Reconnaissance gravity surveys in WA and SA, 1969-1972

BMR Bulletin

196

A. R. Fraser
G. R. Pettifer

DEPARTMENT OF NATIONAL DEVELOPMENT & ENERGY
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

BULLETIN 196

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A. R. Fraser & G. R. Pettifer

PART A. Reconnaissance gravity survey in southwest Western Australia, 1969
by
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PART B. Reconnaissance gravity survey in northwest Western Australia, 1969
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PART C. Reconnaissance gravity survey in central and southeast Western Australia, 1971-72
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PART D. Reconnaissance gravity survey in western South Australia, 1970
by
G. R. Pettifer & A. R. Fraser

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ABSTRACT

Reconnaissance helicopter gravity surveys by the Bureau of Mineral Resources between 1969 and 1972 covered the southern two-thirds of Western Australia and the western part of South Australia at a station density of at least 1 per 120 km^2. Gravity provinces defined from the surveys are mainly correlated with divisions of the Precambrian shield.

The Archaean Pilbara and Yilgarn Cratons are represented by gravity provinces of complex contour pattern, in which local highs correlate with greenstone belts, and lows with granitic intrusions. The Pilbara Craton is much more extensive than its exposed part, as it includes the basement of the Proterozoic Hamersley Basin as well as the Pilbara Block. The central Yilgarn Craton is divided into two gravity provinces along a sinuous line extending between Norseman and Wiluna. In the western province, intense local gravity highs are short and disjointed and trend mainly north, whereas in the eastern province, local highs are longer, trend mainly north-northwest, and are of smaller amplitude and intensity.

The Yilgarn Craton is flanked by elongate gravity lows. One of them correlates with the Perth Basin, but the others extend over Precambrian crystalline rocks and must correspond to mass deficiencies within the shield or at depth within the crust or upper mantle. The deep gravity depression over the Perth Basin is continuous into the Byro and Coolcalalaya Basins, indicating that they are sub-basins of the Perth rather than the Carnarvon Basin.

Gravity ridges bordering the Pilbara Craton to the south and northeast and the Yilgarn Craton to the southeast are attributed to Proterozoic mobile belts containing dense metamorphic rocks. Dense granulites crop out at Fraser Range, on the southeast margin of the Yilgarn Craton, where the amplitude of the gravity ridge is particularly large. A gravity ridge over the Musgrave Block in South Australia is believed to reflect a zone of relatively thin crust; intense local highs in the west are caused by basic intrusions of the Giles Complex.

Gravity relief over the Eucla Basin reflects mainly lateral density variations in the basement, except for a low in the southwestern corner of South Australia, which can be correlated with the Denman Basin. Farther east, discrete highs over the Gawler Block are attributed to local concentrations of gneiss and amphibolite in a mainly granitic basement. A broad gravity depression across the central Gawler Block may be caused by a mass deficiency in the deep crust or upper mantle.

The Officer Basin in South Australia coincides roughly with a deep gravity depression. However, the known thickness of sediments cannot entirely account for the depression, which must be partly due to a regional mass deficiency beneath the basin. Gravity evidence suggests that a basement ridge separates the eastern and western parts of the Officer Basin.

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PART A

Reconnaissance gravity survey in southwest Western Australia, 1969

A. R. FRASER

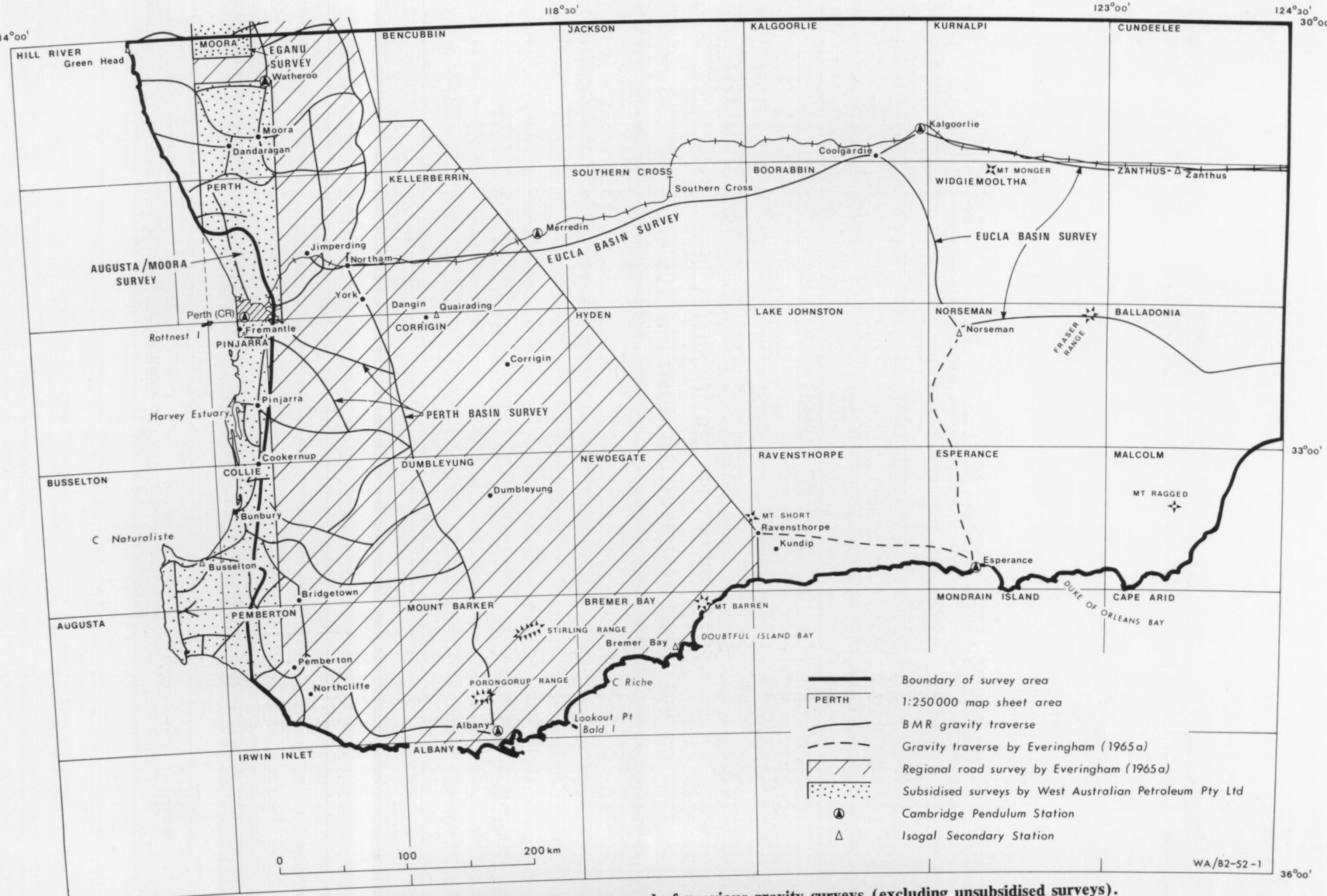

Fig. A1. Location of 1969 BMR gravity survey and of previous gravity surveys (excluding unsubsidised surveys).

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A1. INTRODUCTION

The Bureau of Mineral Resources, Geology and Geophysics (BMR) extended the reconnaissance gravity coverage of Australia by conducting two helicopter gravity surveys in Western Australia during 1969. Both were made under contract to BMR by Wongela Geophysical Pty Ltd, using the 'cell method', described by Hastie & Walker (1962), to establish a grid of gravity stations over the survey areas. The grid spacing was uniformly about 11 km, giving a mean station density of one per 120 km^2. Part A of the Bulletin discusses the results in the southern area (Fig. A1), in which 407 000 km^2 was surveyed over twenty-nine 1:250 000 Sheet areas under the supervision of A. R. Fraser. Ties were made to permanently marked stations of a previous private company survey in the Perth Basin. Bouguer anomaly contours are shown in Plate A1.

The survey area extends over three major structural elements of the southern portion of Western Australia. These are: the Precambrian shield, consisting principally of metasedimentary and meta-igneous rocks, granite, granulite, and gneiss; the Perth Basin, of Phanerozoic sediments; and the Eucla Basin, of Cretaceous and Tertiary sediments. No new readings were taken in the southern part of the Perth Basin, where existing coverage was considered adequate.

A network of graded roads gave good access throughout the survey area and facilitated transport of the crew and fuel. The large number of townships scattered throughout the survey area ensured good communications and supply. In some areas, the use of a helicopter had to be restricted in order to avoid disturbing livestock on farms, and ground transport was used instead.

The survey area extends over part of the Great Western Plateau, which is one of the major topographic features of the Australian continent. In the west, the plateau is separated from the Swan Lowlands by the Darling Scarp. Rainfall is moderate and uniform, and both the plateau and scarp are well dissected by rivers. Terrain is mainly undulating on the plateau except in the south, where prominent topographic features include the Stirling, Porongorup, and Mount Barren Ranges. Elevations vary, generally between 200 and 600 m, although the highest point in the much dissected Stirling Range is 1109 m above sea level.

Vegetation is mainly light on the plateau, and landing spots for the helicopter were located without difficulty in most areas. However, dense scrub near Norseman and heavy timber near Pemberton prevented helicopter access, and several traverses were made along roads instead.

Summaries of the geology of the area and previous geophysical results were prepared from information available up to 1973. Operational statistics and a description of survey methods are given in appendixes (on the accompanying microfiche).

Acknowledgement

I thank the staff of the BMR Cartographic Section who contributed to the drawing of the illustrations.

A2. GEOLOGY

The survey area covers parts of three major structural divisions: the Perth Basin, the Precambrian shield, and the Eucla Basin. The major divisions and subdivisions are shown in Plate A2/C2.

Perth Basin

The onshore part of the Perth Basin extends from the south coast of Western Australia 950 km to the north; it ranges in width from 15 to 90 km and covers an area of 54 000 km^2.

The eastern margin is the prominent Darling Fault, which separates the Precambrian shield from a thick half-graben of sediments which may be more than 7 km thick in the deeper parts. The western margin in the south is the Dunsborough Fault, which separates the basin from the Naturaliste Block of Upper Proterozoic granulite and gneiss. Significant movement along the Darling Fault began in the Late Triassic and continued throughout the Jurassic and Early Cretaceous. The magnitude of the steep gravity gradient which extends along the length of the Darling Fault indicates that the vertical throw is very large. This is confirmed by seismic evidence which suggests that downthrow along the fault near Perth has been about 7.5 km (Mathur, 1974). This movement has given rise to a wedge of Palaeozoic and Mesozoic sediments, thickest in the east of the basin, with basement and sediments generally dipping east. The basin contains a number of subsidiary troughs and ridges which generally strike north. Two deep troughs, where the sedimentary thickness may exceed 7 km, are centred near the towns of Bunbury and Dandaragan.

In the south of the basin, geophysical evidence and drilling have shown that tholeiitic basalt of Cretaceous age fills the valleys of an ancient drainage system. The basalt may have been extruded in association with movement along the Darling Fault.

The names of wells drilled in the Perth Basin are listed in Appendix A3.

Precambrian crystalline units

This account is largely drawn from papers by Prider (1965), Wilson (1969), and McCall (1972). Information on rock ages is extracted from works by Wilson, Compston, Jeffrey, & Riley (1960), Compston & Arriens (1968), and Arriens & Lambert (1969), and the names of tectonic units are those suggested by Daniels & Horwitz (1969).

The western part of the Precambrian shield contains the oldest-known rocks in Australia: granites and gneisses older than 3000 m.y. have been found in the extensive Archaean terrains, which are mainly composed of rocks older than 2600 m.y. Geological investigations have led to the division of the shield into a number of tectonic units, each of which is characterised by some uniformity of structure, age, or general rock type. The subdivisions of the shield wholly or partly within the survey area are the Yilgarn Block, the Albany-Fraser Province, and the Naturaliste Block. Each of these is described below.

Yilgarn Block. This block, composed mainly of Archaean rocks, is characterised by linear greenstone belts trending northerly to northwesterly and enclosed within a large expanse of granitic gneiss. The greenstone belts consist of complex associations of basic and ultrabasic volcanics and penecontemporaneous sills, overlain by clastic sediments and acid volcanics and intruded by massive granites. The block is intruded by easterly trending norite dykes, mainly in the east, and by Upper Proterozoic basic dykes close to its western margin.

The geotectonic pattern and lithology of the greensone belts vary considerably from east to west across the Yilgarn Block. The pronounced linearity of the greenstone belts in the eastern part of the block gives way to a less regular disposition in the west, and, in contrast to the ultrabasic volcanic and subvolcanic assemblages in the Eastern Goldfields area near Kalgoorlie, the ultrabasics close to the western margin of the block tend to be coarsely crystalline serpentinised harzburgite and dunite.

The lithological variation across the Yilgarn Block is reflected by the known distribution of nickel occurrences in Western Australia. All the important nickel deposits so far discovered are associated with the volcanics and shallow-level intrusives of the Eastern Goldfields, rather than with the more coarse-grained ultrabasics of the western half of the Yilgarn Block. McCall (1972) suggested that the changes seen from east to west across the Yilgarn Block reflect progressively deeper levels laid bare by erosion, and that, because of pressure controls on sulphide mineralisation, important nickel deposits are confined to the relatively high crustal zone in the eastern part of the block.

Small remnants of former sedimentary platform covers are present in some areas of the Yilgarn Block. Elongate outliers of unmetamorphosed Proterozoic sediments lie near and parallel to the western, southern, and southeastern margins of the Yilgarn Block, and in COLLIE, WIDGIEMOOLTHA, and CUNDEELEE* there are small outliers of Permian sediments. Minor Tertiary and Recent deposits occur at other localities.

Albany-Fraser Province. Along the south coast of the western part of Western Australia, Precambrian rocks strike east-northeasterly, in marked discordance with the north-northwesterly structural trend in the adjoining Yilgarn Block. Farther east, the trend swings to the northeast and the province is separated from the Yilgarn Block by the northeasterly striking Fraser Fault. Rocks within the Albany-Fraser Province are of Proterozoic age and are therefore substantially younger than the Archaean rocks of the Yilgarn Block.

The rocks along the south coast consist principally of granitic gneisses which are lithologically similar to the rocks of the southwest part of the Yilgarn Block. Near the eastern end of the province, quartzite and associated metasediments, together with coarse gneissic acidic and basic rocks of the granulite facies, crop out. These include rocks of the Mount Ragged Belt, 160 km east-northeast of Esperance, which are possibly the oldest in the Albany-Fraser Province (Prider, 1965). Granite bodies enclosed within granitic gneisses are exposed near Albany, Porongorup Range, Esperance, Duke of Orleans Bay, and at many other localities. They are of two distinct types—an older coarser porphyritic adamellite, and a younger even-grained microgranite which intrudes as sills in the coarser type. Turek & Stephenson (1966) described the granite near Albany as being of anatectic or rheomorphic origin.

Between the western part of RAVENSTHORPE and the western part of MOUNT BARKER lies a discontinuous belt of Middle Proterozoic sediments. The belt evidently coincides with the junction between the Yilgarn Block and the Albany-Fraser Province, as Archaean granite and gneiss crop out to the north of the belt, and Proterozoic high-grade metamorphics and granites to the south. Mount Barren, near the eastern end of the belt, is composed of contorted chlorite-muscovite schists, all of which strike east-northeasterly and dip steeply to the south. At the western extremity of the belt, the Stirling Range rises abruptly from a flat plain; it is composed of flat-lying low-grade metasedimentary rocks such as slate, schist, quartzite, and phyllite, which have been intruded by dolerite dykes. The relation between the Stirling Range and Mount Barren metasediments is not clear. There is no physical link between the two systems, at least in outcrop. Kay (1962; cited by Prider, 1965) suggested that the Stirling Range and Mount Barren beds, and the metasediments between them, were deposited simultaneously in an easterly trending geosynclinal belt.

Turek & Stephenson (1966) used isotopic age evidence in attempting to clarify the stratigraphic relation between the Stirling Range beds and the gneissic complex to the south, and to explain why the low-grade metasediments of the Stirling Range lie in such close proximity to high-grade metamorphic rocks that are younger. They concluded that the Stirling Range beds were metamorphosed during the thrusting from the south of the high-grade metamorphics that now lie adjacent to the Stirling Range. Such a movement could have been a marginal dislocation related to orogenic activity farther south.

Near the town of Ravensthorpe, greenstones and whitestones form a small geosynclinal remnant embedded in granitic gneiss. This structure, known as the Ravensthorpe System (Sofoulis, 1958), extends southeast from Mount Short to Kundip, where the axis is deflected to the west-southwest and follows the general direction of the coast.

In the eastern part of the Albany-Fraser Province a linear belt of high-grade metamorphic rocks extends northeastwards along the southeastern margin of the Yilgarn Block. The belt passes through Fraser Range and adjoining regions of the Fraser Block, which Wilson (1969) described as 'composed mainly of basic pyroxene granulites, many of which appear to have been derived from basalts . . .'. Acidic and basic garnet-bearing granulites are present to the west of Fraser Range; acid granulite and narrow anorthosite layers are predominant in some areas to the east. An extensive flat-lying olivine gabbro sheet cuts the granulite, and in places has been converted to spinel-bearing metagabbro and pyroxene granulite. The metamorphic belt is separated from the gneiss and granite of the southeastern Yilgarn Block by the Fraser Fault, across which there is a Bouguer anomaly gradient of up to 10 mGal/km. Wilson (1969) interpreted some minor structures within the granulite as evidence that the Fraser Fault is a reverse fault with a strong sinistral transcurrent component.

No firm hypotheses have been put forward to explain the evolution of the metamorphic belt, but geochronological evidence places constraints on any proposed mechanism of evolution. Age determinations by

* Throughout this Bulletin, the names of 1:250 00 Sheet areas are printed in capital letters to distinguish them from place names.

Arriens & Lambert (1969) on 17 granulite samples from Fraser Range gave an isochron of unusually high precision, suggesting that metamorphism was either short-lived, or prolonged but ceased abruptly. Faced with these constraints, Arriens & Lambert concluded that the main geological alternatives are: 'deposition of geosynclinal sediments, probably mostly of contemporaneous volcanic origin, followed by orogenic, deep-seated, granulite-facies metamorphism and uplift, all within a few hundred million years; or deep-seated and possibly prolonged reworking under granulite-facies of older crustal rocks . . . ending with rapid uplift'.

Naturaliste Block. This is a narrow strip of high-grade metamorphic rocks forming an outlying part of the shield along the western margin of the southern Perth Basin. It consists predominantly of gneiss and granulite about 650 m.y. old (Compston & Arriens, 1968).

Eucla Basin

The Eucla Basin is broad and shallow, and contains several hundred metres of Tertiary and Cretaceous sediments overlying a basement which is variously composed of Precambrian, Cambrian, and Permian rocks. Its landward margin roughly coincides with the known limit of marine Tertiary deposition north of the Great Australian Bight and encloses an area of about 192 000 km^2. The sediments are mainly organic limestone with minor carbonaceous silt, quartz sand, and conglomerate.

A3. PREVIOUS GEOPHYSICAL RESULTS

Numerous geophysical surveys have been carried out within the survey area by BMR, the Geological Survey of Western Australia, and mining and oil exploration companies. The surveys for which information is available are listed in Appendix A3 and their locations are shown in Figures A1, A2, and A3. The major results of previous geophysical surveys that have some relevance to the present investigation are discussed below.

Gravity surveys

Gravity surveys have been made in the Perth Basin by BMR and West Australian Petroleum Pty Ltd (WAPET), and across the Precambrian shield and Eucla Basin by BMR. Everingham (1965a) has made a regional gravity survey of the southern part of the Precambrian shield.

An extensive gravity survey by BMR in 1951 and 1952 (Thyer & Everingham, 1956) indicated that the Perth Basin is associated with a regional gravity depression of large magnitude and areal extent. The gravity depression was interpreted as the expression of an accumulation of light sediments, up to 10 km thick in places. Steep Bouguer anomaly gradients along the flanks of the gravity depression were attributed to normal faults separating the basin from the Precambrian shield. The Darling and Dunsborough Faults, in particular, show up as prominent gradients in the gravity field.

Regional gravity traverses across the Precambrian shield and Eucla Basin were surveyed in 1954 (Gunson & van der Linden, 1956). The most prominent Bouguer anomaly feature of the profiles is a steep-sided high of 120 mGal amplitude across the Fraser Range. A similar but smaller Bouguer anomaly feature occurs 220 km east of Kalgoorlie. The centre of this feature is on a line projected northeast from the Fraser Range. In the Yilgarn Block, intense local gravity highs were measured over the greenstone belts, and lows over granites. Gravity features in the Eucla Basin were considered to be mainly the expressions of density variations within the basement.

Everingham (1965a) took gravity measurements along a network of roads in the southern part of the Precambrian shield in Western Australia. The main gravity features revealed were: an area of positive Bouguer anomaly in the southwest corner of the shield; elongate gravity depressions along the western, southern, and southeastern margins of the Yilgarn Block; a major gravity ridge associated with basic granulite in the Fraser Range area; and residual gravity highs and lows corresponding respectively to greenstone belts and granites in the Yilgarn Block. Everingham (1965a) attributed the regionally high Bouguer anomaly field in the southwest of the shield to the unusual shallowness of a dense lower crustal layer. He interpreted the elongate gravity depressions south and southeast of the Yilgarn Block as the expressions of the granitic cores of former orogenic zones.

Magnetic surveys

BMR has made aeromagnetic surveys over the Perth Basin and Precambrian shield.

A survey of the Perth Basin in 1957 (Quilty, 1963) confirmed that the Perth Basin consists of a deep elongate basement trough filled with sediments. The maximum thickness of the sediments was estimated to exceed 8 km. The magnetic contours reveal a number of intrabasinal features including subsidiary basement ridges, often near and parallel to the margins of the trough, and near-surface basalt in the southern part of the basin.

BMR aeromagnetic surveys have covered a number of adjoining 1:250 000 Sheet areas in the Yilgarn Block (Fig. A2). Trends in the magnetic contour pattern are closely associated with structural trends in the greenstones and whitestones. The contours indicate that the greenstone belts are generally aligned north-northwest, parallel to the main axes of folding. East-trending magnetic lineaments are also present, and probably correspond to basic intrusives that occupy fissures produced by subsidiary cross-folding.

Seismic surveys

With the exception of a deep crustal reflection and refraction survey of the Precambrian shield by BMR, all seismic surveys have been in the Perth Basin. Most of the seismic surveys by private companies were aimed at locating structural traps for petroleum accumulation and are of only local interest in the analysis of the gravity results. The BMR surveys, however, did provide information on the more regional structures of the basin.

The main traverse line of the Gingin seismic survey (Vale, 1966) crossed the centre of the major gravity depression of the Perth Basin. A sedimentary thickness in excess of 5 km was interpreted and a deep-seated anticline, the Gingin Anticline, was revealed.

The Bullsbrook seismic survey (Walker & Jones, 1966) located a major anticline beneath a synclinal sequence 2 km thick. The anticline is possibly the southern part of the Gingin Anticline.

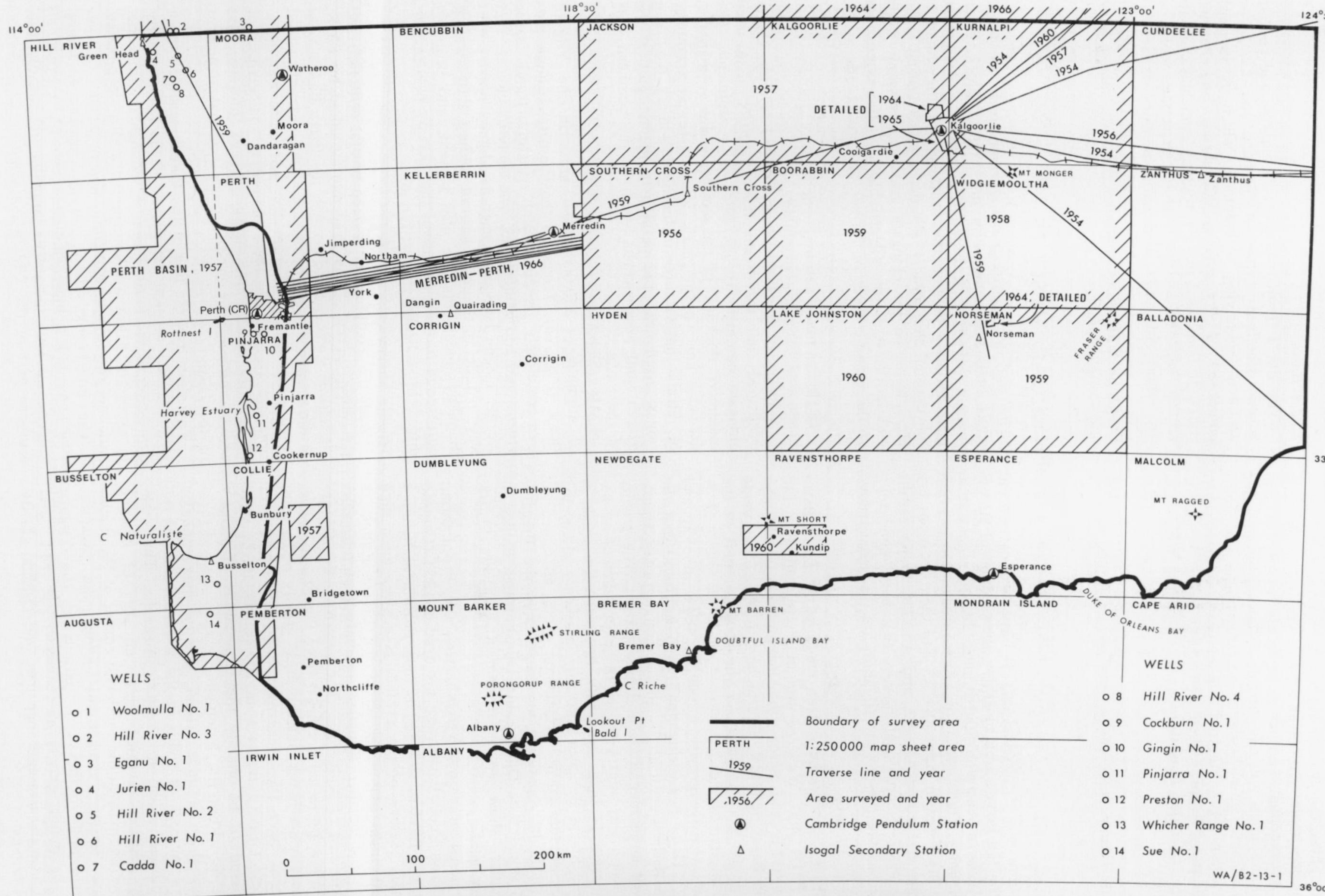


Fig. A2. Previous BMR aeromagnetic surveys, and subsidised wells.

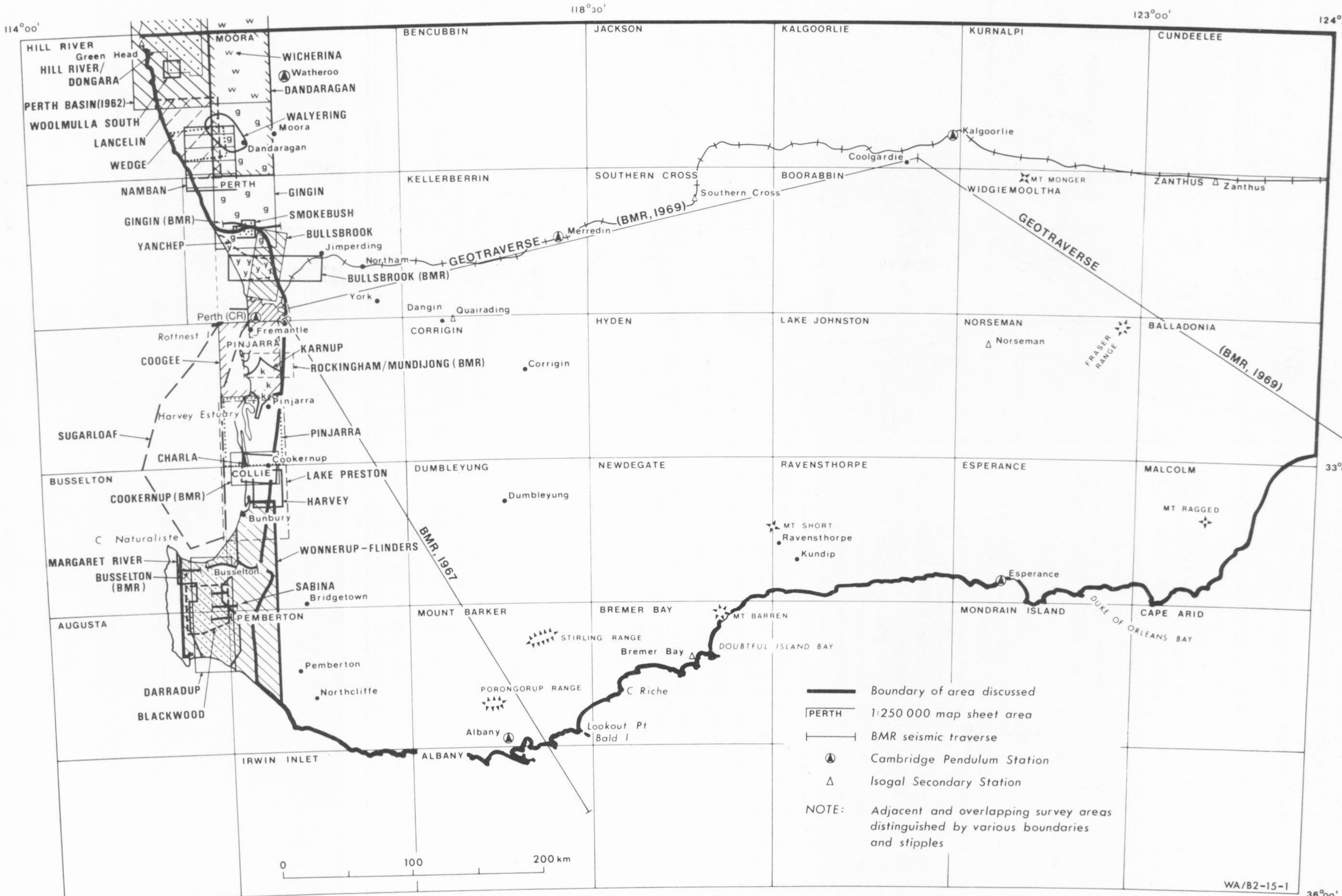


Fig. A3. Previous BMR and subsidised seismic surveys.

The Rockingham-Mundijong seismic survey (Moss, 1962) showed that a sedimentary sequence at least 4 km thick abuts older rocks on a plane that dips 60° to the west and cuts the surface some distance in front of the Darling Scarp. This suggests that the Darling Fault is a normal fault at Mundijong, but it appears to contradict the results of the Cookernup seismic survey (Vale & Moss, 1962), which indicate that Perth Basin sediments at depth may continue east of the Darling Scarp. If the Darling Fault is normal, the reflections recorded east of the Darling Scarp could be associated with local shear zones rather than with overthrusting along the Darling Fault plane.

The Busselton seismic survey (Lodwick, 1962) showed the sedimentary thickness to be at least 2.5 km in the southern part of the Perth Basin. Several major faults were revealed.

Deep crustal studies

Seismic reflection, seismic refraction, and gravity data have been used for the purpose of determining the crustal structure of southwestern Australia.

From seismic refraction data collected at Mundaring Geophysical Observatory since 1959, Everingham (1965b) has shown that the southwestern part of Western Australia has an unusual and complex crustal structure. Under the Perth Basin and the immediately adjoining shield area, the crust is anomalously thick (42-46 km) and consists of two non-sedimentary layers: an upper layer of velocity 6.18 km/s, and a lower layer of velocity 7.24 km/s; the velocity of the upper mantle in this region is about 8.48 km/s. The crustal structure and mantle velocity change from west to east across the shield: in the eastern part of the shield, the crustal thickness is normal for a continental region (35 km) and the lower crustal layer appears to be absent; in addition, the mantle velocity is slightly lower (8.21 km/s) than in the west.

Everingham (1965b) suggested that the locus of the crustal, and possibly upper mantle, change is the Yandanooka/Cape Riche Lineament (Fig. A4). This is a north-northwest-trending line across which regional changes in gravity, geomorphology, and geology take place; it coincides in part with a zone of active seismicity.

Mathur (1974) has used the results of a deep crustal reflection survey by BMR, as well as seismic refraction and gravity data, in an attempt to determine the nature and structure of the crust and upper mantle in southwestern Australia. His conclusions differ in some respects from those of Everingham (1965b). Whereas Everingham concluded that the crust consists of two main layers in the western part of the shield and one in the east, a crustal model computed by Mathur (1974) shows three layers in the western shield area and two in the east. The upper two layers have velocities of 6.12 and 6.67 km/s and probably correspond to Everingham's upper layer, which has a velocity of 6.18 km/s. The basal crustal layer of Mathur has a velocity of 7.42 km/s, thickens substantially from east to west, and probably corresponds to Everingham's 7.24 km/s lower crustal layer. Mathur's measurements of the total crustal thickness—34 km in the east of the shield and 44 km in the west—are similar to those of Everingham. Mathur suggested that the crust thins from 44 km near Perth to 34 km offshore from Albany, and from 34 km near Kalgoorlie to about 32 km near the western end of the Great Australian Bight. There is some evidence for a vertical displacement (down to the west) of 1 or 2 km along the Fraser Fault.

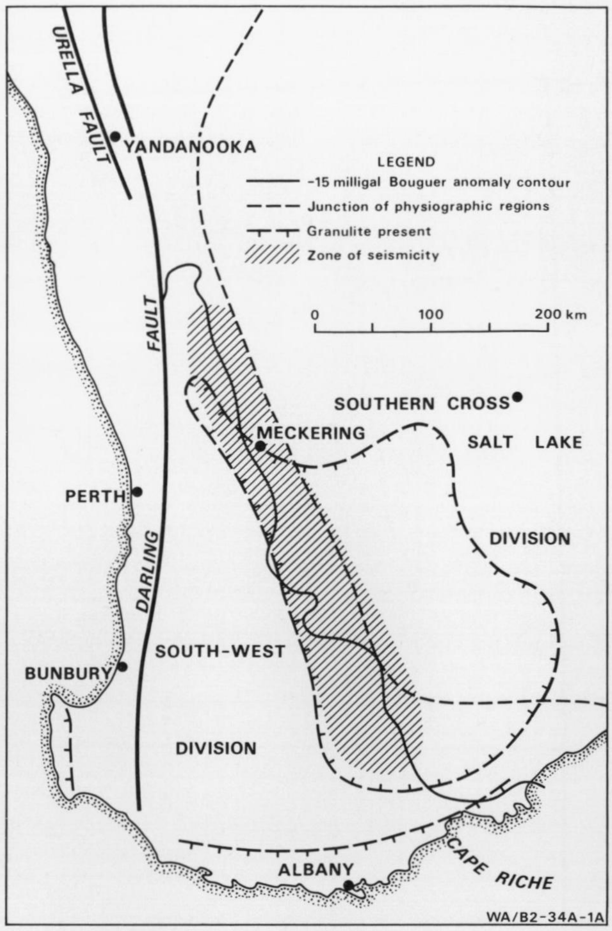


Fig. A4. Features of the Yandanooka/Cape Riche Lineament.

A4. DESCRIPTION AND INTERPRETATION OF GRAVITY RESULTS

Bouguer anomaly contours are shown in Plate A1. Survey statistics and procedures are given in Appendixes A1 and A2.

A rock density of 2.2 g/cm³ was chosen for computing Bouguer corrections. As this density is intermediate between values adopted for gravity surveys of sedimentary basins and values adopted for surveys of hardrock areas, discontinuities between contours interpreted from different surveys are minimised.

Gravity feature nomenclature

Where possible, names used for features extending from previous survey areas into the 1969 survey area have been retained. Previous names that have been shown to misrepresent the position of a province have been modified.

Gravity features are named after physiographic features, towns, railway stations, homesteads, missions, map sheet names, and geological features. A descriptive term such as 'high', 'low', 'complex', 'ridge', 'trough', 'shelf', and 'platform' is included in the name. The terms 'high' and 'low' describe areas in which the Bouguer anomaly level is respectively greater and less than that in surrounding areas; a 'complex' is an area of complex relief; 'ridges' and 'troughs' are elongate highs and lows; and 'shelf' and 'platform' describe broad areas of intermediate Bouguer anomaly level. The word 'Regional' is incorporated in the name of a gravity province; this distinguishes it from a named subordinate gravity feature (referred to as a 'unit' in this Bulletin). Topographic terms such as 'saddle', 'slope', and 'depression' are used in the text to describe some local features of gravity relief.

Gravity provinces

The contoured area has been divided into ten regional gravity provinces. Each of these covers a large area of fairly simple shape in which the gravity field is characterised by uniform contour trend, Bouguer anomaly level, or degree of contour disturbance. Subdivisions of a province are termed 'units', and local Bouguer anomaly closures, lineaments, or gradients within provinces and units are termed 'features'.

Some province boundaries are clearly definable, whereas others are less distinct. The names of provinces wholly or partly defined in the Bouguer anomaly map are listed in Table A1.

With the exception of the Perth Regional Gravity Low, which is the subject of an earlier report (Thyer & Everingham, 1956), each province is discussed in relation to geology and previous geophysical results. The following maps were used to correlate gravity with geological features:

(1) Geological Map of Western Australia (GSWA, 1966).
(2) Tectonic Map of Australia and New Guinea (GSA, 1971).
(3) 1:250 000 Geological Series Maps of BOORABBIN, KALGOORLIE, and WIDGIEMOOLTHA.

The vertical extents of some anomalous masses were calculated using the expression for the gravity effect of an infinite horizontal slab (e.g., Parasnis, 1962). Information on the typical densities of rock types was obtained from Joplin (1963) and is as follows:

Rock type	*Density* (g/cm^3)
Granite	2.67
Gneiss	2.76
Metasediments (whitestones)	2.78
Basic volcanics (greenstones)	2.97
Basic metamorphics	3.01

Naturaliste Regional Gravity High

This is only a partly defined gravity province open to the sea in three directions. The predominant contour trend is northerly, and Bouguer anomaly values range from 0 to +40 mGal.

The province corresponds to the Naturaliste Block, which is composed of Upper Proterozoic granulites and gneisses. The gradient defining its eastern boundary coincides with the Dunsborough Fault, which separates the Naturaliste Block from the Perth Basin. The province is associated with a pronounced magnetic feature which swings sharply to the northwest at its northern end.

Porongorup Regional Gravity Low

This province is a narrow gravity depression extending eastwards from Northcliffe at least as far as Lookout Point, and probably beyond on to the continental shelf. To the north and south it is bounded by gradients of about 1.5 and 2 mGal/km respectively.

The province is roughly coextensive with a large outcrop of Proterozoic granite which forms the western part of the Albany-Fraser Province. The gradient along the northern boundary coincides with the contact between granite and metasediments; the gradient along the southern boundary of the province probably follows the southern margin of the granite, although this lies a short distance beyond the coastline. The steepness of these gradients and the large total Bouguer anomaly change across them (about 40 mGal) suggest that the granitic body is in the form of a steep-sided pluton extending to great depth. If the mean density contrast between the granite and the enclosing rocks is 0.1 g/cm^3, the depth to the lower surface of the granite would be about 10 km.

Gravity troughs similar to the Porongorup Regional Gravity Low, though of larger area and amplitude, flank the Yilgarn Block to the southeast and north. Everingham (1965a) has suggested that such troughs are the gravity expressions of the granitic roots of

TABLE A1. GRAVITY PROVINCES

Province	*Derivation of name*	*Gravity survey in which province first defined*	*Reference*
Perth Regional Gravity Low	City	Perth Basin, 1951-2	Thyer & Everingham (1956)
Naturaliste Regional Gravity High	Cape	Perth Basin, 1951-2	Thyer & Everingham (1956)
Porongorup Regional Gravity Low	Range	New	
Avon Regional Gravity High	River	New	
Narembeen Regional Gravity Shelf	Town	New	
Austin Regional Gravity Complex	Lake	Central Western Australia, 1971-72	Fraser (this volume, Part C)
Carey Regional Gravity Complex	Lake	Central Western Australia, 1971-72	Fraser (this volume, Part C)
Rason Regional Gravity Low	Lake	New	This province is a combination of the Gibson Gravity Depression, to the north (Lonsdale & Flavelle, 1968), and the Dundas Regional Gravity Depression, to the south (Fraser, 1974)
Fraser Regional Gravity Ridge	Range	New	
Eyre Regional Gravity Complex	Hamlet	New	Old name: Gambanga Regional Gravity Low (Fraser, 1974)

former mountain chains which formed as a result of orogenic activity along the margins of the Yilgarn Block.

Avon Regional Gravity High

This triangular province is bounded on all three sides by Bouguer anomaly gradients. The intense gradient over the Darling Fault forms the western boundary; the lesser gradient on the north side of the Porongorup Regional Gravity Low forms the southern boundary; and the gentle gradient associated with the Yandanooka/Cape Riche Lineament forms the eastern boundary. Bouguer anomaly values are higher than in surrounding provinces and increase from about −20 mGal in the east to positive values along the western province boundary.

Though the province extends over Archaean granite, gneiss, granulite, and basic igneous rocks of the southwestern part of the Yilgarn Block, variations in surface geology are not generally associated with local changes in gravity relief. Bouguer anomaly highs close to the Darling Fault in PEMBERTON and PERTH roughly coincide with outcropping or subcropping metamorphic and basic igneous rocks, and a broad shallow low in northwest DUMBLEYUNG is centred over granitic outcrops, but elsewhere in the province there is no consistent relation between gravity and geological features. Most of the contacts between granite and gneiss, for instance, have no gravity gradients associated with them, and a large irregularly shaped granulite terrain (Fig. A4) mapped by Wilson (1969) lies mainly east of the region of high Bouguer anomaly, although its elongation is parallel to the Yandanooka/Cape Riche Lineament.

It is evident therefore that regionally high Bouguer anomalies in the Avon Regional Gravity High cannot be satisfactorily interpreted in terms of surface geology. Furthermore, the rise in Bouguer anomaly value across the Yandanooka/Cape Riche Lineament cannot be explained by crustal thinning due to the proximity of the continental margin, as the lineament is not parallel to the coastline, and seismic evidence (Everingham, 1965b; Mathur, 1974) indicates that the crust thickens rather than thins westwards towards the Perth Basin. It follows that the Yandanooka/Cape Riche Lineament may be, as Everingham contends, the locus of a change in crustal structure. This is implied not only by the otherwise unaccountable change in gravity level, but by the regional nature and linearity of the other features associated with the lineament (Fig. A4).

The Bouguer anomaly change across the lineament varies along its length owing to the presence of relatively local gravity features on each side. If local components of the gravity field were removed, the change in gravity would be about 25 mGal. In terms of Everingham's (1965b) model, this change could be explained by a thickening of about 2.5 km in a 3.0 g/cm^3 lower crustal layer at the expense of a 2.75 g/cm^3 upper crustal layer, depth to the mantle remaining constant. Similarly, for Mathur's (1974) model, thickening by about 4 km in a 3.10 g/cm^3 lower crustal layer at the expense of a 2.94 g/cm^3 intermediate layer, or thickening by 4 km of the intermediate layer at the expense of a 2.78 g/cm^3 upper layer from east to west across the lineament, could account for the observed change in gravity level.

Narambeen Regional Gravity Shelf

This province encompasses an area of gently undulating gravity relief in which Bouguer anomalies generally range from –20 to –50 mGal. The province is bounded to the west by the gentle gradient associated with the Yandanooka/Cape Riche Lineament, and to the south, east, and north by provinces of different contour trend or more disturbed contour pattern.

The province covers a large area of the Yilgarn Block. The smoothness of gravity relief and low level of Bouguer anomaly imply that most of this part of the shield is of uniformly low density; the long-wavelength Bouguer anomaly variations which are observed within the province probably correspond to transitions between granitic and gneissic terrains. For instance, broad shallow gravity lows of about 20 mGal relief in KELLERBERRIN, CORRIGIN, NEWDEGATE, and RAVENSTHORPE are centred over granitic outcrops and may represent large granitic bodies that have intruded slightly denser gneiss and migmatite.

In SOUTHERN CROSS, HYDEN, and BOORABBIN, four highs of sharp relief but small area are superimposed on two broad highs of low relief which trend east and north-northwest. One of the four, an elongate high in HYDEN (feature 1), covers an area in which Archaean sediments crop out. These sediments may be underlain by dense basic rocks, as the density contrast between the sediments and surrounding granitic gneisses is probably too small to cause a gravity high of the observed relief. Small but fairly intense highs in SOUTHERN CROSS and HYDEN (features 2, 3, and 4) can be correlated with outcrops of basic igneous rock; the broad east-trending Bouguer anomaly high on which they are centred is possibly the expression of dense rocks forming the core of an anticline of a cross-fold system, subsidiary to the main north-northwest trend of folding. The presence of basic dykes (coincident with magnetic lineaments) within the area covered by the high is consistent with this interpretation. Slight increases in Bouguer anomaly values in a zone extending eastwards along the northern parts of HYDEN and LAKE JOHNSTON can similarly be interpreted as the expression of dense rocks at the core of an anticline. In the northern part of the Ravensthorpe System, a narrow gravity high of 15-25 mGal relief extends southeastwards from Mount Short to near Kundip, where it abuts the southern part of the Fraser Regional Gravity Ridge.

Correlation between gravity and geology is poor in the northern part of the province. Greenstone bodies in southern BENCUBBIN and eastern KELLERBERRIN have no observable gravity expression, whereas a high of 10-15 mGal relief in western BENCUBBIN occurs in a large expanse of granite, far removed from any greenstone outcrop. Areally small gravity highs in southern JACKSON and western KALGOORLIE are centred over or near greenstone outcrops which are of much greater horizontal extent.

The southeastern boundary of the province is characterised by an abrupt change in contour trend from north or northwest to northeast, and probably coincides with the junction between the Yilgarn Block and the Albany-Fraser Province.

Austin Regional Gravity Complex

Most of this gravity province lies north of the survey area and is discussed by Fraser (this volume, Part C). It covers a large area of the northwestern Yilgarn Block and is characterised by the presence of intense, disjointed, mainly northerly trending residual gravity highs of amplitudes ranging from 30 to 50 mGal. Within the survey area, the province includes an intense west-northwesterly trending high in northern JACKSON. This high coincides with basic igneous outcrop and with a magnetic feature of great intensity. The steep flanks of the gravity high suggest it is the expression of a steep-sided body of dense rock. Assuming the density contrast between this rock and the surrounding gneiss is 0.21 g/cm^3, the calculated depth to the base of the body is about 5 km.

Carey Regional Gravity Complex

This province, which embraces the Eastern Goldfields region of the Yilgarn Block, was originally defined from gravity coverage north of the survey area (Fraser, this volume, Part C). It is characterised by a highly disturbed contour pattern consisting of closely spaced elongate residual highs and lows with a north to northwest trend; the sharp changes in gravity level probably correspond to contacts between the greenstone belts (comprising mainly basic volcanics and subvolcanics) and the intrusive granites.

Within the survey area the contrast in gravity pattern between the Carey Regional Gravity Complex and the area to the west is clearly evident. Whereas residual highs in JACKSON, SOUTHERN CROSS, and HYDEN are small, widely spaced, and of random orientation, residual highs in the Carey Regional Gravity Complex are joined to each other by gravity saddles and show an overall northerly to northwesterly trend. Features 1 and 2, for instance, are only local culminations of a broad elongate belt of high Bouguer anomaly that extends northwards from Norseman to the northern part of KURNALPI. To the west and east, this belt is connected via gravity saddles to other highs: one centred near Ora Banda (feature 3) and another, a circular high, in the area of Mount Monger (feature 4). Features 4, 5, and 6 are all joined together by gravity saddles, but are nonetheless distinguishable gravity features; feature 5, which is a belt of high Bouger anomaly, about 120 km long, trends north-northwest and extends as a gravity spur into the Rason Regional Gravity Low; feature 6 is elongated to the north-northeast but swings abruptly westward at its northern end.

The contrast in gravity pattern between the Carey Regional Gravity Complex and the area to the west can be attributed to a difference between the geometry of the greenstone belts in the two areas. Whereas the greenstone belts in the Eastern Goldfields appear to form an interconnecting system, the belts to the west occur as discrete bodies separated by granitic or gneissic terrain. This implies that either erosional activity was greater in the western part of the Yilgarn Block than in the east, as suggested by McCall (1972), or the Eastern Goldfields and western Yilgarn Block are discrete tectonic units of contrasting geotectonic patterns. The latter interpretation is discussed in more detail by Fraser (this volume, Part C) from results of the gravity coverage of the northern Yilgarn Block.

Residual gravity lows in the Carey Regional Gravity Complex are interpreted as the expressions of granitic batholiths intruding the greenstone belts. Features 7, 8, 9, and 10 can all be correlated directly with granitic outcrops. Features 11 and 12 extend over greenstone/whitestone outcrops, but probably correspond to granitic bodies at shallow depth.

Rason Regional Gravity Low

This is an elongate northeasterly trending gravity trough which has three separate minima below −90 mGal. A steep Bouguer anomaly gradient forms the eastern boundary, and in the west a less steep gradient separates the province from the Carey Regional Gravity Complex. At its southern end it terminates against an area of higher Bouguer anomaly, and to the north it extends beyond the survey area (Fraser, this volume, Part C).

The province occupies a zone about 80 to 100 km wide extending along the southeast margin of the Yilgarn Block adjacent and parallel to the Fraser Range metamorphic belt. The areas of lowest gravity roughly coincide with granitic outcrops, but the amplitudes of the gravity lows are an order of magnitude greater than those associated with granites of the Yilgarn Block to the west. Outcropping metamorphics in the central-northern part of NORSEMAN have no local expression in the contours.

The area covered by the gravity province is generally regarded as part of the Archaean Yilgarn Block (e.g., GSA, 1971). This is supported by the gravity results in so far as a gravity ridge corresponding to an Archaean greenstone belt in KURNALPI continues without much deviation or distortion into the Rason Regional Gravity Low in eastern WIDGIEMOOLTHA, to within about 15 km of the gravity gradient over the Fraser Fault. However, the trend of the province is parallel to the Fraser Range metamorphic belt and to a Proterozoic sedimentary outlier in eastern WIDGIEMOOLTHA; this indicates that the influence of Proterozoic tectonic activity along the southeast margin of the Yilgarn Block may have extended for a considerable distance into the block.

The nature of the regional mass deficiency causing low Bouguer anomaly values is not clear from surface geology. Granitic outcrops in the area of low gravity are no more areally extensive than granitic outcrops in other parts of the Yilgarn Block where the gravity lows are much smaller in area and amplitude. One or both of the following two processes are suggested as possible causes of the regional mass deficiency:

(1) Orogenic activity resulting in the large-scale intrusion of light granites, crustal thickening, or other processes leading to the formation of a mass-deficient zone. Such activity may have been associated with the upthrusting of the Fraser Range metamorphics during the Middle Proterozoic.

(2) Isostatic compensation for the dense Fraser Range metamorphics by displacement of intra-crustal or crust/mantle interfaces, which resulted in a regional mass deficiency that is horizontally more extensive than the metamorphic belt.

Fraser Regional Gravity Ridge

This province is a narrow zone of high Bouguer anomalies extending northeastwards from the coast near Esperance, through Fraser Range, to beyond the northeast corner of the survey area. It is most pronounced at Fraser Range and to the northeast, where it consists of an intense gravity ridge of positive Bouguer anomaly bounded by gradients of up to 10 mGal/km. Peak Bouguer anomaly values of about +40 mGal at Fraser Range and +25 mGal in CUNDEELEE are more than 100 mGal greater than minimum values in the adjoining Rason Regional Gravity Low. South of Fraser Range, the amplitude of the province attenuates abruptly; the province continues to the southwest as a gravity ridge of comparatively low relief. At its southern end the western province boundary is displaced about 80 km to the northwest to encompass a broad high close to the coastline in RAVENSTHORPE.

The steep gradient that forms the northwest boundary of the Fraser Regional Gravity Ridge coincides with the Fraser Fault, which separates the Archaean Yilgarn Block—of granite and gneiss—from Proterozoic granulites and gneisses. Positive Bouguer anomalies in the northern half of the Fraser Regional Gravity Ridge are attributable to a body of dense pyroxene granulite which forms prominent outcrops in the Fraser Range area. The granulite body may extend to a depth of about 10 km, assuming that its mean density is 0.34 g/cm^3 greater than that of the granite to the northwest. The steep gradient along the eastern side of the Fraser Regional Gravity Ridge is possibly the expression of a major fault as it coincides, near Fraser Range, with a seemingly abrupt transition from granulite in the west, to garnet gneiss in the east (Arriens & Lambert, 1969).

The province has been divided into four units of different shapes or gravity levels. From north to south these are the *Kitchener Gravity Plateau* (named after Kitchener railway siding), the *Simon Hill Gravity Ridge* (named after the hill), the *Mount Andrew Gravity Platform* (named after the mountain), and the *Muncalinup Gravity High* (named after the town).

The *Kitchener Gravity Plateau* is an intense gravity high, plateau-shaped in relief, and is probably the expression of a dense tabular body of basic granulite. It is separated from the Simon Hill Gravity Ridge by a gravity saddle, which may be caused by a reduction in the thickness or density of the granulite or by the close proximity of low-density rocks to both the northwest and southeast of the metamorphic belt.

The *Simon Hill Gravity Ridge* is an intense narrow gravity ridge with a peak Bouguer anomaly value of +40 mGal at Fraser Range. It also includes a fan-shaped area of high Bouguer anomaly to the east and southeast of Fraser Range. Locally high Bouguer anomalies at Fraser Range may be associated with the flat-lying olivine gabbro sheet described by Wilson (1969). A slight gravity saddle between the local high at Fraser Range and the high to the southeast is probably related to granite interposed between denser metamorphic rocks. The steep gradient forming the northwest margin of the unit is centred to the east of the boundary between acid and basic granulites in WIDGIEMOOLTHA; it follows that the apparently faulted contact (Fraser Fault?) between the dense basic granulite to the southeast and the lighter crystalline rocks to the northwest dips southeast.

Except for a northeast-trending high in ESPERANCE, Bouguer anomalies in the *Mount Andrew Gravity Platform* are in the range –20 to –40 mGal. The gradients across the northwest and southeast boundaries of the unit are much less intense than those across the unit boundaries to the north; this suggests that horizontal density changes are either deeply buried or near-surface but small and gradual. The local high in ESPERANCE lies on the southerly projection of the axis of the gravity highs associated with the Fraser Range metamorphic belt and is probably the expression of a shallow body of dense basic metamorphic rocks. Tertiary and Quaternary sediments obscure most of the Precambrian basement in the area and prevent positive correlation of the feature with geology.

The *Muncalinup Gravity High* is defined on its northwestern boundary by a gradient of up to 2 mGal/km. Gentler gradients form the northern and southeastern boundaries of the unit. Its seaward extension will remain undefined until gravity coverage of the continental shelf is obtained. High Bouguer anomaly values are probably associated with basic metamorphic rocks which crop out over much of the unit. An outcrop of granite in the centre of the high has no apparent effect on Bouguer anomaly values and must be of small vertical extent or density contrast.

Model studies based on detailed gravity information from the Fraser Range and adjoining areas to the east and west have been made by Anfiloff & Shaw (1973). They interpret the Fraser Range granulites and bordering granites as constituting a structural belt deformed against the Archaean shield by compression in the Proterozoic. Compression is postulated to have caused crustal buckling, which resulted in the formation of two zones of subsidence flanking a zone of uplift. The subsidence is envisaged as leading to the formation and preservation of large granite batholiths, and the uplift as causing the thrusting of mafic granulites into the upper levels of the crust.

Eyre Regional Gravity Complex

This province is a northeasterly trending regional gravity low in which Bouguer anomaly values range from −20 to −60 mGal. It is bounded to the west by the Fraser Regional Gravity Ridge, and to the south and southeast by a gentle Bouguer anomaly rise towards the coastline. It extends northeastwards beyond the area surveyed (Fraser, this volume, Part C).

The province extends over parts of the Eucla Basin, of Tertiary and Cretaceous sediments, and the Albany-Fraser Province, of Proterozoic gneiss, granite, and sediments. Low Bouguer anomaly values are attributed to Precambrian rocks of low density rather than to thick sediments of the Eucla Basin. This is supported by the following observations;

(1) Bouguer anomalies are low in the south of the province, where Precambrian rocks are exposed.
(2) An overall northeasterly contour trend over Precambrian rocks in the south of the province persists over the sediment-covered area in the north.
(3) There is no Bouguer anomaly gradient associated with the boundary of the Eucla Basin.
(4) Boreholes drilled in the Eucla Basin east of the survey area have all encountered a Precambrian basement of granite or gneiss at depths less than 600 m (Peers & Trendall, 1967)

The foregoing observations suggest that the part of the Eucla Basin within the survey area is underlain at shallow depth by a Proterozoic basement of granite and gneiss which is structurally continuous with the part of the Albany-Fraser Province exposed in MALCOLM and eastern ESPERANCE.

A transition from continental to oceanic crust may account for the gentle Bouguer anomaly rise towards the coastline.

Relation between the gravity contour pattern and the regional distribution of mineral occurrences

The locations of reported mineral deposits, both economic and uneconomic, were plotted on the Bouguer anomaly contour map (Plate A1) to determine whether the gravity contour pattern is related to the distribution of mineral deposits. There is a strong tendency for mineral deposits to be concentrated around the residual gravity highs associated with the greenstone belts of the Yilgarn Block.

A5. CONCLUSIONS

The following conclusions are drawn from the analysis of gravity results:

1. Gravity contour trends closely reflect regional structural trends over most of the Yilgarn Block and Albany-Fraser Province. Along the margin of the Yilgarn Block, however, contour trends characteristic of the Albany-Fraser Province persist for some distance into Archaean terrain; this suggests that the influence of Proterozoic tectonic activity extended for some distance into the Yilgarn Block. This is particulary striking along the southeast margin of the Yilgarn Block, where a gravity depression 80 km wide extends parallel to the Proterozoic Fraser Range metamorphic belt.
2. A Bouguer anomaly gradient along the eastern boundary of a region of high Bouguer anomaly over the southwestern part of the Yilgarn Block coincides with a zone of supposed crustal change which gravity evidence suggests may be due to a thickening, from east to west, of a lower or intermediate crustal layer at the expense of a less dense upper layer.
3. The greenstone belts of the Yilgarn Block are associated with residual gravity highs of small area and large amplitude. From gravity evidence the distribution pattern of the greenstone belts differs in the eastern and western parts of the Yilgarn Block. In the Kalgoorlie area the belts appear to form an interconnecting system, whereas in the Southern Cross area they are separated from one another by large areas of granite or gneiss.
4. Low gravity features over the Precambrian shield can generally be correlated with outcropping granitic bodies. The most distinctive features are deep, elongate gravity depressions bordering the Yilgarn Block to the south and southeast. In the Yilgarn Block, a decrease from east to west in the amplitude and intensity of gravity lows associated with granites indicates a corresponding decrease either in their density contrast with the surrounding rocks or in their vertical extent.
5. An intense, narrow gravity ridge extending northeast from Fraser Range is evidently the expression of a partly exposed body of dense pyroxene granulite. The body is estimated to be up to 10 km thick and is probably in fault contact with granite and gneiss to the northwest and southeast. The Fraser Fault is represented by a gradient of about 10 mGal/km and is considered to be a reverse fault and to dip southeast. The gravity ridge extends northeastwards beyond the surveyed area, but with diminishing gravity relief.
6. Gravity relief over the western part of the Eucla Basin probably reflects lateral density variations in the Precambrian basement. As the Bouguer anomaly field is low compared with that in areas of exposed granulite to the northwest, the basement may be composed predominantly of granite and gneiss.

A6. REFERENCES

ANFILOFF, W., & SHAW, R. D., 1973—The gravity effects of three large uplifted granulite blocks in separate Australian shield areas; *in* MATHER, R. S., & ANGUS-LEPPAN, P. V. (Editors)—*Proceedings: Symposium on Earth's Gravitational Field and Secular Variations in Position, University of New South Wales, 1973,* 273-89.

ARRIENS, P. A. & LAMBERT, I. B., 1969—On the age and strontium isotopic geochemistry of granulite-facies rock from the Fraser Range, Western Australia, and the Musgrave Range, central Australia. *Geological Society of Australia, Special Publication* **2**, 377-88.

BARLOW, B. C., 1970—National report on gravity in Australia, July 1965 to June 1970. *Bureau of Mineral Resources, Australia, Record* **1970/62** (unpublished).

COMPSTON, W., & ARRIENS, P. A., 1968—The Precambrian geochronology of Australia. *Canadian Journal of Earth Sciences,* **5**, 561-83.

DANIELS, J. L., & HORWITZ, R. C., 1969—Precambrian tectonic units of Western Australia. *Geological Survey of Western Australia, Annual Report* **1968**, 77.

EVERINGHAM, I. B., 1965a—Gravity anomalies of the Precambrian shield of southwestern Australia. *M.Sc. Thesis, University of Western Australia* (unpublished).

EVERINGHAM, I. B., 1965b—The crustal structure of the southwest of Western Australia. *Bureau of Mineral Resources, Australia, Record* **1965/97** (unpublished).

FRASER, A. R., 1974—Reconnaissance helicopter gravity survey of the southwest of Western Australia, 1969. *Bureau of Mineral Resources, Australia, Record* **1974/26** (unpublished).

GSA, 1971—Tectonic Map of Australia and New Guinea, 1:5 000 000. *Geological Society of Australia, Sydney.*

GSWA (GEOLOGICAL SURVEY OF WESTERN AUSTRALIA), 1966—Geological map of Western Australia. *Government Printer, Perth.*

GUNSON, S., & VAN DER LINDEN, J., 1956—Regional gravity traverses across the Eucla Basin, 1954-55. *Bureau of Mineral Resources, Australia, Record* **1956/145** (unpublished).

HASTIE, L. M., & WALKER, D. G., 1962—Two methods of gravity traversing with helicopters. *Bureau of Mineral Resources, Australia, Record* **1962/134** (unpublished).

JOPLIN, GERMAINE A., 1963—Chemical analysis of Australian rocks, Part I: Igneous and metamorphic rocks. *Bureau of Mineral Resources, Australia, Bulletin* **65**.

LODWICK, K. B., 1962—Busselton seismic reflection survey, Western Australia, 1956. *Bureau of Mineral Resources, Australia, Record* **1962/108** (unpublished).

MCCALL, G. J. H., 1972—The nickel-sulphide-bearing ultramafic rocks and their environment in the Archaean of Western Australia. *24th International Geological Congress,* Section **1**, 354.

MATHUR, S. P., 1974—Crustal structure in southwestern Australia from seismic and gravity data. *Tectonophysics,* **24**, 151-82.

MOSS, F. J., 1962—Rockingham-Mundijong seismic survey, Western Australia, 1956. *Bureau of Mineral Resources, Australia, Record* **1962/107** (unpublished).

PARASNIS, D. S., 1962—PRINCIPLES OF APPLIED GEOPHYSICS. *Methuen's Monographs on Physical Subjects, London.*

PEERS, R., & TRENDALL, A. F., 1968—Precambrian rocks encountered during drilling in the main Phanerozoic sedimentary basins of Western Australia. *Geological Survey of Western Australia, Annual Report* **1967**, 69-77.

PRIDER, R. T., 1965—The geology and mineralization of the Western Australian shield. *8th Commonwealth Mining and Metallurgical Congress,* **1**, 56-65.

QUILTY, J. H., 1963—Perth Basin aeromagnetic survey, Western Australia, 1957. *Bureau of Mineral Resources, Australia, Record* **1963/74** (unpublished).

SOFOULIS, J., 1958—The geology of the Phillips River Goldfield, W.A. *Geological Survey of Western Australia, Bulletin* **110**.

THYER, R. F., & EVERINGHAM, I. B., 1956—Gravity survey of the Perth Basin, Western Australia. *Bureau of Mineral Resources, Australia, Bulletin* **33**.

TUREK, A., & STEPHENSON, N. C., 1966—The radiometric age of the Albany Granite and Stirling Range Beds, southwest Australia. *Journal of the Geological Society of Australia* **13**(2), 449-56.

VALE, K. R., 1966—Seismic reflection survey of the northern end of the Gingin Anticline, Perth Basin, Western Australia, 1955. *Bureau of Mineral Resources, Australia, Record* **1966/149** (unpublished).

VALE, K. R., 1967—Progress of the reconnaissance gravity survey of Australia. (Presented at: *Symposium on the Development of Petroleum Resources of Asia and the Far East,* Tokyo, 1965). *United Nations, New York, Mineral Resources Development Series* **26**(1), 441-55.

VALE, K. R., & MOSS, F. J., 1962—Cookernup seismic survey, Western Australia, 1955-56. *Bureau of Mineral Resources, Australia, Record* **1962/109** (unpublished).

WALKER, D. J., & JONES, B. F., 1966—Bullsbrook seismic survey, Perth Basin, Western Australia, 1964. *Bureau of Mineral Resources, Australia, Record* **1966/203** (unpublished).

WILSON, A. F., 1969—Granulite terrains and their tectonic setting and relationship to associated metamorphic rocks in Australia. *Geological Society of Australia, Special Publication* **2**, 243-58.

WILSON, A. F., COMPSTON, W., JEFFREY, P. M., & RILEY, G. H., 1960—Radioactive ages from the Precambrian rocks in Australia. *Journal of the Geological Society of Australia,* **6**, 179-96.

Note: Additional abbreviated references for previous geophysical and borehole surveys not specifically referred to in the text are given in Appendix A3.

PART B

Reconnaissance gravity survey in northwest Western Australia, 1969

A. R. FRASER

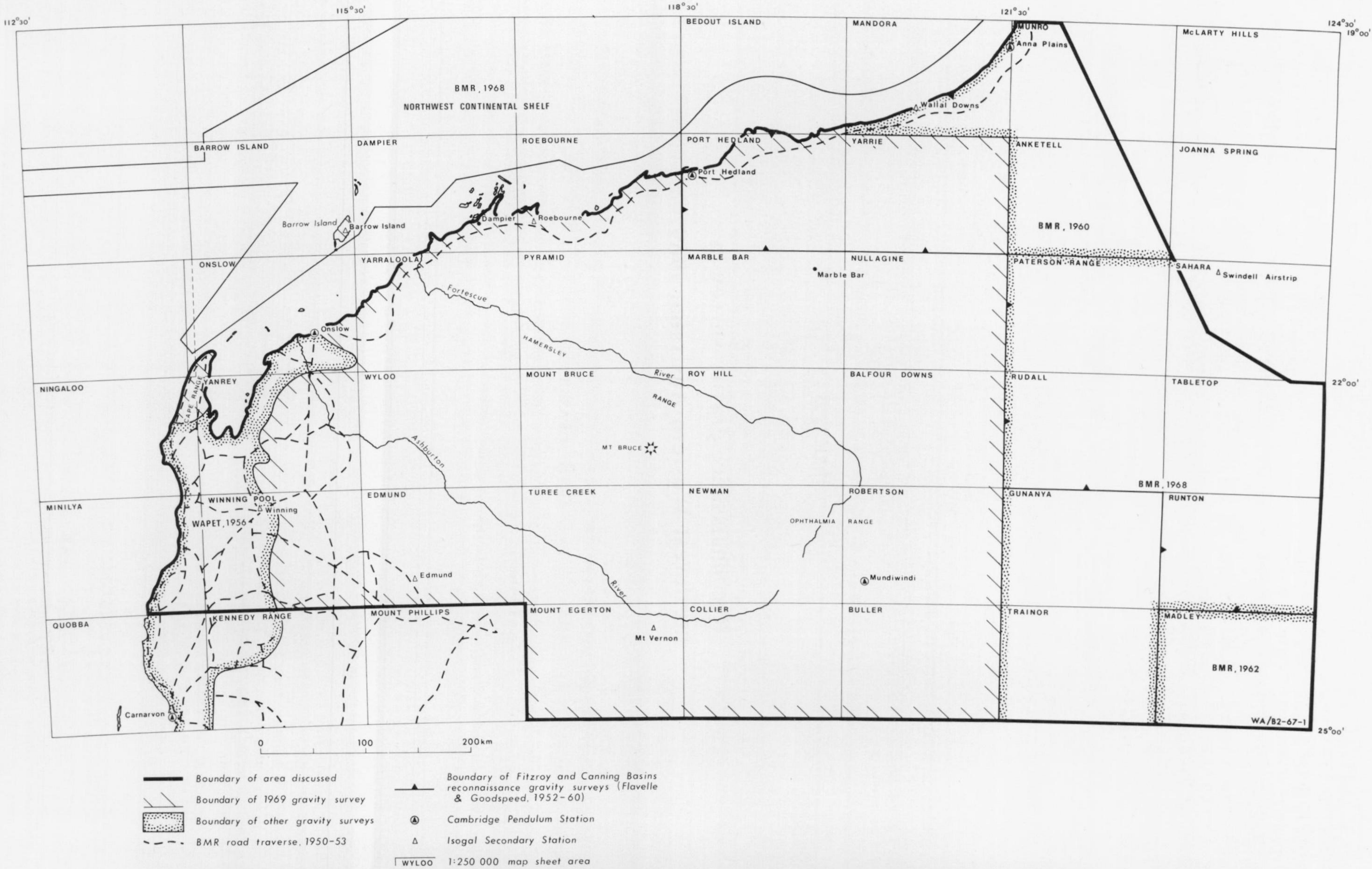


Fig. B1. Location of 1969 BMR gravity survey and of previous BMR and subsidised gravity surveys.

B1. INTRODUCTION

The Bureau of Mineral Resources, Geology and Geophysics (BMR) extended the reconnaissance helicopter gravity coverage of Australia by conducting two surveys in Western Australia in 1969. Both were done under contract to BMR by Wongela Geophysical Pty Ltd using the 'cell method', described by Hastie & Walker (1962), to establish an 11-km grid of gravity stations over the two areas. Part B discusses the results in the northwestern area (Fig. B1), in which 340 000 km^2 was surveyed over twenty-four 1:250 000 Sheet areas under the supervisison of F. Darby and A. R. Fraser. The results of previous gravity surveys by BMR, over the northwest continental shelf and over several 1:250 000 Sheet areas to the east of the northwestern survey area (Fig. B1), are also included in the discussion. Bouguer anomaly contours for the area discussed are shown in Plate B1.

The survey areas extend over the northern part of the Carnarvon Basin, the western tip of the Canning Basin, and a portion of the Precambrian shield. In the Carnarvon Basin, ties were made to a previous survey by West Australian Petroleum Pty Ltd, and new readings were taken only where gravity coverage was considered inadequate.

The topography comprises a duricrusted plateau and gently seaward-sloping coastal plains. Height above sea level on the plateau generally ranges from 500 to 800 m, although several peaks exceed 1000 m; Mount Bruce (1227 m) is the highest point in the State. Erosion by rivers has reduced the plateau in some areas to a series of tablelands and mesas separated by wide valleys. In the Hamersley and Ophthalmia Ranges, folded sediments have been differentially eroded.

Rainfall within the survey area is generally low and irregular, and vegetation is sparse. Landing spots for the helicopter were plentiful, and a network of graded roads generally gave good access and facilitated the transport of crew and fuel.

Summaries of the geology and previous geophysical survey results were prepared from information available up to 1973. Operational statistics and a description of survey methods are given in appendixes.

Acknowledgement

I thank the staff of the BMR Cartographic Section who contributed to the drawing of the illustrations.

B2. GEOLOGY

The survey area extends over the northern half of the Carnarvon Basin, the western tip of the Canning Basin, and all or parts of the Pilbara Block, the Median Belt (Hamersley and Bangemall Basins), the Gascoyne Block, and the Paterson Province. These structural divisions are shown in Plate B2. With the exception of the Canning Basin, whose gravity expression is discussed in another report (Flavelle & Goodspeed, 1962), each structural element is discussed in some detail. The names of wells drilled in the sedimentary basins of the survey area are listed in Appendix B3.

Carnarvon Basin

This is an epicontinental basin of mainly Phanerozoic sediments; it extends on land from Onslow in the north to Geraldton in the south, and eastward from the coast for up to 200 km. Recent sands and alluvium obscure the landward margin of the basin in the north, but centrally in the east the boundary is the junction of Palaeozoic sediments with Precambrian igneous and metamorphic rocks. The southeastern margin is not distinct, and the boundary between the Perth and Carnarvon Basins is arbitrarily defined.

Geophysical and drilling evidence has shown that the Precambrian floor of the basin is irregular, and consists of a number of relatively deep troughs separated by narrow sinuous ridges (Chamberlain, Dooley, & Vale, 1954; Parkinson, 1957; Forsyth, 1960; Spence 1961, 1962; Bow & Turpie, 1964). The main basement ridge is represented by an elongate belt of high Bouguer anomaly and divides the onshore part of the basin meridionally. On either side of the main basement ridge, the sedimentary troughs are represented by gravity depressions.

Pilbara Block

The Pilbara Block constitutes one of the oldest known parts of the Precambrian shield. Archaean granites have generally yielded rubidium-strontium ages in the range 2900 to 3100 m.y., which is considerably older than the 2600 to 2700 m.y. range for most of the granites dated in the Yilgarn Block (Compston & Arriens, 1968).

The following description of the Pilbara Block is largely derived from reviews by Noldart & Wyatt (1961), Prider (1965), and Ryan (1965). The Archaean rocks of the Pilbara Block belong to the Pilbara System, which comprises volcanic and sedimentary successions and igneous intrusives. In the central and eastern parts of the Pilbara Block, the volcanic/sedimentary pile is divided into the Warrawoona and Mosquito Creek Successions. The Warrawoona Succession is the older, and is made up of highly folded metamorphosed basaltic lavas and sills with a minor development of jaspilite. The predominantly clastic Mosquito Creek Succession unconformably overlies the Warrawoona Succession and consists of conglomerate, mudstone, shale, schist, sandstone, slate, and quartzite. In the western part of the Pilbara Block, laterally equivalent volcanic and sedimentary successions that are probably equivalent to the Warrawoona and Mosquito Creek Successions comprise the Roebourne Group.

The main igneous rock type in the Pilbara Block is granite, which occupies large tracts of low-lying country where outcrop is poor. The commonest type is a leucocratic even-grained granite. Noldart & Wyatt (1961) have recognised two main types of granitic intrusives: those that appear to have concordantly intruded the rocks of the Warrawoona Succession, and those that have discordantly intruded the Mosquito Creek Succession.

The Pilbara System in unconformably overlain by a succession of flat-lying unmetamorphosed shallow-water Lower Proterozoic sediments and interbedded volcanics. The predominant rock types are conglomerate and pebbly sandstone, with minor shale and siltstone, interbedded with acid and basic igneous sills or flows. The youngest rocks, thin Tertiary and Quaternary sequences, occur in the valleys of the major rivers draining the Pilbara Block.

The main structural features of the Pilbara Block are the large granitic domes, round which the overlying successions form tight synclinoria. Within the Warrawoona Succession, no overall regional fold trend is apparent, and most of the structural trends and fold patterns follow the margins of the granitic plutons. Fold patterns are simpler in the Mosquito Creek Succession and the Roebourne Group, and follow a regional trend varying from east-northeast to east. The Pilbara System has been subjected to regional superimposed folding along northeast-trending axes. The regional folding postdated or was contemporaneous with folding of the Mosquito Creek Succession, and is believed to have been due to a tangential compressive force imposed on the Pilbara Block from the southeast (Noldart & Wyatt, 1961).

Median Belt

Between the Pilbara and Yilgarn Blocks lies a broad southeast-trending Proterozoic basin containing unmetamorphosed sediments and interbedded lavas. The basin has been termed the Median Belt (Clarke, 1938; Prider, 1965; Hills, 1965) and the Nullagine Basin (Daniels, 1966). The Proterozoic geology of the area is the subject of a paper by Daniels (1966) on which the following account is based.

The Proterozoic succession comprises three main divisions which are separated by angular unconformities. From oldest to youngest these are the Mount Bruce Supergroup, the Bresnahan Group, and the Bangemall Group.

Mount Bruce Supergroup. The lowermost part of the Mount Bruce Supergroup is termed the Fortescue Group, which consists principally of quartzite, flood basalt, pyroclastics, and pillow lava, with interbedded dolomite, pisolite, and shale. The group has a total thickness of about 4300 m, and overlies an Archaean basement of greenstone, jaspilite, and granite, which are exposed as a few small inliers in the cores of domes. Overlying the Fortescue Group is the Hamersley Group, which consists predominantly of hydrogenic rocks such as chert, jaspilite, and dolomite. The group comprises eight formations, of which the Brockman Iron Formation is the thickest, the most widely exposed, and the most important economically. The extensive iron ore deposits of the Hamersley Range occur mainly as hematite in synclinal folds of the Brockman Iron Formation (MacLeod, 1966). Disconformably overlying the Hamersley Group is the Wyloo Group, which consists of coarse clastic sediments, shale, quartzite, dolomite, and minor volcanics. Unlike the sediments of the Hamersley Group, which accumulated under conditions of extreme stability, the Wyloo Group contains a wide variety of lithofacies, suggesting that deposition took place in an unstable environment. This apparent instability during Wyloo Group times was probably the harbinger of a period of major folding which affected the whole of the Mount Bruce Supergroup.

Bresnahan Group. Deposition, folding, and erosion of the Mount Bruce Supergroup was followed by the deposition of a thick series of arenaceous beds named the Bresnahan Group. The nature of the clasts in the sediments indicates that the source material was granitic, and the high proportion of fresh feldspar probably indicates rapid mechanical weathering of the source rock and rapid accumulation in a quickly subsiding basin. Daniels (1966) contended that the source was an Archaean granite mass exposed immediately west of the Bresnahan Group outcrop, and that the basin developed as a result of vertical movement along a fault forming the southwestern boundary of the Archaean inlier. After deposition, the Bresnahan Group was slightly folded about easterly axes, and eroded.

Bangemall Group. The Bangemall Group was laid down unconformably on the Mount Bruce Supergroup and the Bresnahan Group. It is exposed over a wide area south of the Ashburton River. Daniels (1966) has identified formations of dolomite, shale, and orthoquartzite, all of which are intruded by quartz dolerite sills. The main folding of the sequence has been about west to northwest axes and increases in intensity from north to south (Daniels, 1966).

Daniels & Horwitz (1969) divided the Median Belt into two basins (Plate B2)—the Hamersley Basin comprising the Mount Bruce Supergroup and Bresnahan Group sediments to the north, and the Bangemall Basin comprising the Bangemall Group sediments to the south.

Gascoyne Block

The Gascoyne Block consists of low-grade to medium-grade metamorphosed sediments, gneiss, and intrusive granite, and apparently forms the basement to the southern part of the Bangemall Basin. Metamorphism of the sediments dates from the Ophthalmian Orogeny, during which the most intense folding of the Mount Bruce Supergroup took place (GSA, 1971). The metasediments are probably the metamorphosed equivalents of the Mount Bruce Supergroup.

Paterson Province

This province was originally considered to form an easterly extension of the Pilbara Block (Prider, 1965), but was later recognised as a separate tectonic unit and renamed (Daniels & Horwitz, 1969). It consists of Proterozoic metasediments and granite, and appears to form the basement to parts of the Canning Basin in the north and the Bangemall Basin in the south.

B3. PREVIOUS GEOPHYSICAL RESULTS

Numerous geophysical surveys have been carried out within the survey area by BMR and by mining and oil exploration companies. The surveys for which information is readily available are listed in Appendix B3, and their locations are shown in Figures B1, B2, and B3; marine seismic and magnetic surveys are not included. The major results of previous geophysical surveys that could have some relevance to the present investigation are discussed below.

Gravity surveys

Gravity surveys before 1968 were mainly confined to the Carnarvon and Canning Basins. In the Carnarvon Basin, two broad gravity depressions separated by a gravity ridge were revealed. Chamberlain & others (1954) interpreted the gravity relief in terms of basement topography, so that the depressions and ridge were regarded as the expressions of sedimentary troughs and a basement ridge respectively.

The Canning Basin gravity surveys revealed a broad northwest-trending gravity ridge along the southwestern margin of the Canning Basin, and a depression covering most of RUNTON and MADLEY. Using the scant geological evidence available at the time, Flavelle & Goodspeed (1962) interpreted the gravity ridge as the expression of an ancient mobile zone, and the depression as a thick sequence of relatively light Phanerozoic sediments.

Magnetic surveys

Airborne magnetic surveys have covered the entire Carnarvon Basin and parts of the Canning Basin. The BMR aeromagnetic surveys of the Carnarvon Basin clearly delineated the shield/basin boundary; sharp variations in magnetic intensity were recorded over Precambrian rocks, and gradual variations over sediments. The magnetic results are in general agreement with the overall structure of the Carnarvon Basin interpreted from the gravity results: the gravity ridge, interpreted as the expression of a basement ridge, coincides with an elongate band of high magnetic disturbance; and on either side of the ridge the gravity depressions attributed to sub-basins of the Carnarvon Basin correspond to areas of relatively undisturbed magnetic field. The magnetic results also indicate that basement is quite shallow along the coastline between Onslow and Dampier.

The magnetic contour pattern over the north Canning Basin is smooth, and suggests that the Phanerozoic sediments form a thick layer there. The southwestern margin of the basin is represented by a broad band of relatively high magnetic disturbance which roughly coincides with the northwest-trending gravity ridge defined from the regional gravity results.

Seismic surveys

Numerous seismic surveys have been conducted in the Carnarvon and Canning Basins in the search for local structures favourable for the accumulation of petroleum. For the most part, the results of these surveys have only minor relevance in the discussion of gravity results.

Surveys in the Carnarvon Basin generally confirmed the gravity interpretation of Chamberlain & others (1954). Sedimentary sequences ranging from 3000 to 7000 m were measured in the sub-basins of the Carnarvon Basin; locally thinner sections were measured over the inferred basement ridge. In the south Canning Basin, a seismic survey by BMR indicated that the thickness of sediments may exceed 10 000 m in southern MADLEY (Turpie, 1967). This large thickness of sediments is probably the cause of low Bouguer anomaly values in the area.

B4. DESCRIPTION AND INTERPRETATION OF GRAVITY RESULTS

Bouguer anomaly contours are shown in Plate B1. Survey statistics and procedure are given in Appendixes B1 and B2.

A rock density of 2.2 g/cm^3 was chosen for computing Bouguer corrections. As this density is intermediate between values adopted for gravity surveys over sedimentary basins and values adopted for surveys of hardrock areas, discontinuities between contours from one survey and those from an earlier survey to which they are tied are minimised.

No attempt has been made to apply terrain or isostatic corrections to the Bouguer anomalies. The former are not considered necessary since the greater part of the terrain is flat or undulating, and, to apply isostatic corrections, doubtful assumptions would have to be made about the manner in which isostatic compensation is achieved.

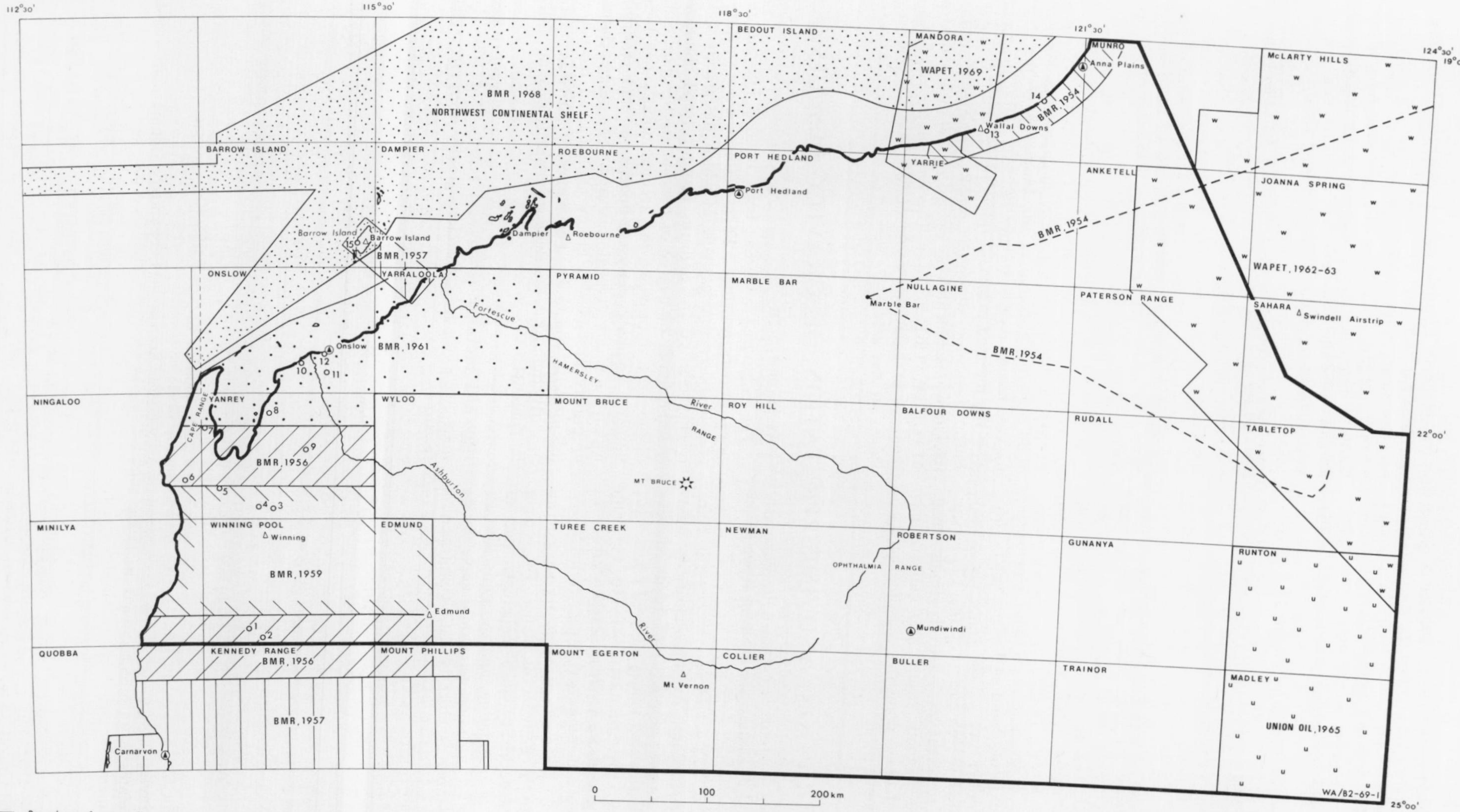
Gravity provinces

The contoured area has been divided into six regional gravity provinces. Each of these covers a large area of fairly simple shape in which the gravity field is characterised by uniform contour trend, Bouguer anomaly level, or degree of contour disturbance. Subdivisions of a province are termed 'units', and local Bouguer anomaly closures, lineaments, and gradients within units are termed 'features'. The nomenclature of gravity provinces is briefly explained in Part A of this Bulletin (pp. 6-7). The names of provines totally or partly defined in the Bouguer anomaly map are listed in Table B1.

Each gravity province is discussed in relation to geology and previous geophysical results. The following maps were used to correlate gravity with geological features:

TABLE B1. GRAVITY PROVINCES

Province	*Derivation of name*	*BMR gravity survey in which province first defined*	*Reference*
Fortescue Regional Gravity Complex	River	New	
Ashburton Regional Gravity Ridge	River	New	
Anketell Regional Gravity Ridge	1:250 000 Sheet area	Fitzroy and Canning Basins, 1952-60	Flavelle & Goodspeed (1962)
		Amadeus and south Canning Basins, 1962	Lonsdale & Flavelle (1968)
Rason Regional Gravity Low	Lake	Southwest Western Australia, 1969	Fraser (this volume, Part A) has combined the earlier defined provinces—the Gibson Gravity Depression, to the north (Lonsdale & Flavelle, 1968), and the Dundas Regional Gravity Depression, to the south (Fraser, 1974)
Teano Regional Gravity Low	Range	New	
Carnarvon Regional Gravity Complex	Town	Carnarvon Basin, 1953	Chamberlain & others (1954)



Boundary of area discussed
WYLOO 1:250 000 map sheet area
Boundary of magnetic survey (Adjacent and overlapping areas distinguished by stipples)
Magnetic traverse
Well
Cambridge Pendulum Station
Isogal Secondary Station

WELLS

1	Wandagee No. 1	9	Paterson No. 1
2	Quail No. 1	10	Onslow No. 1
3	East Marilla No. 1	11	Minderoo No. 1
4	Marilla No. 1	12	Cane River No. 1
5	Remarkable Hill No. 1	13	BMR Wallal 4A
6	Whaleback No. 1	14	Samphire Marsh No. 1
7	Learmonth No. 2	15	Barrow Island No. 1
8	Hope Island No. 1		

Fig. B2. Previous BMR and subsidised magnetic surveys and wells.

(1) Geological Map of Western Australia (GSWA, 1966).
(2) Tectonic Map of Australia and New Guinea (GSA, 1971).
(3) 1:250 000 Geological Series maps of DAMPIER, ROEBOURNE, PORT HEDLAND, YARRIE, ANKETELL, YARRALOOLA, PYRAMID, PATERSON RANGE, WYLOO, MOUNT BRUCE, ROY HILL, BALFOUR DOWNS, TABLETOP, WINNING POOL, EDMUND, TUREE CREEK, NEWMAN, and ROBERTSON.

Fortescue Regional Gravity Complex

This is an oval-shaped province of generally disturbed contour pattern and relatively low Bouguer anomaly level. Gravity relief consists of intense disjointed residual highs and lows preferentially elongated about northeast or northwest axes. The average Bouguer anomaly level drops from close to zero in the northern part of the province to about −60 mGal in the south. The province is separated from the Anketell Regional Gravity Ridge, to the east, by a regional Bouguer anomaly gradient, and from the Ashburton Regional Gravity Ridge, to the south and west, by an arcuate line of steep local gradients extending from the north coast in south DAMPIER to northwestern RUDALL. Offshore, the province is bounded by the seaward continuation of the Anketell Regional Gravity Ridge and a northeast-trending gravity ridge 100 to 150 km from the coastline.

For convenience in discussing local gravity features the province has been divided into four units. In *unit I*, gravity gradients are steeper, and the average Bouguer anomaly level is higher than in units II, III, and IV. Local gravity relief in *unit II* is similar to that in unit I, but the average Bouguer anomaly value is about 20 mGal lower. *Unit III* is characterised by low Bouguer anomalies and a comparative rarity of short-wavelength residual features. In *unit IV*, Bouguer anomaly values average about 20 mGal higher than in unit III.

Unit I covers a large portion of the Archaean Pilbara Block. Variations in gravity relief correspond closely to variations in outcrop: intense gravity highs and lows are associated respectively with greenstone belts (comprising the Warrawoona and Mosquito Creek Successions) and intrusive granites. Steep gradients in the gravity field reflect sharp density variations and steeply dipping contacts between the greenstone and granitic masses. From the spatial relations between outcrops of the various bodies, and anomalies of gravity relief, several local correlations can be made. Features 1, 2, 3, 5, and 10 (gravity highs) in Plate B1 relate to concentrations of basic igneous rock of the Warrawoona Succession. The vertical extent of the largest of these concentrations exceeds 4 km, assuming that their average density is 0.3 g/cm^3 greater than that of adjacent granites. Features 4, 6, 7, 9, 11, and 12 (gravity lows) are the expressions of granitic masses. Feature 8 extends over Mesozoic and Quaternary sediments, but is similar to features 1, 2, 3, 5, and 10, and probably relates to a basic igneous body in the Archaean basement. Feature 13 is similarly interpreted, as the expression of a sediment-covered Archaean granitic body.

Sediments of the Hamersley and Fortescue Groups cover most of *unit II*, but major gravity relief is attributed to lateral variations in density of the Archaean basement. This is inferred from the similarity in gravity pattern between unit II and unit I. Features 6, 7, 8, 10, and 11 do not appear to correspond to any local surface geological structures. Gravity lows (features 2, 3, and 4) are centred near granitic inliers and are attributed to granitic masses within the Archaean basement. Feature 1, an east-trending gravity high, is roughly coextensive with an area in which the lower members of the Fortescue Group are intruded by massive and layered dolerites. Feature 5, a gravity high, coincides with a closed synclinal structure within the Hamersley Group sediments, and feature 9, an intense high near Roebourne, apparently relates to dense Archaean sediments and volcanics that crop out in the area.

Regionally low Bouguer anomalies in *unit III* might be the expression of either:
(1) A thick sequence of relatively light Proterozoic sediments.
(2) A basement composed predominantly of low-density rocks such as granite.

Of these, alternative (2) is more likely. Proterozoic sediments are absent in the north of the unit, where low Bouguer anomalies are clearly attributable to Archaean granites of the Pilbara Block. Farther south, the presence of Archaean basement inliers in widely separated parts of the Hamersley Basin suggests that the Proterozoic sequence is too thin to depress Bouguer anomaly values by as much as 30 mGal. Bouguer anomalies are higher in the adjoining province to the south, where a thick Proterozoic sedimentary sequence is implied by the absence of basement inliers.

Local gravity features in unit III have a close spatial association with anticlines and synclines in the Proterozoic succession. Features 1, 2, and 7, all gravity lows, are centred near outcrops of Archaean granite which form the cores of anticlines in the Proterozoic sequence. Feature 3, also a gravity low, is coextensive with a large exposure of Archaean granite which appears to be overlain by the Fortescue Group to the north, but in the south is overlain by, or faulted against, the Bangemall Group sediments. Gravity highs (features 4, 5, and 6) all coincide with closed synclines in the Mount Bruce Supergroup.

The similar gravity patterns of units I and III, and the coincidence of gravity lows with Archaean granitic inliers, suggest that gravity relief in unit III relates mainly to density variations within the Archaean basement. The close spatial association between gravity relief and Proterozoic structures therefore suggests that granitic and basic igneous masses in the Archaean basement correspond respectively to anticlines and synclines in the overlying Proterozoic sediments. It would follow that Archaean granites formed topographic prominences before the deposition of the Mount Bruce Supergroup, or that the granitic batholiths rose after deposition, doming the overlying sedimentary cover.

In *unit IV*, the average Bouguer anomaly level is about 20 mGal higher than in unit III; this may be the effect of a regional increase in the density of the basement. The eastern margin of the unit evidently corresponds to an age boundary separating Archaean basement to the west from Proterozoic basement to the east. It is near and parallel to an elongate outcrop of Proterozoic granite, which is the westernmost of a number of Proterozoic granites cropping out in the Paterson Province. Features 1 and 5 are centred over Archaean granitic inliers, and feature 3 is close to an outcrop of Proterozoic granite, but local features 2

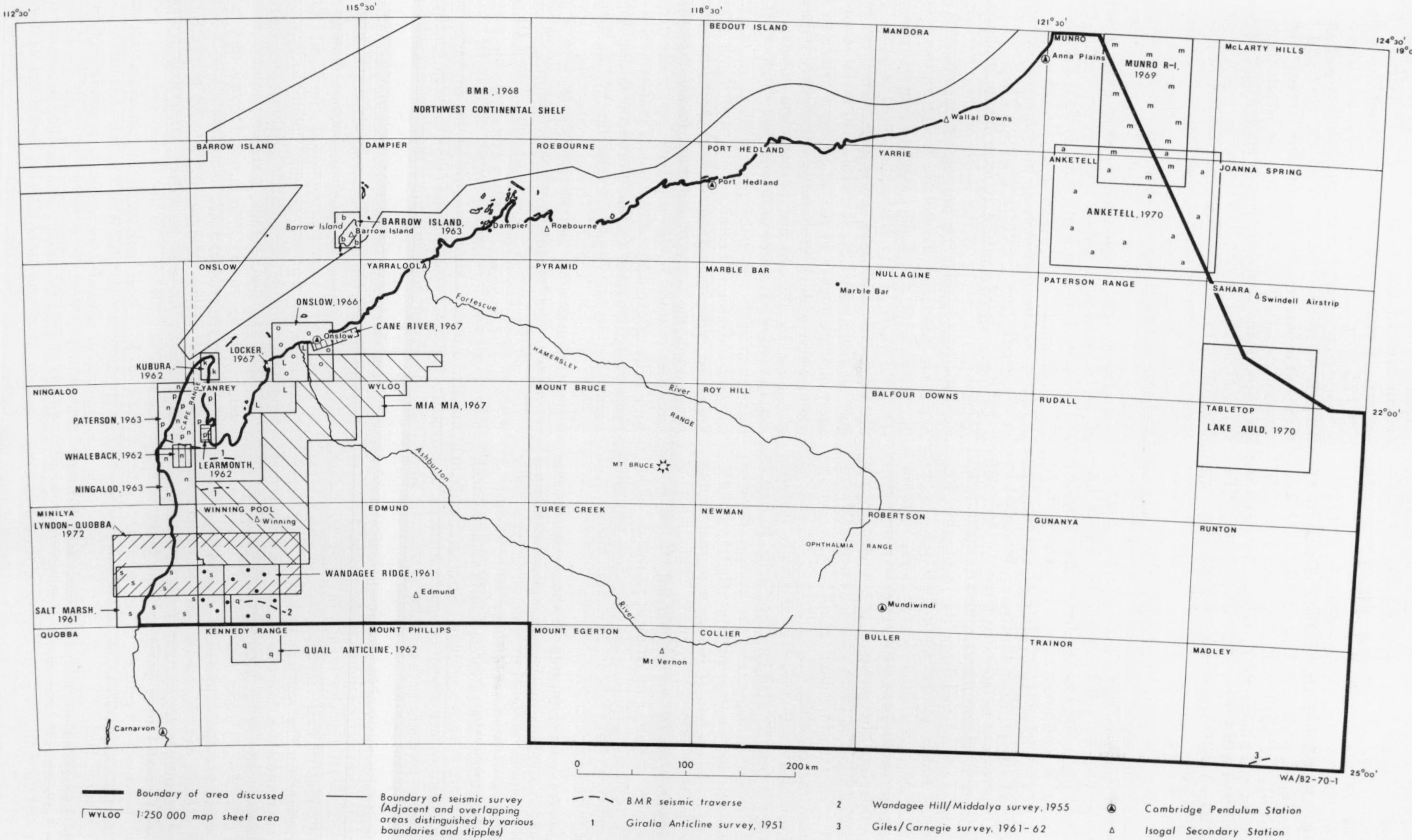


Fig. B3. Previous BMR and subsidised seismic surveys.

and 4 have no apparent relation to surface geology and are interpreted as the expressions of anomalous bodies in the basement.

Ashburton Regional Gravity Ridge

This province is an arcuate band, 60 to 100 km wide, of high Bouguer anomalies extending around the southern perimeter of the Fortescue Regional Gravity Complex. In contrast to the Fortescue Regional Gravity Complex, which is characterised by the presence of intense residual gravity features and an absence of any single predominant trend, the Ashburton Regional Gravity Ridge covers an area of relatively smooth gravity relief in which contour trends are generally parallel to the province margins. The province is most clearly definable between the north coast near Onslow, and Mundiwindi; east of Mundiwindi it is less distinct but may swing northwards to join the Anketell Regional Gravity Ridge. Offshore, the province is separated from an east-northeast-trending gravity ridge, which crosses its northward projection, by a gravity low that is centred near Barrow Island.

The surface geology changes markedly across the northern boundary of the province. Over the western and southern parts of the Fortescue Regional Gravity Complex the main outcropping units are sediments of the Fortescue and Hamersley Groups, with several Archaean basement inliers; Wyloo Group sediments are relatively minor and mostly confined to the cores of the major synclines. In contrast, the Ashburton Regional Gravity Ridge covers an area in which sediments of the Wyloo, Bresnahan, and Bangemall Groups crop out, largely to the exclusion of the Fortescue and Hamersley Groups. Proterozoic granites intruding the Wyloo Group are common, but Archaean granites are absent except for an inlier in WYLOO, where Archaean granites are exposed in the core of an anticline. Faults are numerous near the junction between the two gravity provinces, particularly in the west; most of them occur within the Fortescue Regional Gravity Complex near and parallel to its southern and western margins. In YARRALOOLA, the province boundary coincides roughly with the eastward limit of an extensive Cainozoic/Mesozoic cover. No marked geological changes are evident across the poorly defined gravity province boundary east of Mundiwindi, although in ROBERTSON the boundary is parallel to the axis of folding of Middle Proterozoic sediments (de la Hunty, 1969).

Three local gravity features in the Ashburton Regional Gravity Ridge can be correlated with geological or magnetic features. Features 1 and 2, both gravity highs near the coastline in YARRALOOLA, coincide with the areas of high magnetic disturbance which are probably the expressions of basement rises under the Cainozoic/Mesozoic cover. Feature 3, an intense gravity low in WYLOO, coincides with an anticline in the Fortescue and Hamersley Group sediments; Archaean granite is exposed in the core.

Anketell Regional Gravity Ridge

This province is a broad northwesterly orientated gravity ridge. Its northern part, including its offshore extension, is similar to the Ashburton Regional Gravity Ridge in regard to its relative Bouguer anomaly level, shape, and spatial relation to the Fortescue Regional Gravity Complex, but is of considerably higher and more complex gravity relief. In TABLETOP, the province swings abruptly to east-southeast and becomes narrower, but continues as a sinuous, generally southeast-trending, gravity ridge across the Canning Basin, and joins up with an intense gravity ridge over the Musgrave Block of central Australia (Lonsdale & Flavelle, 1968). Although sediments of the Canning Basin extend across the northern and southern parts of the province, major gravity relief is attributed to a zone of dense metamorphic and granitic rocks in the basement. This is suggested by the approximate coextensiveness of the exposed area of the Paterson Province with the Anketell Regional Gravity Ridge in PATERSON RANGE, RUDALL, TABLETOP, and RUNTON. The Paterson Province consists of low-grade to medium-grade metamorphics intruded by Proterozoic granites. The granitic outcrops tend to be elongate in a northerly to northwesterly direction, roughly parallel to the elongation of the Anketell Regional Gravity Ridge; their alignment contrasts with the randomness of orientation of the Archaean granites in the Pilbara Block. The metamorphic rocks may date from the Ophthalmian Orogeny and are possibly the metamorphosed equivalents of the Wyloo Group sediments (GSA, 1971). A difference in the grade of metamorphism of the Wyloo Group between the Ashburton River area and the Paterson Province is possibly the cause of the difference in Bouguer anomaly level between the Ashburton and Anketell Regional Gravity Ridges.

From the Bouguer anomaly contours it is possible to trace the Paterson Province northwards under the Canning Basin to the coast. It remains conjectural, however, whether the Paterson Province extends far southwards beyond its outcrop in TABLETOP, where the abrupt change in orientation, width, and amplitude of the gravity province suggests a structural discontinuity.

Rason Regional Gravity Low

This province was defined from the results of surveys in 1962 (Lonsdale & Flavelle, 1968), 1969 (Fraser, this volume, Part A), and 1971-72 (Fraser, this volume, Part C). It is a long arcuate gravity trough of varying width and intensity, and extends from RUNTON southwards to NORSEMAN. Low Bouguer anomalies in the north of the province have been attributed to a thick sedimentary sequence (Lonsdale & Flavelle, 1968). However, the southern portion of the province follows the southeast margin of the Yilgarn Block and is clearly related to a regional mass deficiency in the Precambrian shield (Fraser, this volume, Part C).

Teano Regional Gravity Low

This province is separated from the Ashburton Regional Gravity Ridge to the north by an east-southeast-trending gradient. Bouguer anomaly values decrease from north to south across this gradient and attain minimum values of less than −100 mGal along the southern edge of MOUNT EGERTON. The southern part of the province lies in an area surveyed in 1971-72 (Fraser, this volume, Part C).

The province cannot be correlated with any known geological structure. Sediments of the Bangemall Basin extend over most of the province, but the presence of an Archaean granitic inlier in COLLIER indicates that the sediments are too thin to cause a gravity depression of the observed magnitude. Low Bouguer anomaly values may, therefore, be associated with a regional mass deficiency of large vertical extent within the crystalline Precambrian basement.

The province flanks the northern margin of the Yilgarn Block and may have similar tectonic significance to gravity depressions along the southeastern and southern margins of the block (Fraser, this volume, Part A).

Carnarvon Regional Gravity Complex

This province covers an area extending westwards from the Ashburton Regional Gravity Ridge to, and probably beyond, the coastline; its southern part lies south of the survey area (see Fraser, this volume, Part C). The province (north of latitude 24°S) has no single dominant characteristic, but embraces a region of relatively high Bouguer anomaly level in which local gravity features generally have a medium wavelength (30 to 60 km) and an overall northerly trend.

The province extends over the northern parts of the Carnarvon Basin and the Gascoyne Block. Gravity coverage of most of the Carnarvon Basin was obtained by BMR in 1950, 1951, and 1953; the survey results are discussed by Chamberlain & others (1954), who interpreted variations in gravity relief in terms of basement topography—that is, they regarded gravity highs and lows as the expressions of basement ridges and troughs respectively. The results of the 1969 gravity survey appear to be consistent with this interpretation inasmuch as the residual gravity features of the Carnarvon Basin are dissimilar in shape, orientation, wavelength, and amplitude to those of the adjoining shield area to the east. This implies that basement density variations are not likely to be the main cause of Bouguer anomaly variations in the Carnarvon Basin, unless the margin of the basin is the locus of a major change in Precambrian geology.

The relatively high regional Bouguer anomaly level in the northern and western parts of the province is probably an isostatic effect. Thyer (1951) has calculated isostatic corrections which, if applied to the Bouguer anomaly field, would reduce the gravity anomaly level by about 45 mGal at Cape Range, and 30 mGal at Carnarvon and Onslow.

The eastern part of the Carnarvon Regional Gravity Complex extends over part of the Gascoyne Block; gravity contour trends are generally north-northwest, parallel to the main direction of folding and to the preferred orientation of Proterozoic granitic outcrops. The Proterozoic granites show little tendency to be associated with gravity lows, and in this respect differ from the Archaean granites of the Pilbara Block, which are the sources of intense gravity depressions. This suggests one or more of the following:

(1) The Proterozoic granites are of lower density contrast with their enclosing rocks than are the Archaean granites.

(2) The Proterozoic granites have a smaller vertical extent than the Archaean granites.

(3) The Proterozoic granites form a continuous layer beneath the surface, whereas the Archaean granites form discrete batholiths.

Discussion

The Fortescue Regional Gravity Complex and the Ashburton Regional Gravity Ridge are separated by an arcuate line of steep local gradients (henceforth to be termed the 'Pilbara Gradient') extending from the north coast in south DAMPIER to the western part of RUDALL. The total Bouguer anomaly change across the Pilbara Gradient varies, but is generally at least 40 mGal. The change is normally a decrease radially into the Fortescue Regional Gravity Complex except in TUREE CREEK and ROBERTSON, where the gradient is locally reversed. Accompanying this change in Bouguer anomaly level is a distinct change in contour pattern. In the Ashburton Regional Gravity Ridge, Bouguer anomaly features are usually of long wavelength and gentle relief, and are elongated parallel to the margins of the province, whereas in the Fortescue Regional Gravity Complex the features are small, often of sharp relief, and are preferentially elongated about northeast and northwest axes.

On a regional scale, the Pilbara Gradient coincides with what appears from the surface geology to be a major hinge or fault which is downthrown to the south and defines the southern margin of the Hamersley Basin. Numerous faults are close to and often roughly parallel to this margin, at which there is a change in sediment distribution: in the north (corresponding to the Fortescue Regional Gravity Complex) sediments of the Fortescue and Hamersley Groups form the predominant outcrops, while in the south (corresponding broadly to the Ashburton Regional Gravity Ridge) younger sediments of the Wyloo, Bresnahan, and Bangemall Groups are predominantly exposed.

Despite this correlation between regional gravity and geological features, there remains an inconsistency. The Bouguer anomaly level is higher over the presumed downthrown block (where Proterozoic sediments should be thicker) than over the upthrown block, so that an interpretation of the Pilbara Gradient in terms of simple faulting, with the densities of rock layers increasing with depth, is untenable. Three alternative interpretations can be made:

(1) The overall vertical movement of the area corresponding to the Fortescue Regional Gravity Complex has been downwards, resulting in the preservation from erosion of a thick and comparatively light Proterozoic sequence. The presence of younger Proterozoic sediments in the area to the south and west (presumed to be the upthrown block) is explained by relatively minor reverse movement about faults since the deposition of the Wyloo Group sediments.

(2) The Proterozoic sequence has a higher bulk density than the underlying basement and is thicker in the area corresponding to the Ashburton Regional Gravity Ridge.

(3) The Fortescue Regional Gravity Complex and the Ashburton Regional Gravity Ridge represent two distinct basement tectonic units composed of rocks of different densities.

The available evidence suggests that alternative (1) can be discounted. Sediments appear to form only a thin layer in the Fortescue Regional Gravity Complex, and gravity minima generally coincide with granitic inliers. Low Bouguer anomaly values north and east of the Pilbara Gradient are, therefore, attributable to a low-density granitic basement rather than to thick sediments as implied by alternative (1).

Alternative (2) is not so easily discounted, as the Proterozoic sediments contain chert, jaspilite, dolomite, and interbedded volcanics, which together may form a sedimentary pile denser than granite. However, it is difficult to reconcile alternative (2) with the abrupt change in contour pattern across the Pilbara Gradient. A thick pile of dense sediments south and west of the gradient could cause the observed increase in Bouguer anomaly level, but small-scale gravity relief corresponding to local basement inhomogeneities should be similar on either side of the gradient. This is not so: the characteristic trends of the Fortescue Regional Gravity Complex are sharply truncated by contrasting trends in the Ashburton Regional Gravity Ridge.

Alternative (3) appears to be the most likely possibility in view of the following observations and inferences. The Fortescue Regional Gravity Complex broadly encompasses both the Archaean Pilbara Block and the Proterozoic Hamersley Basin. Local gravity features over the Hamersley Basin, where presumed Archaean basement is largely obscured by Proterozoic cover, are similar to those over the Pilbara Block, where they reflect Archaean structural elements. This, together with the absence of any abrupt change in gravity field across the northern boundary of the Hamersley Basin, suggests that the basement of the Hamersley Basin is structurally continuous with the Pilbara Block. In other words, the Fortescue Regional Gravity Complex corresponds to an Archaean craton of which the Pilbara Block is only the exposed part. Since this craton apparently forms an 'island' of older basement surrounded by younger basement, the name 'Pilbara Nucleus' seems appropriate.

The Ashburton Regional Gravity Ridge probably corresponds to a Proterozoic mobile zone. This is inferred from the following evidence:

(1) Sediments of the Wyloo Group, which crop out over much of the province, contain a wide variety of lithofacies; this suggests that the sediments were deposited in an unstable environment (Daniels, 1966).

(2) In the presumed Archaean cratonic area to the north of the Ashburton Regional Gravity Ridge, individual beds of the Fortescue and Hamersley Groups show a marked degree of lateral continuity, indicating that depositional conditions were exceptionally stable. The transition between stable and unstable depositional environments takes place across the Pilbara Gradient, which is considered to mark the boundary between the Pilbara Nucleus and the inferred mobile belt.

(3) Folding of the Mount Bruce Supergroup during the Ophthalmian Orogeny increases in intensity southwards towards the postulated mobile belt (Daniels, 1966).

(4) The Ashburton Regional Gravity Ridge is similar in shape and relative Bouguer anomaly level to the gravity expressions of known mobile belts such as the Halls Creek and King Leopold Mobile Belts (Whitworth, 1970).

(5) The postulated mobile belt is peripheral to an older, presumed craton, and is, therefore, similar in tectonic setting to the Halls Creek and King Leopold Mobile Belts, which girdle the Kimberley Block, and to the Fraser Range metamorphic belt, which borders the southeast margin of the Yilgarn Block.

The density boundary between the Pilbara Nucleus and the inferred mobile belt (henceforth to be termed the 'Ophthalmian Mobile Belt'), although evident from the change in gravity level across the Pilbara Gradient, is not manifested in the surface geology. The shale, sandstone, conglomerate, arkose, greywacke, quartzite, dolomite, and andesitic volcanics of the Wyloo Group are not likely to be denser collectively than the abundant iron formations, dolomite, chert, quartize, and basic volcanics of the Fortescue and Hamersley Groups. It is probable, therefore, that intense folding of the Wyloo Group near the surface during the Ophthalmian Orogeny was accompanied by regional metamorphism of sediments and by igneous intrusion at depth, with the result that the Wyloo Group and older sediments are now denser than the predominantly granitic Pilbara Nucleus to the north and east. That deep-seated regional metamorphism was confined mainly to the area of the Ashburton Regional Gravity Ridge is entirely consistent with the proposed division between the Pilbara Nucleus (stable since the Archaean) and the Ophthalmian Mobile Belt along its southern periphery (active during the Proterozoic).

The Anketell Regional Gravity Ridge is similar to the Ashburton Regional Gravity Ridge in shape, Bouguer anomaly level, and spatial relation to the Pilbara Nucleus. Furthermore, the oldest rock types which it encompasses are the metamorphics of the Paterson Province, which are possibly the metamorphosed equivalents of the Wyloo Group. For these reasons the tentative conclusions of Flavelle & Goodspeed (1962)—that the gravity province relates to an ancient mobile zone—seems to be justified.

Relation between gravity contour pattern and the regional distribution of mineral occurrences

The locations of reported mineral occurrences, both economic and uneconomic, are plotted on the Bouguer anomaly contour map (Plate B1), to determine whether the gravity contour pattern is related to the distribution of mineral deposits. Apart from a tendency for deposits to be concentrated along the zones of steep Bouguer anomaly gradient surrounding residual gravity highs over the Pilbara Block, there is little apparent correlation between the gravity and mineral distribution patterns.

B5. CONCLUSIONS

The following general conclusions are made on the basis of the gravity results:

(1) Residual gravity highs and lows over the Pilbara Block are respectively coextensive with outcrops of greenstone and outcrops of granite. Gravity evidence indicates that an Archaean basement of granite and greenstone underlies Mesozoic and Cainozoic sediments north of the exposed Pilbara Block.

(2) The Pilbara Block is probably only the exposed part of a more extensive Archaean craton which forms the basement to most of the Hamersley Basin. An arcuate line of steep local Bouguer anomaly gradients delineates the southern perimeter of this inferred craton, for which the name 'Pilbara Nucleus' is proposed.

(3) Folding of the Proterozoic sediments of the Hamersley Basin is apparently related to variations within the Archaean basement: gravity and geological evidence combined suggest that synclines and anticlines in the Fortescue and Hamersley Group sediments correspond respectively to greenstones and granites of the underlying Pilbara Nucleus.

(4) A broad arcuate band of high Bouguer anomaly extending around the southern perimeter of the Pilbara Nuceus is interpreted as the expression of a Proterozoic mobile belt composed of rocks

which at depth are denser as a result of regional metamorphism and igneous intrusion.

(5) A broad elongate gravity ridge east of the Pilbara Nucleus encompasses metamorphic and granitic outcrops of the Paterson Province. It is interpreted as the expression of an extensive Proterozoic mobile belt.

(6) An area of low Bouguer anomaly in the south of the survey area is probably part of an elongate gravity depression on the northern border of the Yilgarn Block. Such a depression could have similar tectonic significance to elongate gravity troughs at the southern and southeastern margins of the Yilgarn Block.

(7) Proterozoic granites of the Gascoyne Block and Paterson Province have no appreciable gravity expression, whereas Archaean granites of the Pilbara Block are associated with intense residual gravity lows of large amplitude. This suggests that the Proterozoic granite is of smaller density contrast or vertical extent than the Archaean granite, or that the Proterozoic granite forms a horizontal layer of fairly uniform thickness beneath the surface.

(8) An earlier interpretation that gravity relief over the Carnarvon Basin relates mainly to basement topography (Chamberlain & others, 1954) is unchanged by the results of the 1969 survey.

(9) Examination of the regional distribution of mineral occurrences in relation to the Bouguer anomaly contour pattern shows some concentration of mineral deposits along the zones of steep Bouguer anomaly gradient surrounding residual gravity highs over the Pilbara Block.

B6. REFERENCES

BARLOW, B. C., 1970—National report on gravity in Australia, July 1965 to June 1970. *Bureau of Mineral Resources, Australia, Record* **1970/62** (unpublished).

BOW, G. W. G., & TURPIE, A., 1964—Southern Carnarvon Basin seismic survey, W.A., 1963 (Traverse A, Tamala-Narryer area). *Bureau of Mineral Resources, Australia, Geophysical Progress Report* **1964/6** (unpublished).

CHAMBERLAIN, N. G., DOOLEY, J. C. & VALE, K. R., 1954—Geophysical exploration in the Carnarvon (N.W.) Basin, Western Australia. *Bureau of Mineral Resources, Australia, Record* **1954/44** (unpublished).

CLARKE, E. DE C., 1938—Middle and west Australia; *in* REGIONALE GEOLOGIE DER ERDE. *Akademia Verlag, Leipzig.*

COMPSTON, W., & ARRIENS, P. A., 1968—The Precambrian geochronology of Australia. *Canadian Journal of Earth Sciences,* **5**, 561.

DANIELS, J. L., 1966—The Proterozoic geology of the North-West Division of Western Australia. *Proceedings of the Australasian Institute of Mining and Metallurgy,* **219**, 17-26.

DANIELS, J. L., & HORWITZ, R. C., 1969—Precambrian tectonic units of Western Australia. *Geological Survey of Western Australia, Annual Report* **1968**, 77.

DE LA HUNTY, L. E., 1969—Robertson, Western Australia —1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* **SF/51-13**.

FLAVELLE, A. J., & GOODSPEED, M. J., 1962—Fitzroy and Canning Basins reconnaissance gravity surveys, Western Australia, 1952-60. *Bureau of Mineral Resources, Australia, Record* **1962/105** (unpublished).

FORSYTH, W. A. L., 1960—Carnarvon Basin airborne magnetic and radiometric survey, W.A., 1959. *Bureau of Mineral Resources, Australia, Record,* **1960/132** (unpublished).

FRASER, A. R., 1974—Reconnaissance helicopter gravity survey of the southwest of Western Australia, 1969. *Bureau of Mineral Resources, Australia, Record* **1974/26** (unpublished).

GSA, 1971—Tectonic Map of Australia and New Guinea, 1:5 000 000. *Geological Society of Australia, Sydney.*

GSWA (GEOLOGICAL SURVEY OF WESTERN AUSTRALIA), 1966—Geological Map of Western Australia. *Government Printer, Perth.*

HASTIE, L. M., & WALKER, D. G., 1962—Two methods of gravity traversing with helicopters. *Bureau of Mineral Resources, Australia, Record* **1962/134** (unpublished).

HILLS, E. S., 1965—Tectonic setting of Australian ore deposits; *in* Geology of Australian ore deposits. *Proceedings of the 8th Commonwealth Mining and Metallurgical Congress,*, 1, 3-12.

LONSDALE, G. F., & FLAVELLE, A. J., 1968—Amadeus and south Canning Basins gravity survey, Northern Territory and Western Australia, 1962. *Bureau of Mineral Resources, Australia, Report* **133**.

MACLEOD, W. N., 1966—The geology and iron deposits of the Hamersley Range area, Western Australia. *Geological Survey of Western Australia, Bulletin* **117**.

NOLDART, A. J., & WYATT, J. D., 1961—The geology of portion of the Pilbara Goldfield. *Geological Survey of Western Australia, Bulletin* **115**.

PARKINSON, W. D., 1957—Preliminary report on airborne surveys (scintillograph and magnetometer) of Geraldton-Onslow region, W.A., 1956. *Bureau of Mineral Resources, Australia, Record* **1957/9** (unpublished).

PRIDER, R. T., 1965—The geology and mineralization of the Western Australian Shield; *in* Geology of Australian ore deposits. *Proceedings of the 8th Commonwealth Mining and Metallurgical Congress,* **1**, 56-65.

RYAN, G. R., 1965—The geology of the Pilbara Block, Western Australia. *Proceedings of the Australasian Institute of Mining and Metallurgy,* **214**, 61-94.

SPENCE, A. G., 1961—Carnarvon Basin airborne magnetic and radiometric survey, W.A., 1959. *Bureau of Mineral Resources, Australia, Record* **1961/56** (unpublished).

SPENCE, A. G., 1962—Carnarvon Basin airborne magnetic and radiometric survey, W.A., 1961. *Bureau of Mineral Resources, Australia, Record* **1962/191** (unpublished).

THYER, R. F., 1951—Gravity reconnaissance (1950), N.W. Basin, Western Australia. *Bureau of Mineral Resources, Australia, Record* **1951/69** (unpublished).

TURPIE, A., 1967—Giles-Carnegie seismic survey, Western Australia 1961-62. *Bureau of Mineral Resources, Australia, Record* **1967/123** (unpublished).

WARREN, R. G., 1972—The metallogenic map of Australia and Papua New Guinea. *Bureau of Mineral Resources, Australia, Bulletin* **145**.

WHITWORTH, R., 1970—Reconnaissance gravity survey of parts of Northern Territory and Western Australia, 1967. *Bureau of Mineral Resources, Australia, Record* **1970/15** (unpublished).

Note: Additional abbreviated references for previous geophysical and borehole surveys not specifically referred to in the text are given in Appendix B3.

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PART C

Reconnaissance gravity survey in central and southeast Western Australia, 1971-72

A. R. FRASER

C1. INTRODUCTION

Between October 1971 and October 1972 the Bureau of Mineral Resources, Geology and Geophysics (BMR) made a helicopter gravity survey in central and southeast Western Australia, which completed the reconnaissance gravity coverage of the State (Fig. C1). The survey was conducted under contract by Wongela Geophysical Pty Ltd using the 'cell method', described by Hastie & Walker (1962), to establish an 11-km grid of gravity stations over the survey area; A. R. Fraser and I. Zadoroznyj supervised the field operations. Ties were made to permanently marked stations from previous BMR surveys in adjoining areas and from three previous private company surveys. The results of two of the private company surveys, and of the BMR survey in central and southeast Western Australia, are combined in a Bouguer anomaly contour map (Plate C1).

The survey area covers parts of several regional geological units; these include five Precambrian crystalline units, and six sedimentary basins: the Perth, Carnarvon, Officer, Eucla, Bangemall, and Nabberu Basins.

Topography within the area is dominated by the Great Western Plateau, an undulating peneplain whose height above sea level is generally in the range 400 to 600 m. Vegetation is sparse over most of the plateau, and rainfall varies from fair and regular in the west to low and unreliable in the east. Survey operations were, therefore, only rarely disrupted by bad weather, rugged topography, or thick vegetation.

Summaries of the geology of the area and of previous geophysical survey results were prepared largely from information available up to 1973. A description of survey methods and lists of statistics are included as appendixes.

Acknowledgement

I thank the staff of the BMR Cartographic Section who contributed to the drawing of the illustrations, and I. Zadoroznyj, who assisted in the reviews of the geology and previous geophysical results.

C2. GEOLOGY

The regional geological divisions are shown in Plate A2/C2. Information on boreholes in the sedimentary basins is given in Appendix C4.

Precambrian crystalline units

This review of the geology is based on papers by Prider (1965, 1970), Wilson (1969), and McCall (1972). Information on rock ages is extracted from works by Wilson, Compston, Jeffrey, & Riley (1960), Compston & Arriens (1968), and Arriens & Lambert (1969), and the names of tectonic units are those suggested by Daniels & Horwitz (1969).

The western part of the Precambrian shield contains the oldest known rocks in Australia: granites and gneisses older than 3000 m.y. crop out in extensive Archaean terrains which are mainly composed of rocks older than 2600 m.y. Geological reconnaissance and age dating have led to the division of the shield in Western Australia into a number of geotectonic provinces, each of which is characterised by some uniformity of structure, age, or general rock type. The subdivisions that lie wholly or partly within the survey area are the Yilgarn Block, the Albany-Fraser Province, the Northampton Block, the Gascoyne Block, and the Musgrave Block, which are described below.

Yilgarn Block. This block, one of the oldest parts of the shield, is characterised by linear northerly to northwesterly trending greenstone belts enclosed within a large expanse of granitic gneiss. The greenstone belts consist of complex associations of basic and ultrabasic volcanics and penecontemporaneous sills, overlain by clastic sediments and acid volcanics and intruded by massive granites. The block is intruded by easterly trending norite dykes of Archaean age in the east and by Upper Proterozoic basic dyke swarms in the west.

The geotectonic pattern and lithology of the greenstone belts vary from east to west across the Yilgarn Block. The pronounced linearity of the greenstone belts in the eastern part of the block gives way to a less regular disposition in the west, and, whereas ultrabasic volcanic and subvolcanic assemblages are found in the Eastern Goldfields area near Kalgoorlie, ultrabasics close to the western margin of the block tend to be coarsely crystalline serpentinised harzburgite and dunite. The greenstones near Mount Magnet are characterised by immense layered intrusions containing harzburgitic ultrabasic layers in various states of serpentinisation.

The lithological variation across the Yilgarn Block is reflected by the known distribution of nickel occurrences in Western Australia. All the important nickel deposits so far discovered are associated with the volcanics and shallow-level ultrabasic intrusives of the Eastern Goldfields; no substantial economic deposits have yet been found in association with the coarser-grained ultrabasics of the western half of the Yilgarn Block despite many promising sulphide shows.

McCall (1972) suggested that the changes from east to west across the Yilgarn Block reflect progressively deeper levels laid bare by erosion, and that, because of pressure controls on sulphide mineralisation, important nickel deposits are confined to the relatively high crustal zone in the eastern part of the block.

Albany-Fraser Province. Along the south coast of the western part of Western Australia, Precambrian rocks strike east-northeasterly, markedly discordant with the north-northwesterly trending structures in the adjoining Yilgarn Block. Farther east, the trend swings to the northeast and the province is separated from the Yilgarn Block by the northeasterly trending Fraser Fault. Rocks within the province are of Proterozoic age and are therefore substantially younger than the Archaean rocks of the Yilgarn Block.

At the northeastern end of the province, a linear belt of basic high-grade metamorphic rocks parallel to and southeast of the Fraser Fault, and an associated gravity ridge of unusually large magnitude and intensity, appear to extend for some distance into the survey area. Wilson (1969) studied the high-grade metamorphic rocks near the Fraser Range, and described them as 'basic pyroxene granulites, many of which appear to have been derived from basalts'. The granulites at Fraser Range have been cut by a flat-lying olivine gabbro sheet, the intrusion of which appears to have caused local destruction of the preferred crys-

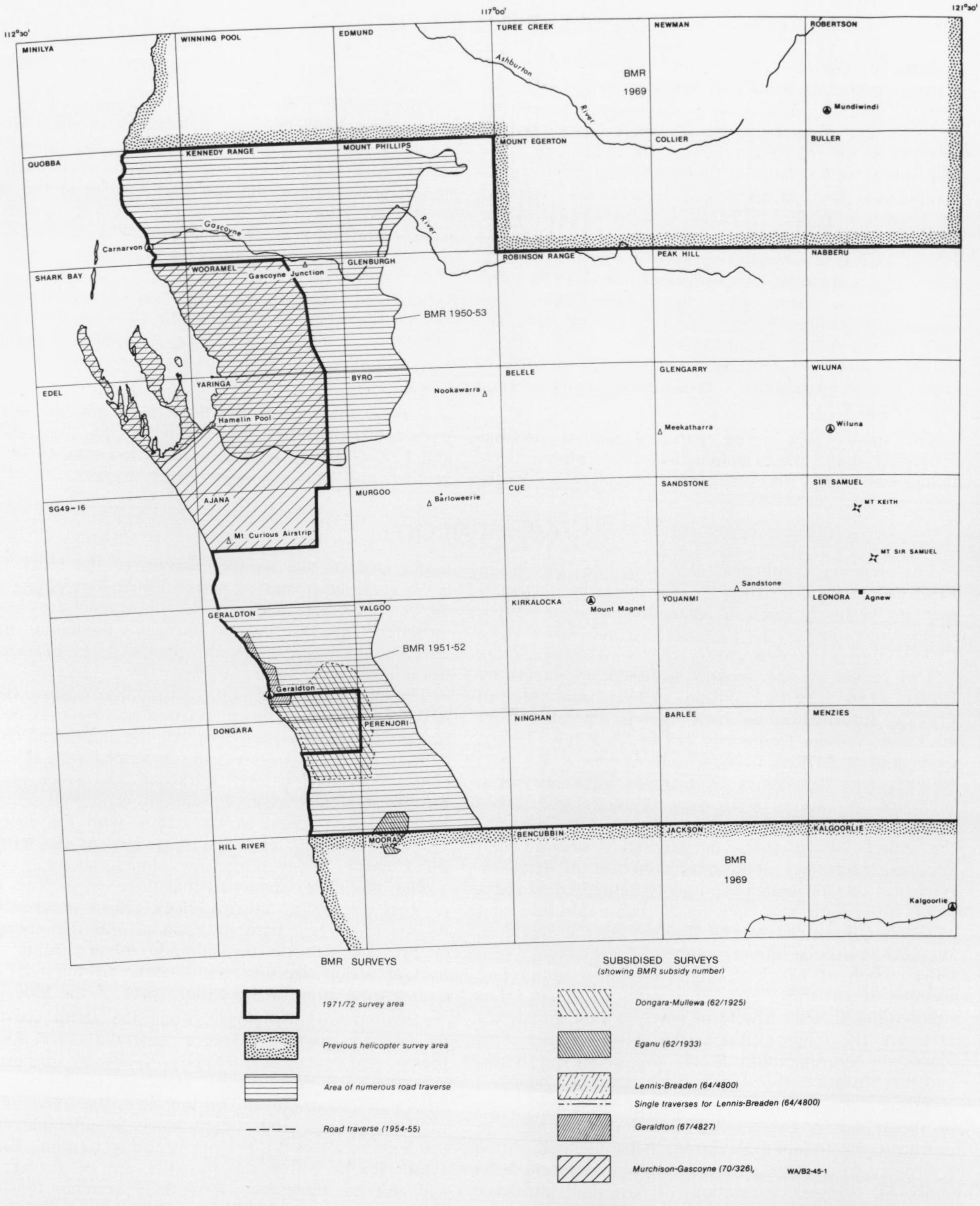
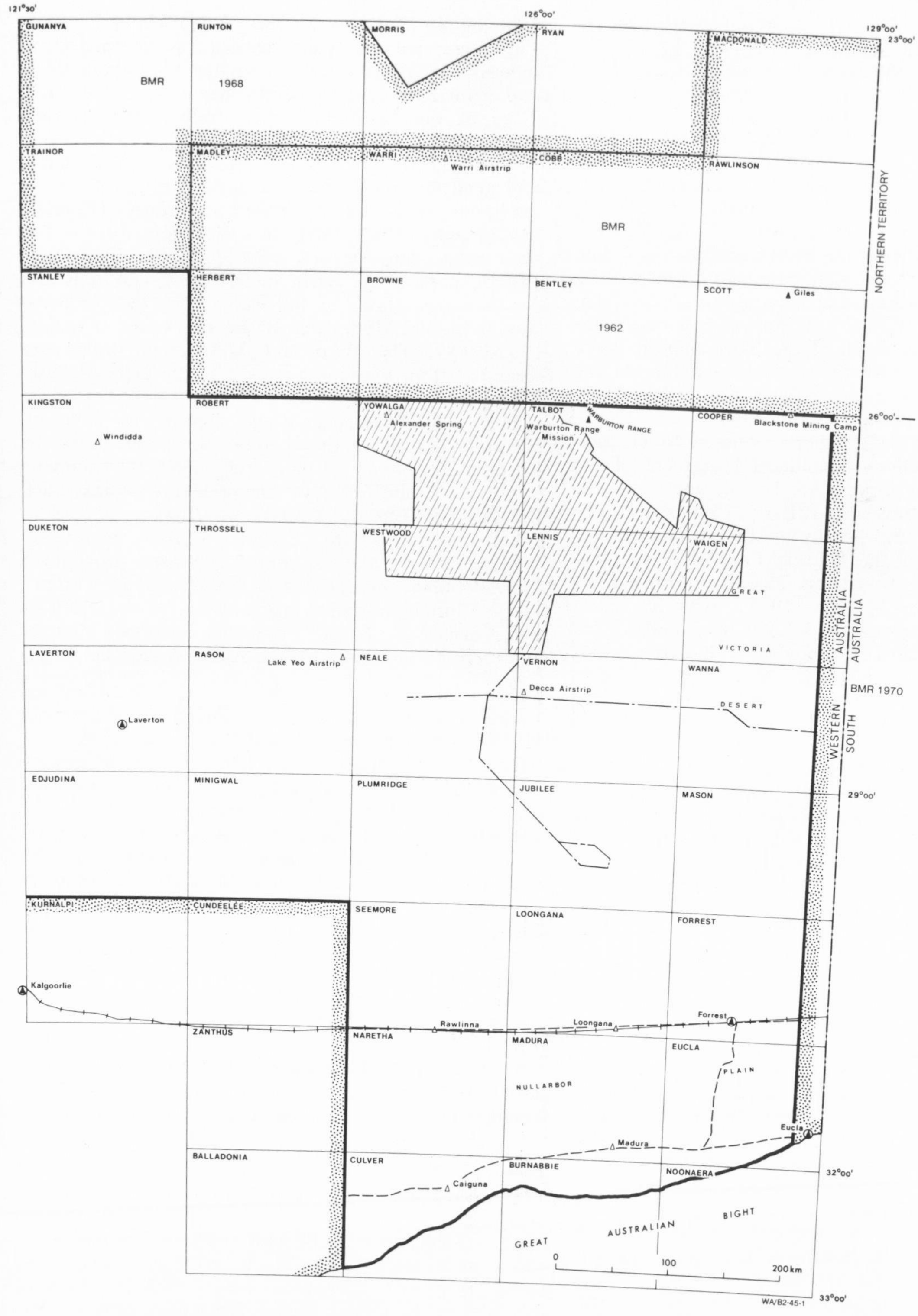


Fig. C1. Location of 1971-72 BMR gravity survey

tallographic orientation of the granulites. Minor structures in the granulites suggest that the Fraser Fault is reverse and southeasterly dipping, with a strong sinistral transcurrent component moving the east block northwards. The tectonic history of the metamorphic belt is unclear, but Arriens & Lambert (1969) have inferred from geochronological evidence that metamorphism was either short-lived, or prolonged but ceased abruptly. They concluded that the main geological alternatives consistent with these constraints are: (a) deposition of geosynclinal sediments, followed by orogenic deep-seated granulite-facies metamorphism and uplift, all within a few hundred million years, or (b) deep-seated and possibly prolonged reworking of older crustal rocks under granulite-facies metamorphism, ending with rapid uplift.

Northampton Block. This is a comparatively narrow strip of crystalline Precambrian rocks forming an outlying part of the shield along the western margin of the northern Perth Basin. It consists of a folded com-



and of previous BMR and subsidised gravity surveys.

plex of acid garnet granulites with minor basic bands of plagioclase-hornblende-pyroxene granulite. The rocks are believed to be the remains of greywackes metamorphosed to the granulite facies. There is no sign of granitic igneous activity. The granulites, estimated to be 1000 million years old, are cut by a northeast-trending dyke swarm.

Gascoyne Block. The Gascoyne Block extends into the northwestern part of the survey area. It is younger than the Yilgarn Block, and comprises mainly granites and metamorphosed sediments and volcanics of probable Early Proterozoic age.

Musgrave Block. The southwestern part of the Musgrave Block extends into the northeastern corner of the survey area. Proterozoic granites, high-grade metamorphic rocks, and basic dykes and sills are exposed in a few scattered inliers. The western part of the block is intruded by granite, and by the Giles Complex, which consists of four main gabbroic sheets each intruded separately. Transecting the block is the northeasterly trending Giles Discontinuity, thought by Horwitz, Daniels, & Kriewald (1967) to be a transcurrent fault.

Perth Basin

The onshore part of the Perth Basin extends from the south coast of Western Australia 950 km to the north; it ranges in width from 15 to 90 km and covers an area of 54 000 km^2. Only the northern part of the basin lies within the survey area.

The eastern margin is the prominent Darling Fault, which separates Precambrian basement from a thick half-graben of sediments that may be more than 7 km thick in the deeper parts. A subsurface basement ridge —the Beagle Ridge, south of the Northampton Block —is considered to mark the western boundary of the onshore part of the northern Perth Basin. The boundary between the Perth and Carnarvon Basins is ill-defined, but has generally been assumed to be near the Northampton Block. Significant movement of the Darling Fault began in the Late Triassic and continued throughout the Jurassic and Early Cretaceous. The magnitude of the steep gravity gradient which extends along the length of the Darling Fault indicates that the vertical throw is very large. This is confirmed from seismic evidence by Mathur (1974), who has computed the downthrow to be 7.5 km near Perth. This movement has resulted in a wedge of Palaeozoic and Mesozoic sediments, thickest in the east of the basin, with basement and sediments generally dipping east. The basin has a number of separate inner troughs and ridges which generally strike north.

The northern Perth Basin is dominated by normal northerly trending faults, usually along basement ridges; minor cross-faults are also present. The fault pattern creates a complexity of fault blocks which may have controlled sedimentation throughout the Mesozoic. Anticlinal features in the region are, therefore, the result of drapings of sediments over basement rises rather than compressional folding. A large north-northwesterly trending fault, the Urella Fault, is considered to form the eastern margin of a large trough, the Dandaragan Trough.

Carnarvon Basin

The Carnarvon Basin is an epicontinental basin of mainly Phanerozoic sediments extending on land from Onslow in the north to Geraldton in the south, and eastward from the coast for up to 200 km. Recent sand and alluvium obscure the landward margin of the basin in the north, but centrally in the east the boundary is the junction between Palaeozoic sediments and Precambrian igneous and metamorphic rocks. The southern margin is the poorly defined boundary between the Perth and Carnarvon Basins.

Early detailed geological investigations depicted the basin as a regional homocline of generally westerly dipping Palaeozoic and Mesozoic sediments. Steeply dipping contacts between Palaeozoic and Precambrian rocks were interpreted as faults or hinges resulting from stress in the basement, and the basin as a whole was considered to have evolved through large-scale tectonism (Condon, 1954). This view was modified after the interpretation of gravity data, in conjunction with seismic and drilling evidence, suggested that the Precambrian basement surface is irregular, and consists of a number of relatively deep troughs separated by narrow sinuous ridges (Chamberlain, Dooley, & Vale, 1954). Condon then (1956) proposed that most of the Palaeozoic/Precambrian contacts, originally described as faults, should be interpreted as depositional unconformities, and that the overall structure of the basin had been controlled by the pre-existing shape of the basement surface rather than by tectonism.

Aeromagnetic and seismic surveys have subsequently confirmed that the Carnarvon Basin consists of several sub-basins separated by basement ridges (Forsyth, 1960; Spence, 1961, 1962; Bow & Turpie, 1964). The main ridge, the Ajana-Wandagee Ridge, divides the onshore part of the basin meridionally and separates the Gascoyne Basin to the west, from the Coolcalalaya, Byro, and Merlinleigh Basins to the east (Condon, 1965-1968). The Byro and Merlinleigh Basins are separated from one another by a partly exposed basement ridge.

The Ajana-Wandagee Ridge appears to have influenced the distribution of Mesozoic sediments in the southern Carnarvon Basin: the northerly plunging Gascoyne Basin, west of the ridge, contains thick sequences of Tertiary, Cretaceous, Jurassic, and older sediments, whereas the Merlinleigh, Byro, and Coolcalalaya Basins to the east contain sediments no younger than Permian, except for a discontinuous Tertiary cover. Silurian sediments cropping out in the south of the Carnarvon Basin probably underlie younger sequences on both sides of the Ajana-Wandagee Ridge.

Nabberu Basin

This account is drawn from the work of Horwitz (1975) and Hall & Goode (1975).

The Nabberu Basin is an elongate basin of mainly Lower Proterozoic sediments. It extends in an east-southeasterly direction for at least 600 km along the northern margin of the Yilgarn Block. The sediments lie unconformably on a basement of Archaean granites and greenstones, and are unconformably overlain in the north by Adelaidean sediments of the Bangemall Basin. In the east, the Nabberu sediments are intruded by dolerite and are partly concealed beneath sediments of the Officer Basin.

The Lower Proterozoic rocks are gently dipping and unmetamorphosed in the south, but become increasingly more deformed and metamorphosed northwards across the basin. Large overturned folds accompany northerly dipping thrusts, and the sediments have been metamorphosed to a maximum grade of granulite facies.

Bangemall Basin

The Bangemall Basin is an easterly trending trough of Adelaidean sediments which lie unconformably on the Gascoyne Block in the west and Lower Proterozoic sediments of the Nabberu Basin in the east. The sediments are possibly continuous with a thick Proterozoic sequence in the Officer Basin. The survey area covers only the southern margin of the Bangemall Basin.

Officer Basin

This account is based on a report by Jackson (1971).

The Officer Basin is a deep, elongate structural depression covering an area of about 345 000 km^2, about three-fifths of which is in Western Australia. It is an intracratonic basin bounded by the Yilgarn Block and the Bangemall Basin in the west, the Musgrave Block and Canning Basin in the north and north-east, the Gawler Block in the southeast, and the Eucla Basin in the south. Jackson correlated the Proterozoic sediments in the Officer Basin with Proterozoic sediments in the Bangemall Basin, and inferred that the two basins may be continuous.

Owing to the lack of geological information, the boundaries of the basin are generally poorly defined, even where not obscured by Recent deposits. The sediments overlie a Precambrian basement which in most areas consists of igneous or metamorphic rock. Geophysical investigations indicate that the basin is asymmetrical in section—its deepest part lying close to its northern boundary; from here the basin gradually shallows southwards.

The western and eastern parts of the basin have contrasting sedimentary sequences. Geological and geophysical investigations suggest that the Officer Basin in Western Australia is composed of a Proterozoic sequence 5500 m thick capped by a thin veneer of Palaeozoic and Mesozoic rocks; five shallow holes drilled in the search for petroleum by Hunt Oil Company in 1965-66 all entered rocks believed to be of Proterozoic age at depths less than 450 m. The Officer Basin in Western Australia is, therefore, considered to be composed mainly of Proterozoic rocks. In contrast, Krieg (1969) described the eastern Officer Basin of South Australia as being composed of a Palaeozoic sequence 4000 m thick overlying a Proterozoic sequence only 900 m thick; a deep stratigraphic well in the eastern Officer Basin (Munyarai No. 1) drilled by Continental Oil Company of Australia Ltd (1969) penetrated 2890 m of sediments no older than Silurian.

Eucla Basin

This account is derived largely from a report by Lowry (1970).

The Eucla Basin is a large arcuate basin covering about 176 000 km^2 onshore and over 100 000 km^2 offshore. In Western Australia it occupies about 133 000 km^2 onshore and more than 50 000 km^2 offshore. It is bounded to the west by the Albany-Fraser Province, to the east by the Gawler Block, and to the north by the Officer Basin. The southern boundary is on the continental shelf in the Great Australian Bight and has not yet been delineated. Most of the basin is occupied by a Tertiary limestone plateau that slopes gently seawards from an altitude of about 240 m in the north to 60 to 120 m in the south. The plateau grades northwards into the Great Victoria Desert, and in the south terminates abruptly in wave-cut limestone cliffs. The uniformity of the limestone succession largely accounts for the featureless nature of the Nullarbor Plain.

The basin is thought to have been formed by subsidence of parts of the Precambrian shield. It is unusually shallow for a basin of such large areal extent; the average onshore thickness is considered to be less than 600 m. Lowry (1970) noted that the Eucla 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 in the Cretaceous, Eocene, and early Miocene was followed by uplift, slight tilting, and minor faulting.

Boreholes in widely separated parts of the Eucla Basin in Western Australia have encountered crystalline basement rocks at depths less than 600 m. Analyses of core samples from these boreholes suggest that the basement is composed of Precambrian granite and gneiss similar to those along the southeast margin of the Yilgarn Block (Peers & Trendall, 1968).

C3. PREVIOUS GEOPHYSICAL RESULTS

Numerous geophysical surveys have been made within the survey area by BMR, the Geological Survey of Western Australia, mining companies, and oil exploration companies. Consideration is given only to those surveys from which information is readily available and which could have some bearing on regional gravity interpretation. These surveys are listed in Appendix C3. Their locations are shown in Figures C1, C2, and C3. The major results are as follows:

Gravity surveys

Previous gravity surveys have been made in the Perth and Carnarvon Basins by BMR, West Australian Petroleum Pty Ltd, and Barewa Oil and Mining NL; over part of the Officer Basin by Hunt Oil Company; and across the Eucla Basin by BMR. Gravity, in association with magnetics, has helped to define the margins and internal structures of the Perth and Carnarvon Basins. A broad low gravity feature in the Officer Basin was assumed to be the expression of a thick sedimentary sequence. Gravity relief in the Eucla Basin was attributed mainly to basement density variations (Gunson & van der Linden, 1956).

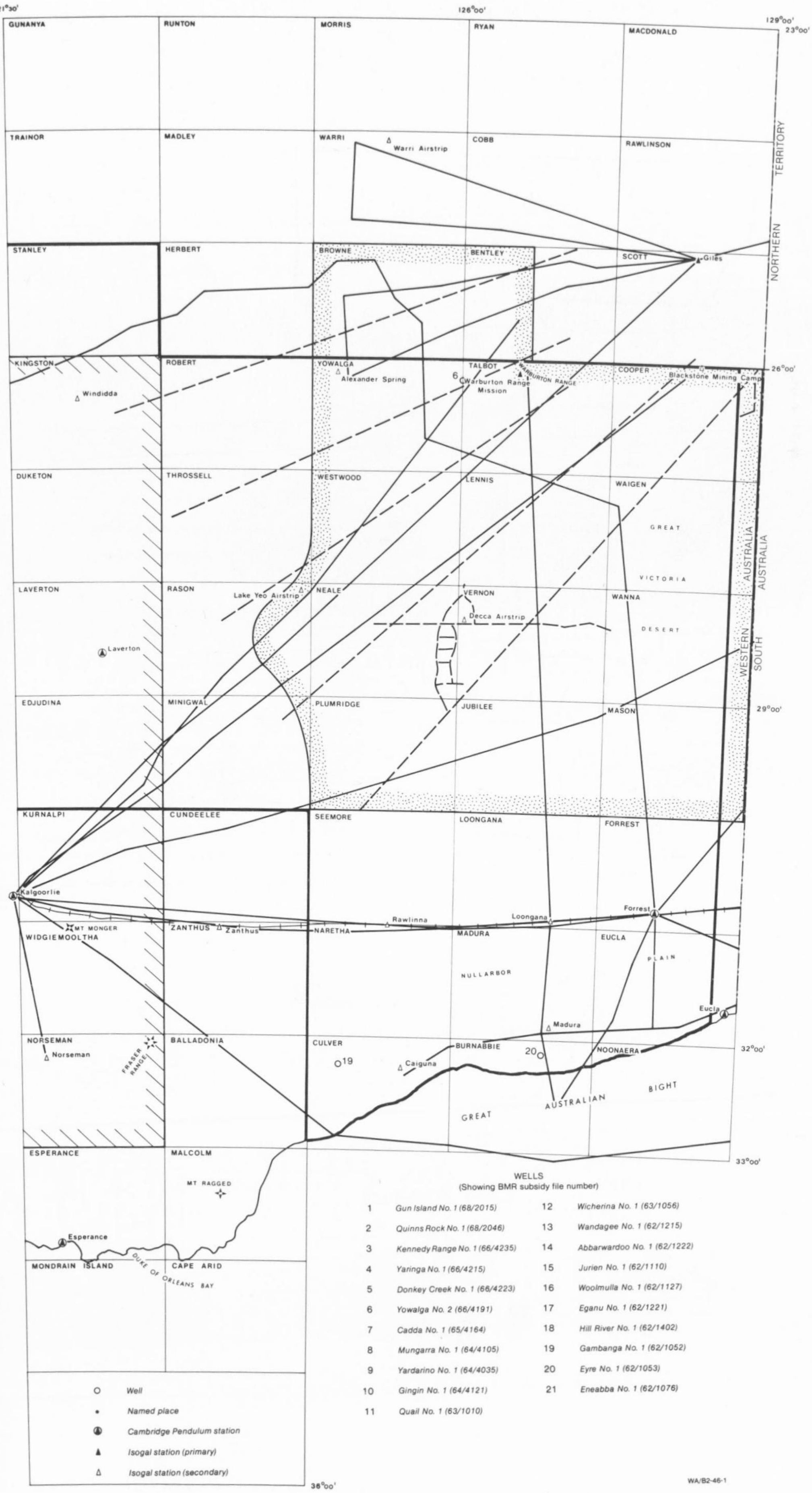
Magnetic surveys

Most of the regional aeromagnetic surveys in the survey area have been carried out by BMR. The whole of the Carnarvon Basin was surveyed between 1956 and 1961, and in 1957 the Perth Basin south of Geraldton was surveyed. From the results of these surveys, contours of depth to magnetic basement were drawn, and faults, basement ridges, and troughs in the two basins were delineated. Offshore aeromagnetic surveys —west of the northern Perth Basin by West Australian Petroleum Pty Ltd, and west of the Carnarvon Basin by Tasman Oil Pty Ltd—defined a number of troughs and ridges.

BMR aeromagnetic surveys also covered a number of adjoining 1:250 000 Sheet areas in the Yilgarn Block. These areas are: BARLEE, MENZIES, EDJUDINA, LEONORA, LAVERTON, SIR SAMUEL, DUKETON, SANDSTONE, YOUANMI, BELELE, CUE, KIRKALOCKA, BYRO, MURGOO, YALGOO, GLENGARRY, WILUNA, and KINGSTON. Magnetic contours are closely related to structures in the greenstone belts, as magnetite-rich banded iron formations are interbedded with the clastic sediments and layered intrusions of which the greenstone belts are composed. The contour maps indicate a predominant north-northwesterly trend and a subsidiary easterly trend; the lattter has been attributed to basic dykes occupying fissures produced by easterly cross-folding.

A small land magnetic survey by Hunt Oil Company in eastern NEALE helped to resolve the source of a large gravity anomaly observed during an earlier gravity survey by Hunt Oil Company. The gravity and magnetic features were attributed to a fault-bounded basement platform capped by dense sedimentary rocks.

Fig. C2. Previous BMR and



subsidised magnetic surveys and wells.

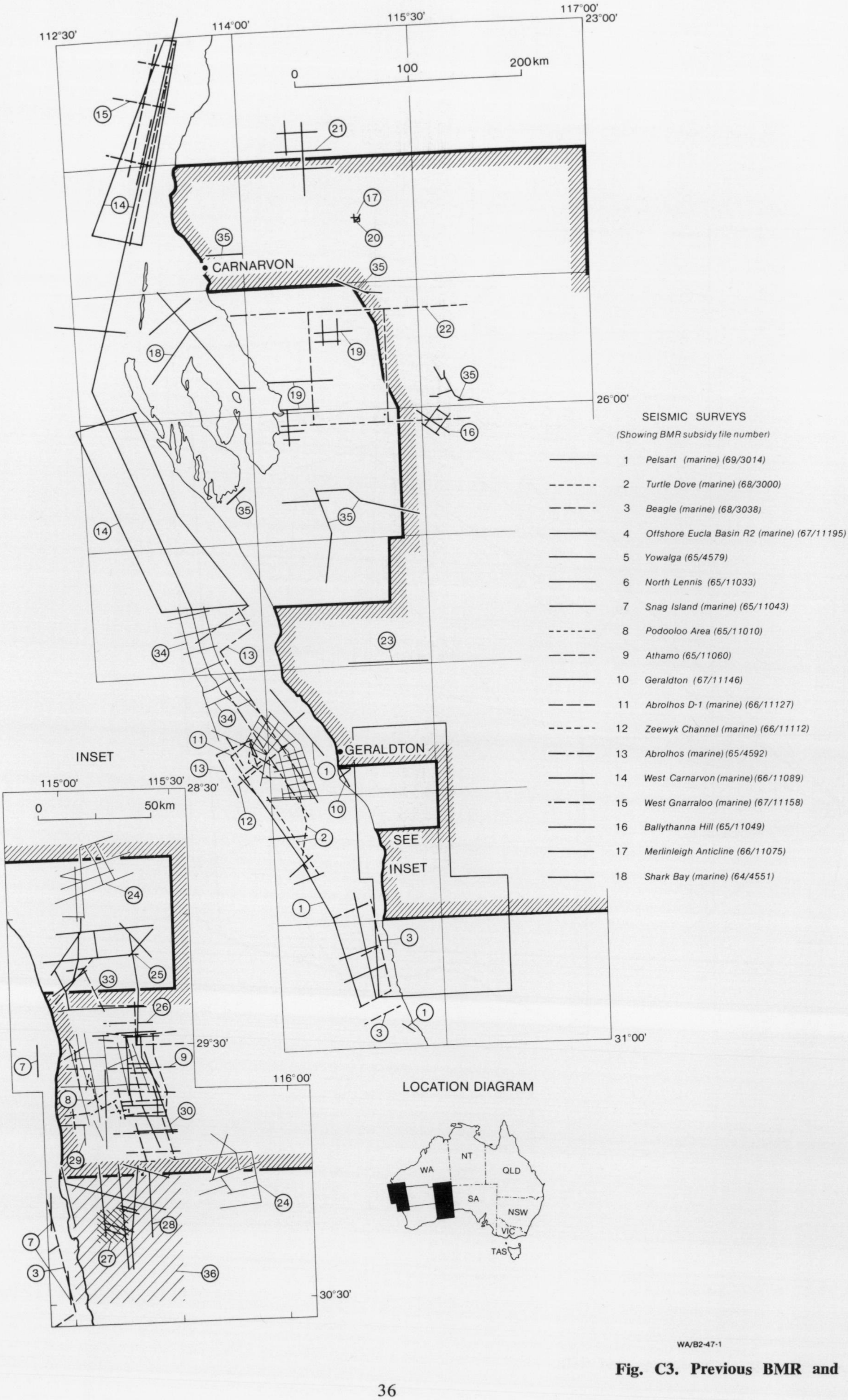
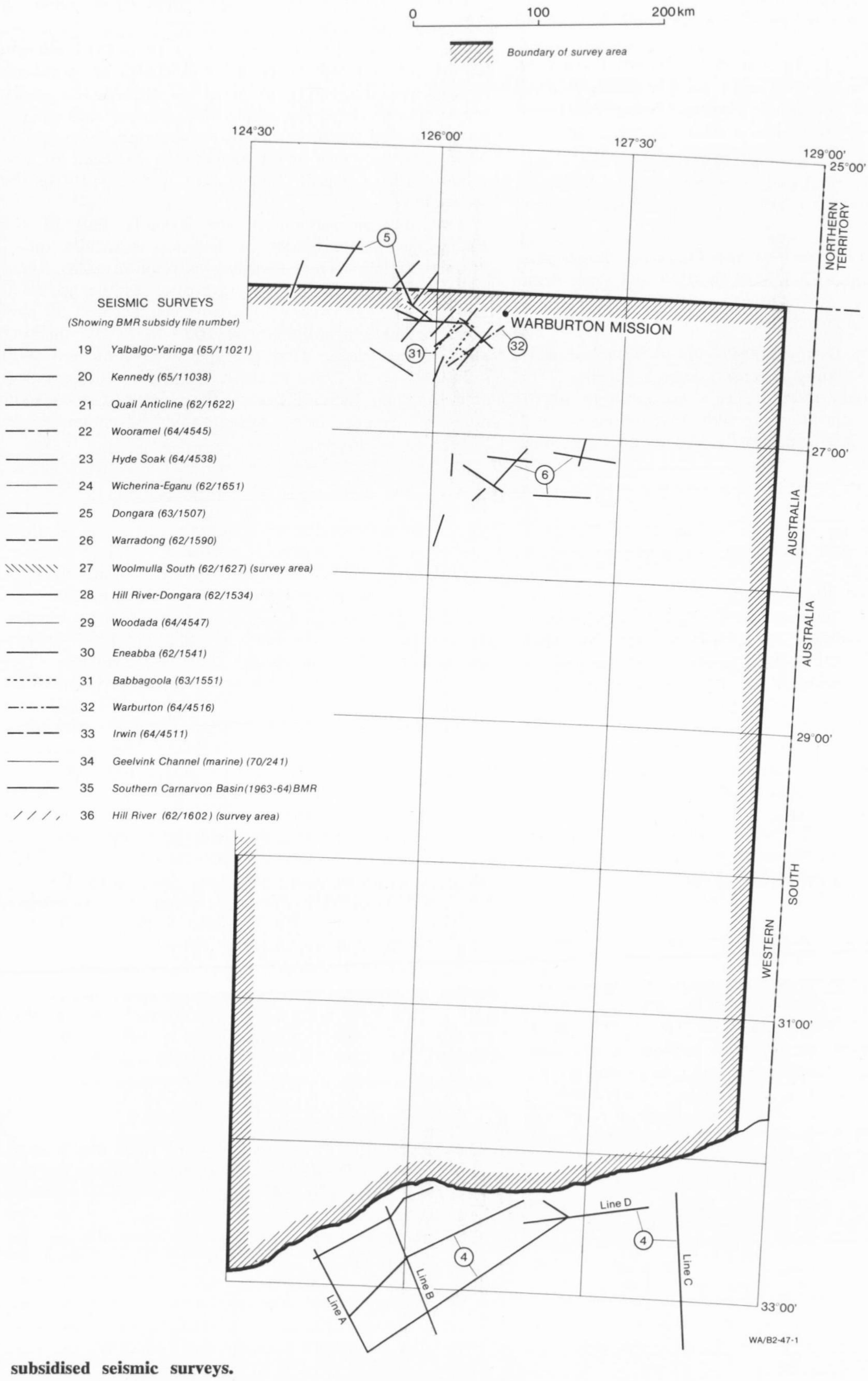


Fig. C3. Previous BMR and



subsidised seismic surveys.

Seismic surveys

In the search for structures favourable for the accumulation of hydrocarbons, numerous seismic surveys have been made in the four Phanerozoic sedimentary basins within the survey area.

Most of the subsidised seismic surveys in the Perth and Carnarvon Basins have covered small areas, and have only minor relevance to regional gravity interpretation. They indicate that the southern Carnarvon Basin and northern Perth Basin are complexly faulted, the majority of anticlinal closures being associated with faulting.

A BMR seismic survey in 1963 covered three subbasins of the south Carnarvon Basin. The following general conclusions are from two unpublished reports of this survey.

(1) The western part of the Gascoyne Basin may contain up to 5 km of Silurian and Ordovician sandstone and limestone (Bow & Turpie, 1964).

(2) The Byro Basin contains up to 3 km of sediments, including at least 1 km of Permian. The predominant structure is a northerly to northeasterly trending syncline that extends to a depth of 3 km and is flanked by two anticlinal structures which are probably associated with basement ridges (Turpie, 1964).

(3) The Coolcalalaya Basin contains about 3 km of sediments (Bow & Turpie, 1964).

(4) The Ajana-Wandagee Ridge underlies sediments 1 to 2 km thick and may represent the westward limit of Permian deposition (Bow & Turpie, 1964).

Hunt Oil Company conducted four seismic surveys in the western Officer Basin in 1963-65. A good reflector was mapped over most of the survey areas, while another reflector, about 0.5 s below and unconformable with the first, was also mapped in YOWALGA and LENNIS. The upper reflector is believed to correlate with a basalt layer interbedded with clastic sediments.

Two marine surveys in the offshore part of the Eucla Basin were made for Tenneco Australia Incorporated in 1967. Data quality was poor in areas where sediments were absent, but improved as the sedimentary sequence thickened. The surveys revealed an average thickness of only about 1000 m in the offshore part of the basin. Two troughs were indicated with sediments up to 2000 m thick. The sediments are notable for their lack of prospective features; even sedimentary drapes over topographic basement highs appear to be absent.

C4. DESCRIPTION AND INTERPRETATION OF GRAVITY RESULTS

Bouguer anomaly contours are shown in Plate C1. Survey statistics and procedure are given in Appendixes C1 and C2.

A rock density of 2.2 g/cm^3 was chosen for computing Bouguer corrections. This density is intermediate between values adopted for gravity surveys over sedimentary basins, and values adopted for surveys of hardrock areas; discontinuities between contours from one survey and those of a previous survey to which they are tied are therefore minimised.

No attempt has been made to apply terrain or isostatic corrections to the Bouguer anomalies. The former are not considered necessary since the terrain is flat or undulating over almost the entire survey area, and, to apply isostatic corrections, doubtful assumptions would have to be made about the manner in which isostatic compensation is achieved.

Gravity provinces

The contoured area has been divided into 15 regional gravity provinces to assist interpretation. Gravity provinces cover large areas of fairly simple shape in which the gravity field is characterised by uniform contour trend, Bouguer anomaly level, or degree of contour disturbance. Where appropriate, provinces are subdivided into units, which are similar to provinces but generally occupy smaller areas. The nomenclature of gravity features is briefly explained in Part A of this Bulletin (pp. 6-7). Table C1 lists the names of all provinces wholly or partly within the survey area.

Each gravity province is discussed in relation to geology, previous geophysical results, and tectonic setting. The Geological Map of Western Australia, 1966, has been used to correlate the gravity features with outcropping rock units.

Carnarvon Regional Gravity Complex

The northern part of this province is defined by Fraser (this volume, Part B). It is characterised by high-amplitude medium-wavelength variations in Bouguer anomaly and a general northerly trend of contour.

Within the survey area, the province is bounded in the east by gradients towards lower Bouguer anomaly areas; its southern and western boundaries lie beyond the coastline and will remain undefined until gravity results from the continental shelf are available. The main features are a strong positive northerly trending gravity spur in the south of the province, and two broad depressions farther north. The northerly prolongation of the spur is a narrow ridge of elevated Bouguer anomalies which can be traced over the entire length of the province. The ridge bifurcates in eastern WOORAMEL, and the divergent limbs partly enclose the easternmost of the two gravity depressions. The province can be divided into several units (Plate C1); within the survey area, these are the *Ajana Gravity Spur,* the *Wandagee Gravity Ridge,* the *Gascoyne Gravity Depression,* the *Merlinleigh Gravity Depression,* and the *Edmund Gravity Shelf.*

Chamberlain & others (1954) have interpreted the results of regional gravity traverses over the central part of the province. Their main conclusion is that gravity relief relates principally to variations in sedimentary thickness rather than to lateral changes of basement density. Corroborative evidence for this is provided by the results of both this—1971-2—and past surveys, and is as follows:

(1) Eastwards from the axis of the Merlinleigh Gravity Depression, Bouguer anomaly values rise towards the Precambrian outcrop.

(2) Precambrian inliers are associated with gravity maxima. This is particularly noticeable in the Ajana Gravity Spur, where a closed Bouguer anomaly maximum exceeding +50 mGal coincides with a large exposure of Precambrian metamorphics. Local gravity maxima are also associated with Precambrian inliers in the wes-

TABLE C1. GRAVITY PROVINCES

Province	*Derivation of name*	*BMR gravity survey in which province first defined*	*Reference*
Carnarvon Regional Gravity Complex	Town	Carnarvon Basin, 1953	Chamberlain & others (1954)
Perth Regional Gravity Low	City	Perth Basin, 1951-52	Thyer & Everingham (1956)
Erabiddy Regional Gravity High	Range	New	
Narembeen Regional Gravity Shelf	Town	Southwest Western Australia, 1969	Fraser (this volume, Part A)
Teano Regional Gravity Low	Range	Northwest Western Australia, 1969	Fraser (this volume, Part B)
Austin Regional Gravity Complex	Lake	New	
Carey Regional Gravity Complex	Lake	New	
Ashburton Regional Gravity Ridge	River	Northwest Western Australia, 1969	Fraser (this volume, Part B)
Yeo Regional Gravity Shelf	Lake	New	
Rason Regional Gravity Low	Lake	Southwest Western Australia, 1969	Fraser (this volume, Part A) has combined the earlier defined provinces, the Gibson Gravity Depression, to the north (Lonsdale & Flavelle, 1968), and the Dundas Regional Gravity Depression, to the south (Fraser, 1974)
Fraser Regional Gravity Ridge	Range	Southwest Western Australia, 1969	Fraser (this volume, Part A)
Blackstone Regional Gravity Ridge	Range	Amadeus and south Canning Basins, 1962	Lonsdale & Flavelle (1968)
Eyre Regional Gravity Complex	Hamlet	Southwest Western Australia, 1969	Fraser (this volume, Part A); old name: Gambanga Regional Gravity Low (Fraser, 1974)
Wanna Regional Gravity Low	Lakes	New	
Officer Regional Gravity Low	Officer Basin	Western South Australia, 1970	Pettifer & Fraser (this volume, Part D)

tern part of GLENBURGH and near the junction of KENNEDY RANGE and MOUNT PHILLIPS.

(3) Low gravity features that are similar in shape, area, and amplitude to the Gascoyne and Merlinleigh Gravity Depressions are absent over the shield rocks immediately adjacent to the sediment-covered area.

The assumption of uniform basement density under the sediment-covered area led Chamberlain & others (1954) to interpret gravity depressions and ridges as the expressions of sedimentary troughs and basement ridges respectively. This interpretation was subsequently vindicated by reflection seismic evidence (Bow & Turpie, 1964) which showed that sediments are 5000 m thick in the southern Gascoyne Basin along latitude 26° 40′E, but only 2000 m thick over the basement ridge to the east, where Bouguer anomaly values are about 25 mGal higher. The required density contrast between basement and sediments to produce this difference in Bouguer anomaly level is calculated to be about 0.2 g/cm^3, assuming that the vertical relief of the basement ridge is small compared with its transverse horizontal extent.

The units as defined relate to structural features, most of which were originally defined from the results of the earlier gravity survey. The Ajana Gravity Spur corresponds to the Northampton Block of Upper Proterozoic granulites; the Wandagee Gravity Ridge to the Ajana/Wandagee Ridge; the Gascoyne and Merlinleigh Gravity Depressions to relatively deep sedimentary troughs, the Gascoyne and Merlinleigh Basins respectively; and the Edmund Gravity Shelf to part of the Gascoyne Block.

Perth Regional Gravity Low

Only the northern part of this province lies within the survey area. The southern part was first identified and described by Thyer & Everingham (1956) from results of regional gravity traverses. The province is a narrow, elongate, north-trending trough of strongly negative Bouguer anomalies and is bounded to the east and west by steep gradients. It extends as a continuous feature between AUGUSTA in the south and GLENBURGH in the north, where it terminates against a gravity saddle.

The province is the combined gravity expression of the Perth, Coolcalalaya, and Byro Basins. The steep gradient along its eastern margin coincides with the fault zone separating basin sediments from exposed shield rocks to the east. The continuity of minimum gravity level across supposed inter-basin boundaries indicates that the Coolcalalaya and Byro Basins may be sub-basins of the Perth rather than the Carnarvon Basin.

Within the survey area, the province can be divided into three units, each of which corresponds to a sub-basin of either the Perth Basin or the Carnarvon Basin. Exceptionally low Bouguer anomaly values in the *Watheroo Gravity Depression* may relate to thick sediments of the Dandaragan Trough, which is one of the deepest parts of the Perth Basin. A steep gradient that defines the eastern margin of the unit in the south follows the Urella Fault, not the Darling Fault, confirming previous indications that the vertical throw of the Urella Fault exceeds that of the Darling Fault in this area. The steep gradient diverges eastwards from the Urella Fault in the north of the unit and rejoins the Darling Fault. The province becomes narrower to the north, and the *Coolcalalaya Gravity Low* is a tenuous, steep-sided gravity trough flanked on both sides by positive anomaly zones. The unit is correlated with the Coolcalalaya Basin of predominantly Palaeozoic sediments. Gradients are steepest along the eastern unit margin, where the basin wall is probably the near-vertical Darling Fault plane. To the west, gentler gradients appear to reflect a gradual shallowing of the basin floor from the deepest part of the basin, which is close to the Darling Fault Zone, towards outcropping or near-surface Precambrian rocks.

Depth to basement in the Coolcalalaya Basin has been estimated from seismic results to be about 3000 m (Bow & Turpie, 1964). This is 1000 m shallower than the adjacent part of the Gascoyne Basin, where, paradoxically, the Bouguer anomaly level is about 30 mGal higher. Two alternative explanations are offered:

(1) The overall density of sediments is lower in the Coolcalalaya Basin than in the Gascoyne Basin.

(2) The density of the basement is lower under the Coolcalalaya Basin than under the Gascoyne Basin.

If the basement is of the same density under both the Gascoyne and Coolcalalaya Basins, then the bulk density of sediments in the Gascoyne Basin would have to be 0.2 to 0.3 g/cm^3 greater than in the Coolcalalaya Basin, in order to produce the observed gravity level difference (basement/sediment density contrast in the Gascoyne Basin is taken as 0.2 g/cm^3). As this seems unlikely on geological grounds, the second alternative is favoured: a basement density contrast between the two basins of 0.2 g/cm^3 extending to a depth of 10 km would produce a gravity level difference of the right order of magnitude. The density contrast between intrusive granite and high-grade metamorphic rock could conceivably be 0.2 g/cm^3. Considerations of the gravity field over the Precambrian shield give further support to the second alternative: the Yilgarn Block is rimmed on its southern, southeastern, and northern margins by elongate gravity depressions, which must be associated with mass-deficient Precambrian rocks as they extend across large tracts of the exposed shield and in some areas correlate with outcropping granite. As the Perth Basin, like the elongate gravity depressions, is peripheral to the Yilgarn Block, the Precambrian basement beneath the basin may conceivably be of unusually low density. It is pertinent that the Perth Regional Gravity Low swings eastwards at its northern end and appears to wrap around the northwest corner of the Yilgarn Block. It then connects across a gravity saddle with a major peripheral gravity depression over Precambrian rocks. The foregoing considerations suggest that negative anomalies over the Perth Basin may be only partly attributable to light Phanerozoic sediments and that a component of the gravity trough relates to low-density rocks within the Precambrian basement.

The *Byro Gravity Low*, the northernmost unit of the Perth Regional Gravity Low, can be correlated with the Byro Basin. It is a northeasterly trending gravity depression bounded to the northwest and southeast by steep gradients. These gradients are associated with faults which form the boundaries of the Byro Basin. Continuity of contour trend between the Coolcalalaya and Byro Gravity Lows indicates that the Coolcalalaya and Byro Basins are connected and are not separated by a basement ridge as inferred by Condon (1965). The total Bouguer anomaly change across each of the two units is about the same, suggesting that the Coolcalalaya and Byro Basins are of about the same depth. This agrees with seismic evidence, which shows that the thickness of sediments in the two basins is about 3000 m (Bow & Turpie, 1964; Turpie, 1964).

Erabiddy Regional Gravity High

This is a newly defined province adjacent to and east of the Perth Regional Gravity Low. It is characterised by a comparatively high Bouguer anomaly level, northerly to northeasterly contour trends, and fairly gentle gravity relief. Bouguer anomalies decrease from positive in the west to about —35 mGal at the eastern province boundary.

The province extends over the northwestern part of the Yilgarn Block and overlying Proterozoic metasediments. In the west, elongate Bouguer anomaly maxima parallel to the margins of the Coolcalalaya and Byro Basins roughly coincide with elongate outcrops of Proterozoic metasediments. The gradual rise in Bouguer anomaly from east to west across the province may relate to an increasing abundance of basic dyke swarms or to an increase in grade of metamorphism, or both. Isostatic effects may also contribute to the Bouguer anomaly rise because the province is close to the continental margin.

Apart from the narrow residual highs along the western province boundary, there is only one local gravity feature of amplitude greater than 10 mGal. This is a gravity high in northern MURGOO, which coincides with an Archaean basic igneous outcrop.

Narembeen Regional Gravity Shelf

Only the northern extremity of this province extends into the survey area. It is described and discussed in detail by Fraser (this volume, Part A).

Teano Regional Gravity Low

The northern part of this province is defined by Fraser (this volume, Part B). It is a broad easterly trending gravity trough bounded by fairly steep gradients in the south and gentler gradients in the north. The province is separated from the Carnarvon Regional Gravity Complex to the west by a gravity ridge, but connects across a saddle with the Perth Regional Gravity Low. In the east the province becomes narrower and appears to terminate in the northwest corner of NABBERU.

The province flanks the northern Yilgarn Block and correlates in part with metamorphic rocks of the Gascoyne Block and the northwestern Nabberu Basin. As metamorphic areas are commonly associated with regional gravity highs, it is inferred that the source of the gravity depression is deep crustal or subcrustal rather than near-surface. The province may correspond to a zone of Proterozoic crustal thickening as a result of severe tectonic activity between the Yilgarn and Pilbara Blocks. The province is adjacent and roughly parallel to the Ashburton Regional Gravity Ridge, and is therefore analogous to the Rason Regional Gravity Low, which extends adjacent and parallel to the Fraser Regional Gravity Ridge along the eastern margin of the Yilgarn Block.

Austin Regional Gravity Complex

This is a newly defined province whose relief is characterised by elongate residual highs, mainly northerly trending, superimposed on a gravity surface which shows a regional northeasterly decrease from —40 mGal in the southwest to —80 mGal in the northeast of the province. The province abuts the Teano Regional Gravity Low to the north, and the Erabiddy Regional Gravity High to the west; it extends southwards into the area surveyed in 1969 (Fraser, this volume, Part A).

The province covers a large area of the western part of the Yilgarn Block. Residual highs can generally be correlated with greenstone outcrops; the low Bouguer anomaly areas between the residual highs correspond to granite or gneiss. The regional Bouguer anomaly decrease to the northeast across the province has no evident surface cause, and may relate to a change in the deep crust, such as crustal thickening, or to a change in the average composition or grade of metamorphism of the rocks.

A predominant northerly trend, apparent in the Bouguer anomaly contours, is not reflected in the outcrop pattern of the greenstones in this area. A north-northwesterly trend of the greenstones (Plate A2/C2), which is prevalent in the eastern part of the Yilgarn Block, is also present in the area covered by the Austin Regional Gravity Complex, but a detailed examination of the relation between gravity contours and regional geology reveals that parts of greenstone outcrops elongated in a north-northwesterly direction (e.g., in SANDSTONE, YOUANMI, and BARLEE) have no associated gravity expression. This indicates either that geological mapping is inaccurate, or that the greenstone belts with a north-northwesterly orientation are surficial or of small density contrast with the enclosing rocks.

Carey Regional Gravity Complex

This province is characterised by elongate northerly to northwesterly trending residual highs and lows. The residual highs are longer, have a different overall trend, and are of smaller amplitude and intensity than residual highs in the Austin Regional Gravity Complex, and it is on these criteria that the two provinces are differentiated. The southern part of the province lies within the area surveyed in 1969, where it includes a broad region of disturbed Bouguer anomaly extending north-northwestwards across KALGOORLIE, KURNALPI, and WIDGIEMOOLTHA (Fraser, this volume, Part A). The western province boundary follows a line of gravity highs which can be traced with varying degrees of confidence from Norseman to north of Wiluna. The eastern province boundary is less clearly definable, but is drawn so as to separate the province from an area of more quiescent gravity field to the east.

Residual gravity highs and intervening areas of low Bouguer anomaly are respectively associated with greenstone belts and enclosing granitic gneisses. Many high gravity features are not precisely coextensive with greenstone outcrop, indicating that the greenstone bodies may vary appreciably in depth or density from place to place. High-grade metamorphic rocks shown on the 1966 Geological Map of Western Australia in western LEONORA and elsewhere in the province have no perceptible gravity expression and must therefore have a density close to the average for this area of the shield.

Correlations between the gravity results and surface geology are difficult in the north of the province, where the Archaean rocks are largely obscured by Lower Proterozoic sediments of the Nabberu Basin. A large triangular gravity high occupying the northwest corner of the province is coextensive with a Lower Proterozoic salient of sediments intruded by gabbroic sills. This suggests that the Proterozoic sequence is either denser than granite and of fairly substantial thickness, or is underlain by dense Archaean greenstone. The depth to magnetic basement in the northeast of GLENGARRY, within the area of high gravity, has been estimated to be about 600 m (Lambourn, 1972). A Proterozoic sequence of this depth would contribute only about 4 mGal to the gravity relief, assuming that its bulk density was 0.15 g/cm^3 greater than the underlying Archaean basement. However, as the Proterozoic/Archaean contact is associated with consistent Bouguer anomaly gradients, and the shape and areal extent of the high gravity feature are unlike those of the gravity highs produced by the greenstone belts farther south, it seems logical to interpret the triangular gravity high as the expression of the Proterozoic sequence, a local maximum in the southwestern part being caused by underlying greenstone. The Proterozoic sequence would have to contain a high proportion of basic igneous rocks and be substantially thicker overall than 600 m as estimated in northeastern GLENGARRY. As the sequence does contain layered basic intrusions, the measured magnetic basement could be much shallower than Archaean basement, and the depth estimate of 600 m would be a misleadingly small value for the total thickness of the sequence.

Parts of the Nabberu and Bangemall Basins cover most of NABBERU, STANLEY, and KINGSTON, in the northeastern part of the province. The depth to magnetic basement has been estimated at 200 to 600 m in central KINGSTON and 2200 m in northeast KINGSTON (Lambourn, 1972). In spite of this considerable variation in thickness of the Proterozoic sequence, gravity relief is attributed mainly to lateral density changes in the Archaean basement. This is suggested by the similarity of gravity pattern between the Proterozoic-covered area and the Archaean granite/greenstone terrain farther south, the continuity of gravity trends across the Proterozoic/Archaean boundary, and the approximate coincidence of the southern part of a gravity high in KINGSTON with a greenstone outcrop south of and adjacent to the Proterozoic sediments.

Comparison between the Austin Regional Gravity Complex and the Carey Regional Gravity Complex. The contrast in gravity pattern between the Austin Regional Gravity Complex and the Carey Regional Gravity Complex relates essentially to differences in both the geometry of the greenstone belts and the density contrast of the greenstone belts with the surrounding granites between the western and eastern parts of the Yilgarn Block. These differences are summarised as follows:

(1) The density contrast of the greenstone belts with the surrounding granites and gneisses is greater in the western than in the eastern Yilgarn Block.
(2) The greenstone belts in the west are generally elongated in a northerly direction, whereas the eastern greenstone belts are aligned along north to northwest axes.
(3) The western greenstone belts are short and disjointed compared with the longer, more-linear belts in the east.

Recent geological evidence is significant with respect to the two provinces. At Jones Creek (SIR SAMUEL), close to the boundary between the two gravity provinces, Durney (1972) has mapped a major unconformity in the Archaean, in which a granitic conglomerate at the base of a greenstone succession (exposed to the east) rests with angular discordance on older granite and greenstone (exposed to the west). The strike of the unconformity, although mapped over only a small north-south distance, is parallel to a line of gravity highs along the western margin of the Carey Regional Gravity Complex. It is suggested that this line of gravity highs corresponds to the westernmost of a series of younger greenstone belts in the Eastern Goldfields, and that the boundary between the Austin Regional Gravity Complex and the Carey Regional Gravity Complex roughly coincides with a major unconformity separating older, lower-level greenstones to the west from younger volcanic and subvolcanic greenstones in the east.

The contention that the boundary between the two gravity provinces is the locus of a major geological change is supported by the known distribution of important mineral occurrences in the Yilgarn Block. The boundary between the Austin Regional Gravity Complex and the Carey Regional Gravity Complex quite closely corresponds to the western boundary of the main nickel province in Western Australia: it passes just west of deposits at Mount Keith, Mount Sir Samuel, Agnew, and Widgiemooltha.

Several alternative tectonic processes could explain the present mass distribution, as deduced from gravity, in the Eastern Goldfields. Of these, two are suggested which could have resulted in a major unconformity between the Eastern Goldfields and the area to the west:

(1) Downwarping of the eastern part of the Yilgarn Block along a hinge, and deposition of thick younger greenstone sequences unconformably on the older basement, followed by isoclinal folding of the sequences along northerly to northwesterly axes.

(2) Welding of alternately volcanic-rich and sediment-rich belts on to the margin of a pre-existing cratonic nucleus (the western part of the Yilgarn Block) by a process of lateral accretion.

Ashburton Regional Gravity Ridge

Only the southeastern tip of this province extends into the survey area. The province has been described and discussed by Fraser (this volume, Part B) and will not be considered here.

Yeo Regional Gravity Shelf

This province is characterised by fairly flat gravity relief with Bouguer anomaly values generally ranging between —40 and —60 mGal. No consistent contour trends are obvious, and in this respect the province contrasts with the Carey Regional Gravity Complex to the west, where trends are north-northwesterly, and the Rason Regional Gravity Low to the east, where trends are northeasterly in the south and northwesterly in the north. The most noteworthy local gravity features are a north-northwesterly elongated residual high in RASON, and a broad easterly trending high in THROSSELL, which swings round to a northerly direction in western WESTWOOD and extends to southwestern BROWNE.

The province extends over the eastern part of the exposed Yilgarn Block, and Proterozoic, Permian, and Tertiary sediments of the Nabberu and Officer Basins. Contour trends are continuous across the shield/sediments boundary, indicating that the sediments form only a thin layer, or are of small density contrast with the underlying basement. The residual high in RASON is conformable in trend and shape with the highs in the greenstone area to the west, so the feature probably corresponds to a basic igneous body in the basement. The results of recent seismic and gravity surveys in the area (Harrison & Zadoroznyj, 1978) suggest that the easterly trending high in THROSSELL is also mainly due to the presence of a dense body within the crystalline basement.

Rason Regional Gravity Low

Only the central part of this province lies within the survey area. Its southern part is defined by Fraser (this volume, Part A), and its northern part lies in an area surveyed in 1962 (Lonsdale & Flavelle, 1968). The province is a broad gravity trough of varying width and intensity, which can be traced from northwest ESPERANCE along a northeasterly path to TALBOT, where it swings to a northwesterly direction and terminates north of the survey area against the Ashburton Regional Gravity Ridge.

Although the province extends across the Officer Basin, low Bouguer anomaly values are considered to reflect a mass-deficient zone within the basement rather than thick sediments. This is suggested by the following observations:

(1) The province is most clearly definable south of the survey area, where Precambrian rocks are exposed.

(2) The province bears no relation spatially to the known shape and structure of the Officer Basin.

(3) The Officer Basin in Western Australia is believed to have a thick Proterozoic sequence continuous with the Bangemall Basin sedimentary sequence. As the Bangemall Basin is not associated with a gravity depression, its Proterozoic sediments may have a bulk density close to the basement average.

(4) The province is part of an almost continuous ring of gravity depressions circumscribing the Yilgarn Block. With the exception of the Perth Regional Gravity Low, these depressions all extend over Precambrian rocks.

The province is similar in tectonic setting to the Teano Regional Gravity Low. It extends parallel to the gravity expression of a Proterozoic mobile belt and may therefore be associated with Proterozoic tectonic activity.

Fraser Regional Gravity Ridge

The southern half of this province was defined by Fraser (this volume, Part A). The province is an elongate gravity ridge of varying width and amplitude, extending northeastwards from the south coast near Esperance to the western part of the Musgrave Block.

Within the survey area the province extends across Officer Basin sediments. Although these mask the source of high Bouguer anomalies, it can be inferred that gravity relief relates mainly to basement density variations, as high Bouger anomalies in the Fraser Range area are clearly associated with the dense, gabbro-intruded basic granulites exposed southeast of the Fraser Fault.

There is a marked reduction in intensity and Bouguer anomaly level of the province between PLUMRIDGE and TALBOT. Although this is mainly due to a general decrease in basement density, the relatively light Officer Basin sediments may also have an attenuating effect on gravity relief. A residual high in NEALE and VERNON is similar in trend, shape, and area to a high in PLUMRIDGE, but its peak Bouguer anomaly value is about 35 mGal lower. Assuming that the sources of the two highs can be approximated by identical infinite horizontal cylinders of density contrast 0.3 g/cm^3 with the enclosing basement, and 0.5 g/cm^3 with the sedimentary cover, and that the cylinder corresponding to the anomaly in PLUMRIDGE is tangential to the surface, the depth to basement in eastern NEALE is calculated to be about 2 km.

The province appears to follow the partly buried southeastern margin of the Yilgarn Block, and may therefore have similar tectonic significance to elongate gravity ridges which girdle the Kimberley and Pilbara Blocks; these have been correlated with Proterozoic mobile zones containing dense metamorphic rocks (Whitworth, 1970; Fraser, this volume, Part B). That Proterozoic tectonic activity southeast of the Yilgarn Block and in the western part of the Musgrave Block may have been related is implied by the continuity of the gravity contour pattern between the Fraser Range area and the western Musgrave Block, the presence in both areas of post-tectonic gabbroic sheet intrusions, and the approximate collinearity of the Fraser Fault and Giles Discontinuity.

Blackstone Regional Gravity Ridge

The northern part of this province was first defined and named by Lonsdale & Flavelle (1968). The province occupies the northeast corner of the survey area and is an intense, narrow, easterly trending gravity ridge, with several peaks exceeding +40 mGal.

It is broadly coextensive with the Musgrave Block, and high Bouguer anomalies can be attributed to the gabbro-intruded metamorphic rocks of which the block is predominantly composed.

Eyre Regional Gravity Complex

This province is bounded by the Fraser Regional Gravity Ridge to the northwest, and by the Wanna Regional Gravity Low to the north and east. It extends westwards into the area surveyed in 1969 (Fraser, this volume, Part A) and southwards beyond the coastline. Four units can be defined within the province: the broad, northeasterly trending *Seemore Gravity Low* and *Gambanga Gravity Low*, in the west; the irregularly shaped *Madura Gravity High*, in the south of the province, whose northwesterly prolongation is sharply truncated by the Fraser Regional Gravity Ridge; and the *Loongana Gravity Complex*, which has several intense residual highs trending north to northeast.

Except for the southwest of the province, where granitic rocks crop out, the basement is covered everywhere by the thin Tertiary and Cretaceous sediments of the Eucla Basin. For this reason, the interpretation of gravity features is conjectural and depends largely on comparisons with gravity relief in areas of exposed basement. The *Seemore* and *Gambanga Gravity Lows* are parallel to the Fraser Regional Gravity Ridge and may therefore, like the Rason Regional Gravity Low, be related to Proterozoic tectonic activity on the margin of the Yilgarn Block. The *Madura Gravity High* corresponds to an area of dense and probably metamorphosed basement, although the regional increase in Bouguer anomaly towards the coastline may relate partly to a transition from continental to oceanic-type crust. The contour pattern in the *Loongana Gravity Complex* resembles that over the greenstone/whitestone terrains of the Yilgarn and Pilbara Blocks; the intense residual highs may therefore correspond to small basic igneous bodies enclosed within gneissic basement.

The shape of the province, and its overall contour pattern, suggest that it may be the expression of a craton welded onto the southeast margin of the Yilgarn Block.

Wanna Regional Gravity Low

This province is characterised by broad smooth gravity relief with Bouguer anomaly values mainly in the range —40 to —80 mGal; its southern part is bounded by a steep linear gradient in the west and by a gentler more irregular gradient in the east.

Although sediments of the Eucla and Officer Basins crop out over the province, low Bouguer anomalies are probably due to light granitic basement, certainly in the south where a borehole near Forrest encountered biotite granite at a depth of only about 300 m (Maitland, 1915; Peers & Trendall, 1967). Since the Bouguer anomaly level is uniformly low north of Forrest, the feature as a whole may correspond to an area of predominantly low-density basement. The only effect of the Officer Basin sediments, in the north of the province, may be to attenuate the gravity expressions of local mass anomalies in the basement, therefore causing flattish gravity relief.

Officer Regional Gravity Low

The easterly trending Officer Regional Gravity Low corresponds to the eastern part of the Officer Basin. Its greater part lies in South Australia; it is described in detail by Pettifer & Fraser (this volume, Part D).

C5. CONCLUSIONS

The following general conclusions are made from the gravity results:

(1) In the southern Carnarvon Basin, gravity relief probably reflects variations in depth to basement. Gravity depressions and ridges are interpreted respectively as the expressions of sub-basins and basement ridges of the Carnarvon Basin.

(2) The gravity expression of the Perth Basin is continuous with those of the Coolcalalaya and Byro Basins, which should perhaps be regarded as sub-basins of the Perth Basin rather than the Carnarvon Basin.

(3) The gravity profile across the Coolcalalaya Basin suggests that the basin floor dips gently east towards a steep wall bounding the basin in the east.

(4) Vertical throw across the Urella Fault probably exceeds that across the Darling Fault in the area where the two faults are parallel.

(5) Rocks underlying the Coolcalalaya Basin sediments may be of appreciably lower density than those under the Gascoyne Basin sediments.

(6) A gradual rise in Bouguer anomaly across the western Yilgarn Block westwards towards the Darling Fault may relate to an increase in grade

of metamorphism or to an increasing abundance of basic dyke swarms, or both. Isostatic effects may also contribute to the Bouguer anomaly rise because the Darling Fault is close to the continental margin.

(7) Extensive gravity depressions along the northern and eastern margins of the Yilgarn Block have no obvious surface cause and must relate to deep crustal mass deficiencies. Their approximate parallelism to elongate gravity ridges—the expressions of Proterozoic mobile belts—suggests that the mass-deficient zones are related to Proterozoic activity.

(8) The central part of the Yilgarn Block is divided into two gravity provinces along a sinuous line extending from Norseman to north of Wiluna. In the western province, intense residual highs are disjointed and mainly northerly trending, whereas, in the eastern province, residual highs are longer, have a predominant northerly to northwesterly trend, and are of smaller amplitude and intensity. The contrast in contour pattern between the two gravity provinces reflects a regional geometric difference between the greenstone belts on either side of the Yilgarn Block. Geological and gravity evidence combined suggest that a major unconformity, close to and parallel to the boundary between the gravity provinces, separates younger greenstone sequences of the Eastern Goldfields from older greenstones and granites to the west.

(9) The boundary between the eastern and western gravity provinces closely corresponds to the known westward limit of the main nickel province of the Yilgarn Block: it passes just west of deposits near Mount Keith, Mount Sir Samuel, Agnew, and Widgiemooltha.

(10) A narrow gravity ridge over the Fraser Range metamorphics continues with reduced intensity across the Officer Basin, and joins up with an intense gravity ridge over the Musgrave Block. The feature apparently follows the partly buried southeastern margin of the Yilgarn Block and is therefore analogous to elongate gravity ridges bordering the Pilbara and Kimberley Blocks; these gravity ridges have been interpreted as the expressions of Proterozoic mobile zones of dense metamorphic rocks.

(11) A well-defined area of disturbed gravity contour pattern to the east of the Fraser Range metamorphic belt may correspond to a craton which is almost totally buried beneath the Eucla Basin sediments.

(12) Low Bouguer anomalies in an area extending from the Musgrave Block southwards to the Great Australian Bight are attributed mainly to low-density rocks within the basement of the Officer and Eucla Basins.

C6. REFERENCES

ARRIENS, P. A., & LAMBERT, I. B., 1969—On the age and strontium isotopic geochemistry of granulite-facies rocks from the Fraser Range, Western Australia, and the Musgrave Range, central Australia. *Geological Society of Australia, Special Publication* **2**, 377-88.

BARLOW, B. C., 1970—National report on gravity in Australia, July 1965 to June 1970. *Bureau of Mineral Resources, Australia, Record* **1970/62** (unpublished).

BOW, G. W. G., & TURPIE, A., 1964—Southern Carnarvon Basin seismic survey, W.A., 1963 (Traverse A, Tamala-Narryer area). *Bureau of Mineral Resources, Australia, Geophysical Progress Report* **1964/6** (unpublished).

BROD, R. J., 1962—Aeromagnetic interpretation (Officer Basin) W.A. *Geophysical Associates International, for Hunt Oil Company* (unpublished).

CHAMBERLAIN, N. G., DOOLEY, J. C., & VALE, K. R., 1954—Geophysical exploration in the Carnarvon (N.W.) Basin, Western Australia. *Bureau of Mineral Resources, Australia, Record* **1954/44** (unpublished).

COMPSTON, W., & ARRIENS, P. A., 1968—The Precambrian geochronology of Australia. *Canadian Journal of Earth Sciences*, **5**, 561-83.

CONDON, M. A., 1954—Progress report on the stratigraphy and structure of the Carnarvon Basin, Western Australia. *Bureau of Mineral Resources, Australia, Report* **15**.

CONDON, M. A., 1956—Depositional structures in the Carnarvon Basin, Western Australia. *Bureau of Mineral Resources, Australia, Record* **1956/68** (unpublished).

CONDON, M. A., 1965-1968—The geology of the Carnarvon Basin, Western Australia. *Bureau of Mineral Resources, Australia, Bulletin* **77** (3 parts).

CONTINENTAL OIL COMPANY OF AUSTRALIA LTD, 1969—Munyarai No. 1, South Australia stratigraphic drilling project, well completion report. *Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts Report* (unpublished).

DANIELS, J. L., & HORWITZ, R. C., 1969—Precambrian tectonic units of Western Australia. *Geological Survey of Western Australia, Annual Report* **1968**, 77.

DURNEY, D. W., 1972—A major unconformity in the Archaean, Jones Creek, Western Australia. *Journal of the Geological Society of Australia*, **19**(2), 251-60.

FORSYTH, W. A. L., 1960—Carnarvon Basin airborne magnetic and radiometric survey, W.A., 1959. *Bureau of Mineral Resources, Australia, Record* **1960/132** (unpublished).

FRASER, A. R., 1974—Reconnaissance helicopter gravity survey of the southwest of Western Australia, 1969. *Bureau of Mineral Resources, Australia, Record* **1974/26** (unpublished).

GUNSON, S., & VAN DER LINDEN, J., 1956—Regional gravity traverses across the Eucla Basin, 1954-55. *Bureau of Mineral Resources, Australia, Record* **1956/145** (unpublished).

HALL, W. D. M., & GOODE, A. D. T., 1975—The Nabberu Basin: a newly discovered Lower Proterozoic basin in Western Australia: *in* Proterozoic geology, abstracts of 1st Australian Geological Convention, Adelaide, 12-16 May 1975. *Geological Society of Australia, Sydney*, 88.

HARRISON, P. L., & ZADOROZNYJ, I., 1978—Officer Basin seismic, gravity, magnetic, and radiometric survey, Western Australia, 1972. *Bureau of Mineral Resources, Australia, Report* **191**.

HASTIE, L. M., & WALKER, D. G., 1962—Two methods of gravity traversing with helicopters. *Bureau of Mineral Resources, Australia, Record* **1962/134** (unpublished).

HORWITZ, R. C., 1975—Provisional geological map at 1:2 500 000 of the north-east margin of the Yilgarn Block, Western Australia. *CSIRO Minerals Research Laboratories, Division of Mineralogy, Report* **FP10** (unpublished).

HORWITZ, R. C., DANIELS, J. L., & KRIEWALD, M. J. B., 1967—Structural layering in the Precambrian of the Musgrave Block, Western Australia. *Geological Survey of Western Australia, Annual Report* **1966**, 56-8.

JACKSON, M. J., 1971—Notes on a geological reconnaissance of the Officer Basin, W.A., 1970. *Bureau of Mineral Resources, Australia, Record* **1971/5** (unpublished).

KRIEG, G. W., 1969—Geological developments in the eastern Officer Basin of South Australia. *APEA Journal*, **9**(2), 8-13.

LAMBOURN, S. S., 1972—Aeromagnetic survey of the Glengarry, Wiluna and Kingston 1:250 000 Sheet areas, W.A. 1970. *Bureau of Mineral Resources, Australia, Record* **1972/120** (unpublished).

LONSDALE, G. F., & FLAVELLE, A. J., 1968—Amadeus and south Canning Basins gravity survey, Northern Territory and Western Australia, 1962. *Bureau of Mineral Resources, Australia, Report* **133**.

LOWRY, D. C., 1970—Geology of the Western Australian part of the Eucla Basin. *Geological Survey of Western Australia, Bulletin* **122**.

McCALL, G. J. H., 1972—The nickel-sulphide-bearing ultramafic rocks and their environment in the Archaean of Western Australia. *24th International Geological Congress, 1972*, Section **1**, 354.

MAITLAND, A. G., 1915—Boring for water on the Transcontinental Railway Line. *Geological Survey of Western Australia, Annual Report* 1914, 13.

MATHUR, S. P., 1974—Crustal structure in southwestern Australia from seismic and gravity data. *Tectonophysics*, **25**, 151-82.

PARASNIS, D. S., 1962—PRINCIPLES OF APPLIED GEOPHYSICS. *Methuen's Monographs on Physical Subjects, London*.

PEERS, R., & TRENDALL, A. F., 1968—Precambrian rocks encountered during drilling in the main Phanerozoic sedimentary basins of Western Australia. *Geological Survey of Western Australia, Annual Report* **1967**, 69-77.

PRIDER, R. T., 1965—The geology and mineralisation of the Western Australian Shield. *8th Commonwealth Mining and Metallurgy Congress*, **1**, 56.

PRIDER, R. T., 1970—Nickel in Western Australia. *Nature*, **226**, 691.

SPENCE, A. G., 1961—Carnarvon Basin airborne magnetic and radiometric survey, W.A., 1959. *Bureau of Mineral Resources, Australia, Record* **1961/56** (unpublished).

SPENCE, A. G., 1962—Carnarvon Basin airborne magnetic and radiometric survey, W.A., 1961. *Bureau of Mineral Resources, Australia, Record* **1962/191** (unpublished).

THYER, R. F., & EVERINGHAM, I. B., 1956—Gravity survey of the Perth Basin, Western Australia. *Bureau of Mineral Resources, Australia, Bulletin* **33**.

TURPIE, A., 1964—Southern Carnarvon Basin seismic survey, W.A., 1963 (Traverse B—Byro Basin). *Bureau of Mineral Resources, Australia, Geophysical Progress Report* **1964/7** (unpublished).

WHITWORTH, R., 1970—Reconnaissance gravity survey of parts of Northern Territory and Western Australia, 1967. *Bureau of Mineral Resources, Australia, Record* **1970/15** (unpublished).

WILSON, A. F., 1969—Granulite terrains and their tectonic setting and relationship to associated metamorphic rocks in Australia. *Geological Society of Australia, Special Publication* **2**, 243-58.

WILSON, A. F., COMPSTON, W., JEFFREY, P. M., & RILEY, G. H., 1960—Radioactive ages from the Precambrian rocks in Australia. *Journal of the Geological Society of Australia*, **6**, 179-96.

Note: Additional abbreviated references for previous geophysical and drilling surveys not specifically referred to in the text are given in Appendixes C3 and C4.

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PART D

Reconnaissance gravity survey in western South Australia, 1970

G. R. Pettifer & A. R. Fraser

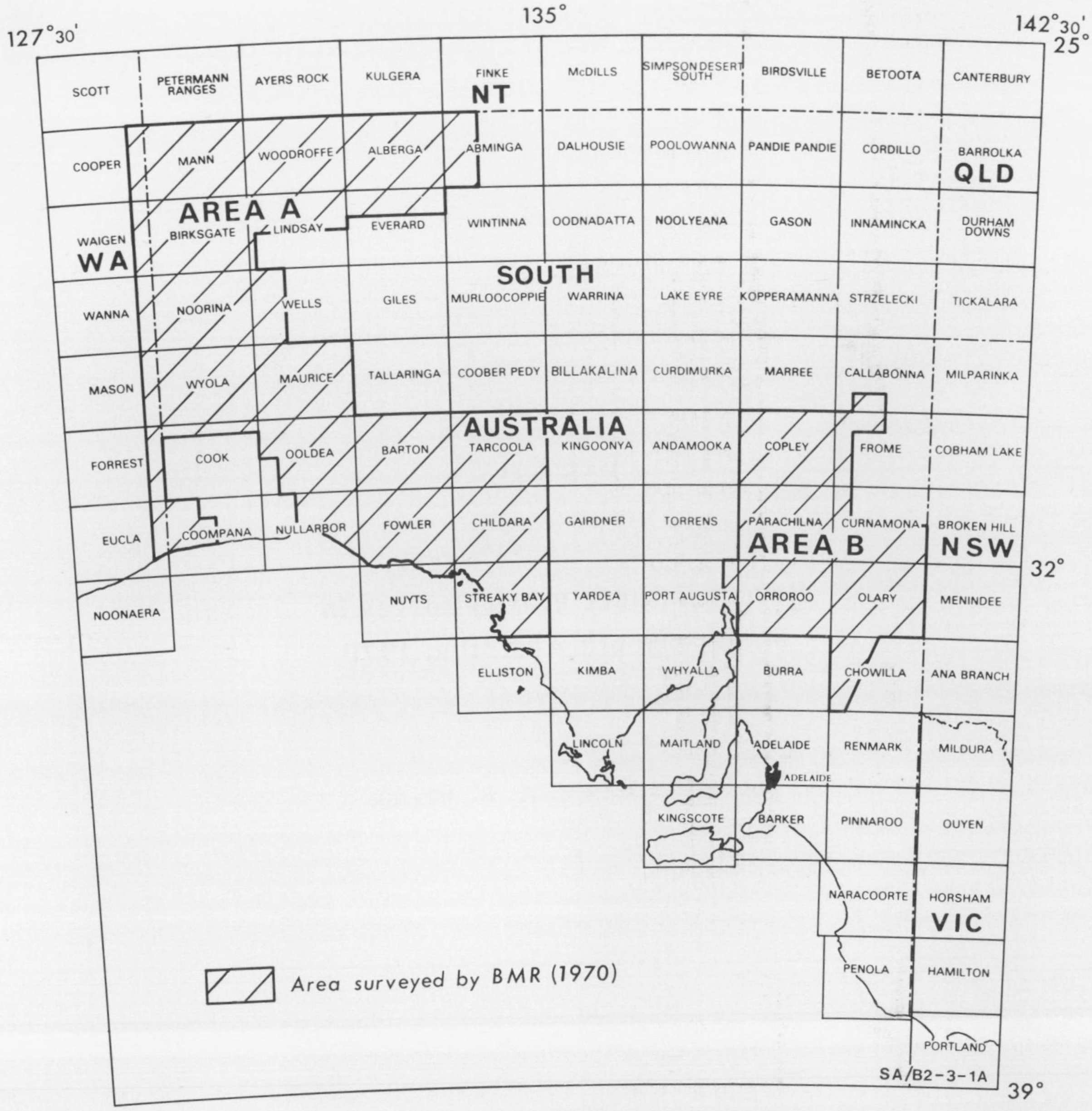

Fig. D1. Location map.

D1. 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 & Walker (1962), to establish a grid of gravity stations over the survey areas. Part D of the Bulletin describes the results from the western survey area, Area A (Fig. D1), in which about 250 000 km^2 were surveyed over all or parts of twenty-one 1:250 000 Sheet areas under the supervision of G. R. Pettifer; the statistics of the survey are given in Appendix D1. The results of the gravity survey in Area B have been discussed by Tucker & Brown (1973).

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 stations to be located 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 the 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 D2).

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 D1) 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.

Part D of this Bulletin was written largely during 1972-73. It summarises the results of previous geophysical surveys and the geology, including subsurface data from wells, all of which 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 and leaves an observed Bouguer anomaly field which reflects only the broad regional structural elements of the crust.

Acknowledgement

We thank the staff of the BMR Cartographic Section who contributed to the drawing of the illustrations.

D2. GEOLOGY

The survey area covers parts of four major tectonic units: the Musgrave Block, the Officer Basin, the Gawler Block, and the Eucla Basin. Because of the sparseness of outcrop, the geology is largely inferred from scattered well data, from geophysical data, and by extrapolation from surrounding areas.

The general tectonic framework within and around the survey area is shown in Plate D2. 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 were dominated by the Gawler Craton*. To the east and northeast was the slightly arcuate Adelaide Geosyncline, while the Musgrave Block dominated at least the northwest, its southern and eastern limits being uncertain. As previously mentioned, orogenies during the Precambrian established the dominant structural trends which controlled Phanerozoic events. Four major phases of sedimentation during the Phanerozoic are evident (Wopfner, 1969): the Cambrian-Devonian, Carboniferous-Permian, Jurassic-Cretaceous, and Paleocene-Miocene.

Gawler Craton

The Gawler Craton is exposed (as the Gawler Block) over a large area of south-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 drillhole and geophysical evidence.

The tectonic history of the Gawler Craton is complex and known in detail only on the eastern and northern Eyre Peninsula, where it is best exposed. A thick sequence of Lower Proterozoic sediments deposited on an Archaean basement was deformed in early Carpentarian times during the Kimban Orogeny (Thomson, 1969), when intense regional metamorphism (dated as 1780 ± 120 m.y.; Compston & Arriens, 1968) established strong northeasterly trends (Whitten, 1966) and produced complexly folded gneisses and migmatites. The Post-Kimban Tectonic Phase (Thomson, 1975a) was characterised by acid volcanism and granite intrusion, with minor sedimentation. Small coarse-grained granite plutons ranging in age from about 1450 to

* B. P. Thomson (1969) used the term Gawler Block for only the exposed Precambrian (shield), 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 refers to the shield area only, and Gawler Craton to the shield and platform areas.

1600 m.y. are widespread over the Gawler Block, but 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 mid-Carpentarian gabbros around Streaky Bay. Mid-Carpentarian sediments several hundred metres thick near Tarcoola (Whitten, 1966) constitute one of a number of sequences deposited in graben-like troughs across the craton from the Tarcoola area to the Middleback Ranges (Thomson, 1975a), in the eastern part of the craton. These sequences have largely been masked by the acid Gawler Range Volcanics (about 1535 m.y.; Compston & Arriens, 1968), remnants of which cover the eastern flank of the Gawler Block in a belt 400 km long by 130 km wide.

The western Gawler Craton is a gneissic complex overlain by sediments of the Eucla Basin. Mallabie No. 1 well (Outback Oil NL, 1969) encountered gneisses at a depth of 1350 m, and a number of water-bores have also encountered a gneissic basement which appears to dip 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 that it consists largely of gneiss and other metamorphic rocks.

Density data for the Gawler Craton are summarised in Appendix D3.

Musgrave Block

The Musgrave Block is well exposed, unlike the Gawler Craton, and has been extensively explored in the search for minerals, especially nickel, with the result that its complex tectonic history is known in some detail. It covers an east-striking elongate area of 80 000 km^2, and gravity evidence suggests that it extends to the northeast under the Great Artesian Basin (Lonsdale & Flavelle, 1968). 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 gneisses, granulites, and quartzites derived from a predominantly silty sedimentary sequence metamorphosed 1650 m.y. ago (Webb, 1973), contemporaneously with the Kimban Orogeny of the Gawler Craton (Thomson, 1975b). Distinct northerly to northeasterly trends of foliations and relict sedimentary structures in the south of the block were probably initiated during this orogeny. The widespread Kulgeran granites were emplaced 1100 to 1140 m.y. ago (Thompson, 1975b), and, after a phase of uplift and erosion, a thick volcanic/sedimentary pile—the Bentley Supergroup (Daniels, 1971a, b)—accumulated in the west of the block, and the Giles Complex mafics and ultramafics intruded the Musgrave-Mann Metamorphics along deep crustal fractures in an east-west belt across the block (Sprigg & Wilson, 1958; Nesbitt & Talbot, 1966). Basic sills and dyke swarms with northwesterly to westerly trends are thought to be related to the Giles Complex. Major tectonism continued, as deep granulite bodies were pushed from the south along the Woodroffe Thrust, and deep grabens—later filled with up to 6000 m of Cambrian? clastics—developed in the Levenger and Moorilyanna areas. Subsequent tectonism was mild, consisting principally of uplift in the Carboniferous during the Alice Springs Orogeny, and renewed uplift of the highland chains in the late Cainozoic (Thomson, 1975b).

Density information for the Musgrave Block is readily available: data supplied by the South Australian Department of Mines are summarised in Appendix D3.

Officer Basin

The Officer Basin (Plate D2) 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, 1969; 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 Eromanga Basins in the region of WINTINNA (Plate D1), 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, during the Ordovician (Krieg, 1969).

Development of the Officer Basin in South Australia evidently migrated eastwards with time: the Palaeozoic sediments thicken from less than 1000 m in the west to at least 2900 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 towards the Gawler Block in 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; exposed granulite in southeastern EVERARD suggests that at least part of the basement is composed of granulite.

Density data on the Officer Basin sediments, determined from measurements on drillhole samples (Continental Oil Co., 1967a, 1968), are summarised in Appendix D3.

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 Albany-Fraser Province, to the east by the Gawler Block, and to the north by the Officer Basin (Plate D2). 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 m in the north to 60 to 120 m 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 (1970) noted 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 m thick. The existence of this trough was confirmed by Mallabie No. 1 well (Outback Oil NL, 1969), which passed through 209 m of Tertiary limestone, clay, and siltstone; 133 m of Cretaceous sediments; 99 m of Permian sandstone and siltstone; 480 m of Cambro-Ordovician? sandstone and siltstone; 289 m of volcanics (tentatively dated as early Adelaidean by Thomson, 1970); and 134 m of probable Proterozoic sandstone. A basement of granitic gneiss was encountered at a depth of 1340 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 (Appendix Fig. D4), are included in Appendix D3.

D3. PREVIOUS GEOPHYSICAL RESULTS

Only a small amount of geophysical work has previously been carried 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 summarised here.

Gravity surveys

Several gravity surveys have been conducted within or near the survey area. They are listed in Appendix D4 and their locations are shown in Figure D2.

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 (Flavelle & Goodspeed, 1962). Local gravity highs that coincide 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, 1968). 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 Trans-Continental 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 the 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 of –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 (Fig. D3) 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 BMR's gravity survey of western South Australia (Plate D1).

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, 1969) 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 D1.

Aeromagnetic surveys

Aeromagnetic surveys flown within or near the BMR gravity survey area are listed in Appendix D4. The contours of estimated basement depth for these surveys are shown in Plate D3.

BMR has co-operated with the South Australian Department of Mines in aeromagnetic surveys over the Musgrave Block (Wells, 1962; Tipper, 1967; Waller, 1968; Shelley & Downie, 1971), the Gawler Block (Quilty, 1962; Whittten, 1963; Young & Gerdes, 1966), and more recently the Eucla Basin (Waller, Quilty, & Lambourn, 1972; Lambourn, 1977); the general objective was to facilitate geological interpretation of poorly exposed areas.

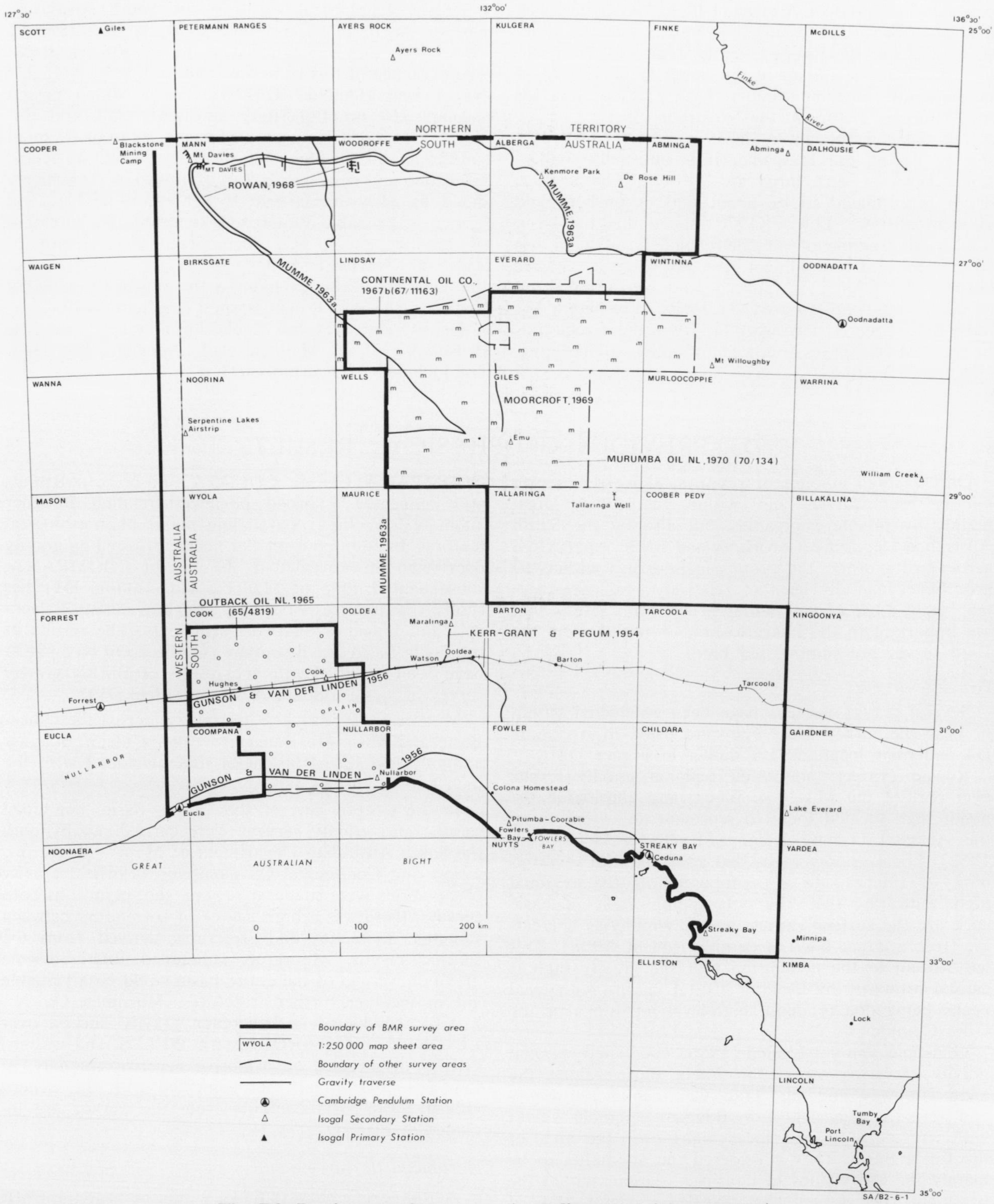

Fig. D2. Previous gravity surveys (excluding unsubsidised surveys).

A survey of the eastern part of the Musgrave Block revealed an easterly extension of the Mann Fault System displaced to the south by an interpreted north-northwesterly trending dextral fault (Waller, 1968) with a horizontal displacement of 16 km at the boundary between WOODROFFE and ALBERGA. From the same survey, a graben structure was postulated in the west of ABMINGA. The aim of a BMR survey that covered a small part of the MANN-WOODROFFE area (Tipper, 1967) was 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 north-eastern LINDSAY (Shelley & Downie, 1971). The results of this survey were more meaningful, and, on the basis of inferred basic intrusions and shearing, a

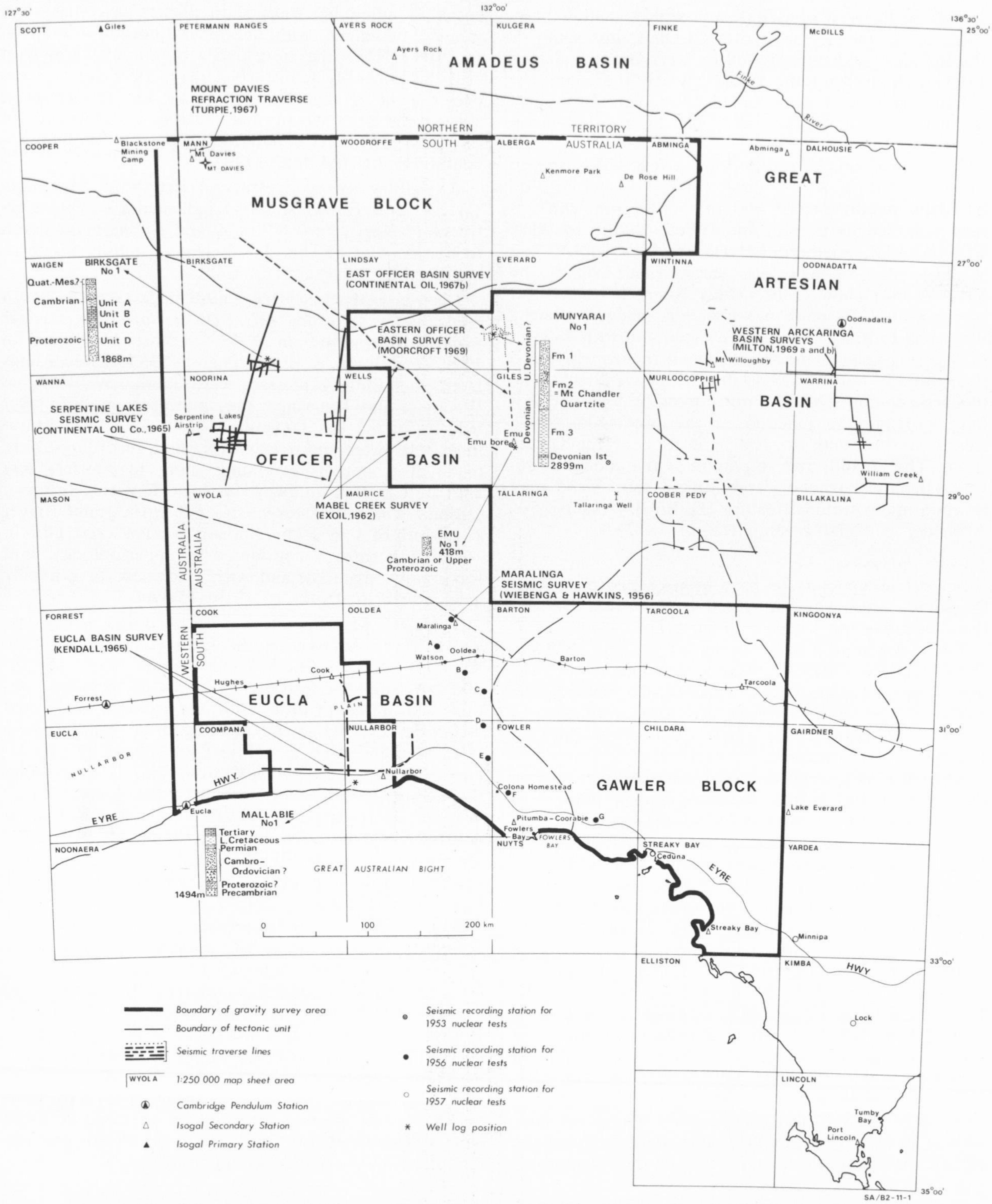

Fig. D3. Previous seismic surveys (excluding unsubsidised surveys) and subsidised wells.

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.

In the Gawler Block, detailed geophysical traverses and drilling on aeromagnetic anomalies in STREAKY BAY revealed intruded plugs of gabbro (Whitten, 1963). Strong northwest-trending magnetic lineaments in the northeast of TARCOOLA and farther north are due to basic dykes that are more than 400 km long and are collinear with similar dyke suites north of the Musgrave Block (D. Boyd, University of Adelaide, personal communication 1973). These dykes may reflect a major structural trend in the Archaean basement.

The results of a BMR aeromagnetic survey of the COOK, OOLDEA, and BARTON Sheet areas (Waller & others, 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.

In a report on the results from a few widely spaced traverses, Quilty & Goodeve (1958) suggested that basement depths exceed 600 m in a region which is now regarded as part of the Officer Basin: southern BIRKSGATE, southern LINDSAY, NOORINA, and WELLS. 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 suggest a highly magnetic intrabasement source and may reflect a major tectonic feature (D. Boyd, University of Adelaide, personal communication 1973).

Seismic surveys

Several seismic surveys have been carried out within the survey area. They are listed in Appendix D4 and their locations are shown in Figure D3.

The Serpentine Lakes survey in western BIRKSGATE and NOORINA indicated a sedimentary thickness of up to 5.2 km (Continental Oil Co., 1965). The eastern Officer Basin surveys gave similar thicknesses farther east (Moorcroft, 1969; Continental Oil Co., 1967b).

Kendall (1965) reported on a reconnaissance seismic refraction survey in the South Australian portion of the Eucla Basin. Three refractors were recorded: two in the velocity range 4.42-5.03 km/s, and another at 5.64-6.10 km/s, which may be similar to a 6.05 km/s 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 (1969a, b) 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/s was obtained consistently from many separate refraction profiles. Coupled with density data for basement rocks, obtained by the South Australian Department of Mines for stratigraphic wells within the Arckaringa Basin (Appendix D3), 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/s. In WINTINNA the coincidence of gravity highs with areas of generally undisturbed magnetic field, and the presence of a high-velocity (6.14 km/s) refractor, suggest the presence of dense carbonate sequences in the basin (Milton, 1969b). 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/s, and a maximum depth to basement of 550 m. The basement density was estimated to be 2.7 g/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/s (Doyle, 1954). The 1956 Maralinga tests were more extensive, and recordings were made at 6 stations extending south to Fowlers Bay and at a station midway between Fowlers Bay and Ceduna. The results revealed a 6.3 km/s granitic layer at a depth of 1 to 2 km. For an 'average' crust (Birch, 1958), 6.3 km/s is considered an upper velocity limit for granitic material, and such velocities are generally encountered at depths of 10 to 15 km.

The 1957 Maralinga tests were recorded at Ceduna, and farther southeast on the Eyre Peninsula at three stations—Minnipa, Lock, and Tumby Bay—450 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/s beneath the Gawler Craton. This is lower than the mantle velocities of both 8.21 km/s recorded in Western Australia and 8.16 km/s estimated 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 longitude 131°E (Mumme, 1963b).

The presence of an intermediate 6.5-7.0 km/s layer was not established by any of the recordings, and Doyle & Everingham (1964) 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: assuming a depth to mantle of 37 km calculated from the seismic refraction results (no intermediate layer established), the maximum thickness from the nomogram of an intermediate layer with a velocity of 7.0 km/s would be 16 km and the total depth to the mantle would be 42 km.

D4. DESCRIPTION AND INTERPRETATION OF GRAVITY RESULTS

Gravity contours from the BMR survey and from surveys by the South Australian Department of Mines and private companies are shown in Plate D1. All the major gravity features have been outlined, but only those within or closely related to the present survey area are described below; the nomenclature of gravity features is briefly explained in Part A of this Bulletin (pp. 6-7).

The contour map has been partitioned in such a way as to simplify the description and interpretation of gravity features, and to emphasise the overall contour pattern. Large areas, usually of fairly simple shape, within which the gravity field is characterised by uniform gravity level, regional contour pattern, or 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 by drilling or by other geophysical surveys. Paucity of density information, and density vari-

TABLE D1. 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 Ridge	Range
		Crombie Gravity Low	Mountain
		Ernabella Gravity Ridge	Mission
Officer Regional Gravity Low	Officer Basin	Birksgate Gravity Low	1:250 000 Sheet area
		Purndoo Gravity Low	Saltpans
Nullarbor Regional Gravity Shelf	Nullarbor Plain	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
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

ability within individual lithological units, creates difficulty in the choice and use of appropriate average densities; this leads to ambiguity in the interpretations.

GRAVITY PROVINCES

Plate D1 shows the boundaries of gravity provinces and units in and around the BMR gravity survey area. Names of provinces and units, together with their derivation, are given in Table D1.

Ayers Rock Regional Gravity Low

The survey area covers only the southern margin of this province, which was first defined by Lonsdale & Flavelle (1968). The province has been interpreted as the expression of a thick sequence 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 into 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 characterised 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 constitute most of the Musgrave Block. The major faults are associated with mafic and ultramafic 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 rock 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 invokes different interpretations for the eastern and western parts of the gravity province.

The third hypothesis is satisfactory insofar as it proposes an extensive 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 body 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. If a mantle ridge beneath the central core of the Musgrave Block is the main 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. It is in agreement with an interpretation by Mathur (1974).

Officer Regional Gravity Low

This is an elongate gravity depression extending eastwards in an arc from southern ALBERGA, through BIRKSGATE, into Western Australia. 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, but its axis is 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.

The *Purndoo Gravity Low,* which was largely defined by the eastern Officer Basin gravity survey (Murumba Oil NL, 1970), coincides generally with the asymmetric eastern Officer Basin, which contains a thick sequence of 4400 m of Proterozoic sediments and unconformably overlying Palaeozoic 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 a change in crustal thickness. The gentle slope towards the south of the unit may reflect a shallowing of the basement, possibly along a northeasterly trending hingeline which developed 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 rocks (Continental Oil Co., 1967a,b). This is in contrast to the Officer Basin farther east where the Palaeozoic sediments are considerably thicker, at least 2900 m. 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.

Effect of deep crustal variations on the amplitudes of the Blackstone Regional Gravity High and the Officer Regional Gravity Low. The Blackstone Regional Gravity Ridge and the Officer Regional Gravity Low form part of a system of intense, easterly trending ridges and troughs which dominate 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 g/cm^3. It follows that horizontal density variations must occur beneath the basin, 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) assumed 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, argued 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 below 20 km. 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 & Shaw, the Officer Basin is underlain by a granitic basement appreciably less dense than the Musgrave Block.

Nullarbor Regional Gravity Shelf

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 characterised 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 value of −15 mGal. Magnetic evidence (Plate D3) 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 inferred basement 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 & others, 1972). A sedimentary sequence 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 Mallabie No. 1 well (Outback Oil NL, 1969), almost 1400 m of Phanerozoic and Proterozoic sediments and volcanics were encountered above a basement of granitic gneiss. The Denman Basin does not appear to be continuous with the Arckaringa Basin as suggested by Wopfner (1969), as the Denman Gravity Low is truncated to the northeast by the Yarle Gravity High of the Christie Regional Gravity High.

The *Cook Gravity Ridge* is an elongate, northwesterly trending zone of high Bouguer anomalies 150 km long, 30 km wide, and about 10 mGal amplitude. It was first partly defined by the Eucla Basin gravity survey (Outback Oil NL, 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 & others, 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 characterised 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 magnetic basement high at a depth of 1.3 km compared with surrounding basement depths of 3.0 km (Plate D3). 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 highs reflect 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 −30 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 northeasterly 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 m in the west. The trend of magnetic anomalies is parallel to the strike of the gravity high (Waller & others, 1972), suggesting 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 Craton.

The *Mulgathing Gravity High* consists of two northeasterly trending gravity highs separated by a gravity depression. Basement is shallow, and the trend of magnetic anomalies is parallel to the gravity contour trend (Waller & others, 1972), 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 north-northeastwards across the central Gawler Block, The large areal extent of the province suggests that it may be caused 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 D2), which coincides with a gravity gradient of 1 mGal/km. The *Malbooma Gravity Low* is also attributed to an abundance of young intrusive granites. The *Jellabinna Gravity Ridge,* however, corresponds to 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 is compatible with the combined assessment of gravity and magnetic data. 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.

D5. CONCLUSIONS

The main conclusions drawn from the analysis of gravity results are summarised 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 roughly 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 g/cm^3. It follows that a regional mass deficiency must exist beneath the basin floor. This could be in the form of a basement density decrease or a thickening of the crust south 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 infra-basin beneath the Mesozoic and Tertiary sediments of the Eucla Basin. Farther north, a west-northwesterly trending gravity ridge and a north-northeasterly trending gravity ridge are not associated with any known magnetic basement ridge; they are attributed to dense zones within the basement. Small, roughly circular highs close to the Western Australian border are probably due to dense intra-basement plugs.

(5) The western part of the Gawler Block has a regionally high Bouguer anomaly level. Several local gravity highs 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 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. Local gravity features in the area can be interpreted as being due to density variations within the Gawler Block.

D6. REFERENCES

ANFILOFF, W., & SHAW, R. D., 1974—The gravity effects of three large uplifted granulite blocks in separate Australian shield areas; *in* MATHER, R. S., & ANGUS-LEPPAN, P. V. (Editors)—*Proceedings: Symposium on Earth's Gravitational Field & Secular Variations in Position, University of New South Wales, 1973,* 273-89.

BARLOW, B. C., 1970—National report on gravity in Australia, July 1965 to June 1970. *Bureau of Mineral Resources, Australia, Record* **1970/62** (unpublished).

BIRCH, F., 1958—Interpretation of the seismic structure of the crust in the light of experimental studies of wave velocities in rocks; *in* BENIOFF, H., EWING, M., HOWELL, B. F., JR, & PRESS, F. (Editors)—CONTRIBUTIONS IN GEOPHYSICS IN HONOUR OF BENO GUTENBERG. *Pergamon, London,* 158-70.

BROD, R. J., 1962—Aeromagnetic interpretation (Officer Basin) W.A. *Geophysical Associates International, for Hunt Oil Company* (unpublished).

COMPSTON, W., & ARRIENS, P. A., 1968—The Precambrian geochronology of Australia. *Canadian Journal of Earth Science,* **5**, 561-83.

CONTINENTAL OIL COMPANY OF AUSTRALIA LTD, 1965—Serpentine Lakes reconnaissance seismic survey. *Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts Report* **65/1104** (unpublished).

CONTINENTAL OIL COMPANY OF AUSTRALIA LTD, 1967a—Birksgate No. 1, well completion report. *Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts Report* **67/4242** (unpublished).

CONTINENTAL OIL COMPANY OF AUSTRALIA LTD, 1967b—Eastern Officer Basin seismic and gravity survey. *Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts Report* **67/11163** (unpublished).

CONTINENTAL OIL COMPANY OF AUSTRALIA LTD, 1968—Munyarai No. 1, well completion report, *Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts Report* **68/2012** (unpublished).

DANIELS, J. L., 1971a—Cooper, Western Australia—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* **SG/52-10**.

DANIELS, J. L., 1971b—Talbot, Western Australia—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* **SG/52-9**.

DARBY, F., & VALE, K. R., 1969—Progress of the reconnaissance gravity survey of Australia. *Bureau of Mineral Resources, Australia, Record* **1969/110** (unpublished).

DOYLE, H. A., 1954—Seismic investigation of atomic explosion in South Australia, October 1953. *Bureau of Mineral Resources, Australia, Record* **1954/64** (unpublished).

DOYLE, H. A., & EVERINGHAM, I. B., 1964—Seismic velocities and crustal structure in southern Australia. *Journal of the Geological Society of Australia,* **11**(1), 141-50.

EXOIL PTY LTD, 1962—Mabel Creek seismic survey. *Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts Report* **62/1588** (unpublished).

EXOIL PTY LTD, 1963—Emu No. 1, well completion report. *Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts Report* **63/1030** (unpublished).

EXOIL PTY LTD, 1964—Eastern Officer Basin airborne magnetometer survey. *Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts Report* **64/4608** (unpublished).

FLAVELLE, A. J., & GOODSPEED, M. J., 1962—Fitzroy and Canning Basins reconnaissance gravity surveys, Western Australia, 1952-60. *Bureau of Mineral Resources, Australia, Record* **1962/105** (unpublished).

GUNSON, S., & VAN DER LINDEN, J., 1956—Regional gravity traverses across the Eucla Basin, 1954-55. *Bureau of Mineral Resources, Australia, Record* **1956/145** (unpublished).

HASTIE, L. M., & WALKER, D. G., 1962—Two methods of gravity traversing with helicopters. *Bureau of Mineral Resources, Australia, Record* **1962/134** (unpublished).

HAWKINS, L. V., & MAGGS, D., 1961—Nomograms for determining maximum errors and limiting conditions in seismic refraction survey with a blind-zone problem. *Geophysical Prospecting,* **9**(4), 526-32.

KENDALL, G. W., 1965—Report on reconnaissance seismic refraction survey in the South Australian portion of the Eucla Basin, 1964. *Department of Mines, South Australia, Geological Survey, Report Book* **60/30**.

KERR-GRANT, C., & PEGUM, D. M., 1954—Gravity survey in the northeastern portion of the Nullarbor Plain and adjacent areas. *Department of Mines, South Australia, Geological Survey, Report* **GS200**.

KING, D., 1951—Geology of the Pidinga area. *Transactions of the Royal Society of South Australia,* **74**(1), 25-43.

KRIEG, G., 1969—Geological developments in the eastern Officer Basin of South Australia. *APEA Journal* **9**(2), 8-13.

LAMBOURN, S. S., 1977—An interpretation of the airborne magnetic and radiometric survey of Coompana, Fowler, Nullarbor, and Nuyts (onshore) 1:250 000 Sheet areas, South Australia, 1972-3. *Bureau of Mineral Resources, Australia, Record* **1977/52** (unpublished).

LONSDALE, G. F., & FLAVELLE, A. J., 1968—Amadeus and south Canning Basins gravity survey; Northern Territory and Western Australia, 1962. *Bureau of Mineral Resources, Australia, Report* **133**.

LOWRY, D. C., 1970—Geology of the Western Australian part of the Eucla Basin. *Geological Survey of Western Australia, Bulletin* **122**.

LUDBROOK, N. H., 1957—The Eucla Basin in South Australia. *Journal of the Geological Society of Australia,* **5**(2), 127-35.

MATHUR, S. P. 1974—A proposal for a deep seismic sounding and associated gravity survey in central Australia. *Bureau of Mineral Resources, Australia, Record* **1974/69** (unpublished).

MILTON, B. E., 1969a—Geophysical investigations of basins marginal to the western Great Artesian Basin. *APEA Journal* **9**(2), 127-35.

MILTON, B. E., 1969b—Western Arckaringa Basin: depths to basement from seismic investigations. *Geological Survey of South Australia, Quarterly Notes* **32**.

MILTON, B. E., 1970—Discovery of a dense lower to middle Palaeozoic limestone, northwest Arckaringa Basin. *Geological Survey of South Australia, Quarterly Notes* **36**.

MOORCROFT, E., 1969—Seismic reflection, refraction, and gravity survey, eastern Officer Basin, 1966. *South Australian Mining Review* **126**, 58-70.

MUMME, I. A., 1963a—Geophysical survey of the Officer Basin, South Australia. *Transactions of the Royal Society of South Australia,* **87**, 119-22.

MUMME, I. A., 1963b—An evaluation of the crustal thickness in the Maralinga area, South Australia. *Transactions of the Royal Society of South Australia,* **87**, 197-8.

MURUMBA OIL NL, 1970—Eastern Officer Basin gravity survey, 1970. *Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts Report* **70/134** (unpublished).

NESBITT, R. W., & TALBOT, J. L., 1966—The layered basic and ultrabasic intrusives of the Giles Complex, central Australia. *Contributions to Mineralogy and Petrology,* **13**(1), 1-11.

OUTBACK OIL, NL, 1965—Eucla Basin gravity survey. *Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts Report* **65/4819** (unpublished).

OUTBACK OIL NL, 1969—Mallabie No. 1, well completion report. *Bureau of Mineral Resources, Australia, Petroleum Search Subsidy Acts Report* **69/2013** (unpublished).

QUILTY, J. H., 1962—Childara/Gairdner airborne magnetic and radiometric survey, South Australia, 1961. *Bureau of Mineral Resources, Australia, Record* **1962/192** (unpublished).

QUILTY, J. H., & GOODEVE, P. E., 1958—Reconnaissance airborne magnetic survey of the Eucla Basin, southern Australia. *Bureau of Mineral Resources, Australia, Record* **1958/87** (unpublished).

ROWAN, I. S., 1968—Regional gravity survey of Mann and Woodroffe 1:250 000 Sheet areas. *South Australian Mining Review* **126**, 71-9.

SHELLEY, E. P., & DOWNIE, D. N., 1971—Mann-Woodroffe aeromagnetic survey, South Australia, 1969. *Bureau of Mineral Resources, Australia, Record* **1971/19** (unpublished).

SPRIGG, R. C., & WILSON, B., 1958—The Musgrave Mountain Belt in South Australia. *Geologische Rundschau* **47**, 531-42.

THOMSON, B. P., 1969—Precambrian crystalline basement. Chapter 1 *in* PARKIN, L. W. (ed.)—HANDBOOK .OF SOUTH AUSTRALIAN GEOLOGY. *Geological Survey of South Australia, Adelaide.*

THOMSON, B. P., 1970—A review of the Precambrian and Lower Proterozoic tectonics of South Australia. *Transactions of the Royal Society of South Australia,* **94**, 193-221.

THOMSON, B. P., 1975a—Gawler Craton—regional geology; *in* KNIGHT, C. L. (Editor)—ECONOMIC GEOLOGY OF AUSTRALIA AND PAPUA NEW GUINEA—1. METALS. *Australasian Institute of Mining and Metallurgy Monograph Series* **5**, 461-6.

THOMSON, B. P., 1975b—Musgrave Block—regional geology; *in* KNIGHT, C. L. (Editor)—ECONOMIC GEOLOGY OF AUSTRALIA AND PAPUA NEW GUINEA—1. METALS. *Australasian Institute of Mining and Metallurgy Monograph Series* **5**, 451-4.

TIPPER, D. B., 1967—Mann-Woodroffe aeromagnetic survey, South Australia, 1965. *Bureau of Mineral Resources, Australia, Record* **1967/89** (unpublished).

TUCKER, D. H., & BROWN, F. W., 1973—Reconnaissance helicopter gravity survey in the Flinders Ranges, South Australia, 1970. *Bureau of Mineral Resources, Australia, Record* **1973/12** (unpublished).

TURPIE, A., 1967—Giles-Carnegie seismic survey, Western Australia, 1961-1962. *Bureau of Mineral Resources, Australia, Record* **1967/123** (unpublished).

WALKER, N. C., & BOTHAM, S. J., 1969—Reconnaissance geological survey of the Streaky Bay and Nuyts 1:250 000 areas. *Department of Mines, South Australia, Geological Survey, Report Book* **68/25** (unpublished).

WALLER, D. R., 1968—Musgrave Block airborne magnetic and radiometric survey, South Australia, 1967. *Bureau of Mineral Resources, Australia, Record* **1968/51** (unpublished).

WALLER, D. R., QUILTY, J. H., & LAMBOURN, S. S., 1972—Eucla Basin airborne magnetic and radiometric survey, S.A., 1970. *Bureau of Mineral Resources, Australia, Record* **1972/60** (unpublished).

WEBB, A. W., 1973—The geochronology of the younger granites of the Musgrave Block. *AMDEL ANI/1/123 Progress Report* **11** (unpublished).

WELLS, R., 1962—Mann area airborne magnetic and radiometric survey, South Australia, 1960. *Bureau of Mineral Resources, Australia, Record* **1962/98** (unpublished).

WHITTEN, G. F., 1963—Investigation of aeromagnetic anomalies, Hundreds Carina, Chandada, and Ripon, western Eyre Peninsula. *Department of Mines, South Australia, Geological Survey, Report on Investigation* **23**.

WHITTEN, G. F., 1966—Notes on the Tarcoola-Kingoonya area. *Department of Mines, South Australia, Geological Survey, Report Book* **62/54** (unpublished).

WIEBENGA, W. A., & HAWKINS, L. V., 1956—Seismic survey at Maralinga, South Australia (1955-1956). *Bureau of Mineral Resources, Australia, Record* **1956/48** (unpublished).

WOPFNER, H., 1969—Depositional history and tectonics of South Australian sedimentary basins. *4th ECAFE Symposium on the Development of Petroleum Resources of Asia and the Far East, Canberra, 1969,* document I & NR/PR.4/57.

WOPFNER, H., 1970—Permian palaeogeography and depositional environment of the Arckaringa Basin, South Australia. *Department of Mines, South Australia, Geological Survey, Report Book* **70/101** (unpublished).

YOUNG, G. A., & GERDES, R., 1966—Central South Australia airborne magnetic and radiometric survey, South Australia, 1966. *Bureau of Mineral Resources, Australia, Record* **1966/224** (unpublished).

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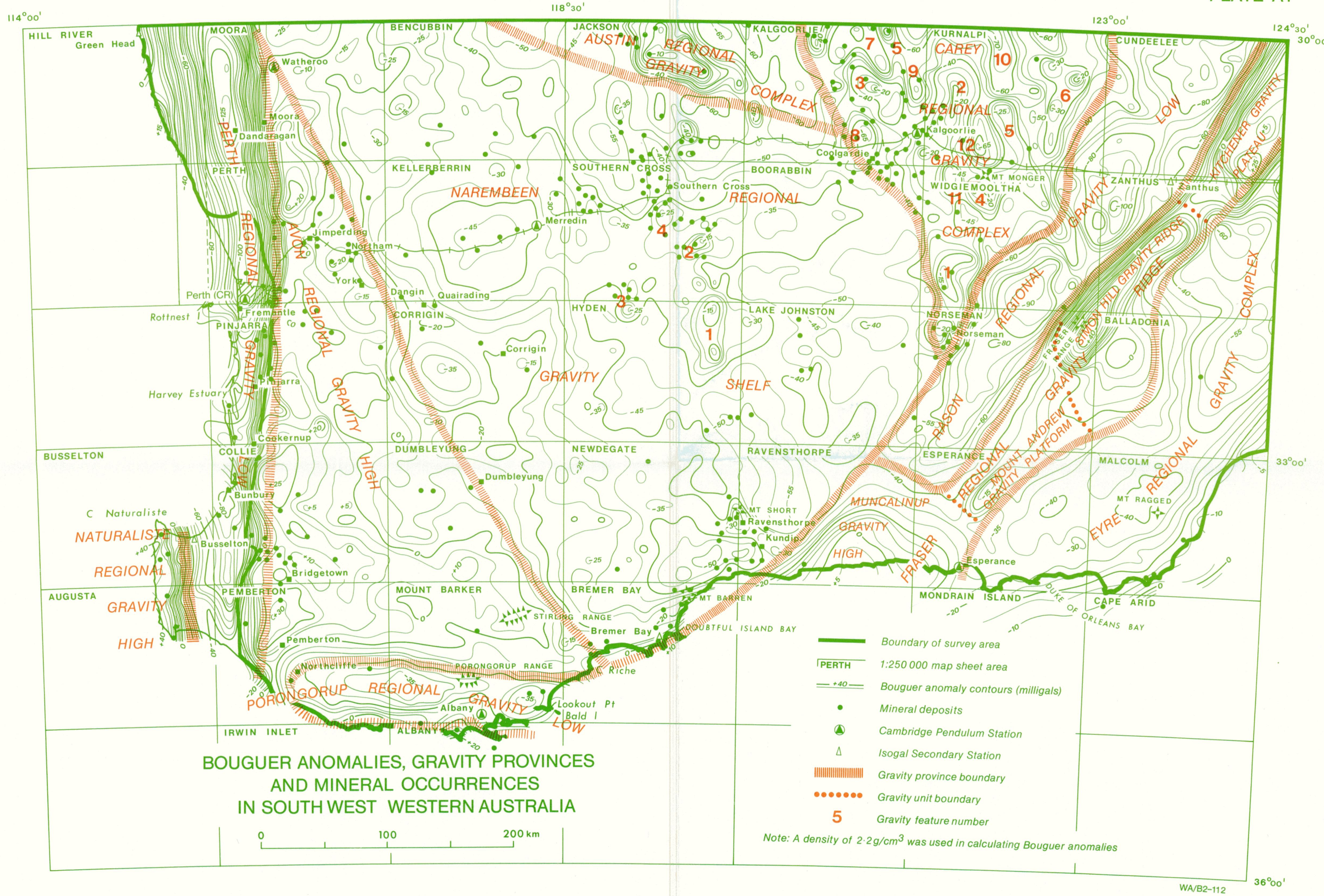
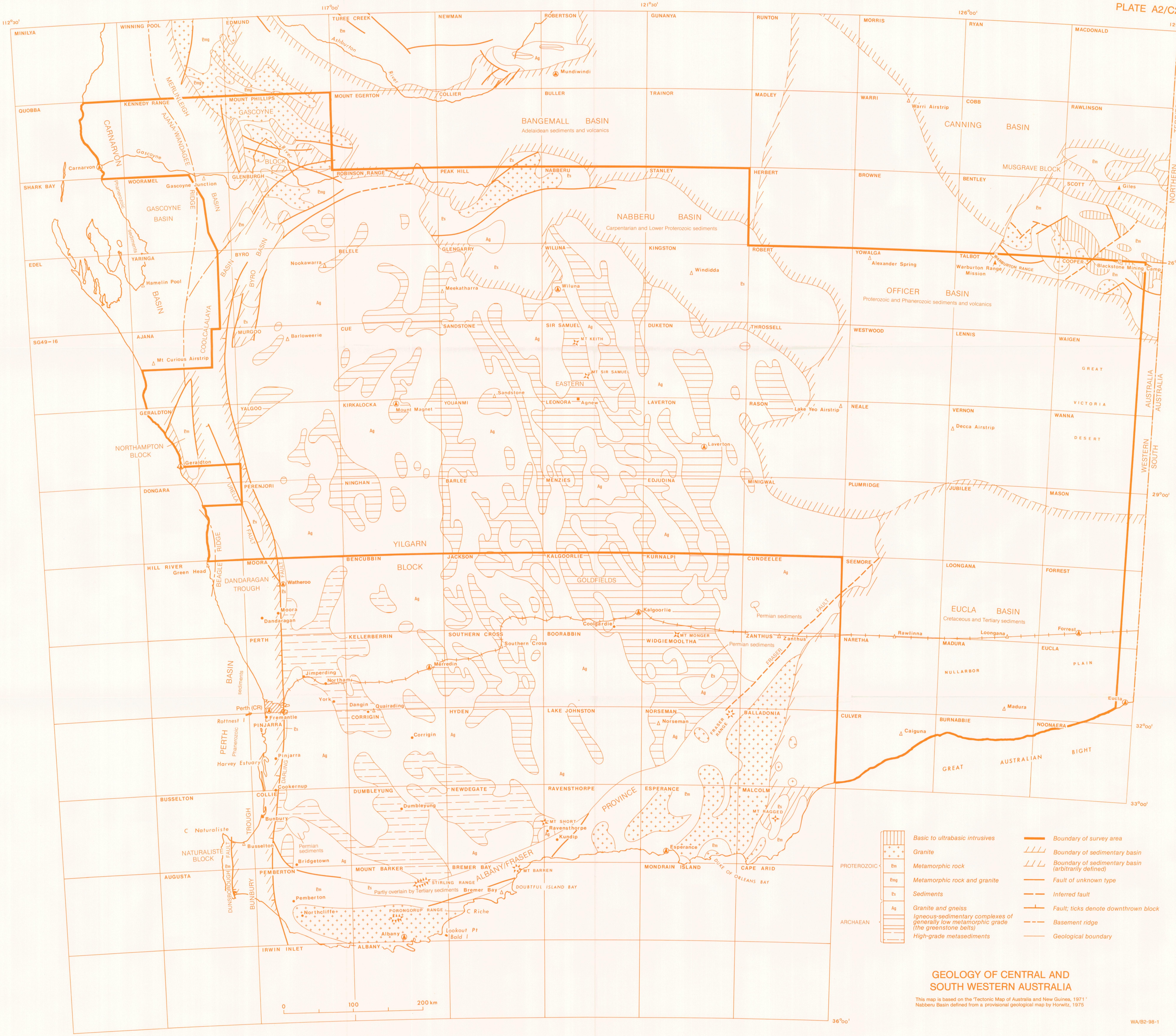
PLATE A1



BOUGUER ANOMALIES, GRAVITY PROVINCES AND MINERAL OCCURRENCES IN SOUTH WEST WESTERN AUSTRALIA

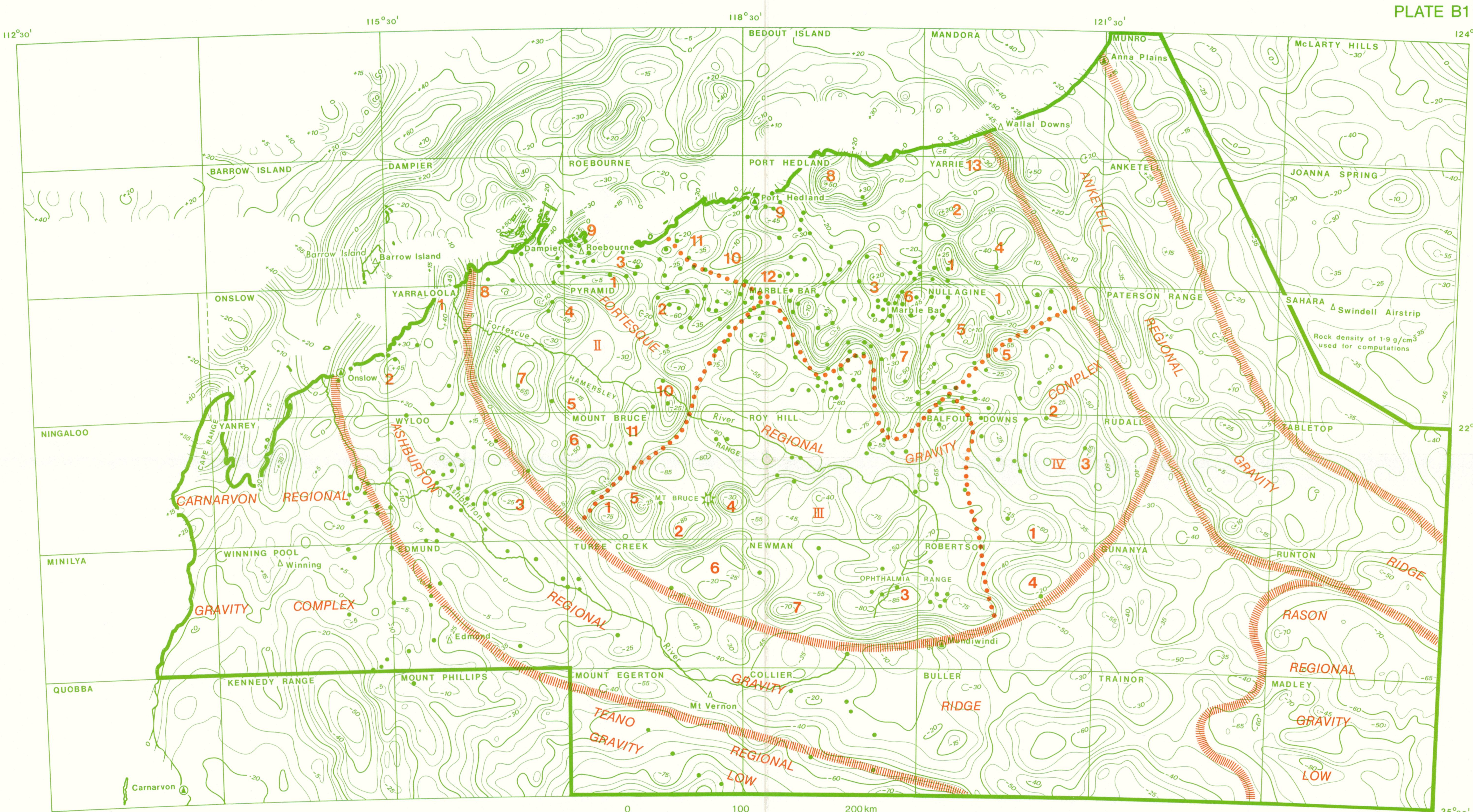


GEOLOGY OF CENTRAL AND SOUTH WESTERN AUSTRALIA

This map is based on the 'Tectonic Map of Australia and New Guinea, 1971'
Nabberu Basin defined from a provisional geological map by Horwitz, 1975

WA/B2-98-1

PLATE B1



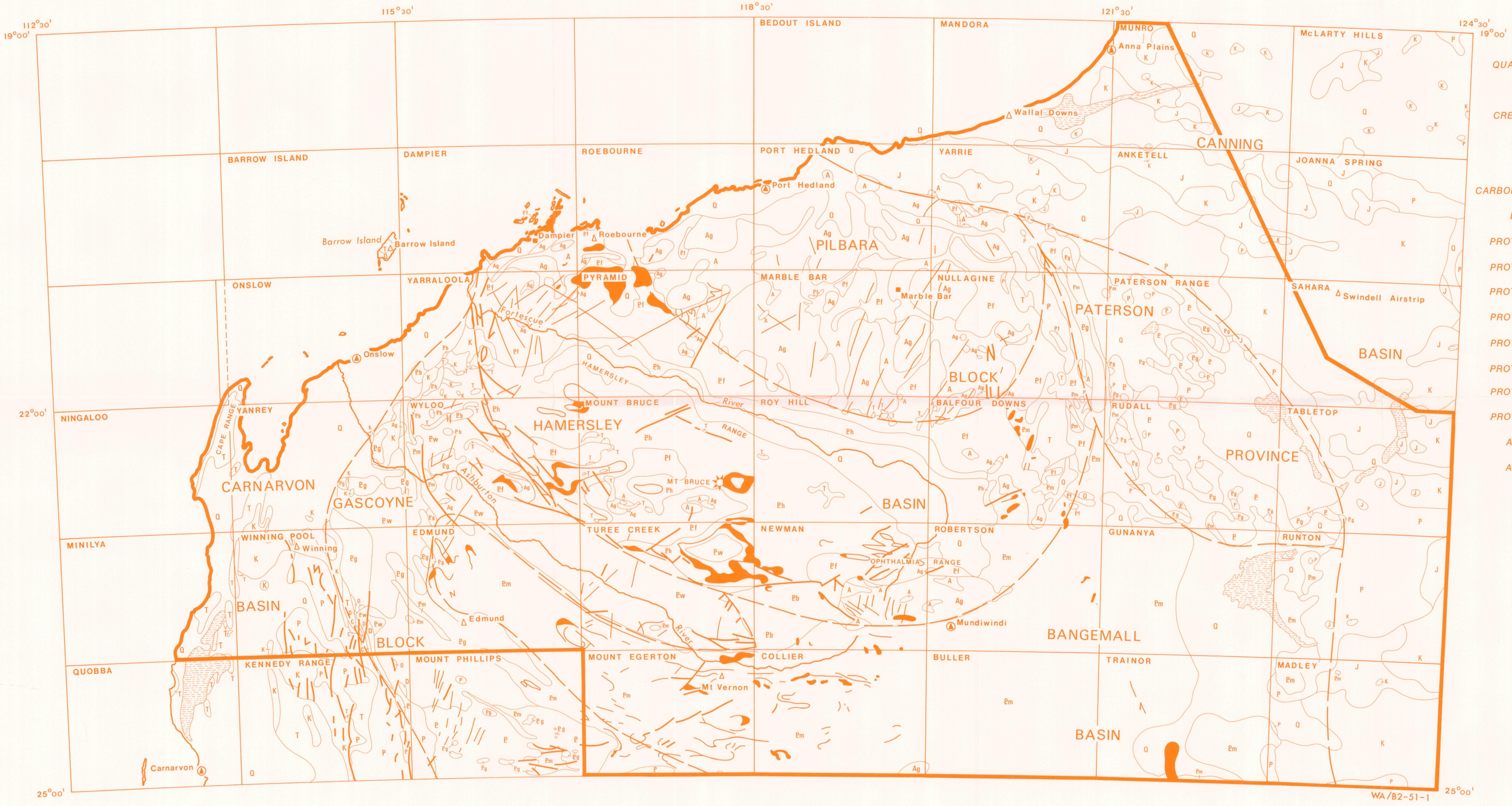
Boundary of area discussed	Bouguer anomaly contours (milligals)
WYLOO 1:250 000 map sheet area	Gravity province boundary
Mineral occurrence	Gravity unit boundary
Cambridge Pendulum Station	5 Gravity feature number
Isogal Secondary Station	

Note: A density of 2·2 g/cm^3 was used in calculating Bouguer anomalies

Note: Information was obtained from the map entitled "Regional Divisions and Reported Mineral Occurrences, Western Australia" (Mineral Division of the WA Chemical Laboratories, 1961), and the "Metallogenic Map of Australia and Papua New Guinea"(BMR, 1972)

BOUGUER ANOMALIES, GRAVITY PROVINCES AND MINERAL OCCURRENCES IN NORTHWEST WESTERN AUSTRALIA

PLATE B2



LEGEND

QUATERNARY	Q	Sediments
TERTIARY	T	Sediments
CRETACEOUS	K	Sediments
JURASSIC	J	Sediments
PERMIAN	P	Sediments
CARBONIFEROUS	C	Sediments
DEVONIAN	D	Sediments
PROTEROZOIC	Ɇm	Sediments and volcanics (Bangemall Group) unconformity
PROTEROZOIC	Ɇb	Sediments and volcanics (Bresnahan Group) unconformity
PROTEROZOIC	Ɇw	Sediments and volcanics (Wyloo Group) disconformity } Mount Bruce Supergroup
PROTEROZOIC	Ɇh	Sediments and volcanics (Hamersley Group) } Mount Bruce Supergroup
PROTEROZOIC	Ɇf	Sediments and volcanics (Fortescue Group) unconformity } Mount Bruce Supergroup
PROTEROZOIC	Ɇg	Granite
PROTEROZOIC	Ɇ	Low to medium-grade metamorphics
PROTEROZOIC		Basic dykes and sills
ARCHAEAN	Ag	Granite
ARCHAEAN	A	Sediments and volcanics (Mosquito Creek and Warrawoona Successions and Roebourne Group)

Note: 1. Drawn from information based on the Geological Map of Western Australia (Geological Survey of Western Australia, 1966) and the Tectonic Map of Australia and New Guinea (Geological Society of Australia, 1971)

2. The Median Belt encompasses the Hamersley Basin and the Bangemall Basin

Boundary of area discussed

WYLOO 1:250 000 map sheet area

Boundary of major structural division (approximate)

Geological boundary — Lake

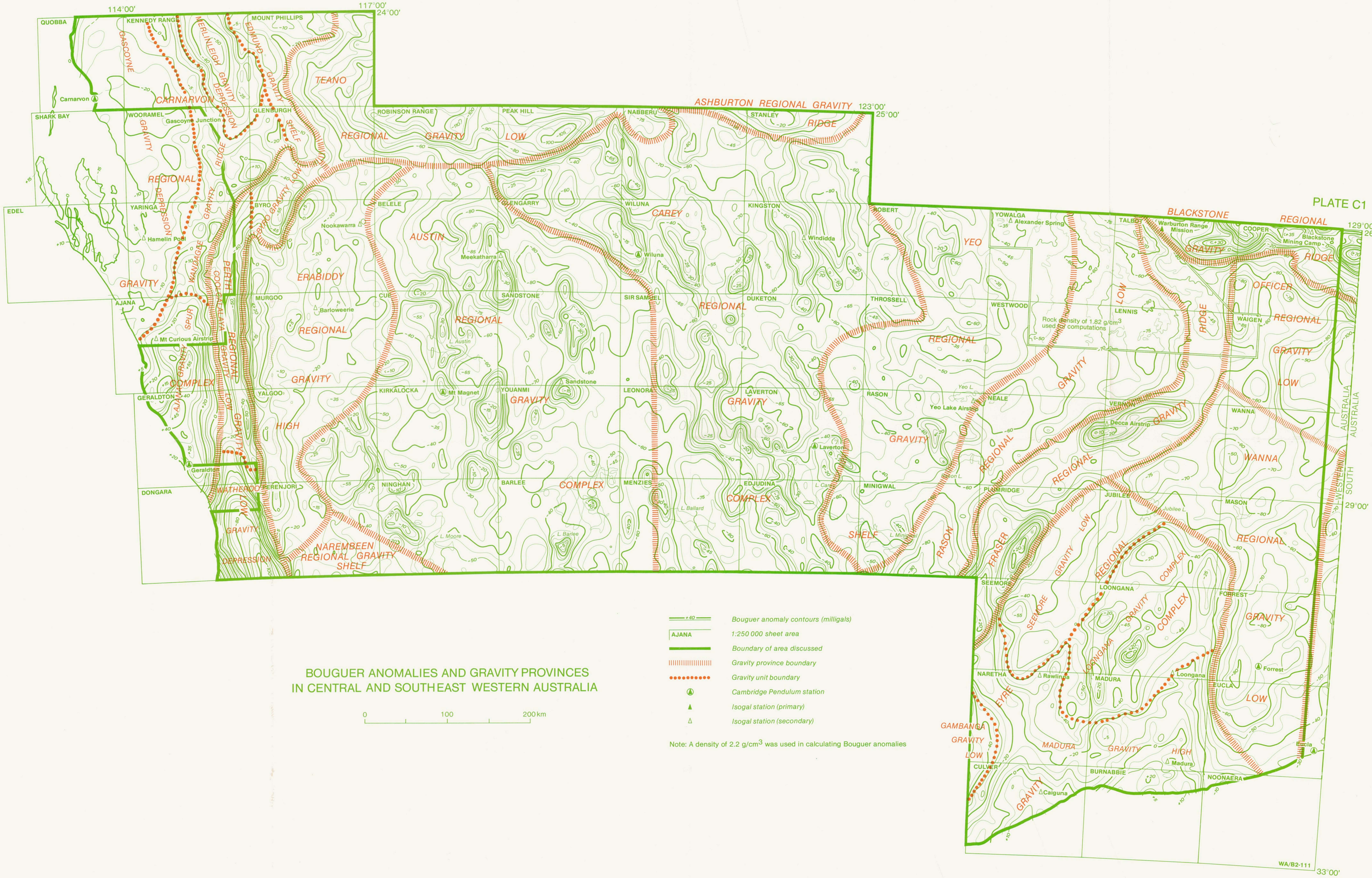
Fault — Cambridge Pendulum Station

Dyke — Isogal Secondary Station

0 100 200 km

GEOLOGY OF NORTHWEST WESTERN AUSTRALIA

PLATE C1



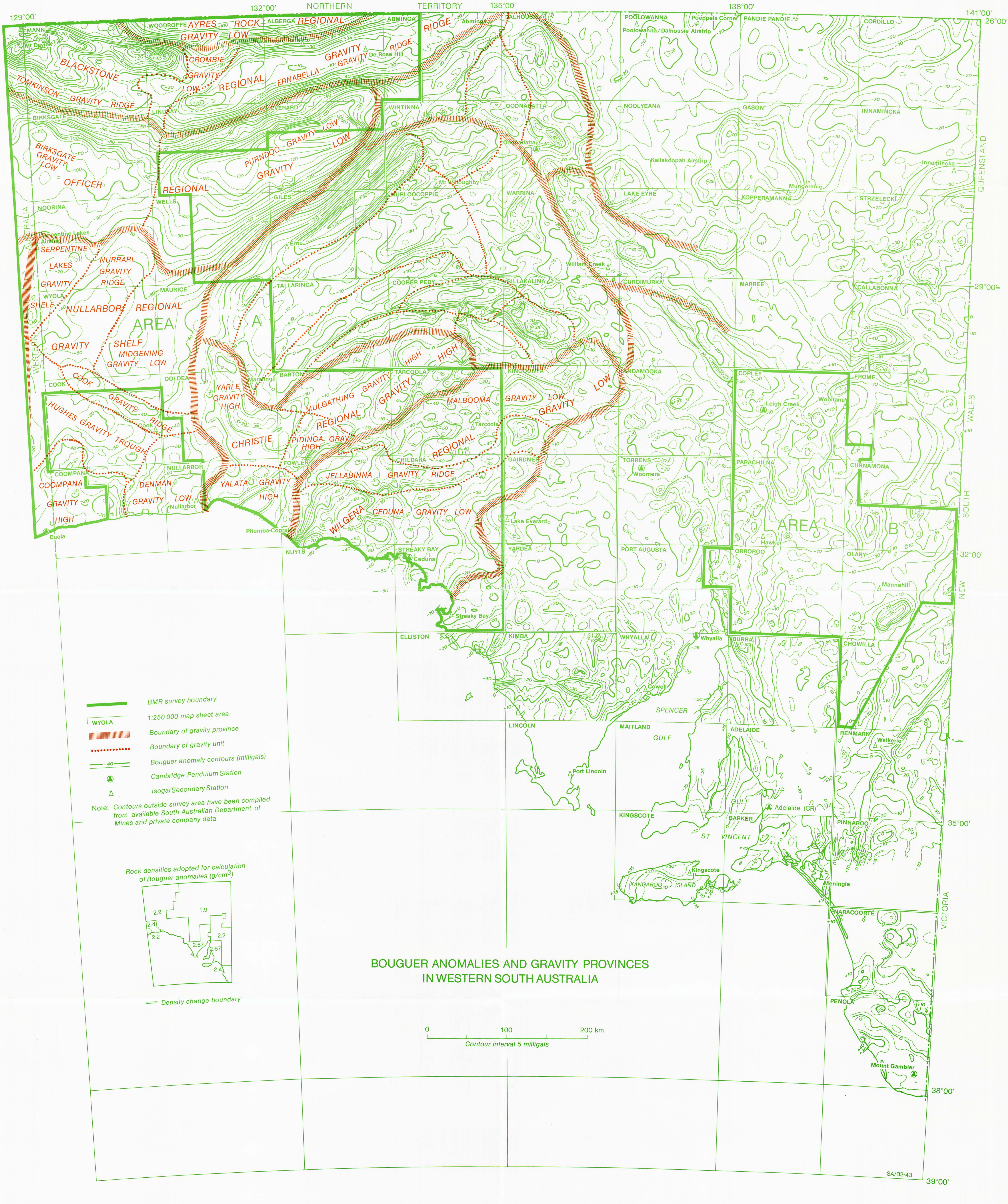
BOUGUER ANOMALIES AND GRAVITY PROVINCES IN CENTRAL AND SOUTHEAST WESTERN AUSTRALIA

0 100 200 km

- Bouguer anomaly contours (milligals)
- AJANA — 1:250 000 sheet area
- Boundary of area discussed
- Gravity province boundary
- Gravity unit boundary
- Cambridge Pendulum station
- Isogal station (primary)
- Isogal station (secondary)

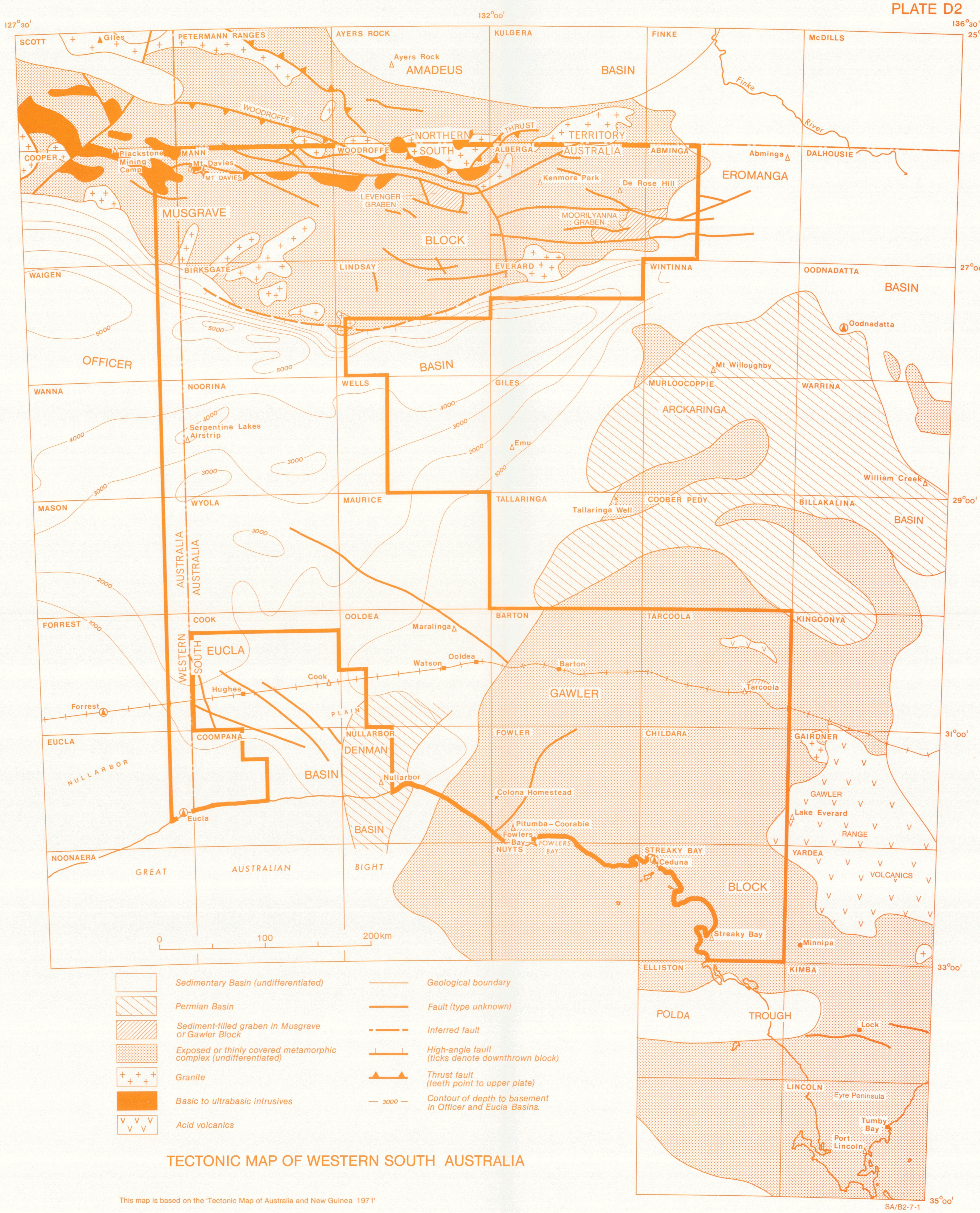
Note: A density of 2.2 g/cm^3 was used in calculating Bouguer anomalies

PLATE D1



BOUGUER ANOMALIES AND GRAVITY PROVINCES IN WESTERN SOUTH AUSTRALIA
BMR survey boundary
1:250 000 map sheet area
WYOLA
Boundary of gravity province
Boundary of gravity unit
Bouguer anomaly contours (milligals)
Cambridge Pendulum Station
Isogal Secondary Station
Note: Contours outside survey area have been compiled from available South Australian Department of Mines and private company data
Rock densities adopted for calculation of Bouguer anomalies (g/cm3)
Density change boundary
0
100
200 km
Contour interval 5 milligals
SA/B2-43
NORTHERN TERRITORY
QUEENSLAND
NEW SOUTH WALES
VICTORIA
WESTERN AUSTRALIA
129°00'
132°00'
135°00'
138°00'
141°00'
26°00'
29°00'
32°00'
35°00'
38°00'
39°00'
AYRES ROCK REGIONAL GRAVITY LOW
BLACKSTONE
TOMKINSON GRAVITY RIDGE
CROMBIE GRAVITY LOW
REGIONAL
ERNABELLA GRAVITY RIDGE
DE ROSE HILL GRAVITY RIDGE
BIRKSGATE GRAVITY LOW
OFFICER
PURNDOO GRAVITY LOW
GRAVITY LOW
REGIONAL
SERPENTINE LAKES GRAVITY SHELF
NURRARI GRAVITY RIDGE
NULLARBOR REGIONAL GRAVITY SHELF
AREA
A
MIDGENING GRAVITY LOW
COOK GRAVITY RIDGE
HUGHES GRAVITY TROUGH
YARLE GRAVITY HIGH
CHRISTIE
MULGATHING REGIONAL GRAVITY HIGH
GRAVITY HIGH
MALBOOMA GRAVITY LOW
PIDINGA GRAV HIGH
REGIONAL
JELLABINNA GRAVITY RIDGE
COOMPANA GRAVITY HIGH
DENMAN GRAVITY LOW
YALATA GRAVITY HIGH
WILGENA
CEDUNA GRAVITY LOW
AREA B
SPENCER GULF
GULF ST VINCENT
KANGAROO ISLAND

PLATE D2

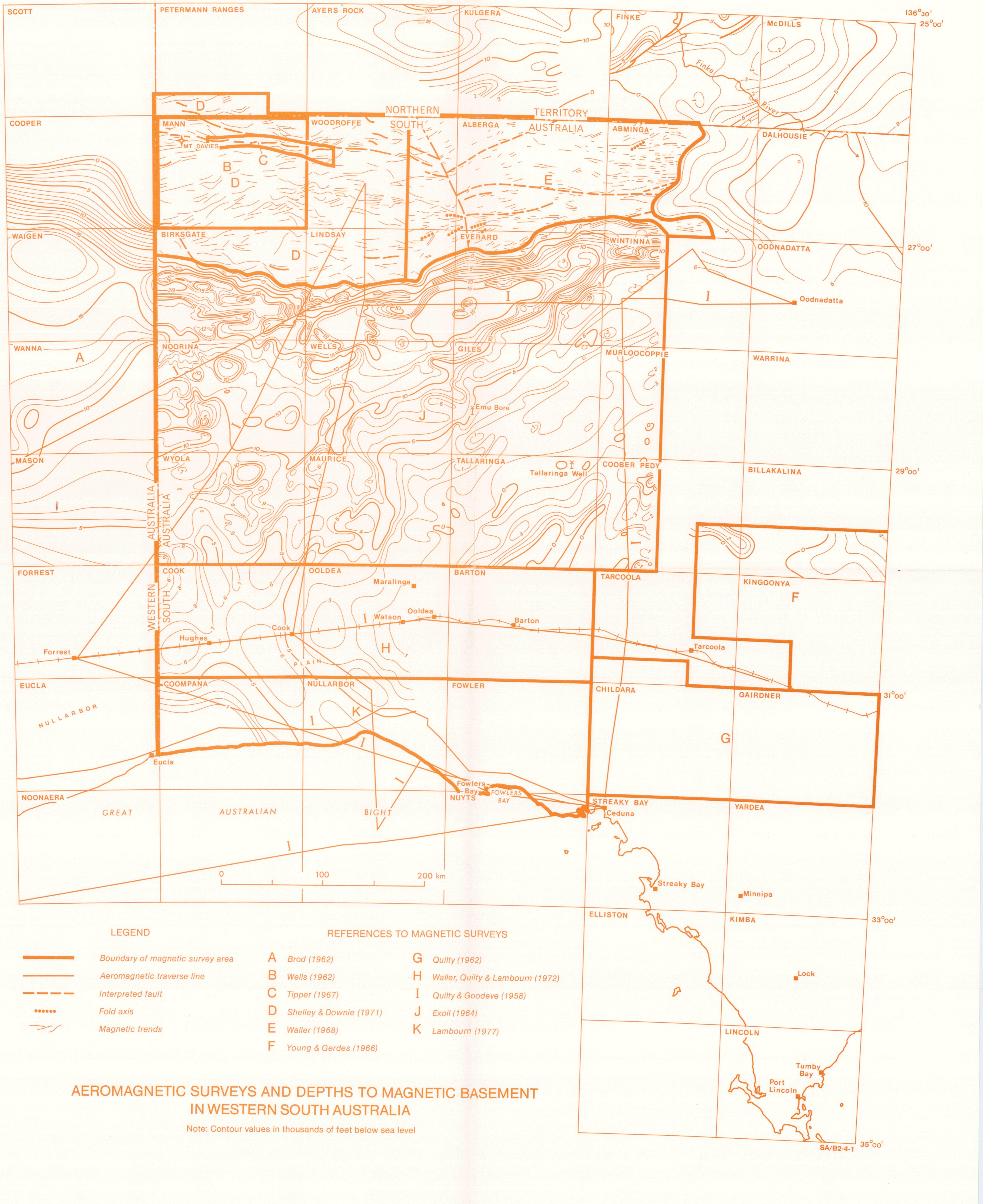


TECTONIC MAP OF WESTERN SOUTH AUSTRALIA

This map is based on the 'Tectonic Map of Australia and New Guinea 1971'

SA/B2-7-1

PLATE D3



AEROMAGNETIC SURVEYS AND DEPTHS TO MAGNETIC BASEMENT IN WESTERN SOUTH AUSTRALIA

Note: Contour values in thousands of feet below sea level

APPENDIX A1. SURVEY STATISTICS

Survey commenced	:	9 May 1969
Survey completed	:	19 September 1969
Total survey days	:	133
Total helicopter days available	:	237 (the first 29 days were conducted as a single-helicopter operation after which two helicopters were used)
Days unserviceable	:	52
Pilot days off	:	15
Days lost during maintenance	:	2
Days lost during bad weather	:	2
Loops flown	:	586
New readings	:	3961
Flying time	:	845 hours
Ferry time	:	124 hours

Statistics by Sheet area

1:250 000 Sheet area	New readings	Flying time h.min	Ferry time h.min	New readings per flying hour	New readings per flying and ferry hour	Loops
BALLADONIA	160	40.35	7.00	4.0	3.4	24
BENCUBBIN	157	28.55	4.30	5.5	4.8	24
BOORABBIN	153	23.15	2.20	6.6	6.0	24
BREMER BAY	64	13.05	2.25	5.5	4.2	9
COLLIE	120	22.20	2.35	5.4	4.9	18
CORRIGIN	162	31.10	5.50	5.2	4.4	24
CUNDEELEE	157	39.05	7.35	4.0	3.4	24
DUMBLEYUNG	158	33.30	5.10	4.7	4.1	22
ESPERANCE	151	41.55	11.00	3.6	2.9	24
HILL RIVER	48	9.15	1.45	5.2	4.5	7
HYDEN	157	33.25	1.40	4.7	4.5	24
JACKSON	157	29.15	3.30	5.4	4.8	24
KALGOORLIE	157	31.50	3.15	5.0	4.5	24
KELLERBERRIN	164	33.45	3.05	4.9	4.5	24
KURNALPI	154	34.20	4.25	4.6	4.0	24
LAKE JOHNSTON	153	35.40	3.00	4.3	4.0	24
MALCOLM	104	29.30	7.30	3.5	2.8	16
MONDRAIN ISLAND	19	4.50	1.00	4.2	3.5	2
MOORA	144	34.55	1.35	5.8	4.6	14
MOUNT BARKER	157	35.25	2.50	4.5	4.2	23
NEWDEGATE	157	34.30	4.05	4.6	4.1	24
NORSEMAN	157	38.00	6.35	4.1	3.5	24
PEMBERTON	104	21.45	4.10	4.8	4.1	17
PERTH	126					12
PINJARRA	101	14.25	1.35	6.2	5.6	15
RAVENSTHORPE	148	32.30	3.30	4.6	4.2	23
SOUTHERN CROSS	160	33.38	2.55	4.8	4.5	24
WIDGIEMOOLTHA	161	41.15	6.30	3.9	3.4	24
ZANTHUS	151	43.35	12.45	3.5	2.7	24

APPENDIX A2. 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 by the 'cell method' (Hastie & Walker, 1962).

Before the helicopter gravity operation, the Survey Branch of the former Commonwealth Department of the Interior (and now in the Department of Administrative Services) 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 called a segment. The segmentation of the survey area is shown in Appendix Figure A1. In the flying of the survey, no loop was allowed to cross a segment boundary. This method of flying meant that each segment could be computed independently for elevation control.

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

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

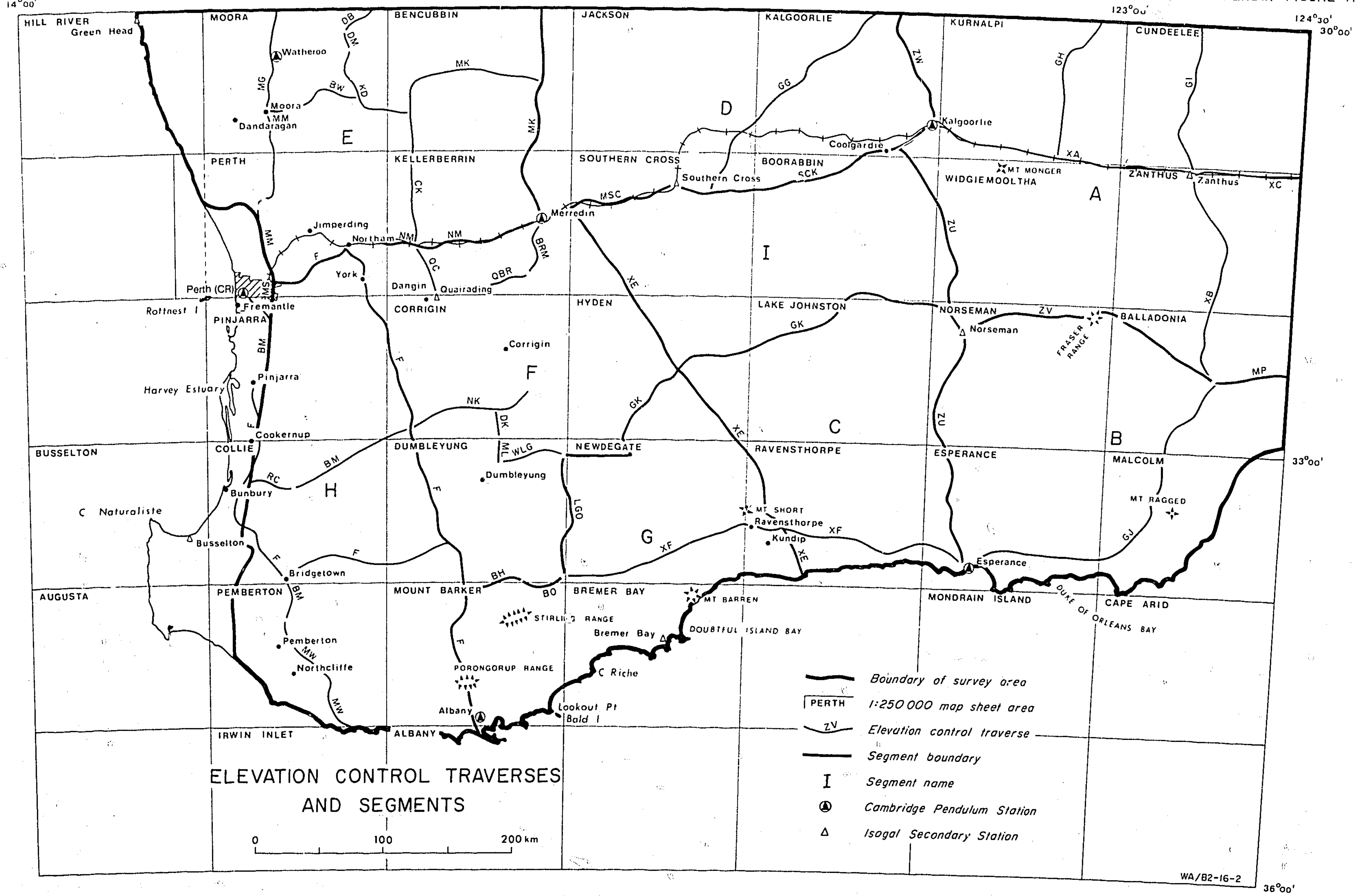
Computing procedure

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 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.

APPENDIX FIGURE A1



ELEVATION CONTROL TRAVERSES AND SEGMENTS

(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 for the fixed nodes computed as free nodes is a good estimate of the accuracy of the heights in any segment.

For the gravity network, only steps (1) and (2) were carried out.

The internal, external, and forecast standard deviations for the elevation and gravity networks are tabulated below. 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 (3).

Segment	Elevation (m)							Gravity (mGal)			
	Internal network		External network		Forecast network			Internal network		External network	
	SD	Max. adj.	SD	Max. adj.	SD	Max. adj.	Max. adj. SD	SD	Max. adj.	SD	Max. adj.
A	1.45	3.80	1.80	5.32	2.62	4.57	1.75	0.04	0.13	0.04	0.12
B	2.03	6.12	2.39	8.21	1.98	4.57	2.31	0.04	0.14	0.04	0.14
C	1.83	5.69	2.61	7.14	2.90	6.40	2.2	0.03	0.07	0.03	0.08
D	1.26	3.84	1.67	4.74	0.94	1.83	1.9	0.05	0.13	0.05	0.13
E	1.11	3.11	1.74	5.38	3.35	6.10	1.9	0.03	0.10	0.03	0.11
F	1.80	5.64	2.12	10.80	1.58	4.27	2.7	0.03	0.08	0.03	0.09
G	1.81	5.11	2.46	7.14	1.95	3.05	1.6	0.03	0.07	0.03	0.07
H	1.56	6.26	2.09	7.93	2.32	3.96	1.7	0.03	0.11	0.03	0.11
I	0.97	3.11	1.54	4.08	2.10	4.57	2.2	0.06	0.19	0.06	0.19

APPENDIX A3. LISTS OF PREVIOUS GEOPHYSICAL SURVEYS AND WELLS WITHIN THE SURVEY AREA

The following lists give the names of and references to BMR and subsidised geophysical and drilling surveys up to 1970. The locations of these surveys are shown in Figures A1, A2, and A3.

The full names of petroleum exploration and development companies referred to in the lists below are: West Australian Petroleum Pty Ltd, Union Oil Development Corporation, and French Petroleum Co. (Aust.) Pty Ltd (now Total Exploration Australia Pty Ltd).

Company reports of subsidised surveys are housed in BMR as Petroleum Search Subsidy Acts (PSSA) Reports, which are unpublished. A few of them have been published, either complete or in summary form, in the BMR PSSA Publication series.

Gravity surveys

Name of survey	Operator	Reference
Perth Basin, 1951-52	BMR	Thyer & Everingham (1956)
Regional gravity traverses across the Eucla Basin, 1954-55	BMR	Gunson & Van der Linden (1956)
Eganu, 1962 (Perth Basin)	WAPET	BMR PSSA Report 62/1933
Augusta-Moora, 1962 (Perth Basin)	WAPET	BMR PSSA Report 62/1935
South Western Australia, 1964	I.B. Everingham	Everingham (1965a)

Magnetic surveys

Name of survey	Operator	Reference
Eucla Basin reconnaissance airborne magnetic, 1954	BMR	BMR Record 1958/87

Name of survey	Operator	Reference
Kalgoorlie-Melbourne, 1956	BMR	H51/B1-1*
KALGOORLIE, BARLEE, JACKSON, and SOUTHERN CROSS airborne magnetic and radiometric, 1956-57	BMR	BMR Record 1958/45
Blackstone Range-Kalgoorlie, 1957	BMR	H51/B1-1*
Perth Basin aeromagnetic, 1957	BMR	Quilty (1963)
KURNALPI-WIDGIEMOOLTHA airborne magnetic and radiometric, 1958	BMR	BMR Record 1959/137
Carnarvon-Perth, 1959	BMR	H50/B1-1*
BOORABBIN and NORSEMAN airborne magnetic and radiometric, 1959	BMR	BMR Record 1961/55
Norseman-Perth, 1959	BMR	H51/B1-1, H50/B1-1*
Ravensthorpe airborne magnetic and radiometric, 1960	BMR	BMR Record 1962/2
LAKE JOHNSTON airborne magnetic and radiometric, 1960	BMR	BMR Record 1962/100
Giles-Kalgoorlie, 1960	BMR	H51/B1-1*
Kalgoorlie detailed aeromagnetic, 1964	BMR	BMR Record 1965/26

* Index numbers to: BMR, 1964 - Magnetic profiles along flight lines. Bureau of Mineral Resources, Australia, Aeromagnetic Reconnaissance Survey (1:1 000 000) Maps (unpublished). These maps show the magnetic profiles along flight lines of only the sections of traverses in the BMR southwest Western Australian gravity survey area, 1969.

Name of survey	Operator	Reference
Norseman detailed aeromagnetic, 1964	BMR	BMR Record 1965/203
Kalgoorlie detailed aeromagnetic, 1965	BMR	BMR Record 1966/104
Merredin-Perth airborne magnetic and radiometric traverses, 1966	BMR	BMR Record 1968/4
	Seismic surveys	
Gingin seismic reflection, 1955 (Perth Basin)	BMR	BMR Record 1956/26, Vale (1966)
Cookernup, 1955-56 (Perth Basin)	BMR	Vale & Moss (1962)
Rockingham-Mundijong, 1956 (Perth Basin)	BMR	Moss (1962)
Busselton seismic reflection, 1956 (Perth Basin)	BMR	Lodwick (1962)
Bullsbrook, 1964 (Perth Basin)	BMR	Walker & Jones (1966)
Deep crustal reflection survey, southwestern Australia, 1967, 1969	BMR	Mathur (1974)
Hill River-Dongara, 1960 (Perth Basin)	WAPET	BMR PSSA Report 62/1534
Perth Basin, 1962	WAPET	BMR PSSA Report 62/1590, BMR PSSA Report 62/1602, BMR PSSA Report 62/1627

Name of survey	Operator	Reference
Wicherina, 1962 (Perth Basin)	WAPET	BMR PSSA Report 62/1651
Gingin, 1963 (Perth Basin)	WAPET	BMR PSSA Report 63/1541
Lake Preston, 1964 (Perth Basin)	WAPET	BMR PSSA Report 64/4501
Darradup, 1964 (Perth Basin)	WAPET	BMR PSSA Report 64/4502
Pinjarra, 1965 (Perth Basin)	WAPET	BMR PSSA Report 65/4578
Blackwood, 1965 (Perth Basin)	WAPET	BMR PSSA Report 65/4591
Bullsbrook, 1965 (Perth Basin)	WAPET	BMR PSSA Report 65/11048
Yanchep, 1965 (Perth Basin)	WAPET	BMR PSSA Report 65/11050
Dandaragan, 1966 (Perth Basin)	WAPET	BMR PSSA Report 66/11065
Karnup, 1966 (Perth Basin)	WAPET	BMR PSSA Report 66/11069
Charla, 1966 (Perth Basin)	WAPET	BMR PSSA Report 66/11071
Wedge, 1966 (Perth Basin)	WAPET	BMR PSSA Report 66/11082

Name of survey	Operator	Reference
Smokebush, 1966 (Perth Basin)	WAPET	BMR PSSA Report 66/11114
Coogee, 1966 (Perth Basin)	WAPET	BMR PSSA Report 66/11125
Sabina, 1966 (Perth Basin)	Union Oil	BMR PSSA Report 66/11154
Margaret River, 1966 (Perth Basin)	Union Oil	BMR PSSA Report 66/11191
Walyering, 1967 (Perth Basin)	WAPET	BMR PSSA Report 67/11143
Lancelin, 1967 (Perth Basin)	WAPET	BMR PSSA Report 67/11182
Sugarloaf, 1968 (Perth Basin)	WAPET	BMR PSSA Report 68/3039
Wonnerup-Flinders, 1968 (Perth Basin)	Union Oil	BMR PSSA Report 68/3060
Harvey, 1969 (Perth Basin)	WAPET	BMR PSSA Report 69/3022
Namban, 1969 (Perth Basin)	WAPET	BMR PSSA Report 69/3025
Harvey D-1, 1969 (Perth Basin)	WAPET	BMR PSSA Report 69/3074

Wells

Well name and no.	Year	Total depth (m)	Operator	Reference
Jurien No. 1	1962	1026	WAPET	62/1110* 55#
Woolmulla No. 1	1962	2811	WAPET	62/1127 54
Eganu No. 1	1962	606	WAPET	62/1221 55
Hill River No. 1	1962	579	WAPET	62/1402 54
Hill River No. 2	1962	116	WAPET	62/1402 54
Hill River No. 2A	1962	494	WAPET	62/1402 54
Hill River No. 3	1962	264	WAPET	62/1402 54
Hill River No. 4	1962	308	WAPET	62/1402 54
Gingin No. 1	1964	4544	WAPET	64/4121
Cadda No. 1	1965	2795	FPC	65/4164
Pinjarra No. 1	1965	4572	WAPET	65/4176
Sue No. 1	1966	3059	WAPET	65/4186 81
Preston No. 1	1966	762	WAPET	66/4219
Cockburn No. 1	1967	3054	WAPET	67/4251
Whicher Range No. 1	1968	4653	Union Oil	68/2005

* BMR PSSA Report number

\# BMR PSSA Publication series number

APPENDIX B1. SURVEY STATISTICS

Survey commenced	:	2 September 1969
Survey completed	:	24 November 1969
Total survey days	:	84
Total helicopter days available	:	157 (first 11 days were conducted as a single-helicopter operation, after which two helicopters were used)
Days unserviceable	:	45
Pilot days off	:	7
Days lost during maintenance	:	3
Days lost during bad weather	:	2
Loops flown	:	467
New readings	:	3297
Flying time	:	556 hours
Ferry time	:	95 hours

Statistics by Sheet area

1:250 000 Sheet area	New readings	Flying time h.min	Ferry time h.min	New readings per flying hour	New readings per flying and ferry hour	Loops
BALFOUR DOWNS	169	31.50	3.50	5.4	4.8	24
BARROW ISLAND	17	2.45	1.25	6.9	4.6	2
BULLER	167	30.40	5.35	5.5	4.7	24
COLLIER	168	32.20	2.35	5.2	4.9	24
DAMPIER	51	9.55	0.55	5.3	5.0	6
EDMUND	167	22.30	6.50	7.5	5.8	24
MARBLE BAR	168	32.25	3.40	5.2	4.7	24
MOUNT BRUCE	169	24.45	5.55	6.9	5.6	24
MOUNT EGERTON	167	38.15	3.50	4.4	4.0	24
NEWMAN	167	30.25	4.35	5.5	4.8	24
NINGALOO	10	2.05	0.00	4.9	4.9	1
NULLAGINE	169	30.05	3.40	5.6	5.1	24
ONSLOW	61	11.15	1.40	5.5	4.9	7
PORT HEDLAND/ BEDOUT ISLAND	162	28.35	2.55	5.7	5.2	22
PYRAMID	167	30.25	4.55	5.5	4.8	24
ROBERTSON	167	18.00	6.20	9.3	6.9	24
ROEBOURNE	91	17.00	1.50	5.4	4.9	13
ROY HILL	169	19.50	6.10	8.7	6.6	24
TUREE CREEK	166	24.10	5.50	6.9	5.6	24
WINNING POOL	112	21.00	2.40	5.3	4.8	16
WYLOO	166	23.20	6.35	7.2	5.6	24
YANREY	114	15.05	5.40	7.6	5.6	16
YARRALOOLA	163	28.00	3.30	5.8	5.2	24
YARRIE	170	31.25	4.20	5.4	4.8	24
	Averages:			6.1	5.1	

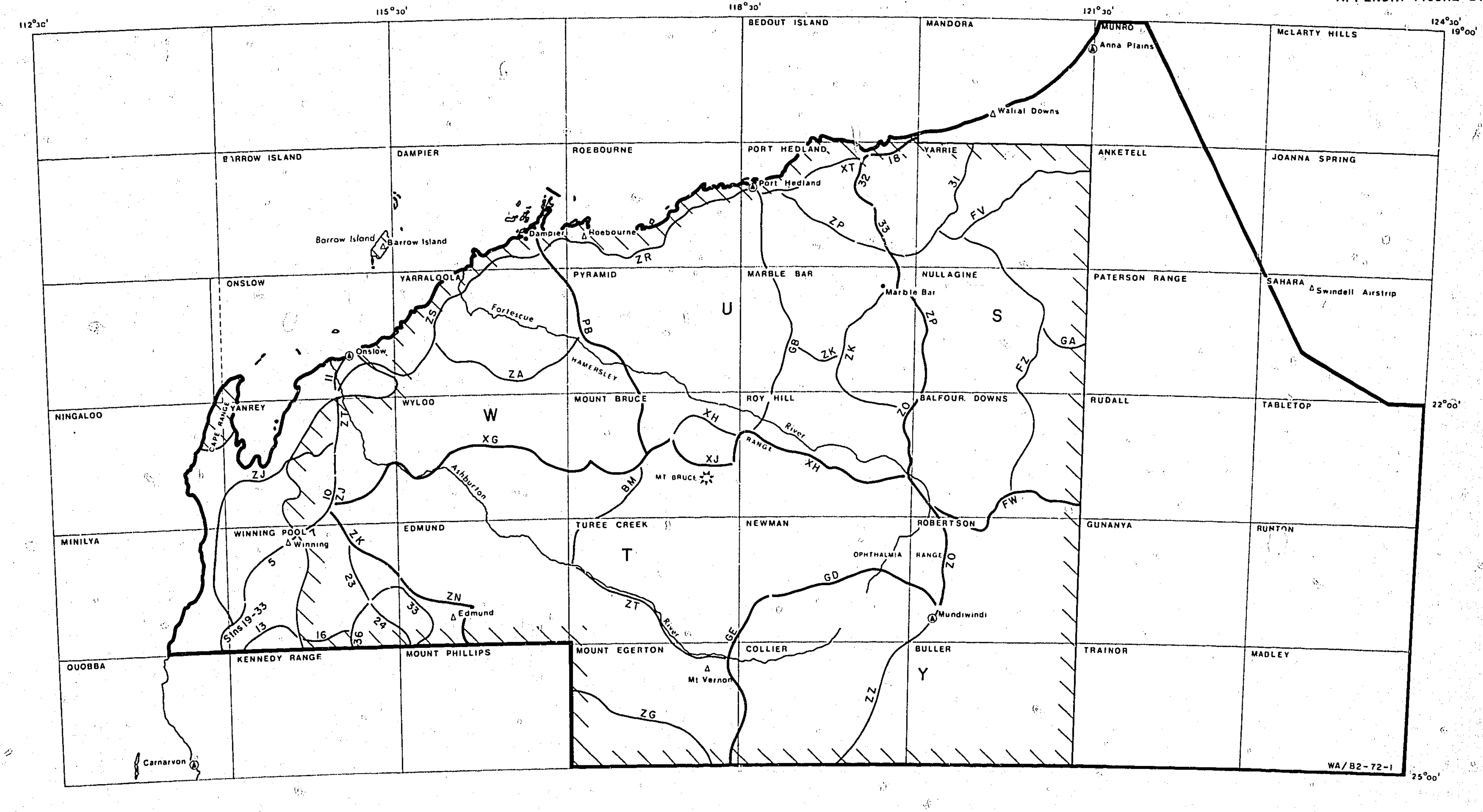
APPENDIX B2. SURVEY PROCEDURE

The field operations and computing procedure are as described for the reconnaissance gravity survey of southwest Western Australia (see Appendix A2). The segmentation of the survey area in northwest Western Australia is shown in Appendix Figure B1.

The internal, external, and forecast standard deviations for the gravity and elevation networks are tabulated below.

Segment	Elevation (m)							Gravity (mGal)			
	Internal network		External network		Forecast network			Internal network		External network	
	SD	Max. adj.	SD	Max. adj.	SD	Max. adj.	Max. adj. SD	SD	Max. adj.	SD	Max. adj.
S	1.22	3.15	1.83	5.57	1.59	4.79	3.01	0.04	0.08	0.04	0.08
T	1.62	4.17	2.58	8.00	3.58	6.46	1.80	0.03	0.07	0.03	0.14
U	1.17	2.94	2.09	8.03	2.20	6.09	2.77	0.03	0.08	0.03	0.08
W	1.61	4.19	2.80	9.23	2.31	4.70	2.03	0.03	0.12	0.04	0.12
Y	1.07	4.31	1.61	3.84	1.50	2.40	1.60	0.03	0.09	0.03	0.09

APPENDIX FIGURE B1



ELEVATION CONTROL TRAVERSES AND SEGMENTS

APPENDIX B3. LISTS OF PREVIOUS GEOPHYSICAL SURVEYS AND WELLS WITHIN THE SURVEY AREA

The following lists give the names and references to BMR and subsidised geophysical and drilling surveys up to 1972. The locations of these surveys are shown in Figures B1, B2, and B3.

The full names of the petroleum exploration and development companies referred to in the lists below are: West Australian Petroleum Pty Ltd, Union Oil Development Corporation, Marathon Petroleum Australia Ltd, and Hematite Petroleum Pty Ltd.

Company reports of subsidised surveys are housed in BMR as Petroleum Search Subsidy Acts (PSSA) Reports, which are unpublished. A few of them have been published, either complete or in summary form, in the BMR PSSA Publication series.

Gravity surveys

Name of survey	Operator	Reference
Geophysical exploration in the Carnarvon (NW) Basin, Western Australia, 1950-53	BMR	Chamberlain & others (1954)
NW Basin, 1950	BMR	Thyer (1951)
Onslow-Derby regional traverse, 1953	BMR	BMR Record 1963/13
Carnarvon Basin, 1956	WAPET	Unpublished
Fitzroy and Canning Basins, 1952-60	BMR,WAPET	Flavelle & Goodspeed (1962)
Amadeus and south Canning Basins, 1962	BMR	Lonsdale & Flavelle (1968)
Northern Territory and Western Australia, 1967	BMR	Whitworth (1970)

Name of survey	Operator	Reference
Canning Basin, 1968	BMR	BMR Record 1969/37
Marine geophysical survey of the northwest continental shelf, 1968	BMR	BMR Record 1969/99

Magnetic surveys

Name of survey	Operator	Reference
Canning Basin aeromagnetic, 1954	BMR	BMR Record 1960/11
Geraldton-Onslow airborne (scintillograph and magnetometer), 1956	BMR	Parkinson (1957)
Carnarvon Basin airborne magnetic and radiometric, 1957	BMR	Forsyth (1960)
Carnarvon Basin airborne magnetic and radiometric, 1959	BMR	Spence (1961)
Carnarvon Basin airborne magnetic and radiometric, 1961	BMR	Spence (1962)
South Canning Basin aeromagnetic, 1962, 1963	WAPET	BMR PSSA Report 62/1728 BMR PSSA Publication 72
Gibson Desert area aeromagnetic, 1965	Union Oil	BMR PSSA Report 65/4610
Marine geophysical survey of the northwest continental shelf, 1968	BMR	BMR Record 1969/99
Offshore Wallal aeromagnetic, 1969	WAPET	BMR PSSA Report 69/3037

Seismic surveys

Giralia Anticline, 1951 (Carnarvon Basin)	BMR	BMR Records 1954/44, 1954/67
Wandagee Hill/Middalya, 1955 (Carnarvon Basin)	BMR	BMR Record 1962/117
Giles-Carnegie, 1961-62 (Canning Basin)	BMR	Turpie (1967)
Wandagee Ridge, 1961 (Carnarvon Basin)	WAPET	BMR PSSA Report 62/1576 BMR PSSA Publication 50
Salt Marsh, 1961 (Carnarvon Basin)	WAPET	BMR PSSA Report 62/1585 BMR PSSA Publication 50
Quail Anticline, 1962 (Carnarvon Basin)	WAPET	BMR PSSA Report 62/1622
Whaleback, 1962 (Carnarvon Basin)	WAPET	BMR PSSA Report 62/1635 BMR PSSA Publication 49
Kubura-Learmonth, 1962 (Carnarvon Basin)	WAPET	BMR PSSA Report 62/1637
Ningaloo, 1963 (Carnarvon Basin)	WAPET	BMR PSSA Report 63/1504
Paterson, 1963 (Carnarvon Basin)	WAPET	BMR PSSA Report 63/1509
Barrow Island, 1963 (Carnarvon Basin)	WAPET	BMR PSSA Report 63/1536
Onslow, 1966 (Carnarvon Basin)	WAPET	BMR PSSA Report 66/11073

Cane River, 1967 (Carnarvon Basin)	WAPET	BMR PSSA Report 67/11159
Locker, 1967 (Carnarvon Basin)	WAPET	BMR PSSA Report 67/11162
Mia Mia, 1967 (Carnarvon Basin/Gascoyne Block)	Marathon	BMR PSSA Report 67/11179
Marine geophysical survey of the northwest continental shelf, 1968	BMR	BMR Record 1969/99
Munro R-1, 1969 (Canning Basin)	WAPET	BMR PSSA Report 69/3081
Anketell, 1970 (Canning Basin)	WAPET	BMR PSSA Report 70/896
Lake Auld, 1970 (Canning Basin/Paterson Province)	WAPET	BMR PSSA Report 70/933
Lyndon-Quobba, 1972 (Carnarvon Basin)	WAPET	BMR PSSA Report 72/891

Wells

Well name and no.	Year	Total depth (m)	Operator	Reference
BMR 4A Wallal	1958	679	BMR	BMR Report 60
Samphire Marsh No. 1	1958	2031	WAPET	BMR PSSA Report 62/1002
				BMR PSSA Publication 5
Wandagee No. 1	1962	1073	WAPET	BMR PSSA Report 62/1215
				BMR PSSA Publication 68
Quail No. 1	1963	3580	WAPET	BMR PSSA Report 63/1010
Marilla No. 1	1963	457	WAPET	BMR PSSA Report 63/1200
				BMR PSSA Publication 68
Minderoo No. 1	1963	610	WAPET	BMR PSSA Report 63/1200
				BMR PSSA Publication 68
Paterson No. 1	1963	2286	WAPET	BMR PSSA Report 63/1211
Whaleback No. 1	1963	1528	WAPET	BMR PSSA Report 63/1319
Learmonth No. 2	1963	1871	WAPET	BMR PSSA Report 63/1327
Barrow Island No. 1	1964	2982	WAPET	BMR PSSA Report 64/4030
Onslow No. 1	1966	2998	WAPET	BMR PSSA Report 66/4218
Hope Island No. 1	1968	1426	WAPET	BMR PSSA Report 68/2003
Remarkable Hill No. 1	1968	3206	Marathon	BMR PSSA Report 68/2050
Cane River No. 1	1971	694	Hematite	BMR PSSA Report 71/751
East Marilla No. 1	1972	638	WAPET	BMR PSSA Report 72/960

APPENDIX C1. SURVEY STATISTICS

The following statistics refer to the initial coverage of the survey area and do not take account of follow-up work.

Survey commenced	:	12 October 1971
Survey completed	:	2 July 1972
Total survey days	:	237
Total helicopter days available	:	208
Days unserviceable	:	7
Pilot days off	:	18
Days lost during maintenance	:	17
Days lost during bad weather	:	2
Loops flown	:	1180
New readings	:	8046
Flying time	:	1472 hours
Ferry time	:	221 hours

Statistics by Sheet area

1:250 000 Sheet area	New readings	Flying time h.min	Ferry time h.min	Loops
AJANA	102	19.15	3.35	14
BARLEE	157	34.50	3.30	24
BELELE	159	31.15	5.05	24
BURNABBIE	46	7.15	-	6
BYRO	159	30.45	5.00	24
COOPER	134	20.20	2.25	19
CULVER	111	16.25	1.35	15
CUE	158	30.00	4.05	24
DONGARA	49	9.30	0.30	6
DUKETON	158	29.10	5.05	24
EDJUDINA	162	26.55	3.50	24
EUCLA	123	19.30	2.45	18
FORREST	130	19.55	1.50	17
GERALDTON	96	17.10	1.30	13
GLENBURGH	161	30.30	4.20	24
GLENGARRY	163	31.00	4.10	24
JUBILEE	159	24.35	3.05	24
KENNEDY RANGE	171	31.10	2.20	24
KINGSTON	158	29.10	7.25	24
KIRKALOCKA	161	32.00	3.15	24
LAVERTON	161	29.15	2.20	24
LENNIS	114	23.10	4.20	16
LEONORA	159	27.55	3.50	24
LOONGANA	157	24.50	3.15	24
MADURA	159	25.40	2.40	24
MASON	130	20.10	4.25	18
MENZIES	162	28.40	3.45	24
MINIGWAL	160	25.25	6.50	24
MOUNT PHILLIPS	169	30.55	2.50	24
MURGOO	160	30.20	3.25	24
NABBERU	180	34.15	4.05	24
NARETHA	160	26.20	3.45	24

1:250 000 Sheet area	New readings	Flying time h.min	Ferry time h.min	Loops
NEALE	162	32.50	3.05	24
NINGHAN	158	24.10	4.00	24
NOONAERA	15	2.25	0.15	2
PEAK HILL	168	32.55	3.05	24
PERENJORI	162	31.10	3.25	24
PLUMRIDGE	156	25.20	3.40	24
QUOBBA	61	12.10	0.40	11
RASON	162	30.20	7.10	24
ROBERT	158	31.45	10.45	24
ROBINSON RANGE	160	30.40	3.40	24
SANDSTONE	158	30.00	3.45	24
SEEMORE	157	24.20	3.05	24
SIR SAMUEL	157	28.30	5.25	24
STANLEY	173	33.40	4.50	24
TALBOT	98	19.45	2.30	12
THROSSELL	159	30.50	5.45	24
VERNON	162	33.00	4.20	24
WAIGEN	122	23.50	12.20	15
WANNA	129	26.45	5.55	19
WESTWOOD	130	26.20	4.00	18
WILUNA	166	31.55	3.15	24
WOORAMEL	56	10.40	0.50	8
YALGOO	162	29.15	4.05	24
YARINGA	39	8.25	2.00	8
YOUANMI	159	29.30	4.05	24
YOWALGA	69	13.30	4.30	9

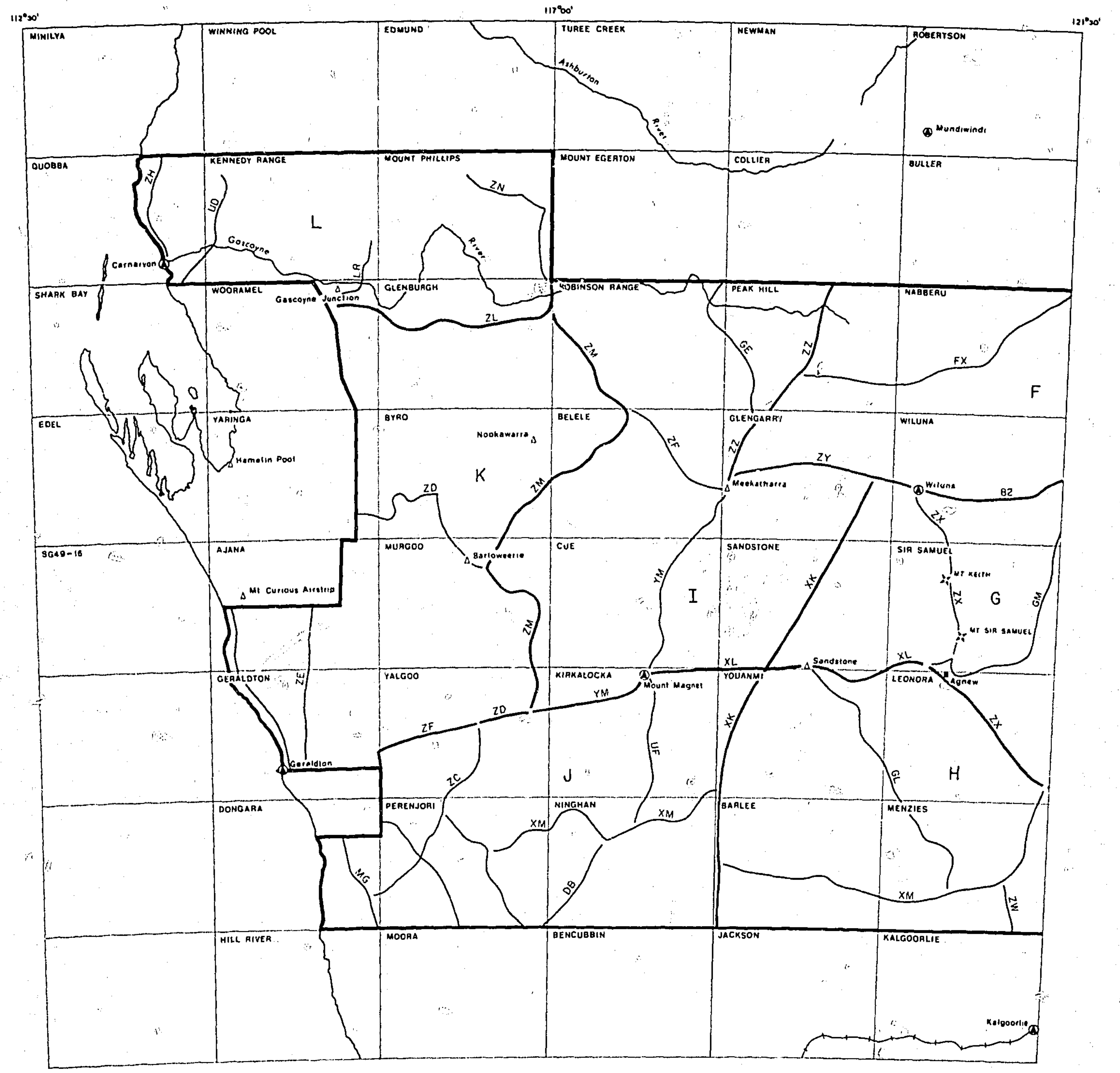
Follow-up work within the survey area was carried out between 17 and 30 October 1972, when 247 new readings were made while checking and further delineating small anomalies in the preliminary contours. One or more follow-up loops were flown on the following 1:250 000 Sheet areas: AJANA, BARLEE, BELELE, CUE, DONGARA, EDJUDINA, FORREST, GLENGARRY, KINGSTON, KIRKALOCKA, LAVERTON, LENNIS, LOONGANA, MADURA, MASON, MENZIES, MINIGWAL, MOUNT PHILLIPS, NINGHAN, PERENJORI, RASON, ROBERT, SEEMORE, SIR SAMUEL, THROSSELL, YALGOO, YOUANMI. The contours (Plate C1) have been amended where necessary, to conform with the results of follow-up work.

APPENDIX C2. SURVEY PROCEDURE

The field operations and computing procedure are as described for the reconnaissance gravity survey of southwest Western Australia (see Appendix A2). The segmentation of the survey area in central and southeast Western Australia is shown in Appendix Figure C1.

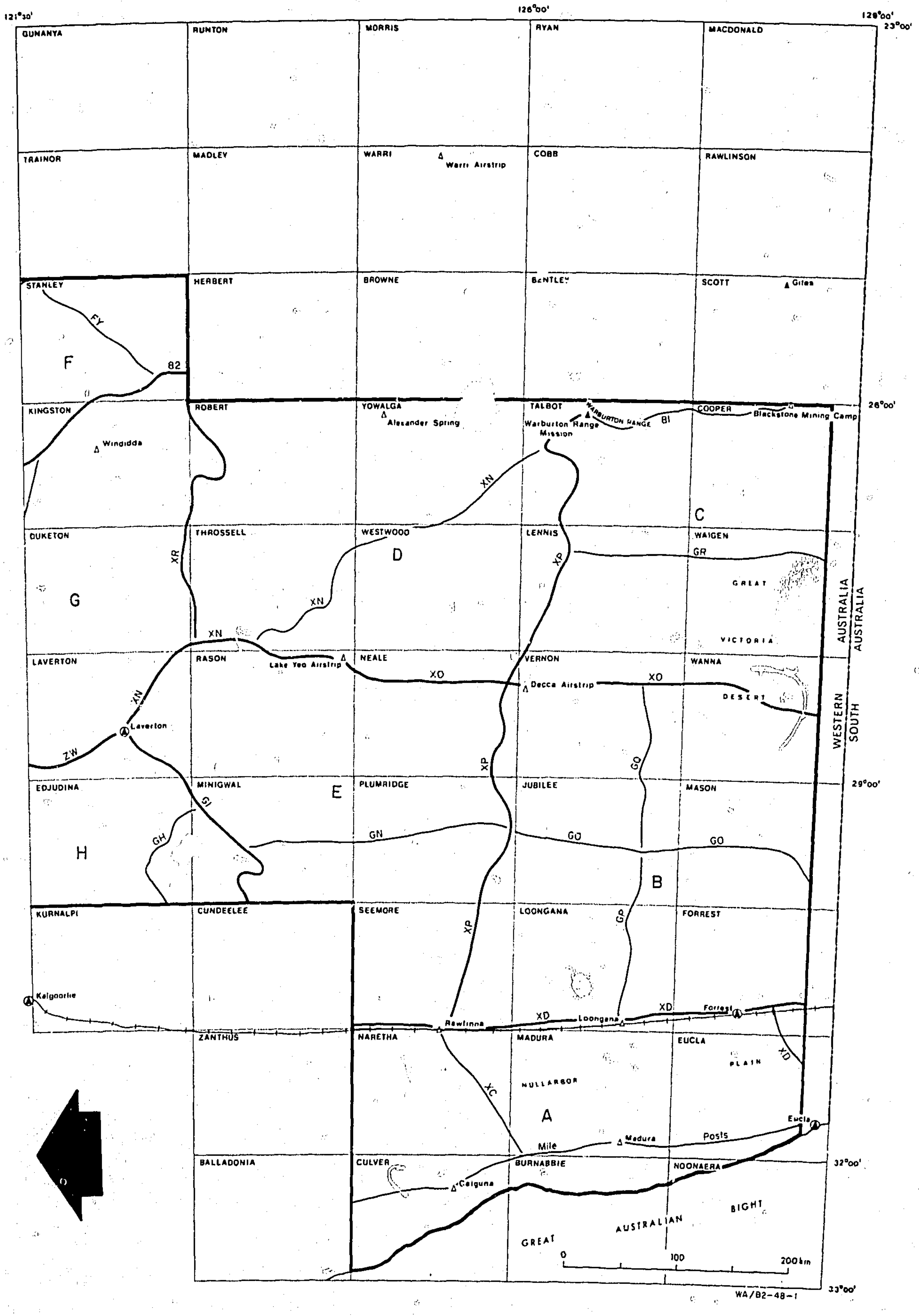
The internal, external, and forecast standard deviations for the gravity and elevation networks are tabulated below.

Segment	Elevation (m)							Gravity (mGal)			
	Internal network		External network		Forecast network			Internal network		External network	
	SD	Max. adj.	SD	Max. adj.	SD	Max. adj.	Max. adj. SD	SD	Max. adj.	SD	Max. adj.
A	1.45	5.04	2.09	6.25	1.65	4.88	3.0	0.06	0.42	0.06	0.04
B	1.43	5.65	1.92	5.55	1.37	4.27	3.1	0.05	0.20	0.05	0.20
C	0.94	2.37	1.73	5.80	1.71	3.05	1.7	0.03	0.13	0.03	0.13
D	1.50	5.13	2.15	9.73	1.92	4.26	2.2	0.04	0.12	0.04	0.12
E	1.35	4.22	1.71	5.28	1.34	4.26	3.1	0.04	0.12	0.04	0.12
F	1.04	3.95	1.86	4.86	1.49	3.66	2.4	0.05	0.20	0.05	0.20
G	1.58	4.29	2.46	7.40	2.29	5.79	2.5	0.03	0.09	0.03	0.09
H	1.77	5.08	2.24	7.22	3.54	9.45	2.6	0.03	0.10	0.03	0.10
I	1.48	6.30	2.20	8.74	1.89	6.10	3.2	0.04	0.14	0.04	0.14
J	1.79	5.78	2.54	7.21	2.47	6.40	2.5	0.03	0.09	0.03	0.09
K	1.42	4.37	2.71	8.43	2.71	6.10	2.2	0.03	0.09	0.05	0.18
L	1.42	3.46	2.42	7.72	1.59	3.66	2.3	0.03	0.10	0.03	0.10



ELEVATION CONTROL TRAVERSES
AND SEGMENTS

APPENDIX FIGURE C1



APPENDIX C3. LISTS OF PREVIOUS GEOPHYSICAL SURVEYS WITHIN THE SURVEY AREA

The following lists give the names of and references to BMR and subsidised geophysical and drilling surveys up to 1970. The locations of these surveys are shown in Figures C1, C2, and C3.

BMR Petroleum Search Subsidy Acts (PSSA) Reports (listed under 'Reference') are unpublished company reports of subsidised surveys, and are housed in BMR. The full names of petroleum exploration and development companies referred to in the lists below are: West Australian Petroleum Pty Ltd, Hunt Oil Co., Barewa Oil & Mining NL, Tasman Oil Pty Ltd, Tenneco Australia Inc., French Petroleum Co. (Aust.) Pty Ltd (now Total Exploration Australia Pty Ltd), BP Petroleum Development Australia Pty Ltd, Canadian Superior Oil (Aust.) Pty Ltd, Continental Oil Company of Australia Ltd, and Exoil Pty Ltd (now Oilmin NL).

Gravity surveys

Name of survey	Operator	Reference
Geophysical exploration in the Carnarvon (NW) Basin, 1950-53	BMR	Chamberlain & others (1954)
Perth Basin, 1951-52	BMR	Thyer & Everingham (1956)
Regional gravity traverses across the Eucla Basin, 1954-55	BMR	Gunson & van der Linden (1956)
Dongara-Mullewa (Perth Basin)	WAPET	BMR PSSA Report 62/1925
Eganu, 1962 (Perth Basin)	WAPET	BMR PSSA Report 62/1933
Lennis-Breaden (Officer Basin)	Hunt Oil	BMR PSSA Report 64/4800

Geraldton (Perth Basin)	WAPET	BMR PSSA Report 67/4827
Murchison-Gascoyne (Carnarvon Basin)	Barewa Oil	BMR PSSA Report 70/326

Magnetic surveys

Offshore West Beagle aeromagnetic	WAPET	BMR PSSA Report 69/3050
Officer Basin aeromagnetic interpretation	Hunt Oil	Brod (1962)
Neale Junction land magnetic	Hunt Oil	BMR PSSA Report 65/4617
West Carnarvon aeromagnetic	Tasman Oil	BMR PSSA Report 65/4615
Eucla Basin airborne magnetic, 1954	BMR	BMR Record 1958/87
Geraldton-Onslow airborne (scintillograph and magnetometer), 1956	BMR	BMR Record 1957/9
Carnarvon Basin airborne magnetic and radiometric, 1957	BMR	Forsyth (1960)
Perth Basin aeromagnetic, 1957	BMR	BMR Record 1963/74
Carnarvon Basin airborne magnetic and radiometric, 1959	BMR	Spence (1961)
Rawlinson Range/Young Range aeromagnetic reconnaissance, 1960	BMR	BMR Record 1961/137
Carnarvon Basin airborne magnetic and radiometric, 1961	BMR	Spence (1962)

BARLEE airborne magnetic and radiometric, 1957	BMR	BMR Record 1965/28 (maps only)
MENZIES and LEONORA airborne magnetic and radiometric, 1964	BMR	BMR Record 1966/15
LAVERTON-EDJUDINA airborne magnetic and radiometric, 1966	BMR	BMR Record 1967/65
SIR SAMUEL/DUKETON airborne magnetic and radiometric, 1967	BMR	BMR Record 1967/136
SANDSTONE-YOUANMI airborne magnetic and radiometric, 1968	BMR	BMR Record 1970/2
BELELE, CUE, KIRKALOCKA, and eastern BYRO, MURGOO, and YALGOO airborne magnetic and radiometric, 1969	BMR	BMR Record 1971/28
GLENGARRY, WILUNA, and KINGSTON aeromagnetic, 1970	BMR	Lambourn (1972)

Seismic surveys

Name of survey	Operator	Coverage (km)	Reference
Pelsart (marine) (Perth-Carnarvon Basins)	WAPET	505	BMR PSSA Report 69/3014
Turtle Dove (marine) (Perth-Carnarvon Basins)	WAPET	379	BMR PSSA Report 68/3[illegible]00
Beagle (marine) (Perth Basin)	WAPET	267 (58 refract)	BMR PSSA Report 68/3038

Seismic surveys

Name of survey	Operator	Coverage (km)	Reference
Offshore Eucla Basin	Tenneco	858	BMR PSSA Report 66/11139
Offshore Eucla Basin R.2	Tenneco	1192	BMR PSSA Report 67/11195
Yowalga (Officer Basin)	Hunt Oil	478	BMR PSSA Report 65/4579
North Lennis (Officer Basin)	Hunt Oil	251	BMR PSSA Report 65/11033
Snag Island (marine) (Perth Basin)	FPC	45	BMR PSSA Report 65/11043
Podooloo (Perth Basin)	FPC	76	BMR PSSA Report 65/11010
Athamo seismic and gravity (Perth Basin)	FPC	410	BMR PSSA Report 65/11060
Geraldton (Carnarvon Basin)	WAPET	48	BMR PSSA Report 67/11146
Abrolhos D-1 (marine) (Carnarvon Basin)	BP Pet. Dev.	200	BMR PSSA Report 66/11127
Zeewyk Channel (marine) (Carnarvon Basin)	BP Pet. Dev.	98	BMR PSSA Report 66/11112

Name of survey	Operator	Coverage (km)	Reference
Abrolhos (marine) (Carnarvon Basin)	BP Pet. Dev.	1224	BMR PSSA Report 65/4592
West Carnarvon (marine)	Canadian Superior	2218	BMR PSSA Report 66/11089
West Gnarraloo (marine) (Carnarvon Basin)	Canadian Superior	885	BMR PSSA Report 67/11158
Ballythanna Hill (Carnarvon Basin)	Conoco	153	BMR PSSA Report 65/11049
Merlinleigh Anticline (Carnarvon Basin)	WAPET	18	BMR PSSA Report 66/11075
Shark Bay (marine) (Carnarvon Basin)	Conoco	257	BMR PSSA Report 64/4551
Yalbalgo-Yaringa (Carnarvon Basin)	Conoco	502	BMR PSSA Report 65/11021
Kennedy (Carnarvon Basin)	WAPET	29	BMR PSSA Report 65/11038
Quail Anticline (Carnarvon Basin)	WAPET	177	BMR PSSA Report 62/1622
Wooramel (Carnarvon Basin)	Conoco	965	BMR PSSA Report 64/4545
Hyde Soak (Carnarvon Basin)	Conoco	64 (45 refract)	BMR PSSA Report 64/4538

Name of survey	Operator	Coverage (km)	Reference
Wicherina (Perth-Carnarvon Basins)	WAPET	459 (600 refract)	BMR PSSA Report 62/1651
Dongara (Perth-Carnarvon Basins)	WAPET	63	BMR PSSA Report 63/1507
Warradong (Perth Basin)	WAPET	55	BMR PSSA Report 62/1590
Woolamulla South (Perth Basin)	WAPET	92	BMR PSSA Report 62/1627
Hill River/Dongara (Perth Basin)	WAPET	275	BMR PSSA Report 62/1534
Woodada (Perth Basin)	FPC	211 (356 refract)	BMR PSSA Report 64/4547
Eneabba (Perth Basin)	WAPET	241	BMR PSSA Report 62/1541
Babbagoola (Officer Basin)	Hunt Oil	55	BMR PSSA Report 63/1551
Warburton (Officer Basin)	Hunt Oil	132 (142 refract)	BMR PSSA Report 64/4516
Irwin (Perth-Carnarvon Basins)	WAPET	43 (34 refract)	BMR PSSA Report 64/4511
Geelvink Channel (Carnarvon Basin)	BP Pet. Dev.	1435) (470 processed)	BMR PSSA Report 70/241

Name of survey	Operator	Coverage (km)	Reference
Southern Carnarvon Basin, 1963 (Traverse A, Tamala-Narryer area)	BMR		Bow & Turpie (1964)
Southern Carnarvon Basin, 1963 (Traverse B, Byro Basin)	BMR		Turpie (1964)

APPENDIX C4. WELLS DRILLED WITHIN THE SURVEY AREA AND AGE SEQUENCES ENCOUNTERED

Drillholes within the survey area include both test bores for minerals in the Precambrian shield and stratigraphic wells in the sedimentary basins. The results of drilling surveys in the shield area are not available for publication. Wells have been confined mainly to the Perth and Carnarvon Basins, where thick Phanerozoic sediments and a relative abundance of potential structural traps for hydrocarbons have attracted the attention of a number of oil exploration companies. Stratigraphic sections from these wells have added greatly to geological knowledge of the two basins. Phanerozoic sediments are shallow and structurally featureless in the Eucla and Officer Basins, and drilling activity has been correspondingly small. Yowalga No. 2, in the western Officer Basin, encountered Proterozoic sediments at about 600 m, and the few bores drilled in the onshore Eucla Basin have generally encountered Precambrian basement at depths less than 600 m.

The age sequences encountered in wells are given in the following table. The main reference for each well is the unpublished BMR PSSA Report; data and results of some of the wells have been summarised in the BMR PSSA Publications. Locations of wells are shown in Figure C2.

Well Latitude Longitude Basin	Operator	Total depth (m)	Ages and thicknesses (m) of rocks encountered		BMR PSSA Report BMR PSSA Publication
Wandagee No. 1	WAPET	1073	Quaternary	8	62/1215
23°53'15"S			Cretaceous	169	68
114°23'51"E			Late Devonian	98	
Carnarvon			Silurian	533	
			Silurian/Ordovician?	262+	
Quail No. 1	WAPET	3580	Quaternary	5	63/1010
23°57'04"S			Permian	2092	
114°29'57"E			Carboniferous	610	
Carnarvon			Devonian	372	
			Silurian	499+	
Abbarwardoo No. 1	WAPET	600	Quaternary	2	62/1222
28°35'10"S			Jurassic	21	55
115°09'35"E			Triassic?	34	
Perth-Carnarvon			Permian	544+	
Wicherina No. 1	WAPET	1686	Quaternary	4	63/1056
28°49'53"S			Cretaceous	15	
115°14'19"E			Jurassic	262	
Perth			Triassic	91	
			Permian	1314+	
Mungarra No. 1	WAPET	609	Quaternary	2	64/4105
28°51'02"S			Jurassic- Early Cretaceous	221	
115°06'55"E			Triassic	30	
Perth			Permian	357+	

Well Latitude Longitude Basin	Operator	Total depth (m)	Ages and thicknesses (m) of rocks encountered		BMR PSSA Report BMR PSSA Publication
Yardarino No. 1 29°13'13"S 115°03'10"E Perth	WAPET	2377	Quaternary Late Triassic- Early Cretaceous Early-Mid-Triassic Permian	9 1928 345 93+	64/4035
Jurien No. 1 30°08'40"S 115°02'54"E Perth	WAPET	1026	Quaternary Triassic Permian Precambrian	24 247 704 48+	62/1110 55
Woolmulla No. 1 30°01'24"S 115°11'28"E Perth	WAPET	2811	Quaternary Triassic Permian Precambrian	4 1228 1541 39+	62/1127 54
Eganu No. 1 29°59'05"S 115°49'35"E Perth	WAPET	600	Quaternary Late Jurassic- Early Cretaceous	5 594+	62/1221 55
Hill River No. 1 30°16'S 115°18'E Perth	WAPET	579	Early Jurassic- Early Cretaceous	 579+	62/1402 54
Gingin No. 1 31°08'32"S 115°49'35"E Perth	WAPET	4544	Quaternary Cretaceous Jurassic	35 1072 3432+	64/4121

Well Latitude Longitude Basin	Operator	Total depth (m)	Ages and thicknesses (m) of rocks encountered		BMR PSSA Report BMR PSSA Publication
Gambanga No. 1 32°16'S 124°50'E Eucla	Exoil	391	Recent Miocene Eocene Santonian Albian Aptian Archaean	2 32 172 168 11 6 1+	62/1052
Eyre No. 1 32°07'S 126°58'E Eucla	Exoil	524	Recent Pleistocene Miocene Eocene Aptian-Santonian Archaean	2 12 2 287 219 3+	62/1053
Kennedy Range No. 1 24°29'45"S 114°59'27"E Carnarvon	WAPET	2227	Permian	2227+	66/4235
Yaringa No. 1 26°03'58"S 114°21'35"E Carnarvon	Conoco	2288	Cretaceous Jurassic Silurian/Ordovician? Ordovician	141 709 671 762+	66/4215
Donkey Creek No. 1 29°37'35"S 115°17'25"E Perth	FPC	3853	Cretaceous Jurassic Triassic	1810 1552 491+	66/4223

Well Latitude Longitude Basin	Operator	Total depth (m)	Ages and thicknesses (m) of rocks encountered		BMR PSSA Report BMR PSSA Publication
Cadda No. 1 30°20'15"S 115°12'48"E Perth	FPC	2795	Quaternary Jurassic Triassic Permian Precambrian	2 166 1864 707 52+	65/4164
Gun Island No. 1 28°53'30"S 113°51'27"E Perth	BP Pet. Dev.	3725	Quaternary Tertiary Cretaceous Jurassic	126 259 516 2817+	68/2015
Quinns Rock No. 1 31°48'01"S 115°30'52"E Perth (offshore)	WAPET	2209	Tertiary Cretaceous Jurassic	292 461 1280+	68/2046
Eneabba No. 1 29°34'14"S 115°19'56"E Perth	WAPET	4179	Quaternary Cretaceous Jurassic Triassic	9 1694 1271 1202+	62/1076 54
Yowalga No. 2 26°10'12"S 125°58'00"E Officer	Hunt Oil	989	Recent Jurassic Permian Late Proterozoic	4 87 312 582+	66/4191

APPENDIX D1. SURVEY STATISTICS

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	:	7754
Follow-up readings	:	44
Loops flown	:	571
Approximate area surveyed	:	250 000 km^2

APPENDIX D2. 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 (and now in the Department of Administrative Services), 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 segmentation of the survey area is shown in Appendix Figure D1. In the flying of the survey, no loop was allowed to cross a segment boundary. This method of flying meant that each segment could be computed independently for elevation control.

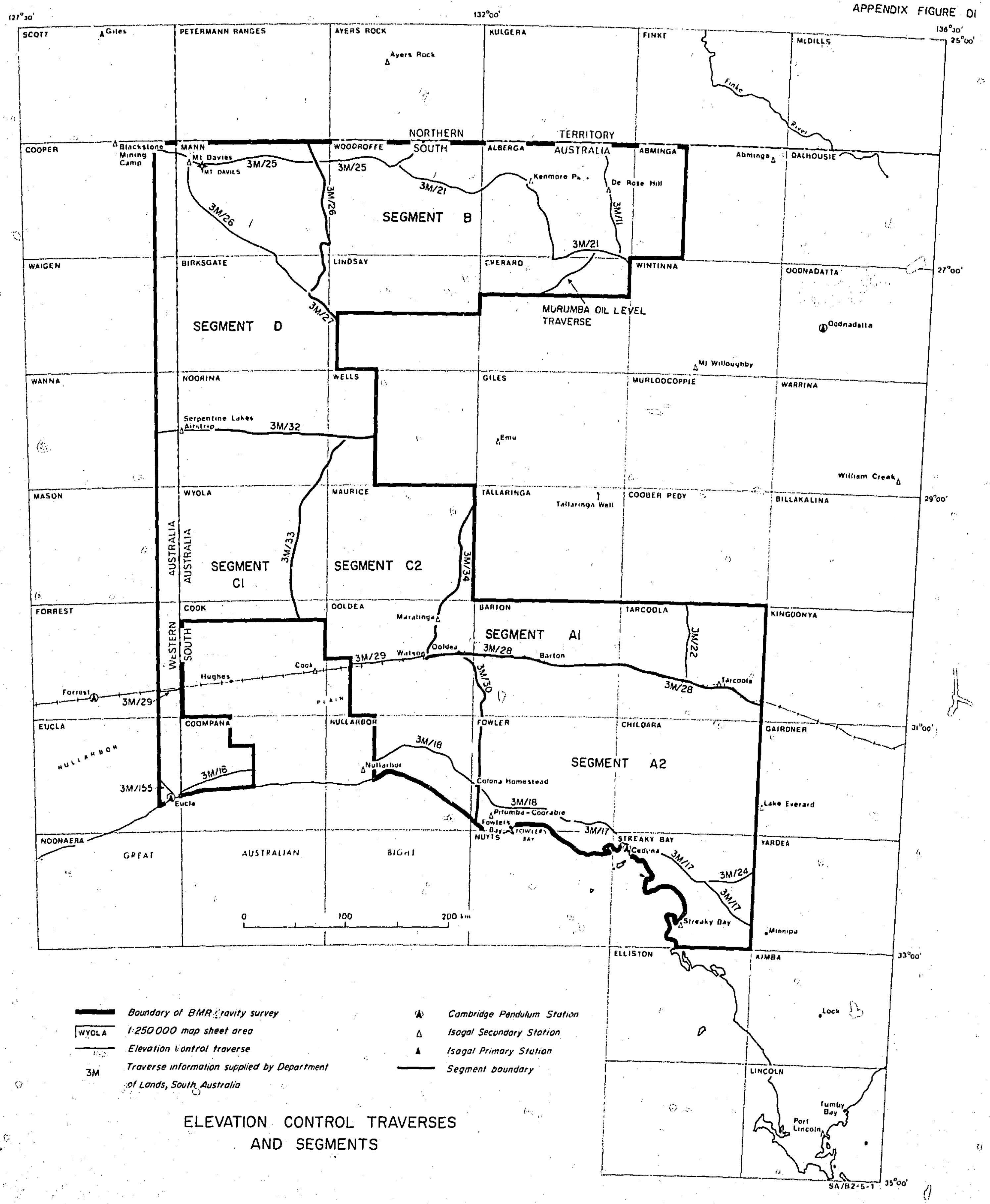
Gravity control on the survey was maintained by tying to accurate gravity stations termed 'Isogal stations' (Barlow, 1970), previously established by multimeter traversing.

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

Computing procedure

The computing procedure is as described for the reconnaissance gravity survey of southwest Western Australia (see Appendix A2). The internal, external, and forecast standard deviations for the gravity and elevation networks are tabulated below.

APPENDIX FIGURE D1



ELEVATION CONTROL TRAVERSES AND SEGMENTS

Segment	Elevation (m)						Gravity (mGal)	
	Internal network		External network		Forecast network		External network	
	SD	Max.adj.	SD	Max.adj.	SD	Max.adj.	SD	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 D3. DENSITY DATA

Gawler Craton

Density information is available from wells which have penetrated the Gawler Craton basement; it is tabulated below:

Well	Location	Depth to basement (m)	Basement rock type	Density (g/cm^3)
Mallabie No. 1 (subsidised)	31°32'S 130°36'E	1330	Granitic gneiss	2.73
Wallira No. 1 (unsubsidised)	29°27'S 134°05'E	286	Granitic gneiss	2.70
Karkaro No. 1 (unsubsidised)	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 g/cm^3 (Wiebenga & Hawkins, 1956; Doyle & Everingham, 1964).

Gabbroic rock south and east of Streaky Bay gave measured densities in the range 2.80 to 3.27 g/cm^3. Densities of 2.54 to 2.64 g/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 g/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 summarised below:

Rock unit	Rock type	Density(g/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
	Granulite	2.70-2.90

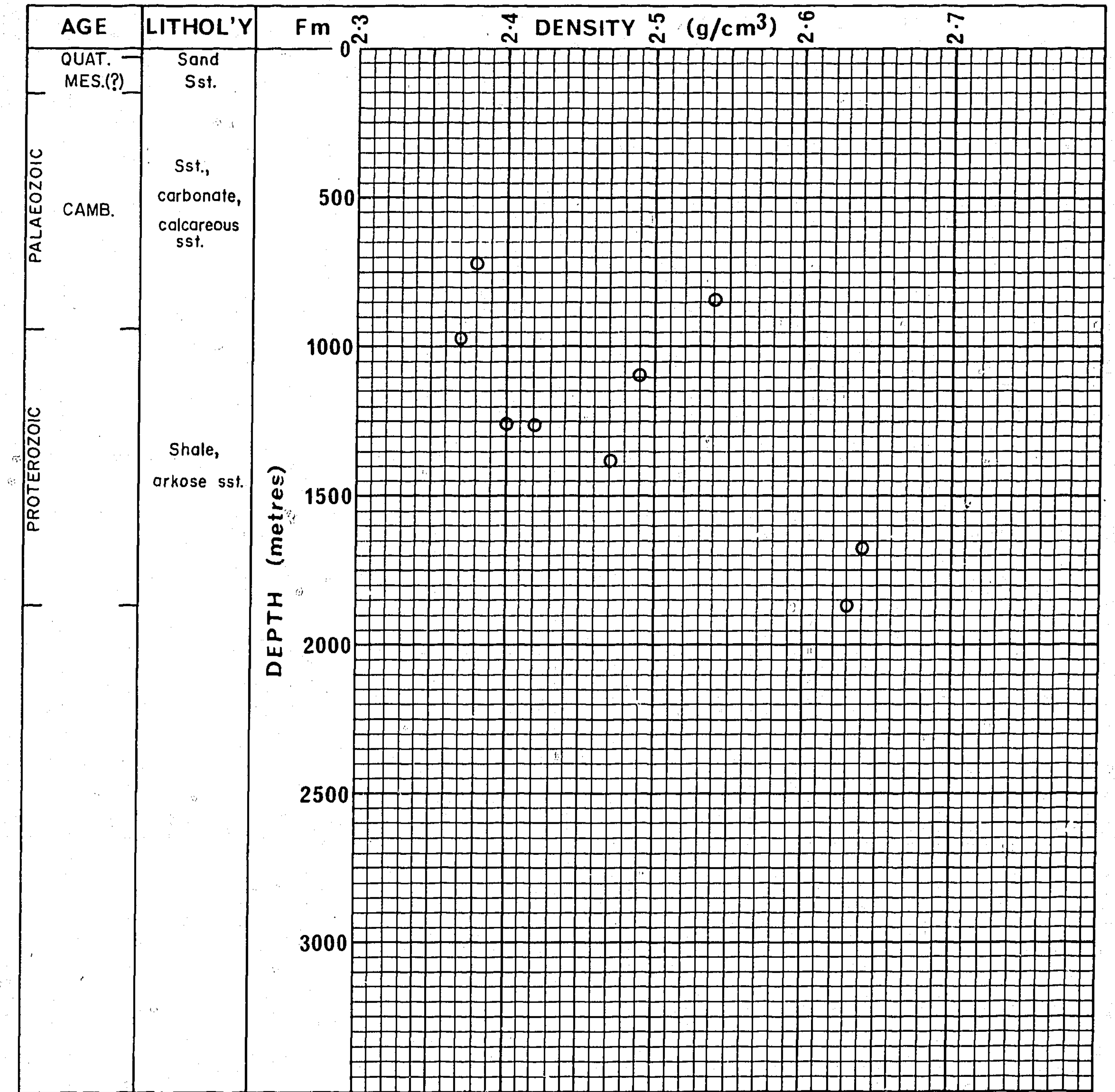
Officer Basin

Density measurements were made on cores from Birksgate No. 1, Munyarai No. 1, and Emu No. 1 wells. The density data for the Birksgate and Munyarai wells are summarised in Appendix Figures D2 and D3. Measurements on cores from the Emu bore indicate sediment densities ranging from 2.10 to 2.61 g/cm^3.

Eucla Basin

The compensated formation density log for Mallabie No. 1 well is shown in Appendix Figure D4.

APPENDIX FIGURE D2

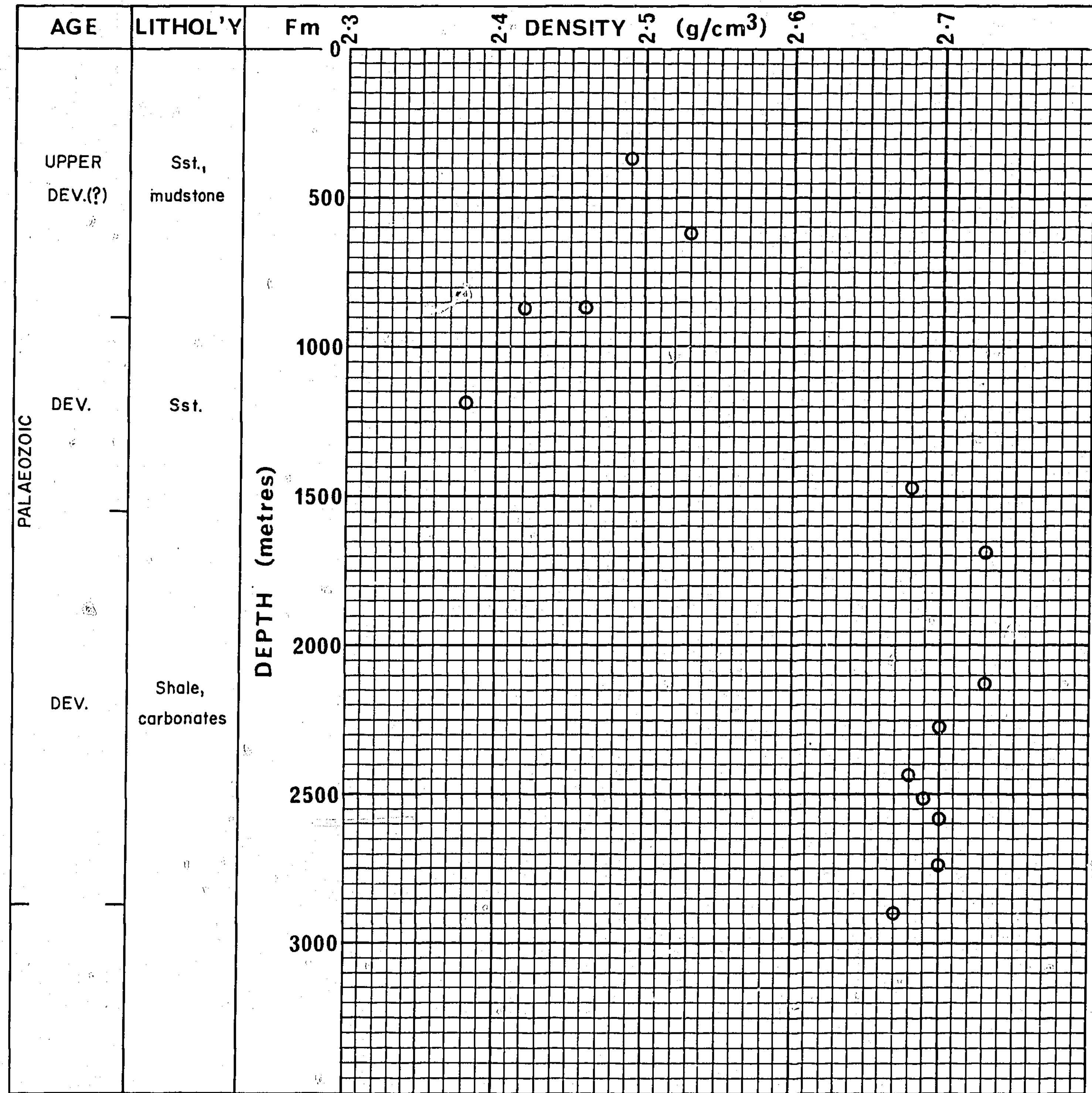


NAME OF WELL	ELEVATION
BIRKSGATE No.1	380 metres
POSITION LAT. 27° 56' 20"S LONG. 129° 58' 10"E	TOTAL DEPTH 1868 metres
1:250 000 AREA BIRKSGATE	SOURCE OF DATA AND PURPOSE OF ANALYSIS CONTINENTAL OIL (DENSITY DATA)
BASIN WESTERN OFFICER BASIN	SUBSIDIZED 67/4242
STATE OR TERRITORY SOUTH AUSTRALIA	DRILLED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

G52/B6-1-1A

FORMATION DENSITY PLOT FOR BIRKSGATE No.1

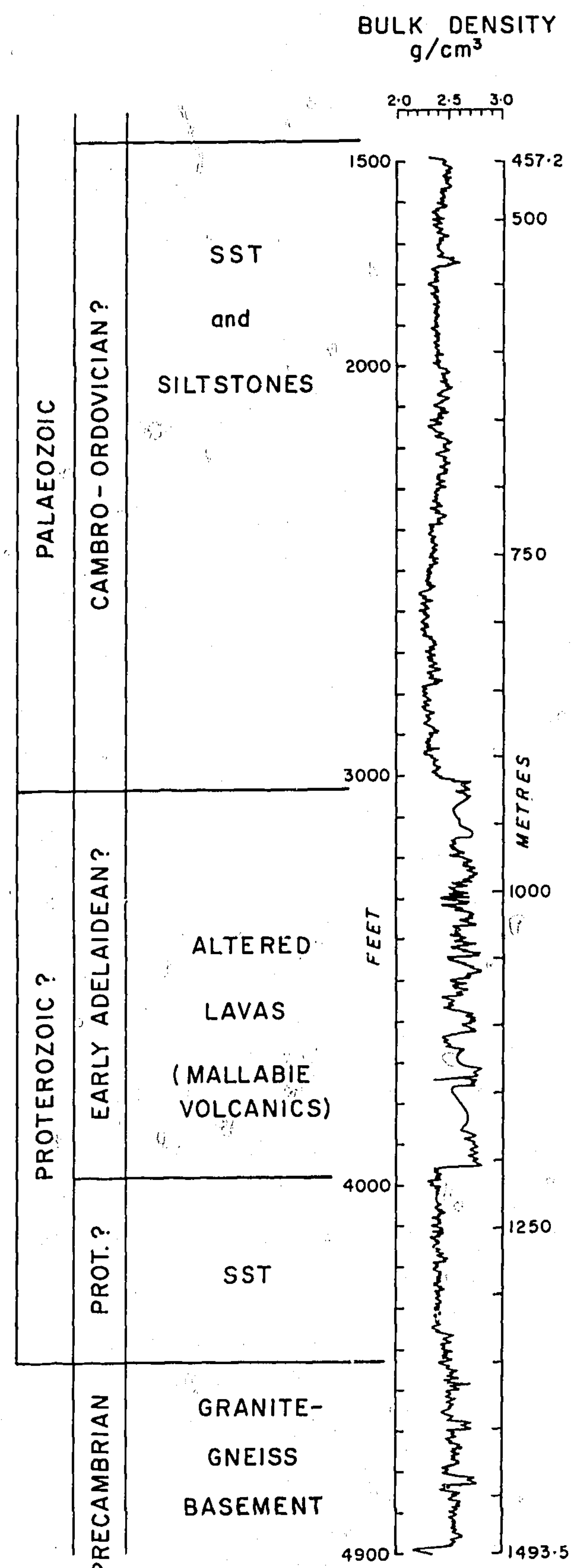
APPENDIX FIGURE D3



NAME OF WELL MUNYARAI No. I	**ELEVATION** 412 metres
POSITION LAT. 27° 41' 53"S LONG. 132°00'03"E	**TOTAL DEPTH** 2899 metres
1:250 000 AREA EVERARD	**SOURCE OF DATA AND PURPOSE OF ANALYSIS** CONTINENTAL OIL (DENSITY DATA)
BASIN EASTERN OFFICER BASIN	**SUBSIDIZED** 68/2012
STATE OR TERRITORY SOUTH AUSTRALIA	**DRILLED BY** CONTINENTAL OIL G53/B6-I-IA

FORMATION DENSITY PLOT FOR MUNYARAI No. I

APPENDIX FIGURE D4



COMPENSATED FORMATION DENSITY
LOG FOR MALLABIE No. 1

APPENDIX D4. LISTS OF PREVIOUS GEOPHYSICAL SURVEYS AND WELLS WITHIN THE SURVEY AREA

The following lists give the names of and references to BMR, South Australian Department of Mines, and subsidised geophysical and drilling surveys up to 1970. The locations of these surveys are shown in Figures D2 and D3 and Plate D3.

Gravity surveys

Name of survey	Reference
Northeastern 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	Outback Oil NL (1965)
MANN and WOODROFFE 1:250 000 Sheet areas	Rowan (1968)
Eastern Officer Basin, 1966	Moorcroft (1969)
Eastern Officer Basin, 1967	Continental Oil Co. (1967b)
Eastern Officer Basin, 1970	Murumba Oil NL (1970)

Magnetic surveys

Name of survey	Reference
Eucla Basin reconnaissance airborne magnetic	Quilty & Goodeve (1958)
Officer Basin aeromagnetic interpretation	Brod (1962)
MANN area airborne magnetic and radiometric, 1960	Wells (1962)
CHILDARA/GAIRDNER airborne magnetic and radiometric, 1960	Quilty (1962)
Eastern Officer Basin airborne magnetometer	Exoil Pty Ltd (1964)
MANN/WOODROFFE aeromagnetic, 1965	Tipper (1967)
Central South Australia airborne magnetic and radiometric, 1966	Young & Gerdes (1966)
Musgrave Block airborne magnetic and radiometric, 1967	Waller (1968)
MANN-WOODROFFE aeromagnetic, 1969	Shelley & Downie (1971)
Eucla Basin airborne magnetic and radiometric, 1970	Waller, Quilty, & Lambourn (1972)
COOMPANA, FOWLER, NULLARBOR, and onshore NUYTS airborne magnetic and radiometric	Lambourn (1977)

Seismic surveys and deep crustal studies

Name of survey	Reference
Seismic investigation of atomic explosion in South Australia, 1953	Doyle (1954)
Maralinga seismic survey, 1955-1956	Wiebenga & Hawkins (1956)
Mabel Creek seismic survey	Exoil Pty Ltd (1962)
Seismic velocities and crustal structure in southern Australia	Doyle & Everingham (1964)
Eucla Basin, South Australia, reconnaissance seismic refraction survey, 1964	Kendall (1965)
Serpentine Lakes reconnaissance seismic survey	Continental Oil Co. (1965)
Eastern Officer Basin seismic reflection and refraction survey, 1966	Moorcroft (1969)
Mount Davies traverse, Giles-Carnegie seismic survey, 1961-62	Turpie (1967)
Eastern Officer Basin seismic survey	Continental Oil Co. (1967b)
Western Arckaringa Basin seismic investigations	Milton (1969a,b)

Drilling surveys

Well name and number	Reference
Emu No. 1	Exoil Pty Ltd (1963)
Birksgate No. 1	Continental Oil Co. 1967a)
Munyarai No. 1	Continental Oil Co. (1968)
Mallabie No. 1	Outback Oil NL (1969)