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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1962/105

FITZROY AND CANNING BASINS, RECONNAISSANCE GRAVITY SURVEYS,

WESTERN AUSTRALIA 1952-60

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by

A. J. FLAVELLE and M. J. GOODSPEED

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SUMMARY

Gravity investigations in the Canning Basin were commenced in 1952, and by 1960 most of the Basin had been covered to some extent. The density of gravity stations varies greatly, however, owing to the difficulty of access to some remote parts of the Basin.

Many previously unknown geological features have been interpreted from the gravity anomalies which, in conjunction with the already geologically-defined structures, help to clarify the relations between the main structural units of the Basin. Several local gravity anomalies have also been investigated. Four cross-sections across the Basin are presented showing the geological interpretation from the Bouguer anomaly profiles.

Recommendations have been made for further geophysical investigations in certain areas of the Basin.

1. INTRODUCTION

The Canning Basin, including the Fitzroy Basin (Plate 1), is the second largest sedimentary basin in Australia, covering an area of at least 175,000 square miles. The stratigraphic sequence, overlying a Precambrian basement, is known to range from Ordovician to Cainozoic and reaches a total thickness of at least 20,000 ft in the Fitzroy Basin. The Canning Basin thus clearly warrants careful study of its commercial oil potential.

Geological investigations in the area began in 1883. Most of the early work was confined to the area of the Fitzroy Basin, where access was easier than in the desert areas of the Canning Basin to the south. Extensive surveys of the Canning Basin as a whole commenced after the second World War and, after 1950, geophysical investigations by gravity, seismic, and aeromagnetic methods have been undertaken to study the subsurface features of the area. Since 1954 a total of over 100,000 ft of drilling has been done by private companies and the Bureau of Mineral Resources, from which considerable stratigraphic information has been obtained.

For a detailed account of the development of geological understanding of the Basin the reader is referred to a report by Veevers and Wells (1961). With the publication of that report, and with the completion of reconnaissance gravity coverage of a large part of the Basin (except its southern limits), an overall assessment of the geophysical results can be undertaken.

This Record presents a preliminary analysis of the available gravity information, taking into account all the information from surface and drill-hole geology published to date. The analysis is preliminary in the sense that a more quantitative analysis of the results remains to be done. The conclusions reached are less detailed than will be possible from the more quantitative analysis but are, it is thought, justified by the results of the analysis so far completed.

The very important contribution of gravity data made available by West Australian Petroleum Pty Ltd (WAPET) is gratefully acknowledged.

2. GEOLOGY

Geological history

This outline of the geological history of the Canning Basin is abstracted from Veevers and Wells (1961).

In the later Precambrian, the crystalline floor of what is now the Canning Basin was probably high land that shed sediments into surrounding areas. Probably before the end of the Precambrian the sediments were folded and uplifted, the crystalline rocks were depressed and, with these movements, the Canning Basin was initiated. Starting at the latest in the lowermost Ordovician, a shallow sea covered at least half the Basin*, and in it were deposited limestone, dolomite, shale, and sandstone. The sea retreated in upper Ordovician times and did not return to the greater part of the Basin until the Permian.

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* In this report, the term 'the Basin' (with a capital letter) is used as a contraction for Canning Basin, including the Fitzroy Basin.

In the upper part of the middle Devonian, sandstone and limestone were deposited in a sea that covered the Fitzroy Basin (Plate 1). The sea floor was broken into blocks of varying height in the early upper Devonian; reefs grew along the edges of high-standing blocks, and conglomerate was deposited at the margin of the Fitzroy Basin; sandstone was deposited in lakes in the north-eastern part of the basin.

Most of these Devonian rocks were probably gently folded and eroded before lower Carboniferous sediments were deposited in the northern part of the Fitzroy Basin. In the upper Carboniferous, thick siltstone and sandstone were deposited in a shallow bay in the western part of the Fitzroy Basin.

In the early Permian thick beds of marine glacial rocks were deposited over the entire Canning Basin. A cycle of alternate deposition, firstly of marine and secondly of estuarine or fresh-water sediments, was repeated two and a half times during the rest of the Permian and during the lower Triassic. The sea then retreated, and these rocks were folded and eroded. The sea slowly advanced over the land from middle Jurassic to lowermost Cretaceous times and slowly retreated in the upper part of the lower Cretaceous.

From the upper Cretaceous to the Recent, the Basin has been land except for local intermittent submergence of the present coast.

Boundaries and structure

The known boundaries of the Canning Basin, as defined by the surface contact between Precambrian and Palaeozoic rocks, are shown on Plate 1.

The north-eastern boundary runs, in general terms, from Oobagooma in the YAMPI area * to the Wolf Creek meteorite crater in the BILLILUNA area. The Proterozoic formations of the Kimberley Block, a pronounced topographically high area, lie immediately north-east of this boundary, which has been mapped in detail.

The eastern boundary runs generally south from the Wolf Creek meteorite crater as far as the mid-point of the northern edge of the WEBB area, where it turns south-west, terminating in the north-eastern corner of the RYAN area. Precambrian outcrop is not continuous along this boundary, which is thus less well-defined.

The southern boundary has not yet been determined because of almost complete blanketing by Recent alluvium.

The south-western boundary runs from the south-western corner of the TABLETOP area in a north-westerly direction as far as the vicinity of Coolya Well in the PATERSON RANGE area, where it turns west-north-westerly and continues to the coast in the vicinity of Port Hedland. A major embayment along the valley of the Oakover River occurs in the eastern half of the NULLAGINE area. Archaean rocks of the Pilbara Block, a topographically high area, lie immediately to the south-west of this boundary, which is well defined.

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* Locality references in capital letters (e.g. YAMPI) refer, in this Record, to the names of the Australia 4-mile series areas. The boundaries of these areas are superimposed as a grid on the relevant maps.

A major structural unit within the Canning Basin is the Fitzroy Basin, an elongated feature, sub-parallel to the north-eastern boundary of the Basin, within which the greatest total thickness of sediments has been deposited. The north-eastern margin of this feature is well defined only at the Pinnacle Fault, which is mapped on the surface, with down-throw to the south-west, near Prices Creek (south-eastern corner of the NOONKANBAH area). The extensions of this feature in both directions require geophysical elucidation.

To the north-west there is evidence of sub-parallel lines of major faulting or flexure between which have been named units of intermediate sedimentary thickness. Of these, reference will be made to the Lennard Shelf, a unit named by Playford and Johnstone (1959), which is described as extending in contact with the north-eastern boundary of the Basin, between the boundary and the Fitzroy Basin. This unit has been further sub-divided by Veevers and Wells (1961).

The Fitzroy Basin is bounded to the south-west by the:

(a) Fenton Fault which is well exposed only in the Barnes Flow area (eastern edge of the MOUNT ANDERSON area), with down-throw to the north-east. Related to it is the

(b) Dampier Fault sub-parallel to the Fenton Fault along the north-western part of its postulated extension. This feature is entirely without surface expression, as far as is known.

The Jurgurra Terrace is the relatively flat area of intermediate thickness of sedimentation between the Dampier and Fenton Faults.

South Canning Basin is the name given to the area of the Basin not included in any of the above units. It has been subdivided by Veevers and Wells (1961).

Detailed examination of the gravity results will show that some of these units can be subdivided. Where there appears to be sufficient evidence, new unit and sub-unit names will be introduced.

Stratigraphy and rock density

An outline of the known stratigraphic sequence will first be presented; then an outline and discussion will be given of the results of density determinations on rock samples from different parts of the sequence, and their importance in the interpretation of the gravity survey results.

Table 1 presents the known stratigraphic sequence. The main reference is Veevers and Wells (1961).

Density measurements have been made on core samples from many drill holes, and data are available from four sources:

(a) BMR stratigraphic holes,

(b) holes drilled by WAPET under Commonwealth Government subsidy,

(c) WAPET exploratory wells,

(d) surface samples from the Geology Department, University of Western Australia.

TABLE 1

Stratigraphic Sequence

Canning Basin Area - Western Australia

Age	Estimated maximum thickness (ft)	Lithology	Facies
Cainozoic	200	Sand dunes, gravel, marl, limestone, conglomerate, duricrust	aeolian fluviatile lacustrine
Unconformity : Tertiary and upper Cretaceous rocks not known			
lower Cretaceous to middle Jurassic	2500	Pisolitic ironstone (positions uncertain)	lacustrine
		Conglomeratic sandstone - Kidson beds	paralic
		Claystone, siltstone with great variety of formation development	neritic
		Coarse to conglomeratic sandstone	littoral
Unconformity : lower Jurassic to upper Triassic rocks not known			
lower Triassic	1800	Plant bearing sandstone - Erskine Sandstone	continental
		Fossiliferous shale - Blina Shale	estuarine
		Plant bearing sandstone - Culvida Sandstone	continental
		Liveringa Formation including: fossiliferous sandstone - Hardman member	marine (shallow water)
		plant bearing sandstone	continental
		fossiliferous greywacke - Lightjack member	marine (shallow water)
		Fossiliferous, fine-grained sandstone - Noonkanbah Formation	marine
Permian	14,500	Fine-grained sandstone with coal seams - Poole Sandstone	freshwater
		Sandstone interbedded with claystone - Lucas beds (position uncertain)	marine
		Fossiliferous sandy limestone- Nura Nura member	marine
		Claystone, siltstone, boulder conglomerate Cuncudgerie Sandstone	marine - glacial to fluvio-glacial to glacigene

Continued on page 5

TABLE 1 (continued)

Age	Estimated maximum thickness (ft)	Lithology		Facies
Permian (continued)		Massive sandstone and tillite - Grant Formation	Claystone, sandstone boulder conglomerate - Paterson Formation	marine-glacial to fluvio-glacial to glacigene
			Tillite, boulder conglomerate - Braeside Tillite	
Carboniferous				
upper	5500(+)	Sandstone, siltstone, shale, thin beds of limestone, dolomite and anhydrite - Anderson Formation		estuarine
lower	1500	Fossiliferous calcarenite, calcareous siltstone - Laurel Formation		marine
Devonian		Calcarenite, sandy limestone, sandstone, siltstone, shale - Fairfield beds		marine
upper to middle	5000(+)	Calcarenite, sandy limestone, limestone breccia, bioherms, biostromes with great variety of formation development		facies complex owing to reef development
		Calcilutite, calcarenite, biostromes - Pillara Formation		marine
Unconformity : lower Devonian - Silurian - younger Ordovician (Caradocian) rocks are not known in the Canning Basin				
Ordovician		Fossiliferous dolomite, sandstone, siltstone - Gap Creek Formation		
(Llandeilian to Tremadocian)	3100(+)	Limestone, calcareous siltstone, sandy dolomite, arkose - Emanuel Formation		marine (shallow water)
		Glauconitic sandstone, shale, calcarenite - Samphire Marsh area		
Unconformity : middle and lower Cambrian rocks are not known in the Canning Basin				
Precambrian	Unknown	Basalt and dolerite, siltstone, sandstone, shale, bands of limestone and dolomite - Mount House beds - Warton beds - Mornington volcanics - King Leopold beds		highly altered with igneous intrusions
		Unsorted sediments with boulders - Walsh Tillite		
		Metamorphic and granitic rocks, diorite, dolerite, schist, gneiss, quartz reefs - Lamboo Complex - Halls Creek metamorphics		

For the purposes of the preliminary interpretations presented here, an average density of 2.60 g/cm^3 has been taken for all post-Proterozoic sediments. As is seen from Figure 4, which shows the variations of density with depth in four of the boreholes, this assumption should not be far from the truth. More detailed consideration of density variations within the sediments will be needed in the final analysis.

Important density variations occur in the Precambrian basement rocks. These have been determined partly from direct measurements on rock samples, and partly from gravity variations which appear in the areas where the different rock types occur at the surface. These rocks may be divided into three types:

(a) relatively unaltered Upper Proterozoic sediments which have a density very close to that of the post-Proterozoic Basin sediments. These occur extensively along the eastern boundary of the Basin.

(b) highly metamorphosed sediments of Lower Proterozoic and Archaean age, such as the Halls Creek metamorphics, intruded by basic igneous rocks. A mean density of approximately 2.73 g/cm^3 applies to these rocks, which are found in the area of the Halls Creek 'Mobile Zone' (Traves, 1955) and alongside the mid-point of the eastern boundary (Arunta Block).

(c) granitic-type rocks similar to the Lamboo Complex which are assumed to underly the Proterozoic rocks in the basement of the Basin and have density close to 2.65 g/cm^3. These rocks occur extensively along the north-eastern boundary of the Basin.

The post-Proterozoic sediments which fill the Basin are intruded by at least two types of igneous rock:

(a) high-density gabbro and dolerite intrusions in the upper Carboniferous, encountered in the Fraser River and Barlee bores (McWhae, Playford, Lindner, Glenister and Balme, 1958; WAPET, 1961; Playford and Johnstone, 1959).

(b) many lamproite (potash and magnesia-rich lamprophyres) plugs intruding the Permian and Triassic of the Fitzroy Basin. The density of these rocks is about 2.40 g/cm^3. They are believed to be of Jurassic age (Prider, 1960).

Tectonic features

Traves (1955) has described two mobile zones which are considered to have influenced sediment deposition close to the north-eastern boundary and the northern extremity of the eastern boundary of the Canning Basin. These are:

(a) the King Leopold Mobile Zone described by Traves (1955) as an extension of the Warramunga Mobile Zone and which overlaps the north-eastern boundary of the Basin and intersects the Halls Creek Mobile Zone in the region of the south-eastern end of this boundary

(b) the Halls Creek Mobile Zone, which runs north-north-easterly from its junction with the King Leopold Mobile Zone, separating the Kimberley Block from the Sturt Block and Arunta Block to the east.

Extensive areas of outcrop of granitic intrusives of Archaean or Lower Proterozoic age occur along the edge of the Kimberley Block within both mobile zones (Tectonic map of Australia, 1960, published by the Bureau of Mineral Resources).

Adjacent to the eastern boundary of the Basin, extensive outcrops of Lower Proterozoic metamorphics with basic intrusions of high density have been mapped.

The Pilbara Block, adjacent to the south-westerly boundary of the Basin, is characterised by outcrops of granitic Proterozoic rocks, with Upper Proterozoic sediments and porphyry in the area of the major embayment which extends into the NULLAGINE area.

The Fenton and Pinnacle Faults are recognised as controlling sedimentation within the Fitzroy Basin. Movement along these faults has been proved during the lower Permian (Guppy, Lindner, Rattigan and Casey, 1958). There is evidence of reversal of throw of the Fenton Fault during Mesozoic times. The delineation of these features, and, if possible, their detailed elucidation (Veevers and Wells, 1961 have advanced a description of the Fenton Fault as a monoclinal flexure) were two of the principal objectives of the 1960 reconnaissance gravity survey. Neither of these very important structures has been adequately clarified from surface geological study and it appears that geophysical methods must be used to elucidate and describe them.

Other possible areas of mobility either have not yet been closely studied, or the older rocks are concealed by Recent alluvium. It will be shown that the gravity data provide much information on probable subsurface configuration in these areas.

3. GRAVITY ANOMALY FEATURES

The gravity results are presented in the form of Bouguer anomaly contours on Plate 2 on which the features, that will be discussed, are numbered. Reference to each feature will be made using these numbers for convenience and brevity.

For convenience in reference, all the numbered anomaly features are listed in Table 2, together with a brief description and, where appropriate, the name suggested for the postulated structural unit that corresponds to the anomaly.

TABLE 2

Gravity anomaly features

Feature Number	Description	Name
1	Pronounced negative anomalies on the granitic complex, YAMPI and LENNARD RIVER areas	
2	Strong gradient trending north-east near Fitzroy Crossing	
3	Line of anomaly 'highs' from Fairfield to Oobagooma	

TABLE 2 (continued)

Feature Number	Description	Name
*4	Line of anomaly 'lows' from north-east of Oscar Range to Oobagooma	Napier Gravity Trough
*5	Line of positive, closed, anomaly features, Prices Creek to Meda No. 1 bore	Oscar Ridge
*6	Continuation of the steep gradient occurring over the Pinnacle Fault in a north-west direction, with two changes in direction, passing south of Meda No. 1 with a west-north-westerly trend	Derby Ramp
7	Steep gradient over the outcrops of the Pinnacle Fault	
8	Strong gradient trending north-easterly from Ruby Plains, GORDON DOWNS area	
9	Pronounced belt of negative anomaly features running from near western edge of MOUNT BANNERMAN area, to the north of Billiluna Homestead	Mount Bannerman Gravity Trough
10	Strong gradient trending north-easterly and passing Billiluna with a pronounced right-angle cross-feature	
11	Gradient broken by Feature 12 trending south from Billiluna Homestead to vicinity of Stansmore Ranges	
12	Pronounced 'low' running north across STANSMORE area, diverging to swing east through Ada Spring and also north into BILLILUNA area	Stansmore Gravity Trough
13	Closed 'high' close to the eastern edge of WILSON area	Wilson Gravity 'High'
14	Closed 'high' near Gregory Salt Lake, north-east corner of CORNISH area	Gregory Lake Gravity 'High'
14A	Reduced gravity gradient between the Mount Bannerman Gravity Trough and the Gregory Lake Gravity 'High'	Minnie Range Gravity Shelf
15	Continuation of a gradient south-east from CROSSLAND area passing close to Godfreys Tank	

* Following Veevers & Wells (1961), these three features comprise the Lennard Shelf

TABLE 2 (continued)

Feature Number	Description	Name
16	Line of negative anomalies trending south-easterly along the deeper part of the Fitzroy Basin.	
16A	Relative gravity 'high' on north-eastern corner of CROSSLAND area	
17	Group of closed anomaly 'highs' in area of Yeeda River Homestead	Yeeda Gravity 'High'
18	Two closed gravity 'lows' north-east of Broome, immediately west of Feature 17	Broome Gravity Depression
19	Absence of gravity gradient over postulated line of the Fenton Fault in Frome Rocks 1 and 2 area	
20	Negative features in the area of the Jurgurra Terrace	
21	Reduced gradient intensity along Fenton Fault north-west from Barnes Flow	
22	Steep gradient along Fenton Fault between Barnes Flow and centre of CROSSLAND area	
23	Change of gradient trend near Camelgooda Hill, MOUNT ANDERSON area	
24	Line of Dampier Fault not positively outlined by anomaly trends	
25	Line of positive anomalies trending east-south-easterly from Broome through LA GRANGE, MOUNT ANDERSON, McLARTY HILLS and CROSSLAND areas	Broome Swell (Veevers & Wells, 1961)
26	Gradient extending south-east from Roebuck Bay to the middle of DUMMER area	
27	Series of alternating 'highs' and 'lows' trending inland on LA GRANGE and MUNRO areas from the coast between Roebuck Bay and Nita Downs	La Grange Platform
28	Absence of any pronounced gradient in McLARTY HILLS area, except for the extreme north-eastern corner	
29	Two closed gravity 'lows' covering the southern part of McLARTY HILLS area	Oasis Gravity Depression

TABLE 2 (continued)

Feature Number	Description	Name
30	An area of relatively high gravity anomalies south of the Oasis Gravity Depression	Joanna Spring Gravity Spur
30A	A broad area of smooth gravity relief between the Joanna Spring Gravity Spur and the South Canning Basin Gravity Depression	Dummer Gravity Platform
31	Strong, somewhat contorted, gradient trending south-south-easterly across ANKETELL area and continuing south-easterly to TABLETOP area	
32	Series of closed 'highs' extending south-south-easterly from MANDORA area into ANKETELL area (postulated to extend into PATERSON RANGE area and possibly farther)	Anketell Gravity Ridge
33	Gradient trending south-easterly from the coast north-east of Wallal Downs	
34	Strong gradient trending south-easterly in the south-west corner of ANKETELL area.	
35	Line of two closed 'highs' extending south-east from Wallal Downs into YARRIE area	Wallal Platform (Veevers & Wells, 1961) Gravity work suggests probably a Ridge
36	Very strong gradient just south-west of Wallal Downs	
37	Very strong gradient trending east-south-easterly along the De Grey River	
38	Closed 'high' with strong gradients near Yarrie Homestead	
39	Closed gravity 'low' extending over the north-western corner of YARRIE area	Wallal Gravity Depression
40	Extensive closed 'low' extending into URAL, WILSON, MORRIS, and RYAN areas	South Canning Basin Gravity Depression
41	Pronounced gravity 'low' on the southern part of RUNTON. The extent of this feature has not been determined because of lack of field coverage.	Gibson Desert Gravity Depression

4. DISCUSSION OF GRAVITY RESULTS

The density of gravity stations in the Basin does not exceed 1 per 50 square miles except in a few small areas. Thus only very broad features can at present be deduced. Likewise, the contour delineation of these features remains subject to adjustment in detail; however, the existence of the features is well established, except possibly in the southernmost part of the area discussed, where contours are shown with broken lines.

The dominant features on the Bouguer anomaly map (Plate 2) are the positive anomalies that trend south-east (principally, the Anketell Gravity Ridge and the gravity expressions of the Broome Swell and Lennard Shelf) and the pronounced negative anomaly which has been named the South Canning Basin Gravity Depression. Less pronounced, but nevertheless important, features from geologic and economic considerations are the gravity expression of the Fitzroy Trough, its extension which has been called the Mount Bannerman Gravity Trough, and the Jurgurra Terrace.

The most pronounced directional trend of the anomalies is the south-east trend of the positive gravity features mentioned above. Other less pronounced directional trends are the north-east trend of the Mount Bannerman Gravity Trough and Gregory Lake Gravity 'High' and the north-south trend of the Stansmore Gravity Trough and Wilson Gravity 'High'.

In some places the positive anomalies are bordered by zones of relatively high gradient, e.g. south of the Virgin Hills on NOONKANBAH area (feature 7), north-east of the Broome Swell on MOUNT ANDERSON, NOONKANBAH, and CROSSLAND areas (features 21 and 22), north-east and south-west of the Anketell Gravity Ridge on ANKETELL area (features 31 and 34), and south-west of Wallal Platform on MANDORA area (feature 36). Within the boundaries of the Basin, these gradients persist over long distances (50 miles or more). The south-western border (feature 26) of the Broome Swell (feature 25) extends across five four-mile areas (LA GRANGE, MOUNT ANDERSON, McLARTY HILLS, CROSSLAND, and DUMMER) but the intensity of the anomaly gradient is not as great as the above-mentioned features.

Referring to the Bouguer anomaly map (Plate 2), the following general features are apparent:

(a) in the vicinity of the Basin boundaries, other than the undefined southern boundary, the trend of the gravity contours is generally well defined and parallel to the boundaries. However, the gradients are not always most intense immediately over the boundary;

(b) within the Basin the anomalies are generally more negative in the south-east. The relative degree to which this trend may be attributable to isostatic effects and thickening of sedimentation will be discussed later,

(c) positive anomaly features are generally sharp, often in the form of ridges, while negative features tend to be broader and more rounded.

In addition to the gravity features described above, gravity expression of the following units, defined by previous authors, can be recognised on the Bouguer anomaly map (Plate 2).

Lennard Shelf: an area of relatively high Bouguer anomaly (features 4 and 5), occupying the north-eastern margin of the Basin and bounded to the south-west by the Pinnacle Fault (feature 7) and its probable extension (feature 6).

Fitzroy Trough: an area of negative gravity anomaly (feature 16) bounded by the Pinnacle Fault (feature 7), the Fenton Fault (features 21 and 22), and their extensions.

Jurgurra Terrace: a small area (feature 20) bounded by the Dampier Fault (feature 24) and the Fenton Fault extension to the north-west.

La Grange Platform: an area (feature 27) lying immediately south-west of the Broome Swell (feature 25). The Joanna Spring Gravity Spur (feature 30) is possibly a sub-division of this unit.

5. INTERPRETATION OF GRAVITY RESULTS

The discussion of the interpretation of the gravity results is subdivided into sections as follows:

- Lennard Shelf
- Fitzroy Trough
- Jurgurra Terrace
- Broome Swell
- La Grange Platform
- Anketell Gravity Ridge
- North-east Canning Basin
- Central and southern Canning Basin
- Gibson Desert Gravity Depression
- Cross-sections (General Discussion)
- Cross-section 1
- Cross-section 2
- Cross-section 3
- Cross-section 4

Lennard Shelf

This unit is bounded to the north-east by Precambrian outcrops and to the south-west by the Pinnacle Fault and its extension. The zone of relatively high Bouguer anomalies (features 4 and 5) that coincides with it, terminates in the north-eastern corner of MOUNT BANNERMAN area, where it is in contact with the Mount Bannerman Gravity Trough. The nature of its north-western termination is not definitely known; according to Carrigy and Fairbridge (1954) it is terminated, together with other units of the northern part of the Basin, by the Leveque Rise, a feature of the continental shelf.

Veevers and Wells (1961) have divided the Lennard Shelf into three sub-units mainly on the basis of the gravity anomalies. These sub-units are:

Derby Ramp. The zone of fairly steep gravity gradient (feature 6) along the contact of the Lennard Shelf with the Fitzroy Trough. This zone is considered to be a region where the basement dips fairly gently towards the deeper parts of the Fitzroy Trough

The north-easterly displacement of this zone close to the Oscar Range indicates a narrowing of the Lennard Shelf in this area.

The area near the Sisters No. 1 bore can be interpreted as a basement plateau at the top of the Ramp (see Plate 3, Cross-section 1).

The relation between the Derby Ramp and the Pinnacle Fault is not clear. The transition between the steep gravity gradient over the Fault and the more gentle gradient of the Ramp is not a sharp one. The question is further complicated by the fact that basement configuration close to the Fault is unknown, and movement may have taken place along more than one fault line. Near Prices Creek, the Pinnacle Fault divides shattered Permian rocks (Grant Formation) on the north-east from unaffected and younger Permian rocks (Noonkanbah Formation) to the south-west. One to two miles north-east of the Pinnacle Fault, and parallel to it, is the Cadjeput Fault, with Ordovician rocks outcropping to the north-east.

Veevers and Wells (1961), after outlining the results of seismic work in this area by Smith (1955), present two alternative cross-sections which are reproduced in Figure 3. Section A-A' shows the main feature as a fault, Section B-B' as a monocline, with the Pinnacle Fault appearing as a near-surface structure only. Both are considered consistent with the seismic results. Section C-C' is a modification of the monoclinal hypothesis which is consistent with the known gravity profile across the Pinnacle Fault. Whether a more detailed analysis of the gravity results will show grounds for preferring any one of the three models so far proposed is a question for further study.

Oscar Ridge. This was defined by Veevers and Wells (1961), and coincides with a series of closed gravity 'highs' with a general north-westerly trend (feature 5). Precambrian rocks crop out at the Oscar Range and at the Virgin Hills. At the Oscar Range the outcrop is quartzite (density 2.64 g/cm^3, Bouguer anomaly +5 milligals) and at the Virgin Hills the outcrop is a granitic complex (density 2.70 g/cm^3, Bouguer anomaly +15 milligals). Farther north, Meda No. 1 and 2 bores were drilled on a geological structure, delineated by seismic methods, that coincided with a culmination of +37 milligals. Meda No. 1 was drilled to 8808 ft and encountered Precambrian schist and quartzite from 8690 ft to total depth. The densities of the cores obtained from Meda No. 1 bore (Figure 5) show that the density of the sediments in this area is not higher than densities measured from other bores (e.g. Grant Range No. 1 or Frome Rocks No. 2). In addition, the density of the basement rocks is close to 'normal' (2.67 g/cm^3). Therefore the unusually high anomaly value of +37 milligals at Meda No. 1 can possibly be attributed to the presence of higher-density material within the basement. An aeromagnetic traverse (Quilty, 1960) across the Lennard Shelf in the vicinity of Meda No. 1 shows an anomaly slightly north of the positive gravity culmination. Therefore the following points about basement configuration and density can be made:

(a) The aeromagnetic anomaly could represent a basement ridge that does not coincide with the positive gravity culmination. It is possible that a removal of the regional gradient in this area would show this.

(b) The high positive Bouguer anomaly could be caused by intra-basement density variations.

In the vicinity of the Pinnacle Fault the gravity expression of the Oscar Ridge appears to be offset to the south-west, although gravity coverage in the north-eastern corner of NOONKANBAH area is lacking. According to Guppy et al (1958) there is approximately 7000 ft of Devonian and Ordovician sediments in the area north of BMR No. 3, on the eastern edge of NOONKANBAH area.

An examination of the gravity 'saddle' between the two closed positive anomalies (feature 5) at the Virgin Hills and Prices Creek suggests that the thickness of the sediments could range from a minimum of 4000 ft up to 8000 ft.

Napier Gravity Trough (feature 4). This coincides with the Napier Platform of Veevers and Wells (1961). Between the Oscar Range and the Precambrian, a syncline in the Devonian is exposed (Guppy et al., 1958). It has a strike parallel to the major features of the Basin. The Bouguer anomaly profile across it (Fig. 2) indicates a residual gravity 'low' over the exposed syncline. A cross-section drawn across the feature, farther north-west (see Plate 4, reference letter C) shows that the syncline might continue in that direction. South of Oobagooma Homestead (YAMPI area) the depth to basement could be as much as 10,000 ft. However, in this area the possibility of relative gravity 'lows' being produced by relatively light basement material (e.g. granite) cannot be excluded.

On the Precambrian itself the anomalies show a logical pattern; the broad, well-defined, negative anomalies (feature 1) coincide with the acid granitic rocks, and the positive anomalies coincide with the dense metamorphic members of the Lamboo Complex (feature 3).

From Fairfield to Oobagooma the edge of the Basin is bordered by a zone of relatively high Bouguer anomalies which are presumably caused by a belt of relatively dense metamorphics of the Lamboo Complex. It can be inferred from the gravity pattern that they swing south-east under the Basin. The metamorphics that were found at the base of the Ordovician near Prices Creek in BMR No. 3 possibly represent a continuation of this belt, because a maximum Bouguer anomaly value of +23 milligals in the Prices Creek area is consistent with a relatively dense basement. Farther south-east the Lennard Shelf appears to be terminated by the Bulka Hills which are situated on a relative gravity 'high' that also appears to be the termination of the Oscar Ridge (feature 5).

West of Oobagooma the sediments overlap on to a promontory of Precambrian sediments surrounding a core of basic meta-sediments. As expected, the feature is characterised by a gravity 'high'. This 'high' could extend seawards across the entrance of King Sound. The positive anomaly on the north-western corner of DERBY area is probably an extension of the Oscar Ridge, but it appears to be narrower than at Meda No. 1.

Fitzroy Trough

The geology of the Fitzroy Trough is fully described by Guppy et al. (1958) and Veevers and Wells (1961). Gravity work on the Nerrima Dome (Plate 2) and the Fenton Fault has been described by Wiebenga and van der Linden (1953). In the north-east the Trough is bounded by the Pinnacle Fault and Derby Ramp and to the south-west by the Fenton and Dampier Faults. The Pinnacle Fault and Derby Ramp have been discussed in a previous section. The Fenton Fault has been investigated by seismic methods near Barnes Flow (Vale and Smith, 1959). The seismic results showed that the structure is probably a fault. The gravity evidence indicates either a fault or a steeply dipping monoclinal flexure. Farther south the steep gradients continue to the south-eastern corner of CROSSLAND area. On this gravity evidence the fault is postulated to continue at least this far but with a progressive reduction in throw. North-west from Mount Density the gradient decreases (feature 19) and near Frome Rocks No. 1 there is actually a slight reversal of the gravity gradient. However, drilling results show that at Frome Rocks No. 1 the Fenton Fault still exists with direction of throw unchanged.

This problem is discussed further in the section on the Jurgurra Terrace. The fault cannot be observed at the surface at Frome Rocks No. 1 and farther north because the surface is covered by Recent deposits and the fault's probable extension farther north is not apparent from the gravity results. According to Trumpy, Guillemot, and Tissot (1960) the fault does not continue much beyond the Frome Rocks No. 1 area.

The Dampier Fault (feature 24) runs from Broome to the vicinity of Camelgooda Hill. It has no surface expression but it is mentioned by Playford and Johnstone (1959) and Trumpy et al. (1960) and its position has presumably been mapped by seismic methods. According to Trumpy et al. it has maximum throw near Broome and minimum throw at its south-eastern end. They also state that at its southern end it is connected to the Fenton Fault by a cross-fault. The position of the Dampier Fault is shown on Plate 1. A zone of moderate gravity gradients (feature 24) coincides with it. The following points are made concerning the gravity results:

(a) The gradient (feature 24) is neither steep nor linear in trend but the gravity data are rather sparse in this area.

(b) The gradient is greatest near Broome, which is consistent with Trumpy's(op.cit.)statement of maximum throw in that area.

(c) The throw (on gravity evidence - see Plates 3 and 4) is about 6000 ft near Broome, reducing to 3000 ft north of Dampier Downs.

Anticlinal Belts (Plate 2). The Bouguer anomalies in general run parallel to the southern anticlinal belt. A detailed study of the gravity and a removal of the regional gravity trends may possibly show residual 'highs' on the anticlinal culminations. This could indicate that the structure persists at depth. Williams (1956), from seismic results obtained indirect evidence that the south-eastern flank of the Poole Range culmination persists at depth.

There is a definite residual gravity anomaly over the Deep Well anticline (Williams, 1955). Removal of the regional effect would increase the positive gravity feature over the Mount Wynne culmination of the northern anticlinal belt. Over the Grant Range culmination there is evidence of a residual 'low'. This feature will be discussed when Cross-sections 1 and 3 are considered.

The south-eastern extent of the Trough. This is not at all clear from the gravity results. Feature 9 is a belt of negative anomalies which, because of its strike and position, appears to be associated with the Halls Creek Mobile Zone. The existence of the 'Lonergan Hinge' as postulated by Casey and Wells (1960) is not supported by gravity evidence. It is more likely (on gravity evidence) that the extremely deep (20,000 ft +) part of the Trough terminates in the north-eastern corner of CROSSLAND area. However, the gravity expression of the Fenton Fault continues in a south-easterly direction to the south-eastern corner of CORNISH area.

To the north-west the negative gravity anomaly corresponding to the trough is restricted by the Yeeda Gravity 'High' (see Cross-section 2).

Jurgurra Terrace

The Jurgurra Terrace occupies a relatively small area (feature 20) between the Dampier and Fenton Faults. It is recognised (Playford and Johnstone, 1959) as a separate unit because of the absence of upper Carboniferous rocks and the thinness of the Permian rocks. The thickness of sediments is believed to range from 7000 to 12,000 ft. With reference to the gravity data the following points are made:

(a) The cross-faults mentioned by Trumpy et al. (1960) can be correlated with feature 23. Even if it is not caused by cross-faulting, feature 23 could represent the south-eastern end of the Jurgurra Terrace. South-east of feature 21 the anomaly is +5 milligals while to the north-west it is -15 milligals (see, however, comments on Cross-section 3).

(b) The density contrast on the Jurgurra Terrace is about 0.05 g/cm^3 more than on surrounding areas (see Fig. 4)

(c) The effect of (b) coupled with a postulated change in basement anomaly could be the cause of negligible gravity difference across the Fenton Fault in the Frome Rocks No. 1 area (see Cross-section 1).

(d) North-west of Frome Rocks the throw of the Fenton Fault is smaller, and on gravity evidence there is no clearly-defined dividing line between the Jurgurra Terrace and the Fitzroy Trough.

Broome Swell

The Broome Swell (feature 25) is represented by a positive gravity anomaly bounded to the north-east by the Fenton/Dampier Faults and to the south-west by feature 26. To the north-west the area has been drilled at three places, viz. at Dampier Downs No. 1 (on the positive gravity culmination) and at Thangoo and Roebuck Bay bores (on the south-western flank). These bores show that at least the north-western section is elevated with respect to the Jurgurra Terrace. The following points with respect to the gravity data can be made:

(a) The gravity anomalies (feature 25) that correspond to the Broome Swell extend south-east to the Dummer Range

(b) The change in Bouguer anomaly from the Broome Swell to the Jurgurra Terrace is too great to be explained solely by change in sedimentary thickness. There could be a change in basement effect (Plate 3).

(c) On gravity evidence the minimum sedimentary thickness occurs near the north-western corner of CROSSLAND area.

La Grange Platform

The La Grange Platform (named by Veevers and Wells, 1961) probably has a larger range of basement depths than Veevers and Wells estimated. The platform (feature 27) consists of an area with alternating maximum and minimum gravity features which, in general, trend south-east. Smith (1960) reports that seismic results show basement at 4400 or 8000 ft near La Grange. The value of 4400 ft is favoured by Veevers and Wells (1961); it appears on geologic evidence to be the more likely of the two alternatives presented by Smith.

The south-easterly extent of the La Grange Platform can be inferred from gravity evidence. Relatively (compared with the La Grange Platform) more-negative features (features 29 and 30) cover McLARTY HILLS and JOANNA SPRINGS areas and represent a change in the characteristics of the Bouguer anomalies. In addition the intensity of the anomalies is different; the south-eastern area is generally one of decreased anomaly gradient.

Anketell Gravity Ridge

The Anketell Gravity Ridge (feature 32) is probably the most prominent positive anomaly feature within the Basin. It is most clearly defined on ANKETELL area where it is bounded by relatively sharp anomaly gradients (features 31 and 34). To the north-west of MANDORA area the Gravity Ridge becomes wider and a geologic unit called the Wallal Platform (Veevers and Wells, 1961) coincides with the most positive (+45 milligals) anomalies (feature 35) within the Basin area. The Wallal Platform is bordered to the south-west by an extremely sharp gravity gradient (feature 36) that marks the boundary between the gravity expression of the Wallal Platform and the Wallal Gravity Depression. Both the Wallal Platform and Wallal Gravity Depression are relatively small in area and for the purposes of this Record will be treated in conjunction with the Anketell Gravity Ridge. The gravity anomaly pattern of the area could possibly be interpreted as described below.

(a) The line of positive anomalies (feature 32) extending from MANDORA area to RUNTON area could, on the evidence of sparse gravity readings in the south-western parts of the Northern Territory and the north-western part of South Australia, extend in a south-easterly direction across the continent. If this is so, then the geological feature that is responsible for the Anketell Gravity Ridge must be an important feature of the crust of Australia. At present, because of the paucity of geological and geophysical data, any comments on this feature must be largely conjectural.

It is possible that feature 32 represents part of an extremely ancient mobile zone, such as that shown in Figure 1 and which marks the north-easterly extent of the ancient Western Australian Shield. The evidence of age determination on Precambrian granites gives some support to this. These age determinations fall into two broad age groups; firstly, ages less than 1700 million years, and secondly, ages greater than 2000 million years. Most granites sampled on the Western Australian Shield area belong to the second group of ages and no granite tested north of the lineament shown on Figure 1 has belonged to the second group.

(b) South of Wallal the gravity gradient (feature 36) could be caused either by a change in depth to basement, or by a change in basement density, or both. A linear change in basement anomaly between the Wallal Platform and the Basin edge is not likely, because the gravity pattern of the Precambrian shows a large range in anomaly size. On Cross-section 2 an attempt has been made to estimate the thickness of the sediments by producing a basement anomaly curve. The difference in milligals between the observed Bouguer anomaly curve and the postulated basement Bouguer anomaly curve is proportional to the thickness of the sediments. The interpretation of Cross-section 2 shows a minor basement depression in the area of the Wallal Gravity Depression. However, it is possible that the negative anomaly of the Wallal Gravity Depression is almost entirely caused by thick sedimentary sequences (20,000 ft +). Since there is no geological evidence supporting the existence of major thicknesses of post-Proterozoic sediments in the area, then it seems probable that any considerable thickness of sediments would be of Proterozoic age.

(c) Between the bores Wallal No. 1 and Samphire Marsh No. 1 there is a slight gravity 'low', which could possibly represent a sedimentary thickness of up to 12,000 ft.

(d) On the Precambrian of the Pilbara Block the anomaly pattern is similar to the pattern north of the Lennard Shelf, i.e., the positive anomalies occur over metamorphic and basic rocks of the Archaean and Lower Proterozoic and the more negative anomalies are over outcrops of granite or granitic gneiss. Some of the gradients over the Precambrian outcrop (features 37 and 38) are extremely intense.

North-east Canning Basin

The North-east Canning Basin includes the following features:

Mount Bannerman Gravity Trough (feature 9)
Gregory Lake Gravity 'High' (feature 14)
Stansmore Gravity Trough (feature 12)
Minnie Range Gravity Shelf (feature 14A)
Wilson Gravity 'High' (feature 13)

The following observations can be made:

(a) From geological observation the MOUNT RAMSAY area appears to be where the King Leopold and Halls Creek Mobile Zones meet. The trends of the anomalies of MOUNT RAMSAY and MOUNT BANNERMAN areas support the geological evidence for this idea (cf features 7 and 8).

(b) The belt of Halls Creek metamorphics which trends north-east is coincident with an anomaly trend of high gradient (feature 8). However, gravity coverage of GORDON DOWNS area is not sufficient to provide accurate anomaly contours north of BILLILUNA area.

(c) The Hardman Basin (Plate 1) (containing Lower Palaeozoic sediments on GORDON DOWNS and DIXON RANGE areas) is probably continuous with the Mount Bannerman Gravity Trough (feature 9). The Trough continues across the Basin boundary without any appreciable change in anomaly magnitude. The gravity minima (feature 9) therefore probably represent the effect of a considerable thickness of Proterozoic sediments on both sides of the Basin boundary. Because Lower Palaeozoic sediments are present in the Hardman Basin, it is possible that similar sediments are present at depth on MOUNT BANNERMAN area.

(d) The structure that causes the anomaly 'lows' of the Mount Bannerman Gravity Trough, branches near Billiluna homestead; a series of 'lows' trends south from there, parallel to the Basin edge. This feature (number 12) has been named the Stansmore Gravity Trough and like the Mount Bannerman Gravity Trough it probably represents a considerable thickness of Proterozoic sediments. In addition, the north-south Trough branches on LUCAS area where there is a pronounced west-north-west anomaly 'low'. It is possible therefore that the influence of the Warramunga Mobile Zone extends this far (Traves, 1955).

(e) The Stansmore Fault is characterised by a steep gradient at its southern end, near the Stansmore Ranges (Plate 2). Towards the north, where its throw is decreased, it crosses the gravity trends obliquely. The main variations in basement depth probably run north from the Stansmore Ranges, following the trend of the Stansmore Gravity Trough.

(f) Owing to the paucity of outcrop and total lack of subsurface (such as seismic) data it must be assumed that the Gregory Lake Gravity 'High' (feature 14) and Wilson Gravity 'High' (feature 13) probably represent shallow basement.

Central and southern Canning Basin

The Central and southern Canning Basin (features 29, 30, and 40) is an area in which the Bouguer anomalies are generally much more negative than anywhere else in the Basin. Feature 40 is the predominating negative feature of the whole Basin. Three gravity features in this area have been named and described. They are:

Oasis Gravity Depression
Joanna Spring Gravity Spur
South Canning Basin Gravity Depression

Some general features of the anomaly pattern of the area are:

(a) Generally the anomalies are smooth with no steep gradients or sudden changes in trends. This could be caused by:

a considerable thickness of undisturbed sediments,
a thin 'veneer' of sediments on a non-complex crystalline basement,
insufficient station density and therefore a loss in definition.

(b) The anomalies become more negative to the south-east. Some possible causes of this are:

a thickening of the sediments from north-west to south-east,
a thickening of the (light) crust towards the centre of the continent with a resultant decrease in Bouguer anomaly.

The decrease in anomaly magnitude could be partially caused by thickening but it is impossible to estimate the relative magnitude of this effect, without more detailed analysis.

Because the gravity coverage in this area is poor it is not possible to accurately define the south-eastern extent of feature 40.

Gibson Desert Gravity Depression (feature 41).

It is interesting to note that the 'possible salt dome' at Woolnough Hills (Veevers and Wells, 1959) is near the south-western corner of MORRIS area and is therefore separated from the South Canning Basin Gravity Depression by the Anketell Gravity Ridge. According to Leslie (1961) the 'dome' has a gypsum core surrounded by Proterozoic sediments. Therefore it must be postulated that a thick Proterozoic sequence exists south-west of the Anketell Gravity Ridge.

Cross-sections (General discussion)

Four cross-sections with Bouguer anomaly profiles and possible geologic cross-sections are presented. Where it has been applicable, the sections have been used to illustrate points made in the foregoing discussion of the results. Therefore remarks made about the cross-section will concern mainly features (gravity or geological) that have not been discussed previously.

Cross-section 1 (Plate 3)

The geological cross-section used in this Plate was drawn from Trumpy et al. (1960). Two types of Bouguer anomaly profile are presented:

(a) Observed Bouguer anomaly - as obtained from Plate 2.

(b) Bouguer anomaly with the gravity effect of the sediments (or basement anomaly) removed. This is the Bouguer anomaly that would result at the surface if the sediments were replaced by material having the same density as the basement. This anomaly can only be calculated at points where the thickness of the sediments is known, and density data on the sediments are available. Thus the control points used in drawing the curve occurred at boreholes that penetrated to basement (or at least at holes that penetrated deep enough to enable a reasonable depth estimate to be made). Between the control points a linear change in anomaly is assumed except where the geological evidence strongly indicates otherwise.

Of course the two anomaly curves, (a) and (b), are identical over areas of basement outcrop. The difference g_z (in milligals) between the two profiles is directly proportioned to the thickness (L) of sediments, the formula used for depth calculations being $L = g_z/12.77\Delta d$ *

The broken line on the geological cross-section shows the sedimentary depth calculated from the above equation. It should be noted that two different density contrasts (sediments to basement) are used. The density data from the boreholes (Fig. 4) were used as a basis for this. The following points on the cross-section can be made, and are discussed under A, B, C, etc, which are marked on Plate 3.

A. The gravity 'high' of the Broome Swell appears quite plainly but the Dampier Fault does not show on the profile calculated from gravity data. This could be partially due to an incorrect selection of basement anomaly. Also the type of formula used is not suitable for calculating or plotting faults.

B. In contrast to Cross-section 3(Plate 5), the gravity expression of the Fenton Fault in this area is totally lacking. However, the evidence obtained from Frome Rocks No. 1 and 2 and Grant Range No. 1 shows that there is considerable displacement across the Fenton Fault. The lack of gravity contrast across the fault can be explained by:

(a) Change in density contrast from the Fitzroy Trough to the Jurgurra Terrace, combined with

(b) a change in basement anomaly across the Fenton Fault.

The lack of gravity expression of the Fenton Fault could also be due to a known considerable thickness of upper Carboniferous sediments in the Fitzroy Trough and none on the Jurgurra Terrace. If the density of upper Carboniferous sediments is close to basement density, then the absence of those sediments from the sequence on the Jurgurra Terrace would cause no change in anomaly across the Fenton Fault. In the area of high anomaly-gradient (features 21 and 22), it is not known whether upper Carboniferous sediments are present in the

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* where L is in kilofeet, Δd= density difference between sediments and basement (g/cm^3)

Fitzroy Trough. However, if they are present, then the large gravity gradients across the Fenton Fault (features 21 and 22) and the smaller gradient further to the north-west (feature 19) cannot be explained solely by changes in thickness of the upper Carboniferous.

It must also be noted that the Fitzroy Trough/Broome Swell boundary (features 21, 22, and 15) is characterised by a steep gravity gradient while the Fitzroy Trough/Jurgurra Terrace boundary is marked by a zero, or small, gravity gradient. The increased density contrast (basement to sediments, with respect to the Fitzroy Trough and Broome Swell) of the Jurgurra Terrace has already been noted. It is possible therefore that the loss of intensity of the gravity gradient along the Fenton Fault is mainly caused by an increase in density contrast within the Jurgurra Terrace.

C. The Grant Range No. 1 bore was drilled on the Grant Range Anticline which is represented, gravitationally, by a distinct 'low'. This feature will be discussed under Cross-section 3.

D. Oscar Ridge (represented by a gravity 'high', feature number 5) could be caused by an intrusive mass of the dimensions and density shown on the cross-section.

E. The interpretation of the cross-section shows a thickening of sediments north of the 67-mile bore. This possible thickening could be an extension of the Fairfield Syncline (Plate 1, LENNARD RIVER area).

Cross-section 2 (Plate 4)

Cross-section 2 was drawn across the Basin from south-west to north-east. It was included in order to show the following points:

(a) near the coast a gravity profile drawn at right angles to the (major) north-westerly trend shows a considerable degree of symmetry; e.g. the gravity 'highs' representing the Wallal Platform and Oscar Ridge are symmetrically placed with respect to a gravity 'low' on the La Grange Platform,

(b) South of Barlee No. 1 a gravity 'low' suggests that the sedimentary thickness between Barlee No. 1 and the Dampier Fault might be considerable. This narrow area of deeper sediments could represent a north-westerly extension of the extremely thick sediments of the Fitzroy Trough,

(c) North of Meda No. 1 there is a suggestion of a thickening of sediments.

Cross-section 3 (Plate 5)

Cross-section 3 is the first of two smaller-scale cross-sections which illustrate a few of the more detailed gravity features. The following features will be mentioned briefly:

(a) the Yeeda Gravity 'High' could represent a thinner sequence of sediments than that in the Fitzroy Trough. However, because of the presence of gabbro and dolerite (Fraser River No. 1 bore), the relative gravity 'high' could partially be caused by these dense intrusives. Unfortunately the thickness and horizontal extent of the gabbro is not known,

(b) When the basement gradient is removed from the observed Bouguer anomaly curve over the Grant Range Anticline, a symmetrical residual gravity 'low' is obtained (Plate 5). This residual 'low' could theoretically be produced by a cylindrical body of the size and density shown on Plate 5. Therefore, on gravity evidence there is a strong suggestion that the Grant Range Anticline is underlain by a body of rock salt or at least of a material of the same density as rock salt.

(c) At the point where the profile crosses the Fenton Fault there is a steep gravity gradient. Quantitative analyses of the anomaly gradient have not been done (in this Record) but the large gradient obviously represents the large throw of the Fenton Fault. The seismic work in the area shows that the throw of the fault at Barnes Flow is about 10,000 ft (Vale and Smith, 1959).

(d) The relatively high anomaly values south of the Fenton Fault represent the Broome Swell. On the drilling evidence obtained on the Broome Ridge farther north-west (e.g. Dampier Downs No. 1), the sedimentary sequence is Mesozoic, Permian, Ordovician, as shown on Cross-section 1 (Plate 3). The postulated 'low' could be caused by:

a south-easterly extension of the Jurgurra Terrace, or

a relatively thicker sequence of sediments within the Broome Swell (i.e. thicker Ordovician), or

the presence of a body of less-dense material such as rock salt. It should be noted that Vale and Smith (1959) recorded a high-velocity refractor (20,000 ft/sec) at 5500 ft depth in this area and interpreted it as being basement. However, in an appendix to the same report Morton raised the possibility of the presence of salt.

Cross-section 4 (Plate 6)

Cross-section 4 was drawn from north to south across the Mount Bannerman Gravity Trough, the Minnie Range Gravity Shelf, and part of the Gregory Lake Gravity 'High'.

The Mount Bannerman Gravity Trough is postulated as representing a considerable thickness of sediments. The gravity trough (feature 9) crosses the Basin boundary and appears to represent a considerable thickness of Upper Proterozoic sediments (see Plate 6). Both Ordovician and Devonian sediments crop out on MOUNT BANNERMAN and therefore it is reasonable to suggest that sediments of these ages are also present within the area representing the Mount Bannerman Gravity Trough.

Since it is postulated that the major part of the gravity 'low' is caused by considerable thickness of the Upper Proterozoic sediments, then it can be assumed that the Gregory Lake Gravity 'High' is due to lack of Proterozoic sediments. It is not possible to speculate (on gravity evidence) on the sedimentary sequence within the area represented by the Gregory Lake Gravity 'High'. It is quite possible that basement is close to the surface (i.e. 2000 to 3000 ft depth). The relatively high anomalies could also in part be caused by basement denser than the basement below the area represented by the Mount Bannerman Gravity Trough.

6. CONCLUSIONS

The following general conclusions, not apparent from known geology, have been formed:

(a) the north-eastern (Oobagooma to Bulka Hills) and south-western (Wallal Downs to Paterson Range) edges of the Basin are characterised by mobile zones wherein there is a relatively thick sequence of sediments,

(b) the north-eastern part of the Canning Basin probably contains thick Proterozoic sediments. (This conclusion was first postulated by Veevers and Wells on geophysical evidence),

(c) the Broome Swell and the coastal part of the La Grange Platform are the shallowest non-marginal units of the Basin,

(d) the South Canning Basin Gravity Depression probably contains thick sediments,

(e) the Anketell Gravity Ridge extends over a long distance and represents a major subsurface feature which adjoins the south-western margin of the South Canning Basin Gravity Depression.

Some conclusions have also been reached on more localised problems. It is considered likely that:

(a) the Napier Gravity Depression contains over 10,000 ft of sediments,

(b) the position of the Derby Ramp and the axis of the Oscar Ridge coincide with gravity features 6 and 5 respectively.,

(c) the deepest part of the Fitzroy Trough is north-west of Nerrima bore,

(d) the Fitzroy Trough is bounded along its long axis by fault and monoclinal systems (Fenton, Dampier, and Pinnacle Faults and the Derby Ramp). To the south-east it merges with the Mount Bannerman Gravity Trough and to the north-west its gravity expression is terminated by the Yeeda Gravity 'High',

(e) the pattern of the Yeeda Gravity 'High' is not aligned north-west, but is controlled by upper Carboniferous laccolithic-type intrusions of gabbro. The maximum thickness of sediments is 20,000 ft,

(f) the Broome Swell is relatively shallow (3000 to 5000 ft) and extends into CORNISH area,

(g) between the Broome Swell and Anna Plains the basement deepens regionally from north-east to south-west (maximum depth 12,000 ft near Nita Downs Homestead),

(h) the Wallal Gravity Depression may contain thick sediments (12,000 ft),

(i) the Proterozoic sedimentation of the North-east Canning Basin could extend without interruption to the Ord Basin,

(j) the shallowest parts of the well-explored non-marginal parts of the Basin are:

on the Broome Swell, in the north-western corner of CROSSLAND area, and

ten miles south-west of Goldwyer No. 1 (LA GRANGE area).

7. RECOMMENDATIONS

The following recommendations are made, not in direct reference to economic considerations, but solely for the extension of the geologic knowledge of the Basin:

(a) the Napier Gravity Depression should be investigated by a detailed gravity survey (i.e. one station per square mile with sufficient control to enable the regional anomaly to be accurately estimated). If the presence of a thick sedimentary sequence is still indicated, seismic methods should be used to detect localised structures,

(b) a seismic survey in the Mount Bannerman/Cornish area should elucidate the problem of the distribution of the Proterozoic sediments in the North-east Canning Basin,

(c) a seismic survey south of Wallal No. 1 bore would resolve the problem of the sedimentary thickness of the Wallal Depression,

(d) Some seismic investigations of the Dampier Peninsula (e.g. continuous profiling between Fraser River No. 1 and Barlee No. 1) would help to solve the problem of the distribution of the gabbro,

(e) helicopter gravity coverage of the southern part of the Basin (one station per 50 square miles),

(f) completion of the gravity coverage of the south-eastern end of the Lennard Shelf.

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APPENDIX A

Computational Methods

It is intended that a separate report be written on computational methods on helicopter surveys. The procedures used on the land surveys of the area need no special mention, being of a purely routine nature.

During 1960, a helicopter survey was done (Plate 1, reliability diagram). Station density was 1 per 50 square miles. The results were reduced in the field. Generally a Bouguer anomaly contour map of a 4-mile area was produced about 1 to 2 days after the readings were completed.

Loop closure corrections for both gravity and altitudes were not attempted in the field. Because altitudes were obtained using barometers, the accuracy was not high. The accuracy was further reduced in certain areas by complete lack of instrument-levelled base stations. However, the weather conditions were very good and the (absolute) error of each station appears to be less than 20 ft. The gravity readings were affected by the necessity of resetting the meter without returning immediately to a previous station for drift control. After loop correction the probable error (Bouguer anomaly) of each station was less than one milligal.

Most of the other gravity surveys were conducted using ground survey teams. The altitudes were then determined by spirit-level or when the base control was good, by barometer. A vehicle-mounted elevation meter was also used to obtain some altitudes. Gravity loop closures were very good.

In 1957 a geophysicist accompanied a geological survey team on a reconnaissance of the southern and eastern portions of the Canning Basin. Transport was by helicopter. Station density was about 1 per 250 square miles.

During the 1960 survey the anomalies were computed in the field for the following reasons:

(a) gross errors in gravity-meter and barometer readings would be detected,

(b) areas of interest could be examined by putting in extra stations.

The requirement expressed in (a) was adequately fulfilled and three gross errors were detected, checked, and corrected. Frequently extra stations were read when areas of interest appeared (e.g. high gradient). However, in several areas there are not enough stations for complete elucidation of the problem. e.g.

King Leopold range area

MOUNT RAMSAY area and the north-east corner of NOONKANBAH area

eastern edge of YARRIE area.

In short, it is not enough while in the field to consider only areas of high gradient or change in trend. Constant watch must be kept on the relation of the local area to the Basin as a whole.

APPENDIX B

History of Surveys

This history of the BMR geophysical investigations of the area is presented below in tabular form. Much of the gravity field work was performed by S. Waterlander and J. R. H. van Son

Year.	Type	Remarks
	(a) Gravity	
1952	Semi-detailed gravity	Studied the Nerrima Dome and Fenton Fault. Report by Wiebenga and van der Linden (1953). Altitudes by barometer and spirit-level.
1953) 1954)	Semi-detailed gravity	Poole Range area and Pinnacle Fault. Altitudes by spirit-level and barometer. Report by Everingham (1962).
1953	Regional gravity	Fitzroy valley area. Altitudes by spirit-level and barometer.
1954	Regional gravity	As for 1953 except that some altitudes obtained by elevation meter.
1954	Semi-detailed gravity	Grant Range area. Spirit-level.
1954	Semi-detailed gravity	Myroodah area. Spirit-level
1955	Semi-detailed gravity	Christmas Creek area. Spirit-level
1955	Regional gravity	Covered the inhabited area of the Basin. Barometer and elevation meter.
1955	Detailed gravity	Broome seismic lines. Spirit-level.
1956	Regional gravity	Canning Basin. Barometer. Two parties.
1957	Regional gravity	Helicopter survey. Barometer.
1960	Regional gravity	Canning Basin (see Plate 1). Barometer. Helicopter survey.
	(b) Seismic	
1952	Seismic refraction	Nerrima Dome area.
1953	Seismic reflection and refraction	Poole Range/Prices Creek area.
1954	Seismic reflection	Poole Range/Christmas Creek area.
1954	Seismic reflection	Deep Well Anticline area
1954	Seismic reflection	Broome area.

Year.	Type.	Remarks
1955	Seismic reflection	Christmas Creek area.
1955	Seismic reflection	Langeys Crossing area
1955	Seismic reflection	La Grange area.
1955	Seismic reflection	Barnes Flow area - study of the Fenton Fault.
1955	Seismic reflection	Broome area.

In 1954 the Bureau of Mineral Resources conducted a regional aeromagnetic survey of the area (Quilty, 1960). WAPET has conducted gravity and aeromagnetic investigations over a large area of the Basin, and seismic surveys in areas of interest. At the present time, most of this work has not been released for publication. WAPET has released gravity data on a 10-mile grid basis. Associated Freney Oil Fields N.L. has done detailed gravity and seismic traversing on their leases. The results have not been published.

Reports on the geology of the area have been compiled by: Veevers and Wells (1961), Guppy *et al.* (1958), Brunnschweiler (1954 and 1957), Traves, Casey, and Wells (1956), McWhae *et al.* (1958), Playford and Johnstone (1959), Reeves (1951), and Teichart (1950). They have all been consulted in compilation of this Record.

APPENDIX C

Deep Bores in the Canning Basin

Name	Authority	Depth (ft)	Bottomed in	Date
Barlee No. 1	WAPET	8101	Upper Carboniferous	1960
Dampier Downs No. 1	WAPET	3028	Ordovician	1956
Fraser River No. 1	WAPET	10,144	Upper Carboniferous (gabbro intrusion)	1955/56
Frome Rocks No.1	WAPET	4003	Rock salt (age uncertain)	1958
Frome Rocks No.2	WAPET	7500	Devonian	1959
Goldwyer No. 1	WAPET	4720	Precambrian	1958
Grant Range No.1	WAPET	12,915	Upper Carboniferous	1954/55
BMR No. 1 (Jurgurra Ck)	BMR	1680	Permian (Poole Sandstone)	1955
BMR No. 2 (Laurel Downs)	BMR	4000	Devonian	1955/56
Meda No. 1	WAPET	8809	Precambrian	1958
Meda No. 2	WAPET	7628	Devonian	1959
Mount Wynne No.3	Freney-Kimberley Oil Co	2154	Permian (Grant Formation)	1923/25
Myroodah No. 1	Associated Freney Oil Fields N.L.	6001	Permian (Grant Formation)	1955/56
Nerrima No. 1	Associated Freney Oil Fields N.L.	9072	Upper Carboniferous	1955
Poole Range No. 3	Freney-Kimberley Oil Co	3264	Permian	1927/30
Prices Creek No. 1	Freney-Kimberley Oil Co	1008	Ordovician	1922
BMR No. 3 (Prices Creek)	BMR	694	Precambrian	1956
Roebuck Bay No.1	WAPET	4000	Ordovician	1956
Samphire Marsh No.1	WAPET	6664	Precambrian	1958
Sisters No. 1	Associated Freney Oil-Fields N.L.	9828	Devonian	1956/57
67-mile bore	W. Aust. Govt	3012	Precambrian	1906/10
Thangoo No. 1A	WAPET	5429	Precambrian	1959/60
BMR No. 4A (Wallal)	BMR	2223	Precambrian	1958

APPENDIX D

Explanation of terms

Many of the units of the Basin have already been named, and the authors concerned have given reasons for their chosen nomenclature. In some cases a geologically named unit has been renamed in geophysical terms where the geophysical evidence is strong enough. The addition of the word 'Gravity' to the unit name denotes that the unit is named mainly on gravity evidence. It must be emphasised that whenever the existence of a unit of a basin is apparent only from gravity evidence then the word gravity must be inserted in the unit name.

The following points should also be noted:

(a) The term 'Gravity Trough' has been used for gravity 'lows' that are elongated and bounded along their long axes by prominent gravity gradients.

(b) A 'Gravity Depression' is used to describe a gravity 'low' that is broader than (a) above; it is not elongated to any great extent.

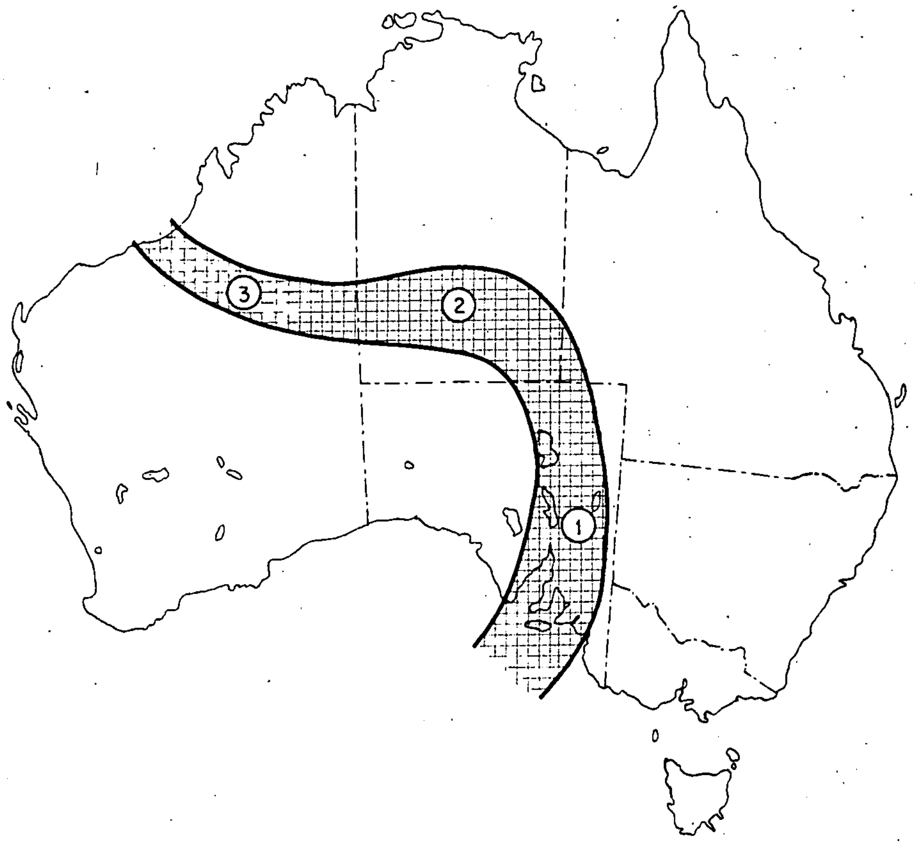
(c) A 'Gravity Ridge' is used to describe a long, narrow, positive gravity anomaly.

(d) The term 'Gravity High' has been applied to positive anomalies of more indefinite shape than (c) above.

(e) 'Gravity Platform' is used to describe an area wherein the Bouguer values show no marked variation.

(f) The term 'Gravity Spur' has been used to describe a relatively small positive gravity feature that is an offshoot of a larger feature.

MODIFIED FROM DAVID (1950)



(1) The Flinders Trough

(2) Amadeus Trough

(3) Possible Continuation

LOWER ADELAIDEAN GEOSYNCLINE
(AND POSSIBLE CONTINUATIONS)

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

G228-40

To accompany Record No. 1962/105

SURFACE GEOLOGY AFTER BMR 4-MILE GEOLOGICAL MAPS, E 51-8, LENNARD RIVER AND E 51-12, NOONKANBAH.

GRAVITY DATA AFTER BMR 4-MILE BOUGUER ANOMALY MAPS, LENNARD RIVER, NOONKANBAH, AND CROSSLAND

LEGEND

- Basic volcanics (basalt, dolerite, lamproite)
- Granitic rocks
- Precambrian sediments and metamorphics

CORRELATION OF GRAVITY AND GEOLOGY

FENTON FAULT TO KING LEOPOLD RANGES

HORIZONTAL SCALE IN MILES

4 0 4 8 12

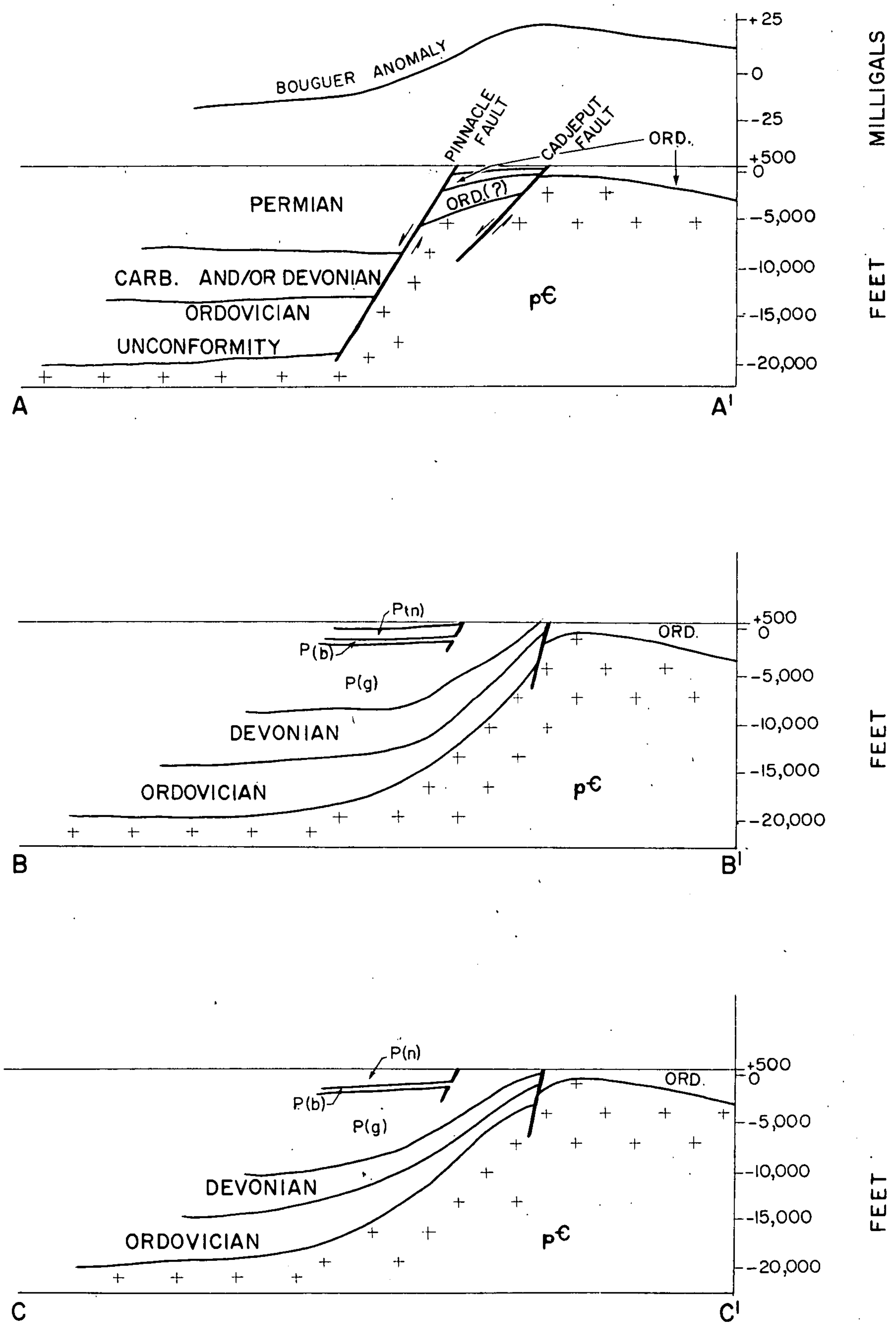
VERTICAL SCALES AS SHOWN

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

G 228 - 41

To accompany Record No 1962/105

FIG. 3



P(n), P(b), P(g) PERMIAN
ORD. ORDOVICIAN
p€ PRECAMBRIAN

HYPOTHETICAL CROSS-SECTIONS

(SECTIONS AA' AND BB' AFTER VEEVERS AND WELLS, 1961)

HORIZONTAL SCALE

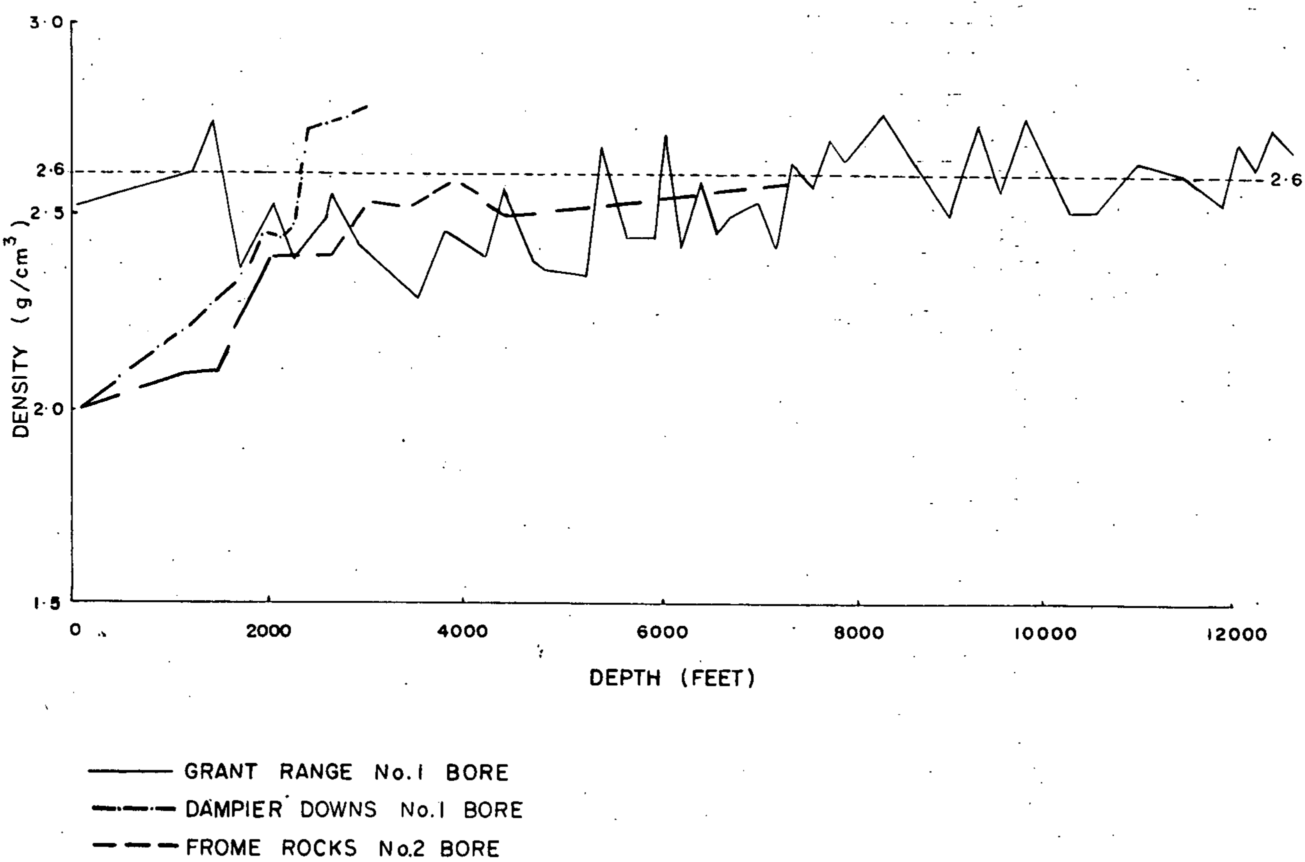
10,000 0 10,000 20,000 FEET

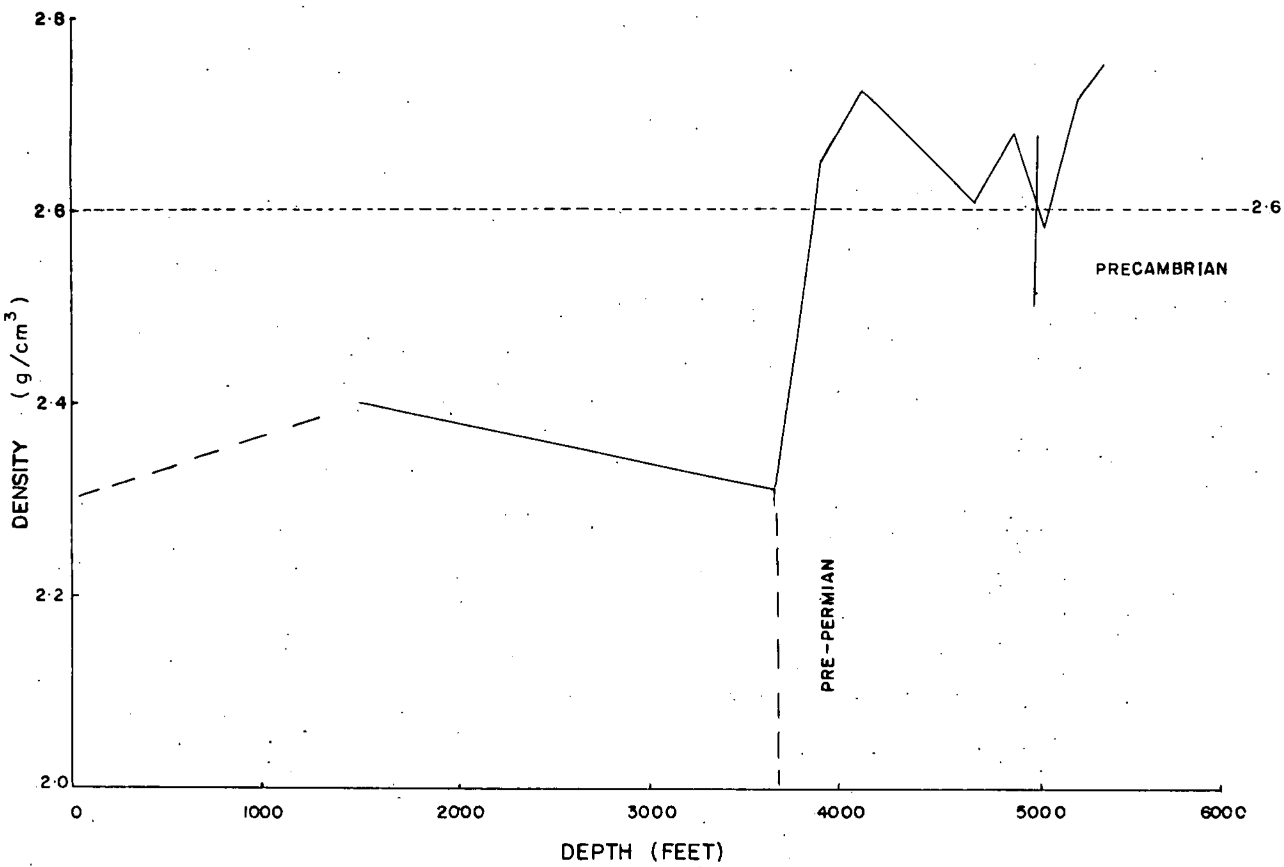
VERTICAL SCALES AS SHOWN

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS G228-42

To accompany Record No.1962/105

FIG. 4





THANGOO No.1 BORE

FITZROY AND CANNING BASINS GRAVITY SURVEYS 1952-1960

DENSITY / DEPTH PROFILES

G 228-43

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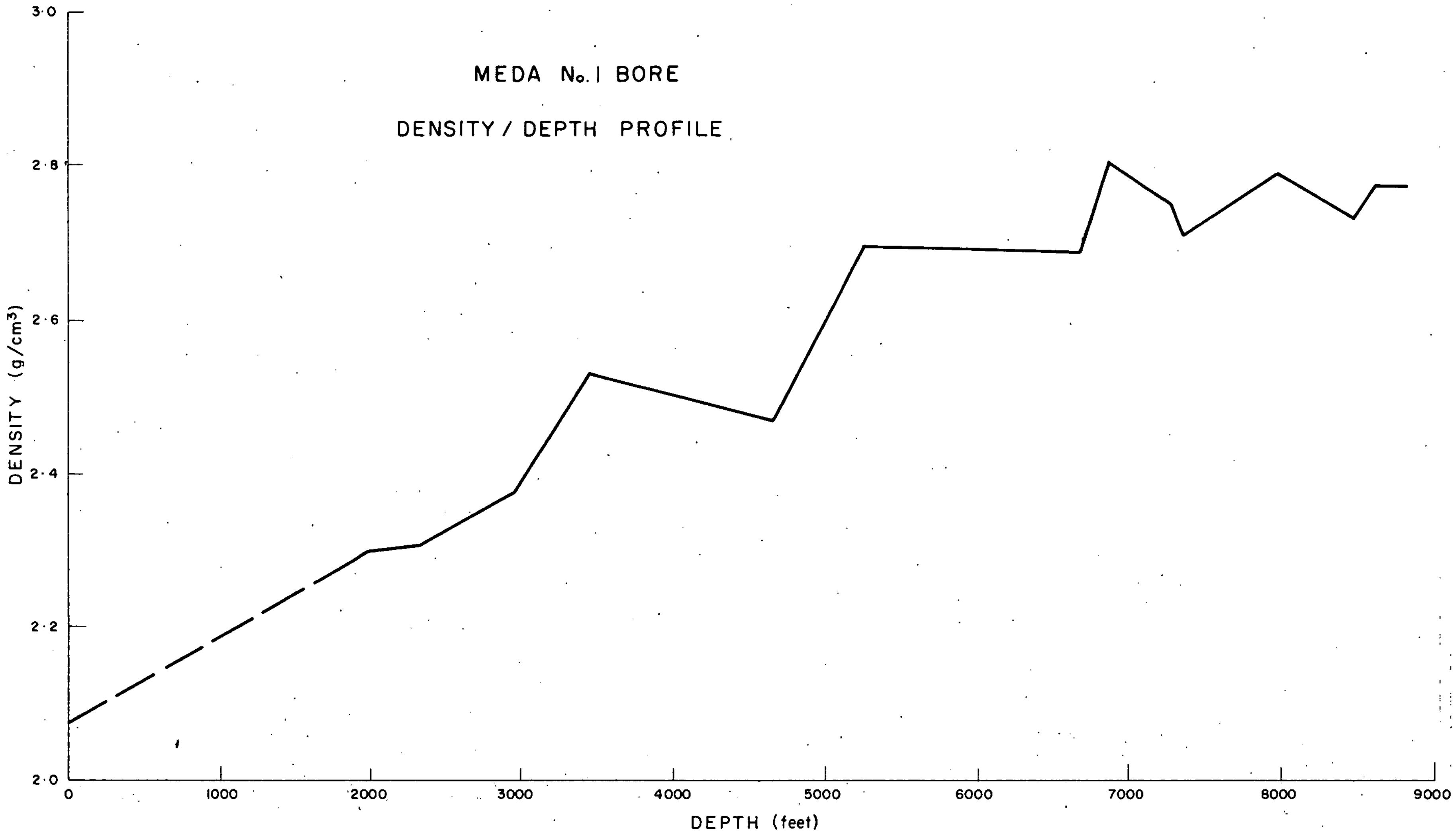
To accompany Record No. 1962/105



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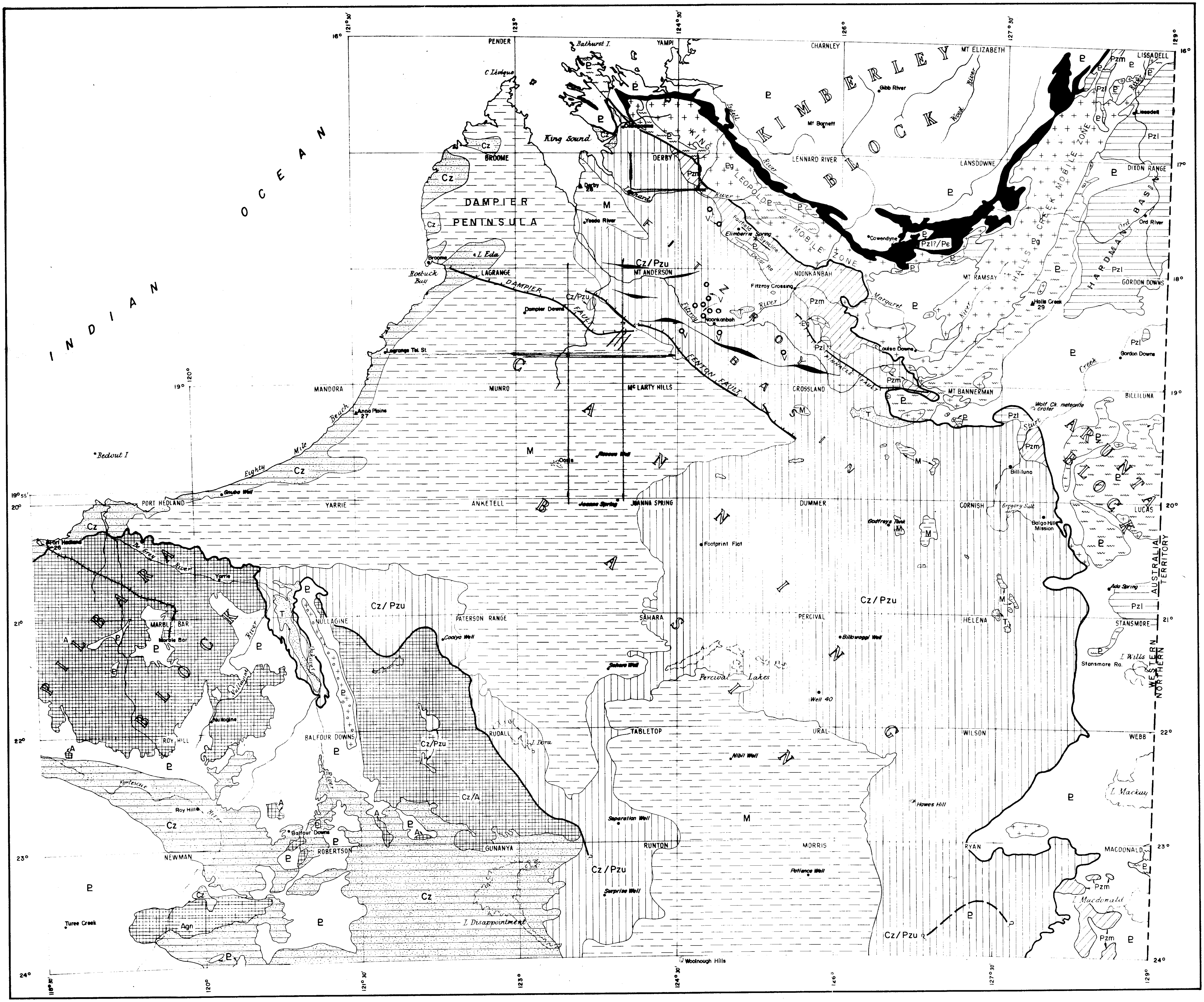
G 228-44

FIG. 5

To accompany Record No. 1962/105



LEGEND

Cz	Alluvium, limestone		Cainozoic
T	Marine and continental sediments		Cainozoic
M	Sandstone, siltstone, shale		Mesozoic
Cz/Pzu	Marine and continental sediments	Upper	Palaeozoic
Pzm	Mainly limestone, shale, sandstone, and siltstone	Middle	Palaeozoic
Pzl	Volcanics in Lower Palaeozoic	Lower	Palaeozoic
Pzl?/P€	Belt of Lower Palaeozoic basic intrusions following edge of Kimberley Block		
P€	Mainly sandstone and shale		Proterozoic
P€	Metamorphic rock		Proterozoic
	Archaean (undifferentiated)		
	Porphyry		
	Granite		
	Leucitite - Lamproite intrusives		
▲28	BMR gravity pendulum station		
DERBY	BMR 4-mile gravity map area		
	Railway		
	Basin boundary		
	Anticlinal culmination		
	Fault		

RECONNAISSANCE GRAVITY SURVEYS (1952-1960)
FITZROY AND CANNING BASINS, WA

GEOLOGY AND MAJOR TECTONIC FEATURES

SCALE IN MILES
40 0 40 80 120

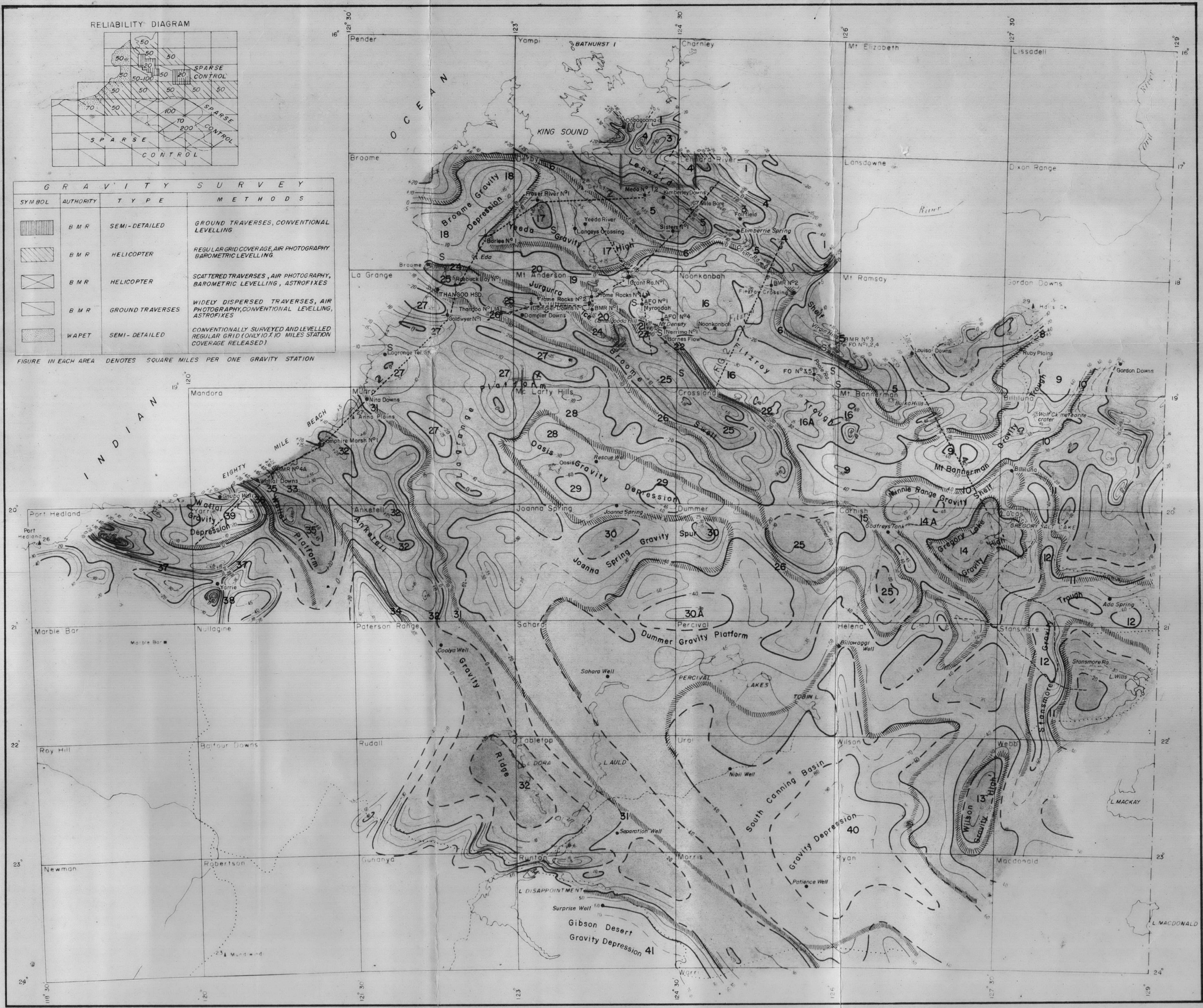
Reference - Division of National Mapping 40 miles to 1 inch topographic map and BMR tectonic map

COMPILED JULY 1961

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS G 228-39-2

To accompany Record No 1962/105

PLATE 2



Isogals (values in milligals)

Yampi — B.M.R. 4-mile gravity map area

▲28 — B.M.R. gravity pendulum station

S — B.M.R. seismic survey

Bore

B.M.R. gravity traverse — Area of sparse control

WAPET gravity traverse — Area of sparse control

Bouguer anomalies are based on the observed gravity values at B.M.R. pendulum stations:

No 26 Port Hedland	978,645.2	milligals
No 27 Anna Plains	978,623.2	"
No 28 Derby	978,519.4	"
No 29 Halls Creek	978,461.4	"

For the calculation of Bouguer anomalies 2.2 g/cm³ has been adopted as an average rock density.

Elevation datum M.S.L., Derby, W.A.

RECONNAISSANCE GRAVITY SURVEYS (1952-1960)
FITZROY AND CANNING BASINS, W.A.
BOUGUER ANOMALIES

SCALE IN MILES

40 0 40 80 120

Reference - Division of National Mapping 40 miles to 1 inch topographic map

Gravity 'High'

Gravity 'Low'

25 — Reference number in text

Gravity unit boundary

3 — Cross-section

COMPILED JULY 1961
REVISED MAY 1962

(Based on G 228-39-8)

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS G 228-39-9A

To accompany Record Nº 1962/105

LEGEND

J	Jurassic (including Mesozoic)
P	Permian
Cu	upper Carboniferous
D	lower Carboniferous and Devonian
O	Ordovician
p€	Precambrian
S	Salt
----	Basement calculated from gravity $L = \frac{g_z}{12{\cdot}77 \times \Delta d}$
A—E	References in text

EXPLANATION

For the calculation of Bouguer anomalies 2·2 g/cm³ has been adopted as an average rock density

Density data obtained from bores

Gravity field surveys by BMR and WAPET

CROSS-SECTION I

(BROOME SWELL TO OSCAR RIDGE)

HORIZONTAL SCALE

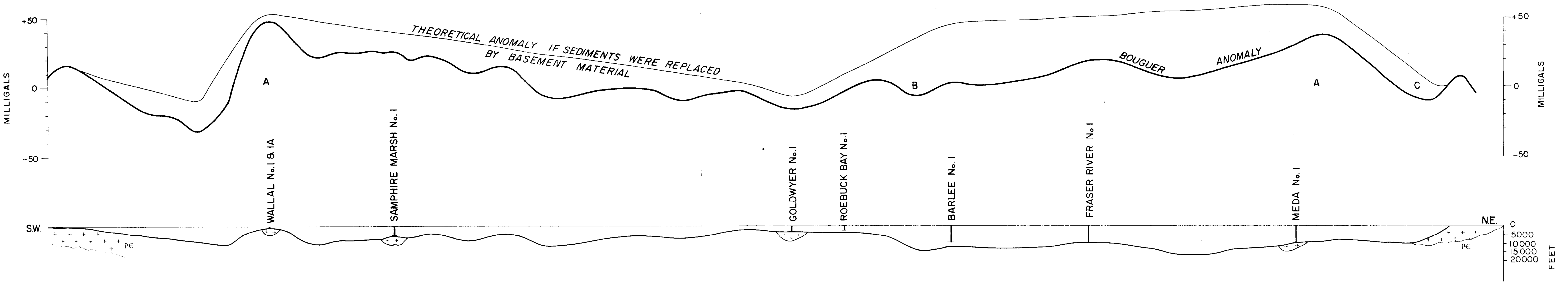
MILES 4 0 4 8 12 MILES

VERTICAL SCALES AS SHOWN

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS
TO ACCOMPANY RECORD No. 1962/105

G 228-45

PLATE 4



EXPLANATION

p€ Precambrian

A_C References in text

Depth to basement calculated from gravity data, $L = \frac{gz}{12.77 \times \Delta d}$

$\Delta d = 0.2\ g/cm^3$

CROSS-SECTION 2

(WALLAL GRAVITY DEPRESSION TO LENNARD SHELF)

HORIZONTAL SCALE

MILES 20 0 20 40 60 MILES

VERTICAL SCALES AS SHOWN

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

TO ACCOMPANY RECORD No. 1962/105

G 228-46

CROSS-SECTION 3

CORRELATION OF GRAVITY AND GEOLOGY

YEEDA GRAVITY 'HIGH' TO BROOME SWELL

HORIZONTAL SCALE IN MILES

4 0 4 8 12

VERTICAL SCALES AS SHOWN

SURFACE GEOLOGY AFTER BMR 4-MILE GEOLOGICAL MAPS, E51-7, DERBY AND E51-11 MOUNT ANDERSON

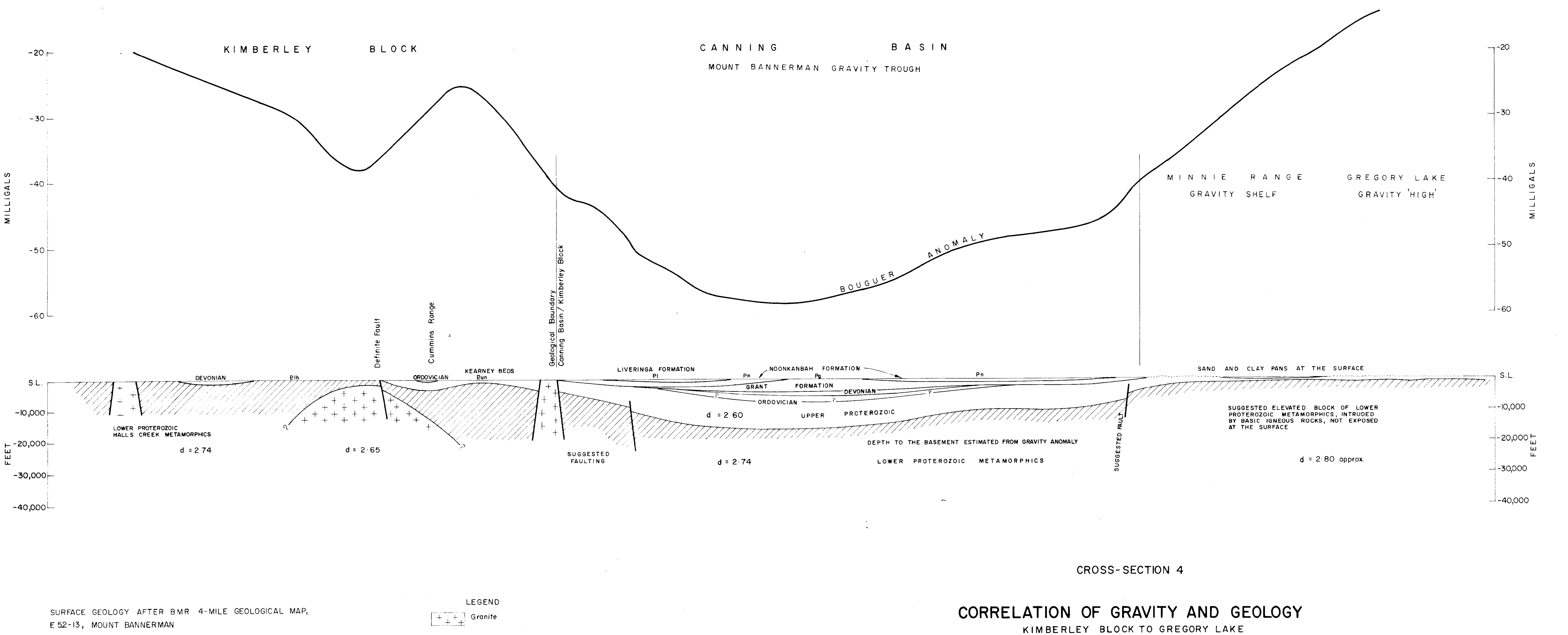
GRAVITY DATA AFTER BMR 4-MILE BOUGUER ANOMALY MAPS, DERBY AND MOUNT ANDERSON

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

G 228-47

To accompany Record No 1962/105

FITZROY AND CANNING BASINS GRAVITY SURVEYS 1952-1960



SURFACE GEOLOGY AFTER BMR 4-MILE GEOLOGICAL MAP, E 52-13, MOUNT BANNERMAN

GRAVITY DATA AFTER BMR 4-MILE BOUGUER ANOMALY MAP, MOUNT BANNERMAN

CROSS-SECTION 4

CORRELATION OF GRAVITY AND GEOLOGY

KIMBERLEY BLOCK TO GREGORY LAKE

HORIZONTAL SCALE IN MILES

4 0 4 8 12

VERTICAL SCALES AS SHOWN

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

G 228-48

To accompany Record No 1962/105