Australia. The eastern Officer Basin was first revealed by the results of an aeromagnetic survey (Quilty & Goodeve, 1958). This survey was followed by a number of geophysical and drilling surveys (Exoil Pty Ltd, 1962, 1963, 1964; Mumme, 1963a; Continental Oil Co., 1965, 1967a, 1967b, 1968; Moorcroft, 1967; Murumba Oil NL, 1970) which determined the overall structure of the basin, and the character and age of the sediments. Krieg (1969) has reviewed the geology of the eastern Officer Basin.

To the north, the basin is separated from the Musgrave Block by faults, but elsewhere the boundaries are not readily definable. Tenuous gravity evidence suggests a possible link between the Officer and Great Artesian Basins near WINTINNA (Plate 1), and the Western Australian part of the basin may be continuous with the Canning Basin. The relation between the Officer and Eucla Basins is uncertain, but it is speculated that the Proterozoic Officer Basin sediments may extend southwards under the post-Ordovician sediments of the Eucla Basin. The Officer Basin may have been linked to the Amadeus Basin, north of the Musgrave Block, in the Ordovician period (Krieg, op. cit.)

Development of the Officer Basin in South Australia evidently migrated eastwards in time, with the result that the Palaeozoic sediments thicken from less than 1000 m in the west to at least 2800 m in the east. The two parts of the eastern Officer Basin may be separated by a basement topographic feature.

Structurally, the South Australian part of the basin is an elongate trough of varying width. The surface axis strikes west-southwest in the east of the basin, but swings around the southern margin of the Musgrave Block and assumes a west-northwesterly orientation just east of the Western Australian border. The eastern part of the basin is asymmetric in section, with the basement rising sharply toward the Musgrave Block in the north but gently to the southeast. A current hypothesis describes the basin as a trough bounded by a hinge in the southeast, and by normal faults in the north.

Little information is available on the composition of the basement. Granulite crops out in southeastern EVERARD suggesting that at least part of the basement is composed of granulite.

Density data on the Officer Basin sediments are obtained from measurements on borehole samples (Continental Oil, 1967a, 1968) and are summarized in Appendix 3.

Eucla Basin

This account is derived largely from Lowry (1970).

The Eucla Basin is a large arcuate basin covering about 176 000 km^2 onshore. It is bounded to the west by the Yilgarn Block, to the east by the Gawler Block, and to the north by the Officer Basin (Plate 2). Its southern boundary lies beyond the coastline in the Great Australian Bight, and is not well defined. Most of the basin is covered by an arid limestone plateau that slopes gently seawards from an altitude of about 240 metres in the north to to 60 to 120 metres in the south. The limestone is largely responsible for the featureless nature of the Nullarbor Plain.

The basin is thought to have evolved through subsidence during the Mesozoic. It is unusually shallow for a basin of such large areal extent. The average depth is estimated to be about 600 m onshore and 1000 m offshore. Lowry (op. cit.) notes that the basin is a good example of an epeirogenic basin as it lies on the edge of a continent, has no volcanics, shows virtually no folding or faulting, and has a low ratio of maximum depth to area. Tectonic deformation has been mild: gentle downwarping from the Cretaceous to early Miocene was followed by uplift, slight tilting, and minor faulting.

Recent geophysical work in the South Australian part of the basin has revealed a largely pre-Mesozoic infra-basin, the Denman Basin, up to 2400 metres thick. The existence of this trough was confirmed by the Mallabie No. 1 well (Outback Oil, 1969), which passed through 188 m of Tertiary limestone, clay and siltstone; 159 m of Cretaceous sediments; 88 m of Permian sandstone and siltstone; 905 m of Cambrian or Ordovician sandstone, siltstone, and volcanics; and 34 m of probable Proterozoic sandstone. A basement of granitic gneiss was encountered at a depth of about 1300 m. Gravity and magnetic evidence suggest that the Denman Basin extends to the northeast, possibly as far as the Arckaringa Basin (Wopfner, 1970).

Density data for the Eucla Basin, taken from the density log of the Mallabie Well (Fig. 5) are included in Appendix 3.

3. PREVIOUS GEOPHYSICAL INVESTIGATIONS

Only a small amount of geophysical work has previously been carried

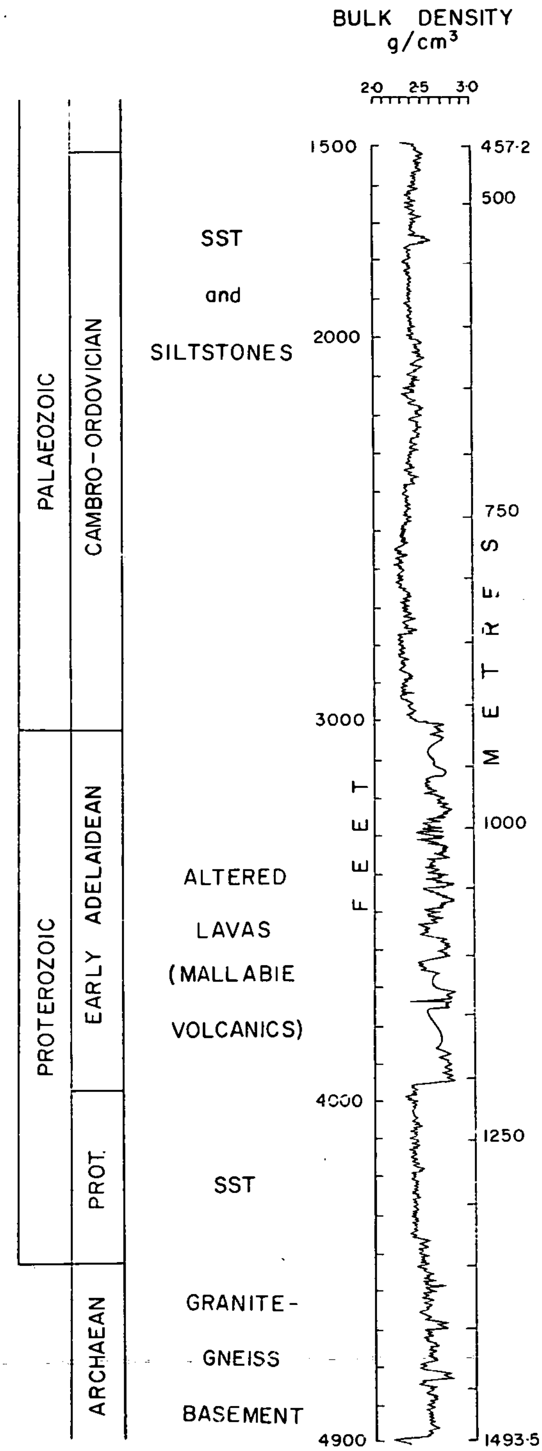
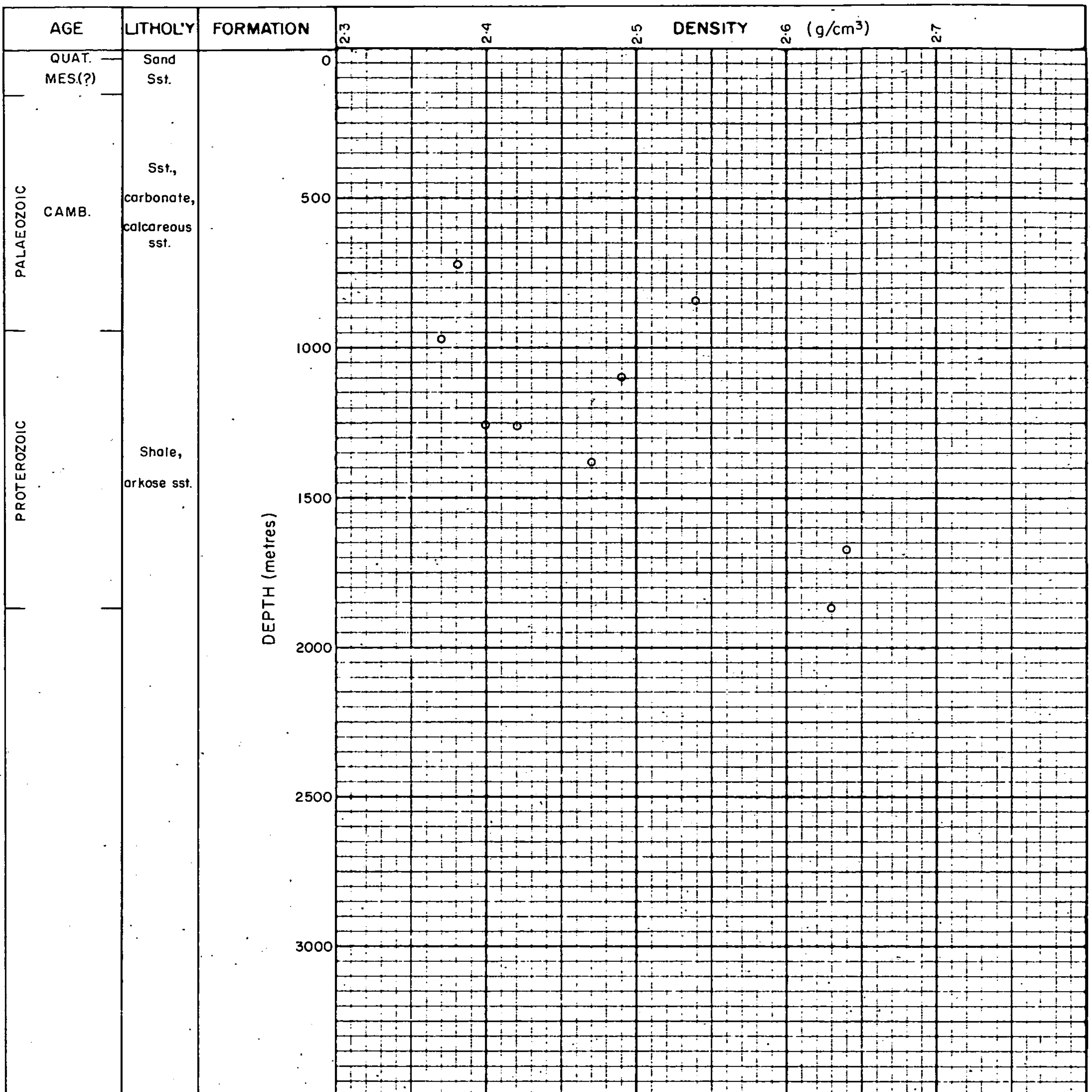


Fig. 5 Compensated formation density log for Mallabie No. 1



NAME OF WELL BIRKSGATE No. 1	**ELEVATION** 380 metres
POSITION LAT. 27° 56' 20" S LONG. 129° 58' 10" E	**TOTAL DEPTH** 1868 metres
1:250,000 AREA BIRKSGATE	**SOURCE OF DATA AND PURPOSE OF ANALYSIS** CONTINENTAL OIL (DENSITY DATA)
BASIN WESTERN OFFICER BASIN	**SUBSIDISED** 67/4242
STATE OR TERRITORY SOUTH AUSTRALIA	**DRILLED BY** OIL DRILLING AND EXPLORATION PTY LTD

(Based on G65-181-1A)

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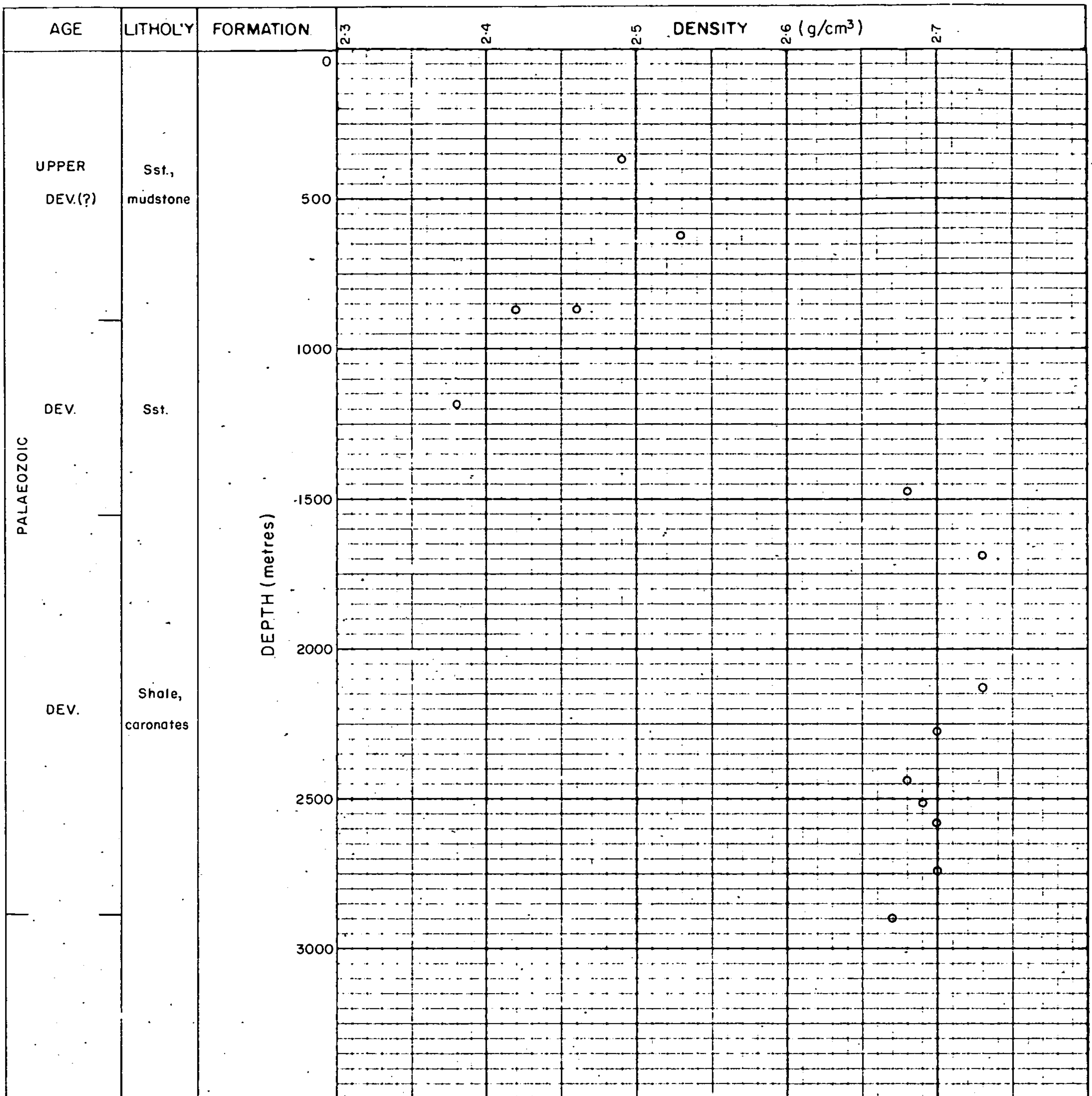
Fig. 6 Formation density plot for Birksgate No. 1

G52/B6-1A



NAME OF WELL	ELEVATION
MUNYARAI No. 1	412 metres
POSITION	TOTAL DEPTH
LAT. 27° 41' 53" S LONG. 132° 00' 03" E	2880 metres
1:250,000 AREA	SOURCE OF DATA AND PURPOSE OF ANALYSIS
EVERARD	CONTINENTAL OIL (DENSITY DATA)
BASIN	SUBSIDISED
EASTERN OFFICER BASIN	68/2012
STATE OR TERRITORY	DRILLED BY
SOUTH AUSTRALIA	CONTINENTAL OIL

(Based on G65-181-1A)
RECORD NO. 1974/88

Fig. 7 Formation density plot for Munyarai No. 1

G53/B6-1A

out within the survey area, mainly by private companies, but also by the South Australian Department of Mines and BMR. Apart from aeromagnetic work, the geophysical surveys within the area have generally been of relatively small areal extent. Only those of substantial size or with results that are important to the interpretation of results from the 1970 survey are summarized here.

Gravity surveys

Several of gravity surveys have been conducted within or near the survey area. They are listed in Appendix 4 and their locations are shown in Plate 3.

Rowan (1968) interpreted regional gravity results over part of the Musgrave Block and considered the major 'high' located there to represent an extension of the Anketell Gravity Ridge (Lonsdale & Flavelle, 1963). Local gravity highs coincident with outcropping ultramafics are superimposed on the regional high indicating that 'the outcropping areas of basic rock are the surface expressions of apophyses emanating from a larger body at depth' (Rowan, op. cit.). This led Rowan to the conclusion that the gravity high is caused primarily by a major crustal feature with local peaks being due to dense high-level intrusions of the Giles Complex.

Gunson & Van der Linden (1956) conducted regional gravity traverses across the Eucla Basin - along the Eyre Highway and the Transcontinental Railway - and revealed generally low Bouguer anomaly values with irregularly spaced, local highs over the area of the Eucla Basin. They considered the anomalies to be mainly expressions of density variations within the basement. The survey also revealed a major high of +20 mGals on the eastern edge of NULLARBOR, and an extensive low reaching -60 mGals extending eastwards from north of Fowlers Bay to Ceduna. The low corresponds to an area of younger granites. The interpretation of the gravity results on a traverse on the road from Colona Homestead to Maralinga by Kerr-Grant & Pegum (1954) suggests the presence in northeast OOLDEA of a trough of at least 900 m of sediments, flanked on the west by a north-trending basement ridge. The southern extension of the trough was not clearly resolved but appears to become shallower. The Eucla Basin survey (Outback Oil NL, 1965) covered parts of COOMPANA, COOK, OOLDEA, and NULLARBOR, and delineated a broad northwest-trending Bouguer anomaly low closely paralleling major photogeological features. In addition a smaller northeast-trending gravity depression was revealed in the east of COOMPANA; subsequent drilling of Mallabie No. 1 (Plate 4) has shown that it corresponds to a trough of mainly Palaeozoic and Upper Proterozoic sediments. The results of the Eucla Basin gravity survey (Outback Oil NL, 1965) have been included with the results of the present survey (Plate 1).

Mumme's (1963a) gravity traverse across the Officer Basin and Musgrave Ranges revealed a major Bouguer anomaly low of -100 mGal that coincided with the then known basinal axis.

In the eastern part of the Officer Basin, combined seismic and gravity surveys were carried out by both the South Australian Department of Mines (Moorcroft, 1968) and Continental Oil Company (1967b); gravity observations were made at seismic shot-points. In both surveys, there was a high degree of correlation between Bouguer anomalies and structures derived from the seismic results. Moorcroft concluded that full scale gravity coverage of the entire basin could be a valuable aid in locating further structures. Murumba Oil NL (1970) conducted a helicopter gravity survey over LINDSAY, EVERARD, eastern WELLS, and western GILES. It revealed an extensive negative anomaly, as low as -145 mGal, that coincided with the eastern Officer Basin. The contours from this survey are included in Plate 1.

Aeromagnetic surveys

Aeromagnetic surveys flown within or near the BMR gravity survey area are listed in Appendix 4. The contours of estimated basement depth for these surveys are shown in Plate 5.

In a report on the results from a few widely spaced traverses, Quilty & Goodeve (1958) postulated basement depth exceeding 700 m in a region covering parts of BIRKSGATE, LINDSAY, NOORINA, and WELLS which is now regarded as part of the Officer Basin. A reconnaissance aeromagnetic survey by Exoil (1964) showed the Officer Basin to be a broad trough with 1800 m of non-magnetic material along a hinge-line forming the southern flank, and with 4800 m of sediment near the northern edge of the trough, which is apparently faulted against the Musgrave Block. The magnetic contours reveal a north-trending high, 100 km long, crossing the junction of the two major strike trends of the South Australian portion of the Officer Basin. The breadth and amplitude of the anomaly suggests a highly magnetic intra-basement source and may reflect a major tectonic feature (D. Boyd, pers. comm.).

BMR has co-operated with the South Australian Department of Mines in aeromagnetic surveys over the Musgrave Block, the Gawler Block, and more recently the Eucla Basin; the general objective was to facilitate geological interpretation of poorly exposed areas. Various surveys have together covered parts of the Gawler Block (Quilty, 1962; Whitten, 1963; Young & Gerdes, 1966) and the Eucla Basin (Waller, Quilty & Lambourn, 1972). Detailed geophysical traverses and drilling on aeromagnetic anomalies in STREAKY BAY revealed intruded plugs of gabbro (Whitten, op. cit.). Strong northwest-trending magnetic lineaments in the northeast of TARCOOLA and farther north are due to basic

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dykes that are more than 400 kms long and are collinear with similar dyke suites north of the Musgrave Block (D. Boyd, pers. comm.). These dykes may reflect a major structural trend in the Archaean basement.

A survey of the eastern part of the Musgrave Block revealed extensions of the Mann and Davenport Faults displaced to the south, thereby supporting evidence of a major north-trending dextral fault with a horizontal displacement of 16 km at the boundary between the WOODROFFE and Sheet areas (Waller, 1968); a graben structure was postulated in the west of ABMINGA. A BMR survey that covered a small part of the MANN-WOODROFFE area (Tipper, 1967) aimed to determine whether the basic and ultrabasic rocks of the Giles Complex are continuous beneath Cainozoic cover. The survey results were not conclusive and the interpretation was hampered by lithological variations within the Cainozoic cover. This survey was followed by a detailed survey, with 1.6 km line spacing, over MANN, eastern WOODROFFE, northern BIRKSGATE, and northeastern LINDSAY (Shelley, 1971). The results of this survey were more meaningful, and, on the basis of inferred basic intrusions and shearing, a major tectonic feature in southwest MANN was interpreted. The aeromagnetic results suggest that the northern edge of the Officer Basin is about 10 km north of its previously interpreted position, and is in fault contact with the Musgrave Block.

The results of a BMR aeromagnetic survey of the COOK, OOLDEA, and BARTON Sheet areas (Waller et al., 1972) indicate large parallel negative anomalies that coincide with a north-striking photogeological feature in the west of COOK and with a shallow basement across the northeast of OOLDEA, just south of the trough of sediments found by Kerr-Grant & Pegum (1954). Apparently the trough, which represents the extreme southwest limit of the Permian Arckaringa Basin, is not connected with the Permian Denman Basin.

Seismic surveys

Several seismic surveys have been carried out within the survey area. They are listed in Appendix 4 and their locations are shown in Plate 4.

The Serpentine Lakes survey in western BIRKSGATE and NOORINA indicated a sedimentary thickness of up to 5.2 kms (Continental Oil Co., 1965). The eastern Officer Basin surveys gave similar thicknesses farther east (Moorcroft, 1967; Continental Oil Co., 1967b).

Kendall (1965) reported on a reconnaissance seismic reflection survey in the South Australian portion of the Eucla Basin. Three refractors

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were recorded: two in the velocity range 4.42-5.03 km/sec, and another at 5.64-6.10 km/sec, which may be similar to a 6.05 km/sec refractor measured on Proterozoic outcrops near Mount Davies by Turpie (1967). The results reveal a northwest-trending basement trough about 1.5 km deep.

Milton (1969) has reported on extensive seismic investigations in the relatively shallow Arckaringa Basin, to the east of the BMR gravity survey area. The basin is underlain by granitic basement of the Gawler Craton, from which a refraction velocity of about 5.7 km/sec was obtained consistently from many separate refraction profiles. Coupled with density data for basement rocks, obtained by the South Australian Department of Mines from stratigraphic wells within the Arckaringa Basement (Appendix 3) this suggests a uniform granitic basement throughout the area. Metamorphic rocks in adjoining areas show higher velocities than granitic basement, with an upper limit of 7.0 km/sec. In WINTINNA the coincidence of gravity highs with areas of generally undisturbed magnetic field, and the presence of a high velocity (6.14 km/sec) refractor, suggest the presence of dense carbonate sequences in the basin (Milton, op. cit.). Stratigraphic drilling has confirmed this (Milton, 1970).

A shallow seismic refraction survey at Maralinga (Wiebenga & Hawkins, 1956) indicated a basement refraction velocity of 5.8 km/sec. The basement density was estimated to be 2.7 gm/cm^3.

Deep crustal studies have been undertaken in South Australia by recording refracted arrivals from nuclear explosions at Emu in 1953, and at Maralinga in 1956-57 (Doyle & Everingham, 1964). Recordings from the Emu explosion were made by BMR at Woomera and Tallaringa; they indicate a granitic layer velocity of 6.3 km/sec (Doyle, 1954). The 1956 Maralinga tests were more extensive and recordings were made at 5 stations in a line extending south to Fowlers Bay, and at a station midway between Fowlers Bay and Ceduna. The results revealed a 6.3 km/sec granitic layer at a depth of 1 to 2 km. For an 'average' crust (Birch, 1958), 6.3 km/sec is considered an upper velocity limit for granitic material, and such velocities are generally encountered at depths of 10 to 15 km. Shallow refraction profiles for near-surface corrections indicate basement velocities in the range 5.70-5.88 km/sec and a maximum depth to basement of 0.55 km.

The 1957 Maralinga tests were recorded at Ceduna, and farther southeast on the Eyre Peninsula at three stations 300 to 700 km from the test site. A series of recording stations with offsets of up to 1200 km was also established along the Eyre Highway to Kalgoorlie. Mantle wave refractions indicated a mantle P-wave velocity of 8.05 km/sec beneath the Gawler Craton. This is lower than the mantle velocities of both 8.21 km/sec recorded in Western Australia and estimated 8.16 km/sec in eastern Australia (Doyle & Everingham, 1964). Mantle depths are estimated to be 35 to 39 km. This agrees with estimates made from gravity data observed along 131°E longitude (Mumme, 1963b).

The presence of an intermediate, 6.5-7.0 km/sec layer was not established by any of the recordings, and Doyle and Everingham (op. cit.) concluded that it may be present, but thin. Using standard nomograms for seismic refraction blind zone problems (Hawkins & Maggs, 1961), a maximum likely thickness of the intermediate layer can be calculated. If the depth to mantle calculated from the seismic refraction results, assuming no intermediate layer, is 37 km; assuming an intermediate layer with a velocity of 7.0 km/sec is present, its maximum thickness from the nomogram would be 16 km and the total depth to the mantle would be 42 km.

4. DESCRIPTION AND INTERPRETATION OF RESULTS

Gravity contours from the BMR survey, and surveys by the South Australian Department of Mines and private companies are shown in Plate 1. All the major gravity features have been outlined, but only those within or closely related to the present survey area are described in this report.

The contour map has been partitioned in such a way as to simplify the description and interpretation of gravity features, and to emphasize the overall contour pattern. Large areas, usually of fairly simple shape, within which the gravity field is characterized by uniform gravity level, regional contour pattern, and degree of contour disturbance are termed gravity provinces. Gravity units are subdivisions of provinces.

Each province is described briefly and a preliminary interpretation is given. Since more than one explanation for a gravity feature is possible, plausible alternatives are sometimes presented. The interpretations may eventually be tested drilling or by other geophysical surveys. Paucity of density information, and density variability within individual lithological units, creates difficulty in the choice and use of appropriate average densities; this leads to ambiguity in the interpretations.

Gravity feature nomenclature

Where possible, names used for features extending from previous survey areas into the present survey area have been retained. Previous names that have been shown to misrepresent the position of a province have been adapted or modified.

In formally naming gravity features, the descriptive terms high, low, ridge, trough, and shelf have been used. The terms 'high' and 'low' describe areas in which the Bouguer anomaly level is respectively greater and less than that in surrounding areas; 'ridges' and 'trought' are elongate highs and lows; and a 'shelf' is a broad area of intermediate Bouguer anomaly level. Topographic names such as saddle, slope, and depression have also been used in the text to describe some local features of gravity relief.

Plate 1 shows the boundaries of gravity provinces and units in and around the BMR gravity survey area. The name assigned to each, together with its derivation, is given in Table 1.

Table 1. Gravity Provinces and Units

Province	Derivation of Name	Unit	Derivation of Name
Ayers Rock Regional Gravity Low	Ayers Rock		
Blackstone Regional Gravity Ridge	Range	Tomkinson Gravity High	Range
		Crombie Gravity Low	Mountain
		Ernabella Gravity Ridge	Mission
Wanna Regional Gravity Low	Lakes	Birksgate Gravity Low	1:250 000 Sheet area Saltpans
		Purndoo Gravity Low	
Nullarbor Regional Gravity Shelf	Railway station	Hughes Gravity Trough	Railway station
		Denman Gravity Low	Railway camp
		Cook Gravity Ridge	Railway station
		Midgening Gravity Low	Native dam
		Nurrari Gravity Ridge	Lakes
		Serpentine Lakes Gravity Shelf	Lakes
		Coompana Gravity High	Rock

Table 1 (cont.)

Province	Derivation of Name	Unit	Derivation of Name
Christie Regional Gravity High	Mountain	Yalata Gravity High	Aboriginal reserve
		Pidinga Gravity High	Rock hole
		Mulgathing Gravity High	Rocks
		Yarle Gravity High	Lakes
Wilgena Regional Gravity Low	Homestead	Ceduna Gravity Low	Township
		Jellabinna Gravity Ridge	Rocks
		Malbooma Gravity Low	Township

Ayres Rock Regional Gravity Low

The survey area covers only the southern margin of this province, which was first defined by Lonsdale & Flavelle (1963). The province has been interpreted as the expression of a thick section of mainly Upper Proterozoic sediments bounded to the south by a large overthrust, the Woodroffe Thrust. Crustal downwarping may also contribute to the low Bouguer anomaly feature.

Blackstone Regional Gravity Ridge

This province is a broad, slightly arcuate band of high Bouguer anomaly extending from the Warburton Range area of Western Australia through the northwest of South Australia to beyond the Finke River in the Northern Territory. Its western and eastern parts were previously termed the Blackstone Regional Gravity High and the Finke Regional Gravity Ridge (Darby & Vale, 1969).

The province has been divided into three units. The Tomkinson Gravity Ridge extends in to Western Australia. It is a ridge of complex contour pattern, 400 km long and 50 to 100 km wide. Local positive culminations of up to + 60 mGal. occur in the Western Australian part of the unit. The Ernabella Gravity Ridge extends in an east-northeasterly direction from the south of WOODROFFE into the Northern Territory. It is characterized by smooth gravity relief, in contrast to the Tomkinson Gravity Ridge. The Crombie Gravity Low is an irregularly shaped saddle that separates the two other units.

The axis of the Blackstone Regional Gravity Ridge roughly coincides with the central axis of the Musgrave Block. However, the province covers only the central core of the block and does not extend to its margins. The easterly trend of the province is parallel to the predominant strike direction of faults, but cuts across the main northeasterly trend of the granulites which consttitute most of the Musgrave Block. The major faults are associated with gabbroic intrusions of the Giles Complex, particularly in the west.

Four possible geological interpretations of the Blackstone Regional Gravity Ridge are listed below. Each of these is examined in relation to the observations.

1. The elongate high that constitutes the province is due to dense granulites making up the central core of the Musgrave Block. Residual highs superimposed on the regional gravity ridge reflect local basic bodies of high density intruding the granulite core at high level.
2. The Tomkinson Gravity Ridge to the west reflects a large body or series of bodies of igneous intrusives at depth from which emanate local apophyses that crop out as the Giles Complex. The Ernabella Gravity Ridge to the east corresponds to the dense granulite core of the Musgrave Block.
3. The province coincides with massive basic intrusions in both the east and the west. Local high-level intrusions in the west produce a complex gravity field, whereas a more even distribution of igneous material in the east results in a more smoothly varying gravity field.
4. The province corresponds to an area of relatively shallow crust where dense rocks of the lower crust and upper mantle are anomalously close to the surface. Local highs in the Tomkinson Gravity Ridge are caused by high-level basic intrusions.

The first hypothesis would account for the close spatial relation between the Blackstone Regional Gravity Ridge and the Musgrave Block, if the central core of the block is appreciably denser than along the margins. However, it fails to explain the disparity between gravity and metamorphic trends, as the pattern of density distribution within the granulites would be unlikely to differ significantly from the general metamorphic structural pattern. The first hypothesis can therefore be considered unlikely to be the primary cause of regionally high Bouguer anomalies.

The second hypothesis fails to explain the discordance of metamorphic and gravity trends in the Ernabella Gravity Ridge. Furthermore, it fails to meet the criterion of simplicity, for it involves different interpretations for the eastern and western parts of the gravity province.

The third hypothesis is satisfactory insofar as it proposes an igneous source of high-density material and therefore overcomes the necessity for parallelism of gravity and metamorphic trends. It accounts for the parallelism of the gravity ridge with major faults since most basic igneous intrusions are fault-bounded. However, whereas the gravity field over an igneous complex is usually complex, gravity relief in the Ernabella Gravity Ridge is notably smooth. This suggests that the high Bouguer anomalies in the east of the gravity province are unlikely to be due to a purely igneous source of high-density material.

The fourth hypothesis is consistent with all the observations. A mantle ridge beneath the central core of the Musgrave Block could be the cause of the regional gravity ridge. Major faulting and associated basic igneous intrusive activity along the axis of the gravity ridge could have resulted from upwarping of the mantle. The hypothesis satisfactorily accounts for the smoothness of contour pattern in the east compared with the west, the parallelism of the gravity ridge with faults rather than with metamorphic trends, and the observation that the gravity ridge covers only the central part of the Musgrave Block. As none of the other hypotheses can explain all the observations, the fourth is considered to be the best interpretation of the Blackstone Regional Gravity Ridge.

Wanna Regional Gravity Low

This is an elongate gravity depression extending eastwards in an arc from southern ALBERGA, through BIRKSGATE, into Western Australia, then southwards to the coast. Its Western Australian part is discussed by Fraser (in press). In South Australia the province is bounded to the north by gradients of the order of 2 mGal/km, and to the south by gentler gradients ranging from 0.3 to 1.5 mGal/km. It covers the deepest part of the Officer Basin, and its axis is located about 20 to 40 km north of the basinal axis as defined from magnetic and seismic results.

The province is formed by two closed gravity lows which are separated by a gravity saddle. These are: in the east, the Purndoo Gravity Low, in which the minimum Bouguer anomaly value is -145 mGal, and in the west, the Birksgate Gravity Low, in which the minimum Bouguer anomaly value is 110 mGal.

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The Purndoo Gravity Low, which was largely defined by the Murumba Oil Gravity Survey (Murumba Oil NL, 1970), coincides generally with the asymmetric eastern Officer Basin, which contains a thick section of 4400 m of Palaeozoic sediments unconformably overlying Proterozoic sediments. The steep northern slope, centred to the north of the faulted northern margin of the basin, may be due in part to a regional southerly decrease in density of the Musgrave Block metamorphics, or to horizontal density changes deep within the crust. The gentle slope towards the south of the unit may reflect a shallowing of the basement, possibly along a northeast-trending hinge-line during Palaeozoic times.

The Birksgate Gravity Low extends in a west-northwesterly direction across BIRKSGATE and northern NOORINA, and corresponds closely to a deep trough of Proterozoic sediments overlain by Palaeozoic, mainly Cambrian, sediments. Drilling and seismic evidence reveal 950 m of Palaeozoic sediments overlying 4200 m of Proterozoic section (Continental Oil Co., 1967a,b). This is in contrast to the eastern Officer Basin which contains at least 2800 m of Palaeozoic sediments. The gravity saddle separating the Birksgate Gravity Low from the Purndoo Gravity Low may represent the boundary between the eastern Officer Basin, containing thick Palaeozoic sediments, and the mainly Proterozoic western Officer Basin. This boundary may be in the form of a basement rise; magnetic basement contours indicate a basement ridge passing through the junction of BIRKSGATE, LINDSAY, NOORINA, and WELLS.

Like the Purndoo Gravity Low, the Birksgate Gravity Low is bounded by a steep slope to the north and a gentle slope to the south. The northern slope, located to the north of the northern margin of the Officer Basin, may be due to a decrease in density of the Musgrave Block as well as to faulting of the relatively light Officer Basin sediments against the Musgrave Block. The gentle slope along the south of the Birksgate Gravity Low probably reflects a gradual shallowing of the basement away from the deepest part of the Officer Basin.

<u>Effect of deep crustal variations on the amplitudes of the Blackstone Regional Gravity High and the Wanna Regional Gravity Low</u>

The Blackstone Regional Gravity Ridge and the Officer Regional Gravity Low form part of a system of intense, east-trending ridges and troughs which dominates the gravity pattern in central Australia. The large amplitudes of these ridges and troughs can be only partly explained by density variations in the top few kilometres of the crust. For instance, Proterozoic and Phanerozoic sediments of the eastern Officer Basin account for only -60 mGal of the 145 mGal amplitude of the Purndoo Gravity Low assuming a basement/sediment density contrast of 0.3 gm/cm^3. It follows that horizontal density variations must occur beneath the basins, either within the basement or at greater depth in the crust.

Two theories have been put forward to explain the gravity pattern in central Australia. Mathur (1974) assumes a two layer crust which varies in thickness from 25 km in the high-gravity areas to 45 km in the low-gravity areas. Anfiloff & Shaw (1974), taking an opposing viewpoint, argue that all the major anomalies can be attributed to the juxtaposition of dense granulite bodies against relatively light basin-covered granite bodies; the crust is assumed to be horizontally uniform beneath 20 km depth.

According to Mathur's model, the Musgrave Block and Officer Basin would correspond to regions of relatively thin and thick crust respectively; according to the model of Anfiloff and Shaw, the Officer Basin is underlain by a granitic basement, appreciably less dense than the Musgrave Block.

<u>Nullarbor Regional Gravity Shelf</u>

This province occupies the southwestern corner of South Australia and extends into the southeastern part of Western Australia. It covers parts of the southern Officer Basin and the Eucla Basin. Bouguer anomaly values are of intermediate magnitude, and generally range from -20 to -60 mGal. Gravity relief is characterized by the presence of medium wavelength highs and lows of various shapes and trends.

The province has been divided into seven units. The Coompana Gravity High in the southwest of the province attains a maximum of -15 mGal. Magnetic evidence (Plate 5) suggests it represents a topographic rise in the basement of the Eucla Basin. The slope along the northeast of the unit roughly coincides with an inferred fault and probably reflects a rapid deepening of the basement away from the topographic rise.

The Hughes Gravity Trough (Outback Oil NL, 1965) coincides with a known trough, possibly of Upper Proterozoic sediments. The depth to magnetic basement is calculated to be 2500 m (Waller et al., 1972). A sedimentary section of this thickness could account for the depressed Bouguer anomaly values.

The Denman Gravity Low is evidently caused by the Denman Basin, an infra-basin of mainly Palaeozoic sediments beneath a Tertiary limestone cover. In the Mallabie No. 1 bore (Outback Oil NL, 1969) 1000 metres of Phanerozoic sediments were encountered above an Archaean basement of granitic gneiss. The Denman Basin does not appear to be continuous with the Arckaringa Basin as inferred by Wopfner (1969) as the Yarle Gravity High of the Christie Regional Gravity High sharply truncates the Denman Gravity Low to the northeast.

The Cook Gravity Ridge is an elongate, northwest-trending zone of high Bouguer anomalies 150 km long, 30 km wide, and of about 10 mGal amplitude. It was first partly defined by the Eucla Basin Gravity Survey (Outback Oil N.L. 1965), and questionably attributed to an intra-sediment structure. The feature is probably the expression of a dense zone within the basement; recent aeromagnetic results (Waller et al., 1972) give no indication of a basement ridge associated with the Cook Gravity Ridge, and the dominant trend of magnetic anomalies, which almost certainly reflects the main basement trend, is parallel to the Cook Gravity Ridge.

The Midgening Gravity Low extends in a north-northeasterly direction across eastern WYOLA and western MAURICE. Bouguer anomaly values are lowest in the western half of the unit, where they may be caused by either local thickening of sediments or a density decrease in the basement. Magnetic basement contours indicate a sinuous basement trough, about 2000 m deep, extending through the west of the unit. This suggests that sediment thickening may at least partly account for the low Bouguer anomaly values.

The Nurrari Gravity Ridge is an elongate feature of 15 to 20 mGal relief, and extends in a north-northeasterly direction from the western end of the Cook Gravity Ridge into the zone between the Purndoo and Birksgate Gravity Lows. Seismic survey results give no indication of a basement topographic ridge associated with the gravity feature. In the Mabel Creek Seismic Survey (Exoil, 1962) record quality is generally poor and the region of the Nurrari Gravity Ridge is characterized only by a lack in continuity of reflections. Neither the Serpentine Lakes Seismic Survey (Continental Oil Co., 1965) nor magnetic basement contours show evidence for a basement rise that corresponds to the Nurrari Gravity Ridge. It is inferred that the Nurrari Gravity Ridge may correspond to a dense zone within the basement rather than to a basement topographic feature.

The Serpentine Lakes Gravity Shelf includes two local highs of 10 to 15 mGal relief. The northern high coincides with a strong basement high at a depth of 1.5 km compared with surrounding basement depths of 3.3 km (Plate 5). However, seismic results (Continental Oil Co., 1965) failed to detect the supposed basement high and indicated a constant basement depth of about 4 km across the area of the magnetic feature. This suggests that the gravity and magnetic high reflects a dense, magnetic, intra-basement plug. The southern gravity high is similar in shape area and amplitude to the northern one and is probably of similar origin.

Christie Regional Gravity High

This province is made up of a number of discrete gravity highs which have a predominant northeasterly trend. Bouguer anomaly values range from -25 to +30 mGal and average about +5 mGal. The province occupies the western part of the Gawler Block and overlaps on to the Eucla Basin. Four units are defined.

The northeast-trending Pidinga Gravity High extends over a region of known shallow basement. High Bouguer anomalies probably reflect a local abundance of gneiss and amphibolite in a predominantly granitic basement. Gneisses and associated migmatites having a strong northeast foliation crop out in small inliers in the area of the gravity high (King 1951).

A similar interpretation can be applied to the Yalata Gravity High which is similar in trend, shape, and amplitude to the Pidinga Gravity High.

The Yarle Gravity High is an intense, arcuate gravity ridge with a general northwesterly trend. Basement crops out over the eastern part of the feature and deepens gradually to about 2000 metres in the west. The trend of magnetic anomalies is parallel to the strike of the gravity high; this suggests that the source of high Bouguer anomalies lies within the magnetic basement. The gravity high is probably the expression of a high-grade metamorphic zone within the Gawler Block.

The Mulgathing Gravity High consists of two northeast-trending gravity highs separated by a gravity depression. Basement is shallow and the trend of magnetic anomalies is parallel to the gravity contour trend, indicating that gravity relief reflects density variations in the basement. The two gravity highs probably represent areas of mainly gneissic basement, whereas the gravity low may correspond to granite.

Wilgena Regional Gravity Low

This is a broad gravity depression which extends northeastwards across the central Gawler Block. The large areal extent of the province suggests that it may be cuased by a deep-seated mass deficiency, possibly within the upper mantle. This is supported by seismic refraction evidence: refraction velocities in the upper mantle obtained from an analysis of refracted arrivals from the 1957 nuclear tests at Maralinga (Doyle & Everingham, 1964) indicate an anomalously low mantle velocity beneath the Gawler Block.

The province is divided into three units which appear to have near-surface sources. The Ceduna Gravity Low coincides with a region of young intrusive granites (Walker & Botham, 1969). The probable low density of these granites may account for low Bouguer anomaly values. A particularly large intrusion in FOWLER is bordered to the west by the Pintumba Fault (Plate 2), which coincides with a gravity slope of 1 mGal/km gradient. The Malbooma Gravity Low is also attributed to an abundance of young intrusive granites. The Jellabinna Gravity Ridge, however, corresponds with a region of disturbed magnetic field and is interpreted as representing a belt of older gneisses within the basement.

The subdivision of the province into three gravity units agrees with a subdivision suggested from a combined assessment of gravity and magnetics. The younger intrusive granites are less magnetic than older gneisses so that gravity highs generally correspond to magnetically disturbed areas, and gravity lows to magnetically quiet areas.

5. CONCLUSIONS

The main conclusions drawn from the analysis of gravity results are summarized as follows:

1. In the north of the survey area, an intense gravity ridge extends eastwards along the axis of the Musgrave Block. The ridge cuts across the general northeasterly metamorphic trend but is parallel to major faulting. It is believed to correspond to a zone of relatively shallow crust where dense rocks of the lower crust and upper mantle are anomalously close to the surface. Local Bouguer anomaly highs in the western part of the gravity ridge are correlated with near-surface basic intrusives of the Giles Complex.

2. The deepest part of the Officer Basin coincides approximately with a deep gravity depression bounded by a steep slope to the north and a gentler slope to the south. However, the axis of the gravity depression is displaced about 20 to 40 km north of the known basinal axis, and calculations show that the sediments in the Officer Basin could cause only 40 percent of the amplitude of the depression, assuming a basement/ sediment density contrast of 0.3 gm/cm^3. It follows that a regional mass deficienty must exist beneath the basin floor. This could be in the form of a basement density decrease or a thickening of the crust from the direction of the Musgrave Block.

3. A gravity saddle which coincides in part with a magnetic basement high extends in a northerly direction across the gravity depression over the Officer Basin. The saddle may be the expression of a basement ridge forming a natural boundary between the eastern Officer Basin, which contains thick Palaeozoic sediments, and the mainly Proterozoic western Officer Basin.

4. Gravity relief in the southwest of South Australia is attributed variously to basement topographic features and to intra-basement density contrasts. A gravity high and a gravity low adjoining the coastline correspond respectively to a basement rise and a Proterozoic/Palaeozoic infrabasin, beneath the Mesozoic and Tertiary sediments of the Eucla Basin. Farther north, a west-northwest-trending gravity ridge and a north-northeast-trending gravity ridge are not associated with any known magnetic basement ridge; they are attributed to dense zones within the basement. Small, approximately circular highs close to the Western Australian border are probably due to dense intra-basement plugs.

5. The western part of the Gawler Block is an irregular area of high Bouguer anomaly level. Several discrete gravity highs are apparent within this area; all are attributed to dense bodies within the Gawler Block - probably local concentrations of amphibolite and gneiss enclosed in a mainly granitic basement.

6. A broad gravity depression extends northeast wards across the central Gawler Block. Seismic refraction evidence suggests the depression may be caused by a deep-seated mass deficiency, possibly within the upper mantle. Local gravity features in the area can be interpreted as being due to density variations within the Gawler Block.

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APPENDIX 1 - SURVEY STATISTICS (AREA A)

Survey commenced:	15 April 1970
Basic grid completed:	11 September 1970
Follow-up completed:	1 October 1970
Total helicopter days available:	259
Days unserviceable:	66
Pilot days off:	17
Days lost owing to bad weather and maintenance:	13
Total flying days:	163
New readings (mainland):	7754
New readings (island):	24
Follow-up readings (all mainland):	44
Loops flown:	571
Approximate area surveyed:	400 000 km^2

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APPENDIX 2 - SURVEY PROCEDURE

Field operations

The field operations were carried out by a geophysical contractor, Wongela Geophysical Pty Ltd of Sydney, using the methods adopted on previous BMR reconnaissance helicopter gravity surveys. All traversing was done using the cell method of flying (Hastie & Walker, 1962).

Before the helicopter gravity operation, the South Australian Department of Lands, and the Survey Branch of the former Commonwealth Department of the Interior optically levelled and photo-identified a network of elevation traverses. The bench-marks on these traverses were elevation control stations for the survey, and an area enclosed by the traverses is a segment. The elevation control traverses and the segmentation of the survey area are shown in Plate 6. In flying the survey, no loop was allowed to cross a segment boundary. This method of flying meant that each segment could be computed independently.

Gravity control on the survey was maintained by tying to previously established more accurate gravity stations termed 'Isogal stations' (Barlow, 1970).

Horizontal control was maintained by accurately pinpricking aerial photographs and plotting station positions on 1:250 000 photocentre base maps.

Computing

The results were computed at Monash University using a CDC 3200 computer. For the barometric results, each segment was computed three times:

1. With only one fixed elevation node. This is computed to determine the internal accuracy of the segment, and systematic errors are not taken into account.
2. With all of the fixed elevation nodes. This is computed to determine the external accuracy of the segment and to obtain the final station elevations for the computation of Bouguer anomalies. In this computation, systematic errors are corrected, so that the external standard deviation of the adjustments is always higher than the internal standard deviation.

3. With half the fixed elevation nodes. This is computed to determine the forecast standard deviation. Enough fixed points are included to eliminate systematic errors, and the difference between the true elevation and measured elevation at the 'unfixed fixed' nodes is a good estimate of the accuracy of the heights in any segment.

For the gravity network, only the first two were carried out.

The internal, external, and forecast network adjustments are shown in Table 2. The internal and external standard deviations are the standard deviations of the least-squares adjustments to legs in the network. The forecast standard deviation is the standard deviation of differences between true and measured elevations for those fixed nodes which were computed as free nodes, as in the third step.

TABLE 2 Network Adjustments

Segment	Elevation (metres)						Gravity (mGal)	
	Internal		External		Forecast		External	
	S.D.	Max adj.	S.D.	Max adj.	S.D.	Max adj.	S.D.	Max adj.
A1	0.15	0.36	0.24	0.68	0.38	1.04	0.04	0.13
A2	0.35	1.07	0.38	1.37	0.32	0.78	0.06	0.19
B	0.32	1.23	0.36	1.52	0.52	1.32	0.04	0.11
C1	0.20	0.54	0.23	0.66	0.29	0.71	0.05	0.15
C2	0.21	0.68	0.31	0.94	0.36	1.11	0.04	0.17
D	0.30	0.72	0.39	1.60	0.48	1.14	0.04	0.15

APPENDIX 3 - DENSITY DATA

Gawler Craton

Density information is available from boreholes which have penetrated basement on the Gawler Block. This information is tabulated below.

TABLE 3. Density data for Gawler Block

Borehole	Location	Depth to basement (m)	Rock type	Density (gm/cm^3)
Mallabie No. 1	32° 32' S 130° 36' E	1330	Granitic gneiss	2.73
Wallira No. 1	29° 27' S 134° 05' E	286	Granitic gneiss	2.70
Karkaro No. 1	28° 36' S 133° 46' E	475	Biotite Adamellite	2.62

Estimates of basement density have also been made from values of seismic P-wave velocities. At Maralinga and between Maralinga and Fowlers Bay, the basement density was estimated to be 2.7 gm/cm^3 (Wiebenga & Hawkins, 1956; Doyle & Everingham, 1964).

Gabbroic material south and east of Streaky Bay gave measured densities in the range 2.80 to 3.27 gm/cm^3. Densities of 2.54 to 2.64 gm/cm^3 were measured for adamellites of the Gawler Block (Whitten, 1963), and younger intrusive granites have estimated density values of 2.65 to 2.70 gm/cm^3.

Musgrave Block

Detailed density information is available for rocks of the Musgrave Block, mainly as a result of active exploration for nickel in the area. It is summarized below:

TABLE 4. Density data for Musgrave Block

Rock unit	Rock type	Density (gm/cm^3)
Giles Complex and associated rock units	Norite	2.81 - 3.04
	Dolerite	3.07
	Gabbro	2.91 - 3.03
	Picrite	3.22 - 3.25
	Pyroxenite	3.30 - 3.32
	Anorthosite	2.78 - 2.85
Musgrave-Mann Metamorphics	Gneiss	2.80 - 2.88
	Granulites	2.70 - 2.90

Officer Basin

Density measurements were made on cores from the Birksgate No. 1, Munyarai No. 1, and Emu No. 1 bores. The density data for the Birksgate and Munyarai bores are summarized in Figures 6 and 7. Measurements on cores from the Emu bore indicate sediment densities ranging from 2.10 to 2.61 gm/cm^3.

Eucla Basin

The compensated formation density log for the Mallabie No. 1 bore is shown in Figure 5.

APPENDIX 4 - PREVIOUS GEOPHYSICAL AND DRILLING SURVEYS IN OR NEAR THE SURVEY AREA

The following lists give the names of and references to geophysical and drilling surveys conducted before 1970. The locations of these surveys are shown on Plates 3, 4, and 5.

GRAVITY SURVEYS

NAME OF SURVEY	REFERENCE
Gravity survey in the northeastern portion of the Nullarbor Plain and adjacent areas.	Kerr-Grant & Pegum, 1954
Regional gravity traverses across the Eucla Basin, 1954-55	Gunson & Van der Linden, 1956
Geophysical survey of the Officer Basin	Mumme, 1963a
Eucla Basin gravity survey	Outback Oil NL, 1965
Regional gravity survey of Mann and Woodroffe 1:250 000 areas	Rowan, 1968
Gravity survey, eastern Officer Basin	Moorcroft, 1968
Eastern Officer Basin gravity survey	Continental Oil Co., 1967b
Eastern Officer Basin gravity survey, 1970	Murumba Oil NL, 1970

AIRBORNE MAGNETIC SURVEYS

NAME OF SURVEY	REFERENCE
Reconnaissance airborne magnetic survey of the Eucla Basin	Quilty & Goodeve, 1958
Officer Basin aeromagnetic survey, W.A.	Brod, 1962
Childara/Gairdner aeromagnetic and radiometric survey 1961	Quilty, 1962

NAME OF SURVEY	REFERENCE
Mann area airborne magnetic and radiometric survey	Wells, 1962
Eastern Officer Basin airborne magnetometer survey	Exoil, 1964
Central South Australia airborne magnetic and radiometric survey, 1966	Young & Gerdes, 1966
Mann/Woodroffe aeromagnetic survey, 1965	Tipper, 1967
Musgrave Block airborne magnetic and radiometric survey, 1967	Waller, 1968
Aeromagnetic survey, Mann/ Woodroffe area, 1969	Shelley, 1971
Eucla Basin airborne magnetic and radiometric survey, 1970	Waller, Quilty & Lambourn, 1972

SEISMIC SURVEYS AND DEEP CRUSTAL STUDIES

NAME OF SURVEY	REFERENCE
Seismic investigations of atomic explosion in South Australia, October 1953	Doyle, 1954
Seismic survey at Maralinga, South Australia	Wiebenga & Hawkins, 1956
Mabel Creek seismic survey	Exoil, 1962
Maralinga seismic survey, 1955-56	Wiebenga & Hawkins, 1956
Seismic velocities and crustal structure in South Australia	Doyle & Everingham, 1964
Reconnaissance seismic survey in the South Australian portion of the Eucla Basin, 1964	Kendall, 1965

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SEISMIC SURVEYS AND DEEP CRUSTAL STUDIES (Continued)

NAME OF SURVEY	REFERENCE
Serpentine Lakes reconnaissance seismic survey	Continental Oil Co., 1965
Seismic reflection and refraction survey, eastern Officer Basin, 1966	Moorcroft, 1967
Giles-Carnegie seismic survey, W.A. 1961-62	Turpie, 1967
Eastern Officer Basin seismic survey	Continental Oil Co., 1967b
Seismic investigations, western Arckaringa Basin	Milton, 1969

DRILLING SURVEYS

NAME OF BOREHOLE	REFERENCE
Birksgate No. 1	Continental Oil Co., 1967a
Munyarai No. 1	Continental Oil Co., 1968
Mallabie No. 1	Outback Oil NL, 1969
Emu No. 1	Exoil, 1963

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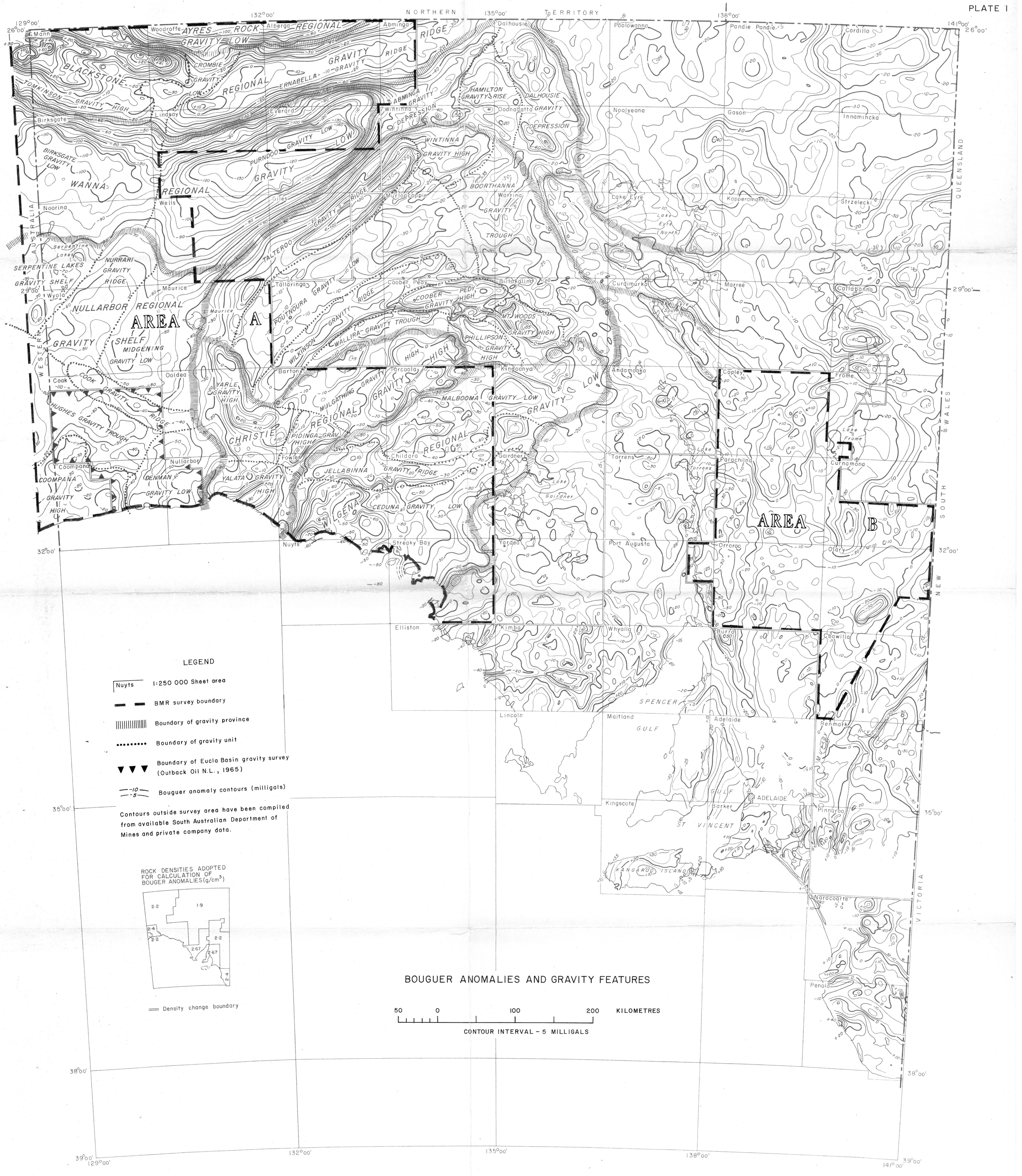
PLATE I

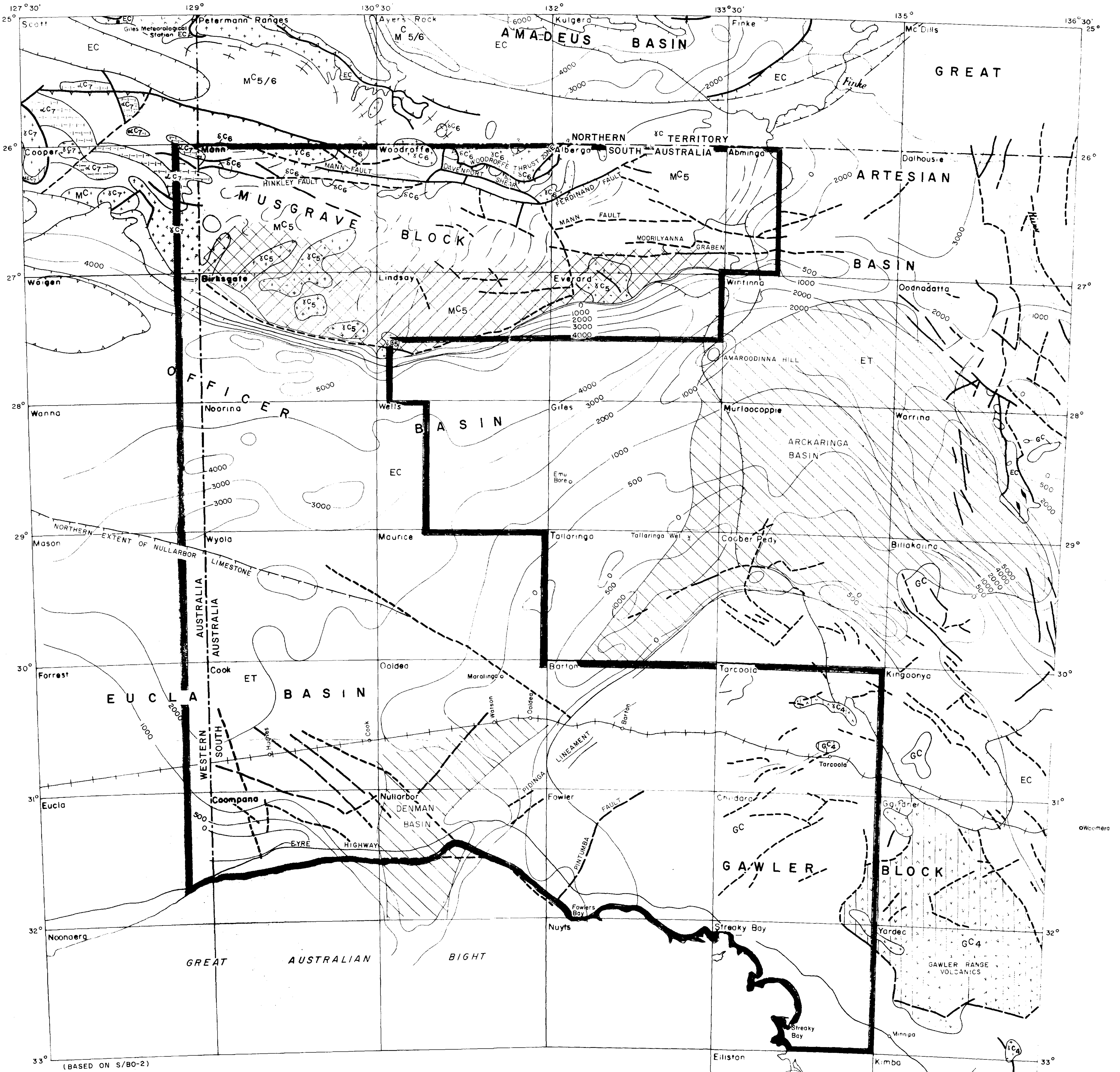


BOUGUER ANOMALIES AND GRAVITY FEATURES

Based on SA/B0-7

Record No. 1974/88

SA/B2-13-4



STRUCTURAL SYMBOLS

(If features are approximate, lines are dashed, if concealed, dotted)

- Boundary of tectonic domain
- Other geological boundaries
- Visible / inferred / Concealed } Faults
- Anticlinal axis
- General trends
- Tectonic uplifts affecting craton cover
- Tectonic downwarps affecting craton cover
- 500 Basement contours in metres below sea-level
- Areas of intense platform deformation
- Transitional basin
- Permian Basin
- Survey area
- COOK 1:250 000 Sheet area

ET	Eastern Australian Platform (Undeformed Mesozoic sediments)
EC	Trans-Australian Platform (Upper Proterozoic to ? Ordovician sediments)
GC	Gawler Block (Undifferentiated)
MC	Musgrave Block

C4	Tectonism	1400-1650 m.y.
C7	"	1000 m.y.
C6	"	1000-1200 m.y.
C5	"	1200-1400 m.y.

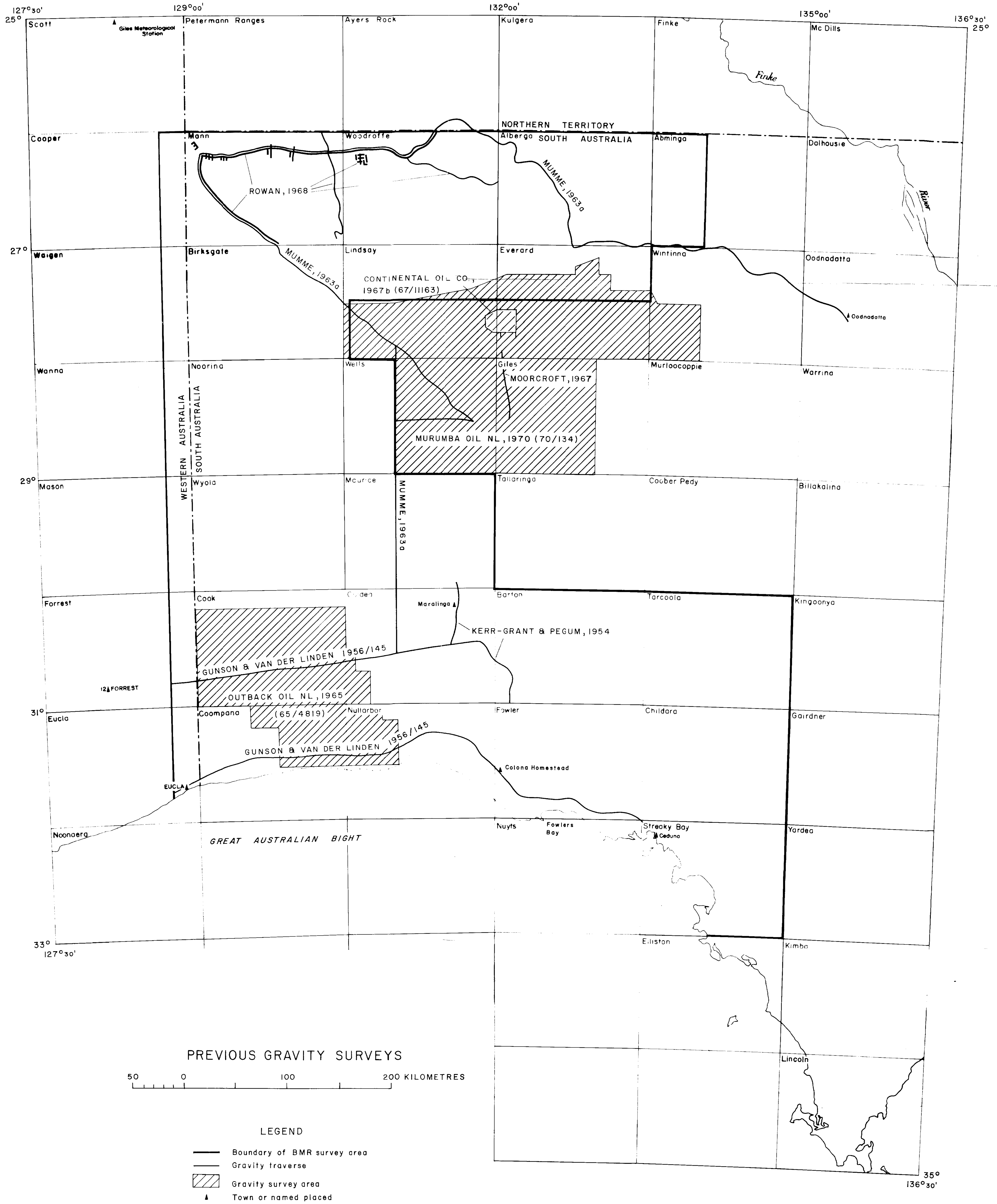
IGNEOUS ROCKS

+ γ +	Granites
α	Diorite and gabbro intrusives
δ	Basic to ultrabasic intrusives
^ > < ^	Acid volcanics

TECTONIC MAP

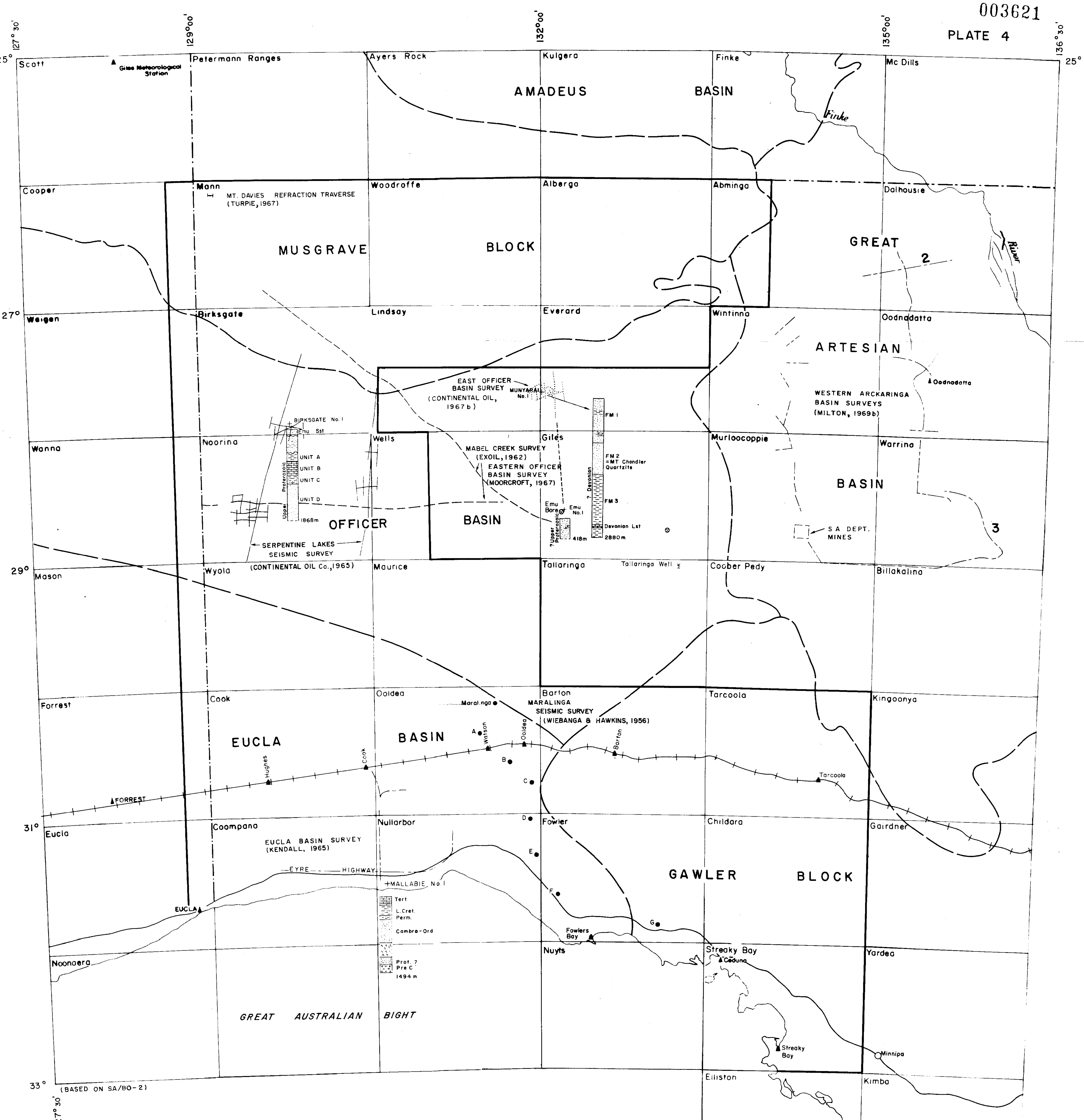
50 0 100 200 KILOMETRES

This map is based on a preliminary compilation of the Tectonic Map of Australia prepared by the Geological Society of Australia, August 1969.


127°30'
129°00'
132°00'
135°00'
136°30'
25°
27°
29°
31°
33°
35°
Scott
Giles Meteorological Station
Petermann Ranges
Ayers Rock
Kulgera
Finke
Mc Dills
Finke
River
NORTHERN TERRITORY
SOUTH AUSTRALIA
Cooper
Mann
Woodroffe
Albergo
Abminga
Dalhousie
ROWAN, 1968
MUMME, 1963a
Waigen
Birksgate
Lindsay
Everard
Wintinna
Oodnadatta
CONTINENTAL OIL CO.
1967b (67/11163)
Wanna
Noorina
Wells
Giles
Murloocoppie
Warrina
MOORCROFT, 1967
MURUMBA OIL NL, 1970 (70/134)
WESTERN AUSTRALIA
SOUTH AUSTRALIA
Mason
Wyola
Tallaringa
Coober Pedy
Billakalina
Forrest
Cook
Barton
Tarcoola
Kingoonya
Maralinga
KERR-GRANT & PEGUM, 1954
GUNSON & VAN DER LINDEN 1956/145
FORREST
OUTBACK OIL NL, 1965
(65/4819)
Eucla
Coompana
Nullarbor
Fowler
Childara
Gairdner
GUNSON & VAN DER LINDEN 1956/145
Colona Homestead
EUCLA
Noonaera
GREAT AUSTRALIAN BIGHT
Nuyts
Fowlers Bay
Streaky Bay
Ceduna
Yardea
Elliston
Kimba
Lincoln
PREVIOUS GRAVITY SURVEYS
50 0 100 200 KILOMETRES
LEGEND
Boundary of BMR survey area
Gravity traverse
Gravity survey area
Town or named placed

003621

PLATE 4



SEISMIC SURVEYS AND SUBSIDIZED BOREHOLES

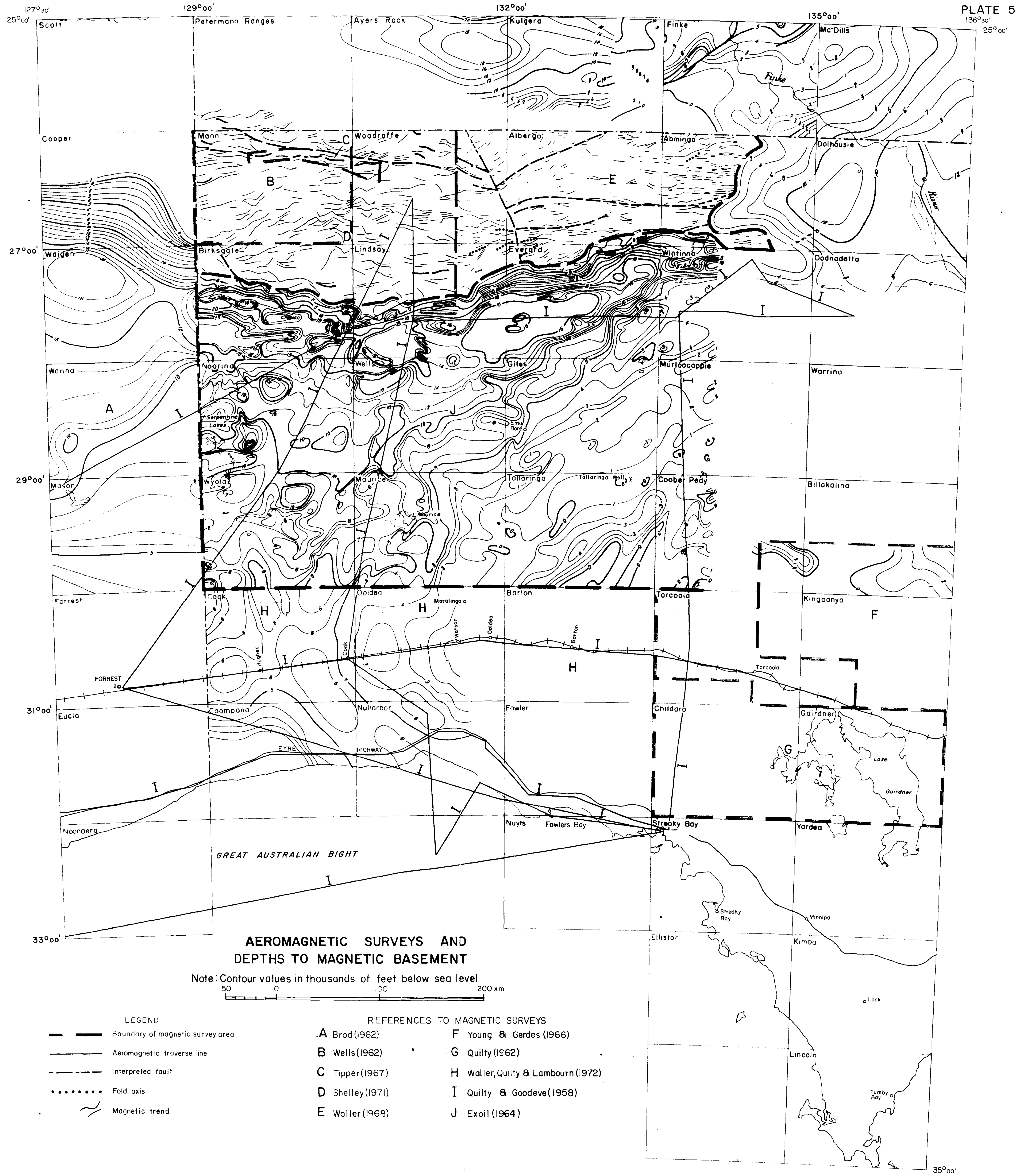
50 0 100 200
KILOMETRES

LEGEND

- Boundary of gravity survey area
- Boundary of tectonic unit
- Seismic traverse lines
- + Borehole
- ⊗ Seismic recording station for 1953 nuclear tests
- ● Seismic recording station for 1956 nuclear tests
- ○ Seismic recording station for 1957 nuclear tests
- ▲ Town or named placed

Record No. 1974/88

SA/B2-11



AEROMAGNETIC SURVEYS AND DEPTHS TO MAGNETIC BASEMENT

Note: Contour values in thousands of feet below sea level

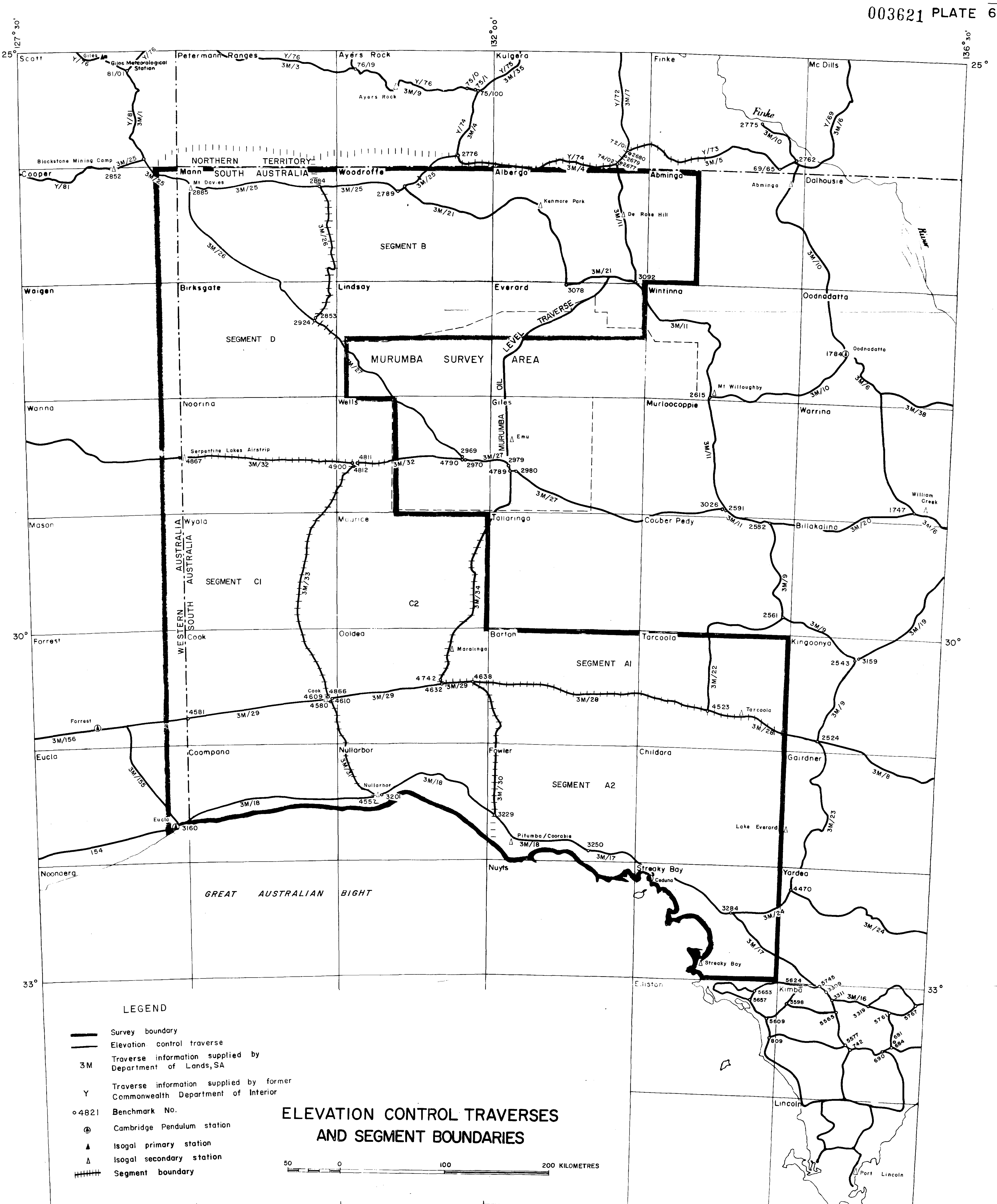
50 0 100 200 km

LEGEND

- Boundary of magnetic survey area
- Aeromagnetic traverse line
- Interpreted fault
- Fold axis
- Magnetic trend

REFERENCES TO MAGNETIC SURVEYS

A Brod (1962)	F Young & Gerdes (1966)
B Wells (1962)	G Quilty (1962)
C Tipper (1967)	H Waller, Quilty & Lambourn (1972)
D Shelley (1971)	I Quilty & Goodeve (1958)
E Waller (1968)	J Exoil (1964)



(BASED ON S/80-2)