DEPARTMENT OF
MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

1974/181

CANNING BASIN GRAVITY SURVEYS, 1953-1962

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FOREWARD

This report was written by Mr Flavelle before 1967. The subject matter is not therefore up to date. Some usages in this report are not those presently in use by the Bureau of Mineral Resources, in particular the nomenclature of gravity provinces and the use of non-metric units.

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ILLUSTRATIONS

SUMMARY

A Bouguer anomaly map covering the Canning Basin and adjacent areas is presented. The density of gravity stations varies greatly, partly owing to the difficulty of access to some remote parts of the Basin.

An analysis of the major Bouguer anomaly features has shown that the Canning, Amadeus, and Officer Basins do not form a single structural entity. Basement ridges of regional extent separating the three Basins from each other have been delineated.

Within the Canning Basin the gravity data delineate the Broome Gravity Ridge and Anketell-Warri Regional Gravity Ridge as two bordering zones of tectonic activity separated by the La Grange Gravity Platform, which is a relatively stable zone.

The features in the Bouguer anomaly pattern have been designated as provinces and units, and a separate analysis of each unit has been made. From this analysis many unknown geological features have been derived which, in conjunction with the already geologically defined structures, help to clarify the main structural divisions of the Basin. The possible extent of the Palaeozoic Fitzroy Basin has been outlined, and an extensive area of possible Upper Proterozoic sedimentation in the Northeast Canning Basin defined. An extensive Bouguer anomaly low within the South Canning Basin indicates a thick sequence of sediments.

Rock density data, mainly from determinations made on cores, show three major density discontinuity planes within the sedimentary column: Mesozoic to Permian, Permo-Carboniferous to Lower and Middle Palaeozoic, and Upper Proterozoic to Lower Proterozoic.

1. INTRODUCTION

The Canning Basin, which includes the Fitzroy Basin (Plate 2) covers an area of at least 175 000 square miles and is the second largest sedimentary basin in Australia. The stratigraphic sequence, overlying an early Precambrian basement, is known to range from Upper Proterozoic to Cainozoic and reaches a total thickness of at least 20 000 ft in the Fitzroy Basin.

Geological investigations in the area began in 1883, and 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. The tempo of investigations increased after the second world war. Since 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 by private companies and the Bureau of Mineral Resources has provided much stratigraphic information.

For a detailed account of the development of geological understanding of the Canning Basin the reader is referred to a report by Veevers & Wells (1961). Marginal areas to the south and southeast have been described by Wells (1963); Wells, Forman & Ranford (1961); Forman (1963); and Wells, Ranford & Cook (1963).

This report presents a study of the available gravity information, and relates it to known geology including the published information from surface surveys and borehole logging. Selected profiles have been more closely studied to provide a basis for a more general study. The study has been extended to the south outside the limits of the basin to include the structural relations of the Canning, Amadeus, and Officer Basins.

The very important contribution of unpublished 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 taken from Veevers & Wells (1961). The account of sedimentary development refers only to the Palaeozoic and Mesozoic rocks. Very little systematic work has been done on the Upper Proterozic sediments, and the Canning Basin, as geologically conceived, does not include sediments of this age.

In the Proterozoic, the crystalline basement under the Canning Basin was probably high land that deposited sediments onto surrounding areas. Before the end of the Precambrian the sediments were folded and uplifted, the crystalline rocks were depressed, and the Canning Basin was formed. Starting late in the Early Ordovician, a shallow sea covered at least half of the Basin*, and in it were deposited limestone, dolomite, shale, and sandstone. The sea retreated in Late Ordovician time and did not return to the greater part of the Basin until Permian time.

In the upper part of the Middle Devonian, sandstone and limestone were deposited in a sea that covered the Fitzroy Basin (Plate 2). 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 northeastern 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 Late 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 freshwater sediments, was repeated two and a half times during the rest of the Permian and during the Early Triassic. The sea then retreated, and these rocks were folded and eroded. The sea slowly advanced over the land from the Middle Jurassic to the Early Cretaceous and slowly retreated in the upper part of the Early Cretaceous.

From Late Cretaceous to Recent time, the Basin has been a land surface except for a 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 in Plate 2.

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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.

The northeastern boundary has been mapped in detail and runs from Oobagooma in the YAMPI area * to the Wolf Creek meteorite crater in the BILLILUNA area. The Upper Proterozoic formations of the Kimberley Block, a pronounced topographically high area, lie immediately northeast of this boundary.

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 southwest, terminating in the northeastern 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 southwestern boundary runs from the southwestern corner of the TABLETOP area in a northwesterly direction as far as the vicinity of Coolya Well in the PATERSON RANGE area, where it turns west-northwest 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 southwest of this well defined boundary.

A major structural unit within the Canning Basin is the elongated Fitzroy Basin containing the Fitzroy Trough, which is subparallel to the northeastern boundary of the Basin; it has a total thickness of sediments of about 20 000 ft. The northeastern margin of this feature is well defined only at the Pinnacle Fault, which is mapped on the surface with downthrow to the southwest near Prices Creek (southeastern corner of the NOONKANBAH area). The extensions of this feature in both directions require geophysical definition.

To the northwest there is evidence of subparallel lines of major faulting or flexure, between which areas of intermediate sedimentary thickness have been recognized. Of these, reference will be made to the Lennard Shelf, a unit named by Playford & Johnstone (1959). This area is described as extending in contact with the northeastern boundary of the Basin, between that

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* The names of 1:250 000 Sheet areas are written in capital letters to distinguish them from ordinary place names. Boundaries of the Sheet areas are superimposed as a grid on the relevant maps.

boundary and the Fitzroy Trough. This area has been further subdivided by Veevers & Wells (1961).

The Fitzroy Trough is bounded to the southwest by:

(a) The Fenton Fault, which is well exposed only in the Barnes Flow area (eastern edge of the MOUNT ANDERSON area), with downthrow to the northeast.

(b) The Dampier Fault, which is related to and subparallel to the Fenton Fault along the northwestern part of its suggested extension. This feature is entirely without surface expression.

The Jurgurra Terrace is an 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 & Wells (1961).

Stratigraphy

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

Tectonic features

Traves (1955) has described two mobile zones which are considered to have influenced sediment deposition close to the northeastern 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, which overlaps the northeastern boundary of the Basin and intersects the Halls Creek Mobile Zone in the region of the southeastern end of this boundary.

TABLE 1

Stratigraphic sequence, Canning Basin area

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 - Bilina 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 sand limestone - Nura Nura Member		marine
Grant Formation		Claystone, siltstone, and boulder conglomerate - Cuncudgerie Sandstone		marine - glacial
		Massive sandstone & tillite	Claystone, sandstone and boulder conglomerate - Paterson Formation	to fluvioglacial
			Tillite, boulders and conglomerate - Braeside Tillite	to glacigene

TABLE 1 (Cont.)

Age	Estimated maximum thickness (ft)	Lithology	Facies
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, and shale - Fairfield Beds	marine
Upper to Middle	5000+	Calcarenite, sandy limestone, limestone breccia, bioherms, and biostromes with great variety of formation development	facies complex owing to reef development
		Calcilutite, calcarenite, and biostromes - Pillara Formation	marine
Unconformity: Lower Devonian-Silurian-younger Ordovician (Caradocian) rocks are not known in the Canning Basin			

Ordovician		Fossiliferous dolomite, sandstone, and siltstone - Gap Creek Formation	
(Llandellian to Tremadocian)	3100+	Limestone, calcareous siltstone, sandy dolomite, and arkose - Emanuel Formation	marine (shallow water)
		Glauconitic sandstone, shale, and calcarenite - Samphire Marsh area	marine (shallow water)
Unconformity: Middle and Lower Cambrian rocks are not known in the Canning Basin			
Precambrian	12 000 ± (Gibson Desert area) 8000 + (GORDON DOWNS) Unconformity	Siltstone, sandstone, shale, limestone, dolomite, basalt, dolerite, and tillite	
Precambrian (Upper Proterozoic and older).	Unknown	Igneous rocks, mainly granitic; intrusive into Lower Proterozoic metamorphics	
Precambrian (Upper Proterozoic and older)	Unknown but probably exceeds 30 000 ft in places (e.g. Halls Creek Metamorphics)	Highly metamorphosed and folded sediments; extensive igneous intrusions	

(b) The Halls Creek Mobile Zone, which extends north-northeast from its junction with the King Leopold Mobile Zone and separates the Kimberley Block from the Sturt Block and Arunta Block to the east.

Extensive outcrops of Archaean or Lower Proterozoic granitic intrusives occur along the edge of the Kimberley Block within both mobile zones (Tectonic map of Australia, 1960, published by BMR). Adjacent to the eastern boundary of the Basin, extensive outcrops of Lower Proterozoic metamorphics with dense basic intrusions have been mapped.

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

The Fenton and Pinnacle Faults are recognized as having controlled sedimentation within the Fitzroy Basin. Movement along these faults has been proved during the Lower Permian (Guppy et al., 1958). There is evidence of reversed throw on the Fenton Fault during Mesozoic times. The delineation of these features, and elucidation of their structural details (Veevers & Wells, 1961, have described the Fenton Fault as a monoclinal flexure) were two of the principal objectives of the 1960 reconnaissance gravity survey (see Appendix D). Neither of these very important structures is clearly expressed in the surface geology, and geophysical methods (seismic, magnetic, and gravity) have made substantial contributions to their definition.

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 a probable subsurface configuration in these areas.

Geology of adjacent areas

In 1962, the Gibson Desert was covered by a BMR geological reconnaissance (Wells, 1963). Generally the area is characterized by flat-lying Permian and Mesozoic sediments. Older sediments of Upper Proterozoic and Palaeozoic age have been mapped at the Iragana Hills. Upper Proterozoic sediments have also been mapped within the cores of

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diapiric structures at Woolnough Hills and in MADLEY. In the southeast margin of the Gibson Desert, in BENTLEY and SCOTT, extensive outcrops of igneous and metamorphic rocks of Precambrian age have been mapped.

The distribution of the Upper Proterozoic and older Palaeozoic sediments is almost completely masked by the Permian, Mesozoic, and Quaternary sediments. Diapiric structures occur in the region, however, and suggest that in some areas at least there is a considerable thickness (10 000 + ft) of sediments.

The sedimentary succession in the Amadeus Basin ranges in age from Upper Proterozoic to Middle Palaeozoic. The maximum sedimentary thickness exceeds 20 000 ft (Forman, 1963; Wells, Ranford & Cook, 1963).

In general terms the Amadeus Basin sedimentation can be related to two separate periods of activity:

(a) During the Upper Proterozoic, sedimentation took place along the southern margin of the Amadeus Basin, and this phase was terminated by tectonic activity which occurred at the end of the Upper Proterozoic.

(b) During the Lower Palaeozoic, the locus of sedimentation shifted northward and the greatest thickness of this age occurs along the northern margin of the Amadeus Basin.

3. BOUGUER ANOMALY FEATURES

The major geological structure - viz. basin and surrounding non-basin areas - is clearly reflected in the Bouguer anomaly pattern (Plate 3). This gross pattern has been subdivided into successively smaller entities as follows:

Gravity Provinces: This may be the Bouguer anomaly expression of a major geological entity such as the Kimberley Block or Fitzroy Basin, or may be an extensive coherent Bouguer anomaly feature that does not correspond to an established geological entity (e.g. the Munro Gravity Platform).

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Gravity Units: These are Bouguer anomaly features of subregional extent. They may or may not correspond to a known geological entity. Each unit is identified by a capital letter in Plate 3 and in the text.

Gravity Subunits: These are relatively small Bouguer anomaly features that are identified by the unit letter preceded by a number.

Names given to all the Bouguer anomaly features have been chosen to identify the location and describe the feature. Definitions of the terms used are given in Appendix B.

Table 2 lists all the Bouguer anomaly province, unit, and subunit names established from the gravity data described in this report. A precise description of each gravity feature is given, and any obvious association between gravity features and geological features is either mentioned or implied by the grouping.

TABLE 2

NAMES AND DESCRIPTIONS OF THE BOUGUER ANOMALY FEATURES

Unit	Description	Name
KIMBERLEY BLOCK		
	The features mapped northeast of the basin form part of the anomaly pattern over the Kimberley Block. As the area of the block has as yet no systematic gravity coverage, the few subunits noted are here grouped together as a single Unit.	
A	Group of anomalies lying northeast of the Basin boundary in YAMPI, LENNARD RIVER, and west MOUNT RAMSAY.	Kimberley Regional Gravity Platform
FITZROY BASIN		
	The Fitzroy Basin includes the area of thick sediments called the Fitzroy Trough and associated areas such as the Lennard Shelf and Jurgurra Terrace (McWhae et al., 1958). This Province has been defined from geological evidence, but it and its component parts are recognizable as gravity features in the Bouguer anomaly map.	

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B	Lineament of gravity 'lows' from northeast of the Oscar Range to Oobagooma. This corresponds to the Napier Platform of Veevers & Wells (1961).	Napier Gravity Depression
C	Line of positive closed anomaly features running from the Bulka Hills to northwest DERBY. Corresponds to the Oscar Ridge and Derby Ramp of Veevers & Wells (1961).	Oscar Gravity Ridge
D	Area of relatively low Bouguer anomaly values extending from south BROOME to northwest MOUNT BANNERMAN. Approximately equivalent to the Fitzroy Trough of Playford & Johnstone (1959).	Fitzroy Regional Gravity Complex
E	Group of closed Bouguer anomalies in the area of the Dampier Peninsula.	Yeeda Gravity Platform
F	Extensive gravity 'high' trending southeast from LA GRANGE to CORNISH. Corresponds to the Broome Swell of Veevers & Wells (1961) and Broome Ridge of Playford & Johnstone (1959).	Broome Gravity Ridge

NORTH EAST CANNING BASIN

This term has been used by Veevers & Wells (1961) to describe the area centred mainly about MOUNT BANNERMAN, BILLILUNA, CORNISH, and LUCAS.

The area also corresponds to a recognizable gravity province.

G	Series of relatively high gravity features on southeast MOUNT RAMSAY, northeast MOUNT BANNERMAN, and west GORDON DOWNS, having a pronounced northeast trend.	Halls Creek Gravity Ridge
H	Pronounced belt of negative anomaly features extending from west MOUNT BANNERMAN to the north of Billiluna Homestead.	Mount Bannerman Gravity Depression

Unit	Description	Name
I	Pronounced 'low' running north across STANSMORE, diverging to swing east through Ada Spring and also north into BILLILUNA.	Stansmore Gravity Trough
J	Relatively high Bouguer anomaly features on east BILLILUNA and northeast LUCAS.	Billiluna Gravity Plateau
K	Gravity 'high' extending south from northeast CORNISH to northwest RAWLINSON. This unit is an extension of the Bloods Range Gravity Ridge and is partly equivalent to the Barons Gravity Plateau (Lonsdale & Flavelle, 1963).	Thornton Gravity Ridge

MUNRO REGIONAL GRAVITY PLATFORM

An area of low Bouguer anomaly relief has been mapped over MUNRO, McLARTY HILLS, LA GRANGE, and adjacent areas.

Unit	Description	Name
L	Series of alternating 'highs' and 'lows' trending inland from the coast in LA GRANGE and MUNRO.	La Grange Gravity Plateau
M	Extensive gravity 'low' in McLARTY HILLS.	Oasis Gravity Depression
N	Gravity 'high' trending east along north ANKETELL, JOANNA SPRING, and DUMMER.	Joanna Springs Gravity Ridge

ANKETELL-WARRI REGIONAL GRAVITY RIDGE

An extensive gravity 'high' extending from the coast on MANDORA to BENTLY has been called the Anketell-Warri Regional Gravity Ridge.

Unit	Description	Name
O	A group of intense relatively high Bouguer anomalies in MANDORA, northeast YARRIE, and west ANKETELL.	Mandora Gravity Plateau

Unit	Description	Name
P	*Gravity 'high' in RUDALL, southwest TABLETOP, and northeast RUNTON. Gravity coverage in this area is sparse.	Rudall Gravity Plateau
Q	Elongate regional 'high' in WARRI, BENTLEY, and MORRIS.	Patience Well Gravity Plateau.

SOUTH CANNING REGIONAL GRAVITY LOW

A gravity 'low' extending over SAHARA, PERCIVAL, northeast TABLETOP, URAL, HELENA, west WILSON, southwest DUMMER, south JOANNA SPRING, and southeast ANKETELL. The gravity coverage in this area is sparse and it is considered that while the existence of the gravity features is proven, their shapes and internal structures are conjectural. The Gravity Province has been divided into three ill defined units:

R	A broad area of smooth gravity relief south of the Joanna Springs Gravity Ridge.	Dummer Gravity Platform
S	Area of relatively higher gravity anomaly in HELENA and south CORNISH.	Helena Gravity Shelf
T	Extensive closed 'low' extending over URAL and WILSON	Ural Gravity Depression

PILBARA BLOCK

This is an area of relatively intense anomalies extending from the south into PORT HEDLAND and west YARRIE. The feature is only partly defined.

U	Small intense closed 'highs' and 'lows' in PORT HEDLAND and west YARRIE.	Pilbara Gravity Plateau

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* Later gravity work by WAPET (1963d) in SAHARA, PERCIVAL, URAL, TABLETOP, and RUDALL has shown that the Anketell-Warri Regional Gravity Ridge may not be continuous from PATERSON RANGE to RUDALL. WAPET's sparse gravity data in northeast RUDALL suggest that the Ridge is possibly displaced to the west by a gravity 'low'.

In this area Traves, Casey & Wells (1956) have mapped extensive outcrops of granite. The WAPET gravity data have not been incorporated in Plate 3.

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The following gravity Provinces are outside the boundaries of the Basin, but are briefly described below. The regional structural significance of these features will be discussed in Chapter 4.

GIBSON REGIONAL GRAVITY LOW

This is the name given to the region of gravity 'lows' extending over RUNTON, MADLEY, HERBERT, BROWNE, and west WARRI.

COBB REGIONAL GRAVITY LOW

This is the name given to the gravity 'low' extending southeast from RYAN through COBB to northeast SCOTT.

BLACKSTONE REGIONAL GRAVITY HIGH

This is a region of gravity 'highs' in southeast BENTLEY, south SCOTT, southwest PETERMANN RANGES, and extending into TALBOT, COOPER, and MANN.

AMADEUS REGIONAL GRAVITY LOW

This is a region of very low Bouguer anomaly values, most pronounced in MOUNT RENNIE and MOUNT LIEBIG and extending east to Alice Springs. It extends westward into MACDONALD and RAWLINSON.

PAPUNYA REGIONAL GRAVITY RIDGE

This is the east-trending line of high Bouguer anomaly values extending from north MOUNT RENNIE to north of Alice Springs. It is bounded to the south by a strong gravity gradient.

OLGA REGIONAL GRAVITY RIDGE

This is an east-trending line of high Bouguer anomaly values extending from west RAWLINSON to HENBURY. Its western portion is distinguished as a separate Unit - the Bloods Range Gravity Ridge.

AYERS ROCK REGIONAL GRAVITY LOW

This is a Bouguer anomaly 'low' region lying mainly in south AYERS ROCK and south KULGERA with an embayment extending into north PETERMANN RANGES and a suggested narrow extension towards south MANN.

4. REGIONAL INTERPRETATION OF GRAVITY RESULTS

Plate 3 illustrates the major gravity trends within the Canning Basin and adjacent areas to the south and southeast. They are:

(1) The Canning-Fitzroy Basin, in which all major trends are northwest.

(2) The northeast margin of the Canning Basin, in which some of the major trends are northeast and north.

(3) The Papunya Regional Gravity Ridge, the Amadeus Regional Gravity Low, the Ayers Rock Regional Gravity Low, and the eastern part of the Bloods Range Gravity Ridge, in which east trends predominate.

(4) The Gibson Regional Gravity Low, in which the dominant trend is west-northwest.

(5) The area west of the Amadeus Basin and southeast of the Canning Basin in which the Bouguer anomaly trends do not have any characteristic direction. No quantitative analysis of the Bouguer anomaly pattern within this area will be attempted here.

Areas (1) and (2) constitute the Canning Basin, as geologically conceived, and the discussion in this chapter will be limited mainly to these two areas. The predominantly northwest trend of the Bouguer anomaly pattern in the area corresponds to the regional geological trend.

The northwest trend of the Bouguer anomalies is the most noteworthy property of the Bouguer anomaly pattern over the Canning Basin. It is considered exceptional, because the trend is at right angles to the strike of the continental margin. In most of Australia, and the world generally, Bouguer anomaly features near the continental margins are parallel to the strike of the continental shelf.

The fact that neither the Bouguer anomaly nor the geological trend is parallel to the continental margin implies that the expected major structures with trends parallel to the edge of the continental margin may be discovered offshore from the Canning Basin.

Two important gravity minima exhibit a northwest trend. They are the Fitzroy Regional Gravity Complex (Unit D) and the South Canning Basin Regional Gravity Low. They are associated with three prominent gravity ridges, the Anketell-Warri Regional Gravity Ridge (O, P, and Q), the Broome Gravity Ridge (F), and the Oscar Gravity Ridge (C).

The Mount Bannerman Gravity Depression (H) and Halls Creek Gravity Ridge (G) trend northeast and appear to be related to the Halls Creek Mobile Zone.

The eastern margin of the Basin is characterized by two south-trending features: the Stansmore Gravity Trough (I) and the Thornton Gravity Ridge (K).

Properties of regional gravity features

On a regional scale three types of Bouguer anomaly patterns are recognized:

1. Regions of relatively high Bouguer anomaly value, including gravity ridges (linear patterns) and regional gravity 'highs' or gravity plateaus (non-linear patterns).

2. Regions of relatively low Bouguer anomaly which are usually adjacent to gravity ridges and are variously described as regional gravity 'lows', gravity depressions, or gravity troughs according to their shape and size.

3. Regions over which the Bouguer anomaly values show no marked variation or contrast; these have been called gravity shelves or platforms.

Consideration of the properties of regional Bouguer anomaly features leads to certain conclusions regarding some of the probable geological properties of the sources of the Bouguer anomalies. Simple interpretative criteria which may be used are shown below.

A. Gravity Ridges

Feature characteristic	Physical property of source	Geological implication
1. High Bouguer anomaly	implies high-density source	implies high-grade metamorphic rocks and/or basic or ultrabasic igneous rocks.

Feature characteristic	Physical property of source	Geological implication
2. High Bouguer anomaly gradients	implies large horizontal density variations	implies high grade metamorphic activity and/or basic igneous activity or faulting
3. Linearity of Bouguer anomaly feature		implies association with geosynclinal activity

On this basis the source of a gravity ridge of regional magnitude is probably a basement ridge of metamorphic and/or igneous rocks which was associated at one time with geosynclinal activity. From consideration of structural geology a basement ridge probably marks the axis of an ancient geosyncline.

B. Gravity Depressions and Regional Gravity Lows

Feature characteristic	Physical property of source	Geological implication
1. Low Bouguer anomaly	implies low-density source	implies sediments and/or acid igneous rocks
2. Absence(on a regional scale) of high Bouguer anomaly gradients within the gravity 'low'	implies no large horizontal density variations	implies sediments and/or acid igneous rocks
3. Association with gravity ridges	implies absence of tectonic activity within the basement	implies sediments associated with geosynclinal activity associated with gravity ridges

On this basis regional gravity 'lows' which exhibit the above properties are probably caused by a considerable thickness of sediments, a massive acid igneous body, downwarping of the crust, or a combination of two or more of these possibilities.

The above criteria apply to a relatively simple situation in which the following assumptions are implicit:

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(1) All thick sediments are associated with geosynclinal activity.

(2) The geosynclinal cycle is typical (Fairbridge, 1963) and has been completed.

(3) The individual gravity Provinces or Units are attributable to tectonic activity from a particular geosynclinal cycle.

These assumptions, particularly (3) are almost certainly not generally realized, and the tectonic picture derived from gravity data using the above reasoning must be modified to maintain consistency with known geological data.

As shown in Appendix A there is a major density discontinuity between unaltered Upper Proterozoic sediments and crystalline basement. Therefore the extent of the Basin as deduced from an analysis of the Bouguer anomalies will include sediments of Upper Proterozoic to Tertiary age. As noted in Chapter 2 the geological concept of the Canning Basin includes sediments ranging in age from Cambrian to Lower Cretaceous.

Interrelation of Canning, Amadeus, and Officer Basins

Geologically the southern margin of the Canning Basin is unknown. Thin flat-lying Permian and Mesozoic sediments effectively mask the presence and distribution of Upper Proterozoic and Lower and Middle Palaeozoic sediments.

Canning/Amadeus Basin relations

The major development of east-trending gravity features, namely the Amadeus Regional Gravity Low and the Papunya Regional Gravity Ridge, terminates in MOUNT RENNIE. These two gravity Provinces are related to one another. The following comments bear on the significance of the two Provinces.

1. The Papunya Regional Gravity Ridge represents a zone of tectonic activity, which has been shown by radioactive dating methods to be of Middle Palaeozoic age.

2. The Amadeus Regional Gravity Low covers an area over which sedimentary rocks of Lower Palaeozoic age occur.

3. The extensive central part of the Amadeus Regional Gravity Low corresponds to the eastwest extent of the Papunya Regional Gravity Ridge.

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4. Point (3) above suggests that the tectonic events giving rise to the two Provinces are related to each other.

5. Geological mapping in the area has shown that the Lower Palaeozoic sediments over the area of the Amadeus Regional Gravity Low are shelf sediments and that geosynclinal sedimentation took place within the area of the Papunya Regional Gravity Ridge.

6. Because of the sparse outcrop over the western part of the Amadeus Basin, the extent of the 'Ridge-Low' complex in this direction will mark the western extent of relatively thick Lower Palaeozoic sediments in the Amadeus Basin.

Upper Proterozoic sedimentation within the Amadeus Basin is associated with late Upper Proterozoic tectonic activity (Forman, 1963), which produced the Bloods Range Gravity Ridge. Geological mapping in BLOODS RANGE has shown that:

1. A basement 'high' in southwest BLOODS RANGE corresponds geographically with the Bloods Range Gravity Ridge.

2. The Upper Proterozoic sediments north of the basement 'high' (see 1 above) thicken toward the south.

3. The tectonic events which caused the folding of the Upper Proterozoic sediments are not related to subsequent tectonism, which caused the folding of the Lower Palaeozoic sediments.

It would therefore appear that the Bloods Range Gravity Ridge and its extension mark the axis of tectonic activity which took place at the close of the Upper Proterozoic. The Bloods Range Gravity Ridge extends east to HENBURY and west to southwest RAWLINSON. In RAWLINSON the ridge joins another ridge which trends north. The part of the north-trending ridge which occurs within the northeast Canning Basin has been called the Thornton Gravity Ridge (K).

It is suggested that the Bloods Range Gravity Ridge and Thornton Gravity Ridge represent a present-day basement high. Tectonic activity along both ridges might not have been contemporaneous and could have been renewed during the Palaeozoic. However, the evidence cited above suggests that extensive sediments of Upper Proterozoic age would exist along one or both margins of both ridges and that any Lower Palaeozoic geosynclinal or shelf sedimentation would not be continuous across this barrier.

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Canning/Officer Basin relations

The southwest margin of the gravity expression of the Canning Basin is the Anketell-Warri Regional Gravity Ridge. Its southern extension has not been mapped and it is possibly the most extensive gravity 'high' in Australia. Its structural significance is discussed below:

(a) The Gravity Ridge is believed to mark an axis of tectonic activity ranging in age from Lower Proterozoic to very early Cambrian. Sediments and metamorphic rocks ranging in age from Lower Proterozoic to Palaeozoic (Wells, 1963) and age determinations made from the basement in Samphire Marsh No. 1 (WAPET, 1961d) suggest that tectonic activity along the Anketell-Warri Gravity Ridge ranged in age from Lower Proterozoic to Lower Palaeozoic.

(b) Associated sedimentation on either side of the gravity ridge is most probably of Upper Proterozoic age.

(c) It represents a major element of an ancient Proterozoic geosynclinal zone which runs from southeast South Australia to northwest Western Australia. The West Australian Shield lies wholly to the southwest of this geosynclinal zone.

(d) Most Precambrian Blocks lying to the northeast of this feature are younger than those of the West Australian Shield.

(e) Any deep sedimentation on either side of the Gravity Ridge, which is associated with the axis of tectonic activity, could differ in lithology or age.

(f) Therefore any sedimentation in the South Canning and Officer Basins is likely to have been unrelated either in lithology or in age.

Canning Basin

The major gravity ridges mapped within the Fitzroy Basin are the Oscar Gravity Ridge and Broome Gravity Ridge. On the assumption that these two ridges can be related to tectonic activity, the following postulates are consistent with current geological knowledge:

(1) The Oscar (C) and Halls Creek (G) Gravity Ridges are related and mark axes of Proterozoic geosynclinal activity.

(2) Because the Upper Proterozoic King Leopold Beds are intensely folded along the axes of the Oscar Ridge it is possible that the main cause of the Oscar Gravity Ridge (C) is dense rocks deformed and uplifted during the late Proterozoic or early Cambrian.

(3) The Halls Creek Gravity Ridge (G) coincides with the Lower Proterozoic Halls Creek Metamorphics. Geological mapping across the Old Halls Creek Fault has shown this feature to have been active during the Proterozoic, which suggests that tectonic activity in this region continued from the early Proterozoic into the very late Proterozoic or early Cambrian (Smith, 1963).

(4) The Ordovician rocks of the Canning Basin are of shelf origin and there is no evidence to suggest the whereabouts or presence of geosynclinal sedimentation. On the basis of gravity data it is possible to suggest three areas where thicker Ordovician sediments may be present.

(a) Thick sediments of Ordovician age could be present in the Fitzroy Trough, which correlates with a Bouguer anomaly 'low'. In this respect it should be noted that the phyllite found at the bottom of Thangoo No 1A could be of Cambrian age (Veevers & Wells, 1961) suggesting that the Broome Ridge was the focus of tectonic activity during the Cambrian and Ordovician Periods.

(b) The Joanna Springs Gravity Ridge (N) trends east, and it is suggested that tectonic activity associated with this ridge was contemporaneous with the Middle Palaeozoic tectonic activity associated with the Papunya Regional Gravity Ridge. The sedimentation associated with adjacent gravity 'lows' (units M and R) would then have as its source Lower Palaeozoic rocks. This hypothesis is purely speculative and is only supported by the generalized structural considerations of Hills (1956), which illustrate zones of tectonism in which activity has extended from the Precambrian to the Tertiary. In addition, different zones which are parallel with each other could be of the same age.

(c) Renewed activity along the Anketell-Warri Regional Gravity Ridge could have resulted in Cambro-Ordovician sedimentation along the margins of this Ridge. Thick Lower Palaeozoic sediments could occur in the South Canning Basin.

(5) Tectonic activity during the Devonian caused differential uplift in the Lennard Shelf. The Pinnacle and Fenton/Dampier Fault systems were initiated during the Devonian, and gravity and geological evidence suggest that thick Devonian sediments are present in the Fitzroy Trough.

5. REGIONAL CROSS-SECTIONS

Two cross sections are presented (Plates 4, 5). They show:

(a) An averaged Bouguer anomaly, the values of which have been obtained by averaging station values over a strip 33 miles wide.

(b) A curve showing the deviation of the averaged Bouguer anomaly from the value expected in that area using Woollard's (1962) elevation versus Bouguer anomaly conversion curve. This is called the elevation-corrected Bouguer anomaly.

The mean elevation and mean Bouguer anomaly values were obtained by averaging station values over approximately 1000 square miles. A 50-percent overlap with the preceding area was used for each calculation. A world continental average elevation versus Bouguer anomaly curve was used to obtain a theoretical Bouguer anomaly value for the computation points. The value obtained from a mean Bouguer anomaly versus an elevation-dependent Bouguer anomaly is shown in the plates as the elevation-corrected Bouguer anomaly curve.

The following should be noted with respect to the world average elevation versus Bouguer anomaly curve and the resultant elevation-corrected Bouguer anomaly curve.

(a) The elevation Bouguer curve is a world average and therefore any values for the curve which are close to zero should be an elevation-corrected Bouguer anomaly indicative of normal crustal thicknesses.

(b) Extensive areas of thick sediments would give negative elevation-corrected anomaly values.

(c) Abnormal crustal thicknesses would give values for the corrected Bouguer curve which deviate appreciably from zero.

With respect to the elevation-corrected Bouguer anomaly curve in Plate 4 the following should be noted:

(a) The profile runs at right angles to the coast from MUNRO to SCOTT, and the subsurface structure of the area is largely unknown. As a first approximation it can be assumed that the elevation-corrected Bouguer anomaly curve reflects regional variation in sedimentary structure, and not variations in crustal thickness.

(b) Areas B, D, F, and H are positive anomalies and D, F, and H correspond to the Patience Well Gravity Plateau, Bloods Range Gravity Ridge, and Blackstone Gravity Plateau respectively.

(c) The negative anomaly C corresponds to the South Canning Regional Gravity Low and has a maximum amplitude of -42 mGal. For a density contrast of 0.15 g/cm^3, this would imply a sedimentary thickness of 22 000 ft.

(d) Anomalies E and G correspond to the Cobb Gravity Depression and have magnitudes of -25 and -28 mGal respectively. Thicknesses of 13 000 ft and 14 500 ft respectively are implied.

(e) In the area of anomaly H, Precambrian rocks, some of them basic and dense, crop out. It is assumed that the mass excess causing a maximum anomaly of +53 mGal, is composed of dense near-surface rocks of Precambrian age. Unfortunately the southeastward extent of anomaly H has not been mapped.

(f) Anomalies D and F are positive and it is therefore assumed that they correspond to areas of shallow basement. This is suggested by aeromagnetic data.

Thus anomalies C, D, E, F, and G can be interpreted in terms of variations of sedimentary thickness. Anomaly F can also be interpreted in terms of relatively shallow basement density variations. In summary:

(1) The sparse aeromagnetic data suggest that anomaly C, a pronounced negative feature, is caused by thick sediments.

(2) There is no geological evidence to suggest that anomalies E and G have a non-sedimentary source.

However, there are other alternative explanations:

(a) The main source of the anomalies is due to horizontal density variations within the basement.

(b) Anomalies C, D, E, F, G, and H are essentially caused by changes in the thickness of the crust, and any variations caused by changes in sedimentary thickness and basement densities are of minor importance.

Anomaly B is a positive feature of small amplitude and large areal extent. It does not correspond in position to the Joanna Springs Gravity Ridge. Anomaly A lies within the Munro Gravity Platform. It can be seen from Plate 4 that the Bouguer anomaly in this area becomes more positive towards the coast, but the elevation-corrected Bouguer anomaly becomes more negative. There are two possible explanations:

(a) The change of 18 mGal in Bouguer anomaly from B to A is caused by a thickening of the sediments.

(b) The change is caused by a thickening of the crust.

If crustal thickening is the correct explanation then this area may be related to the Gulf Coast of USA in Texas and Louisiana. In this area deep seismic work by L.C. Pakister (pers. comm.) has shown that the crust thickens in the direction of the coast. This is accompanied by a regional rise in the Bouguer anomaly, despite the fact that the sediments thicken rapidly in the area. It is thought that the thickening of the crust is associated with convection in the upper mantle and that this in turn is in some way connected with the development of the extremely thick sediments in the area. The sediments in the area are of Mesozoic and Tertiary age, cover an extensive area, and are more than 40 000 ft thick.

Recent aeromagnetic work (Woodside, 1964) has suggested that a considerable thickness of sediments is developed offshore from the Canning Basin. The rather indefinite correlation between the two areas presents the possibility of a thick sedimentary development offshore from the Canning Basin.

The second profile (Plate 5) is a section drawn parallel to the coastline and crosses the trend of the major units of the Basin at right angles. The Fitzroy Trough shows up as a gravity 'low' of -18 mGal and the Oasis Gravity Depression as a 'low' of -20 mGal. The elevation-corrected Bouguer anomaly curve is generally parallel to the observed Bouguer anomaly curve. No additional geological information can be deduced from a study of the corrected Bouguer anomaly curve. However, the 'highs' over the Broome and Oscar Gravity Ridges have been amplified with respect to the 'low' over the Fitzroy Trough. If a straight-line regional is drawn from the Broome Gravity Ridge to the Oscar Gravity Ridge, then the negative residual has a maximum value of -18 mGal for the observed Bouguer anomaly curve and -36 mGal for the elevation-corrected Bouguer anomaly curve.

Since the elevation-corrected Bouguer anomaly curve is related to a world average elevation versus Bouguer anomaly relation, it is similar to an isostatic anomaly profile. The average value for the elevation-corrected Bouguer anomaly is +0.6 mGal, which is very close to zero and suggests therefore that the area crossed by the profile in Plate 5 is in isostatic equilibrium.

6. CORRELATION OF BOUGUER ANOMALIES WITH OTHER DATA

When interpreting the gravity data the degree of correlation with other geophysical and geological data narrows the range of ambiguity in the interpretation. In cases where zero or reverse correlation is obtained there must be a reason, and this reason will be of geological significance.

Correlations with other data have been studied in three areas. A correlation has been made between gravity and geology in the Billiluna area, between gravity and seismic data on the Gogo Anticline, and between gravity and aeromagnetic in the Wallal/Mandora area.

Billiluna area

A composite gravity/geology map of BILLILUNA (Plate 7) is shown at a scale of 1:500 000. Precambrian igneous, metamorphic, and sedimentary rocks crop out over most of the area. South and southwest of the Wolf Creek Meteorite Crater, sediments of Ordovician, Devonian, Carboniferous, and Permian age crop out. A large important area of basement rocks has been covered by gravity reconnaissance, so enabling correlation of gravity with basement rock types.

The area falls within the northeast Canning Basin and the gravity units occurring within the area shown by Plate 7 are:

(a) Mount Bannerman Gravity Depression (H), which occupies the northwest part of Plate 7.

(b) The Billiluna Gravity Plateau (J), which occupies the eastern two-thirds of Plate 7.

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(c) The northern extremity of the Stansmore Gravity Trough (I), which occupies most of the southwest part of Plate 7.

(d) The northern extremity of the Thornton Gravity Ridge (K), which occupies the extreme southwest part of Plate 7.

(e) The Halls Creek Gravity Ridge (G) which occupies the extreme northwest part of Plate 7.

The Bouguer anomaly pattern can be divided into two groups:

(1) Units H and I are larger and relatively smooth.

(2) In contrast to Units H and I, Unit J is composed of Bouguer anomalies which are smaller and more intense.

In general terms therefore, density variations within the source of Unit J are greater than within the source of Units H and I.

On the basis of likely gross density variations, the following may be expected:

(a) The highly metamorphosed Lower Proterozoic sediments will be represented by Bouguer anomaly 'highs'.

(b) The Lewis Granite, being acidic, will give rise to Bouguer anomaly 'lows'.

(c) Thick accumulations of Upper Proterozoic sediments will give rise to Bouguer anomaly 'lows'.

(d) Thick accumulations of Palaeozoic and younger sediments will give rise to Bouguer anomaly 'lows'.

The basement in this area is at the base of the Upper Proterozoic and therefore consists of Lower Proterozoic metamorphics and granites with a gravity pattern which should consist of gravity features with rather small amplitude. Three Bouguer anomaly 'highs' occur east of the Basin boundary (1J, 2J, 4J). Anomaly 2J and the southern part of 4J can be correlated with the metamorphics ((a) above). Feature 1J occurs over outcropping Upper Proterozoic sediments. It is suggested that all three features have Lower Proterozoic metamorphics as their principal source.

Granite crops out within feature 3J and around the northern and western margins of feature 2J. A granitic source is suggested for feature 3J and also for anomaly 5J, which appears to be an extension of feature J. The granites occurring between 1J and 2J are characterized by a narrow gravity 'low' which trends north and also appears to be related to 3J. The granites which crop out over the northern part of 2J are interpreted as a relatively small intrusion which would not noticeably affect the Bouguer anomaly pattern.

No great thickness of Upper Proterozoic sediments has been mapped within the area of the Billiluna Gravity Platform. It is therefore considered that their contribution to the gravity pattern within unit J is not important.

The most prominent negative Bouguer anomalies in Plate 7 are the Mount Bannerman Gravity Depression (H), a southwest trending gravity 'low' north of Billiluna homestead, and the Stansmore Gravity Trough (I), which trends south from Billiluna homestead. Intense and important gravity gradients (8H and 4I) mark the eastern border of both units. These two gravity 'lows' and the marginal gradient (8H and 4I) form the eastern margin of the gravity expression of the Canning Basin. In this respect the following should be noted:

(1) Unit I which trends north, lies immediately west of the geological margin of the basin. This anomaly therefore probably represents a considerable thickness of sediments. If a density contrast of 0.15 g/cm^3 is assumed, then a sedimentary thickness of 15 000 ft would result. Further south on LUCAS and STANSMORE the gravity trough appears to be associated with Upper Proterozoic sedimentation (see Chapter 4). Therefore the age of any sediments present would range from Permian which outcrops at the surface to Upper Proterozoic.

(2) The axis of the Mt. Bannerman Gravity Depression (H) crosses the margin of the basin at right angles about 15 miles south of Billiluna Homestead. No diminution in anomaly value is detected as the unit crosses the basin boundary. It is therefore postulated that the principal source of this Gravity Unit is a considerable thickness of Upper Proterozoic sediments. If a density contrast of 0.15 g/cm^3 is assumed then 20 000 ft of sediments could occur within the area of Unit H.

(3) The possibility that both major gravity 'lows' have a granite body as their principal source must be considered. However, a sedimentary source is postulated because:

(a) From surface geological considerations the decrease in the Bouguer anomaly occurs in areas where an increase in sedimentary thickness occurs.

(b) The largest negative Bouguer anomaly feature (3J) on east BILLILUNA which is attributed to a granitic source is not comparable in extent and magnitude with the Mt. Bannerman Gravity Depression (H) and the Stansmore Gravity Trough (I).

(c) An aeromagnetic traverse across the Mount Bannerman Gravity Depression on Mt. BANNERMAN suggests that thick sediments occur in that area.

In summary therefore:

(1) Over basement, the 'highs' are caused by Lower Proterozoic metamorphics and the 'lows' are generated by granites.

(2) Extensive gravity 'lows' are caused, where there is no evidence to the contrary, by a thick sequence of sediments.

(3) The more complex structure of the basement produces anomalies which are smaller and more intense than those apparently associated with sedimentation.

<u>Gravity/aeromagnetic correlation</u>

At the time of writing (January, 1964)* the results of a recent aeromagnetic survey and earlier surveys by WAPET were not available to the author for detailed study. The aeromagnetic data referred to in this report have been collected by BMR (Quilty, 1960).

Plate 8 shows aeromagnetic profiles for the coastal part of the Canning Basin. Gravity profiles are also superimposed on aeromagnetic profiles 1P-7P and 2P-8P shown on Plate 8.

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* <u>Note</u>

Since this chapter was written the results of this survey have been published (WAPET, 1964b). With respect to the gravity data some of the major conclusions drawn from the aeromagnetic survey were:

(a) Unit M, which is a gravity 'low', corresponds to an area of relatively shallow magnetic basement.

(b) The sedimentary thickness over the area of the South Canning Regional Gravity Low exceeds 30 000 ft in some areas.

(c) Anomaly 1K, a gravity 'high', corresponds to an area which according to the interpretation of the aeromagnetic data has a sedimentary thickness exceeding 20 000 ft.

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The gravity Provinces and Units crossed by the two profiles are:

(1) Anketell-Warri Regional Gravity Ridge (O,P,Q,)

(2) La Grange Gravity Platform (L)

(3) Broome Gravity Ridge (F)

(4) Pilbara Gravity Plateau (U)

The following comments refer to the degree of correlation between the two types of data.

(1) The aeromagnetic profile over the Anketell-Warri Regional Gravity Ridge is slightly more disturbed than that over the La Grange Gravity Platform.

(2) Two major magnetic anomalies, X and Y (Plate 8) can be related to intense gravity gradients bordering a marked gravity 'high' which is a part of the Anketell-Warri Regional Gravity Ridge.

(3) Magnetic anomaly Z trends east, but this direction is not definite. Anomaly Z corresponds to a small gravity 'low' most likely caused by sediments, and probably has the same source as the gravity feature.

(4) Magnetic anomaly W trends east and represents a change in basement type. It possibly marks the boundary between the basement rocks underlying the Broome Gravity Ridge and La Grange Gravity Platform. The gravity expression of this (basement) contact is the gradient forming the southwest margin of the Broome Gravity Ridge. However, magnetic anomaly W trends east across anomaly 1L, and near the coast it is three miles south of the southern extremity of anomaly 16F. The sources of Bouguer anomaly 1L and magnetic anomaly W could therefore originate from different levels. It is possible, therefore, that the change in magnetic properties across W is not accompanied by a change in density and that gravity anomaly 1L is unrelated to magnetic anomaly W.

Magnetic anomalies X and Y border anomaly 10 and it has been noted that both are associated with steep Bouguer anomaly gradients. It is assumed that the source of anomaly 10 is an upthrust block of metamorphics and volcanics of relatively high susceptibility bordered by a basic volcanic intrusion.

From the foregoing it can be seen that in some areas the correlation between magnetic and gravity anomalies is simple and both the magnetic and Bouguer anomaly can be attributed to the same source. However, in other areas no such correlation can be seen, and therefore it is not possible to make a general statement about the relations between aeromagnetic and Bouguer anomalies in the Canning Basin.

Gravity/seismic correlation

A considerable amount of seismic reflection and refraction work has been done by WAPET (1963e, 1963f) over the Gogo Anticline and adjacent areas. The Gogo Anticline is situated 20 miles southeast of Fitzroy Crossing and occupies the northwest margin of feature 8C.

The anticline is bordered on the southwest by the northwest extension of the Pinnacle Fault. Its northwest margin is also believed to be faulted. Seismic reflections which have been identified as basement (WAPET, 1963e, 1963f) show that the sediments become thinner to the north and northeast. Gravity data and seismic reflection data also indicate that the sediments are affected by faults trending north-northeast.

Plate 9 shows a geological cross-section through the anticline. Horizons established by seismic work have been used to establish a probable position of basement, which is the base of the Permian, and the position of the faults (WAPET, 1963e, 1963f).

There is an absence of direct correlation between the seismic reflection data and gravity data in three areas:

(1) The basement 'high' across the anticline, as revealed by shallowing reflections, does not produce a gravity 'high'.

(2) North of the anticline the sedimentary thickness decreases but there is a reduction in the Bouguer anomaly.

(3) The steepest part of the gravity gradient on the south side of the anticline does not correspond to maximum thickening of the sediments as deduced from seismic reflections.

Point (1) above suggests that the Lower and Middle Palaeozoic sediments which form the anticline have a density close to that of the basement. A decrease in the Bouguer anomaly north of the anticline (see 2 above) could be caused by:

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(1) Intrabasement density variations, or

(2) A decrease in density of the sediments

The relatively steep gravity gradient on the south side of the anticline (see 3 above) corresponds to the point where a strong reflection interpreted as a basement reflection could not be followed farther. Therefore, there is possibly a major fault in the sediments at this point (Plate 9).

A derived Bouguer anomaly curve * is shown on Plate 9. The densities used in this calculation are as shown.

When considered together the seismic and gravity results strongly suggest that there is considerable lateral density variation in the Middle and Lower Palaeozoic sediments, and that at least 30 000 ft of sediments are present southwest of the anticline. The density of the body used in the calculation was probably too low and the slope of the derived curve at the southwest end of the profile is also too low. This suggests that near-surface faulting is present, and that therefore the base of the Permian is also displaced by the Pinnacle Fault.

7. MARGINAL AREAS

As shown in chapter 4, the southern margin of the Canning Basin is probably a basement ridge represented gravimetrically by major gravity ridges. The area to the south and southwest of these gravity ridges has been fully covered by reconnaissance gravity surveys. In contrast the bordering areas to the southwest, east, and northeast have only partial gravity coverage.

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* In Plate 9 and Plates 20, 21, and 23 which show the geological sections derived, Bouguer anomaly values have been calculated for the various geological sections using a variety of density values. No attempt has been made to adjust the geological section in order to obtain a theoretical Bouguer anomaly curve which corresponds exactly to the observed Bouguer anomaly curve. This procedure was not justified because of the uncertainty regarding the specification of the regional basement anomaly. A short description of the method used in calculating the derived Bouguer anomaly is given in Appendix E.

Kimberley and Pilbara Blocks (Plate 6)

Because of the lack of control the gravity pattern over these geologically defined Provinces is known only in those areas marginal to the Canning Basin and only from scattered ground traverses. The Pilbara Gravity Plateau (U) forms part of the Pilbara Block. Geologically, the Pilbara and Kimberley Blocks are considered to be areas which have been tectonically stable since the early Proterozoic. Further work, particularly aeromagnetic, gravity surveys, and radioactive dating techniques, could alter or modify this concept.

The following comments refer to units A and U:

(1) Generally the anomalies are small and relatively intense, suggesting, as one would expect, large near-surface density variations.

(2) The relative 'lows' generally correspond to granite and granitic gneiss. (e.g. 2A, 5A, 6A, 7U, 9U, and possibly 1U and 10U).

(3) The relative 'highs' correspond to Lower Proterozoic metamorphic rocks. (e.g. 1A, 3A, 4A, 4U, 6U, and 8U).

(4) Anomalies 1U and 10U are possibly caused by Upper Proterozoic sediments or by granites.

The Halls Creek Gravity Ridge (G) could be a component of the Kimberley Block. Here it is tentatively included within the Northeast Canning Basin Province.

Stansmore area

A large relative 'high' (6J) has been partly defined in STANSMORE. It is tentatively assumed to be connected with unit J around the eastern extension of unit I. The source of the anomaly is probably metamorphic rocks related to the Halls Creek Metamorphics.

Billiluna area

The significance of the gravity pattern over the Proterozoic rocks in BILLILUNA has been discussed in Chapter 5. The relatively small intense anomalies in the eastern two-thirds of BILLILUNA were interpreted as being caused by Lower Proterozoic, metamorphic, and granitic rocks.

8. FITZROY BASIN

The geology of the Fitzroy Basin has been described in recent years by Guppy et al. (1958), Brunnschweiler (1957), and Veevers & Wells (1961). The gravity Province which corresponds to the Fitzroy Basin comprises five gravity units (B-F).

With the exception of Unit E, the overall trend of the Bouguer anomalies is northwest. Unit E does not have a general overall trend and occupies a position which from consideration of the distribution of sediments, should be a part of Unit D.

Density variations (see Appendix A) within the sedimentary column suggest that the major gravity 'lows' within this Province should represent the area of major Permo-Carboniferous sedimentation.

Napier Gravity Depression (Unit B)

The Napier Gravity Depression (Plate 6) flanks the northeast margin of the Basin boundary as an extensive narrow gravity 'low'. Northeast of the Oscar Ranges the Unit corresponds to a syncline in the Devonian Fairfield Beds. It is possible that the northwest continuation of this depression delineates an axis of relatively thick sediments on southeast YAMPI. Plates 10 and 12 show Bouguer anomaly cross-sections across the depression. Plate 10 is a section across feature 2B of this unit on YAMPI.

With respect to the section in Plate 10, the following should be noted:

(1) If the two positive culminations (1A and 3A) reflect near-surface basement and the negative feature 2B represents sediments, then a maximum of 10 000 ft of sediments could be present. The basement is assumed to be metamorphic with a density of 2.80 g/cm^3. Sediments of Devonian age or older with a density of 2.6-2.7 g/cm^3, are assumed to be present.

(2) If feature 2B represents sedimentary development, then the steep gradient on the northeast margin indicates that it is faulted.

(3) By assuming a planar contact between bodies and by applying the analysis described by Bott (1962) to the second derivative curve it can be shown that the contact dips southwest. This in turn suggests that the major density discontinuity is between the basement and the sediments.

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(4) If thick sediments are the source of anomaly 2B they could consist of:

(a) Relatively light Devonian offshore facies.

(b) Other Devonian and Ordovician sediments.

(c) Local thickening of Permian sediments.

(d) A thick wedge of relatively light Proterozoic metamorphics such as quartzite.

(5) Despite the fact that the second-derivative analysis (3 above) suggests a sedimentary source, the possibility of a non-sedimentary source cannot be eliminated. (see 4(d) above).

Plate 10 shows a second derivative profile * based on accurate station values read at ½-mile intervals. The reasons for preparing a second-derivative curve are:

(1) Maxima and minima on the curve can be used to denote points at which density discontinuity planes change direction (Bott, 1962).

(2) Rapid fluctuations in value can be used to establish the presence of near-surface variations either of density or of density discontinuity planes.

With respect to this curve it should be noted that:

(1) The curve has a high frequency and the wavelength in places approximates the station separation. Very often only one point delineates 'highs' and 'lows' on the curve. It is evident therefore that closer station spacing would be needed to delineate fully some of these gravity features.

(2) As noted above, the maxima and minima over the steep gradient suggests a plane which dips south at about 10 degrees. However, two maxima and minima suggest complex faulting.

(3) The high frequency and amplitude in the second-derivative profile over anomaly 2B suggest near-surface faulting and large lateral density fluctuations.

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* A short description of the method used in obtaining the second derivative is given in Appendix E. The method is based on one described by Bott (1962).

(4) The curve shows smaller, low-frequency fluctuations over the extension of anomaly 1A. This can be attributed to likely lower density variations within a basement ridge.

(5) Plate 11 shows a second-derivative vertical profile along a short traverse at right angles to the profile on Plate 10 and within feature 2B. The curve is relatively flat, as is the Bouguer anomaly curve, suggesting that any structural features are aligned parallel to this traverse.

(6) Plate 12 is a cross-section near Napier Downs. In this area the sedimentary thickness could, on the basis of gravity data, be 2000-4000 ft. A small 'low' occurs where the traverse crosses the Napier Escarpment. This is a topographic effect and a smoothed curve is shown.

A water bore at Old Napier Downs struck basement at 1580 ft (Guppy et al, 1958) and the gravity data suggest that it was drilled on a slight basement ridge which is an extension of the source of anomaly 4A. Anomalies 4B and 5B which are en echelon with 2B, lie southeast of this postulated ridge. Anomaly 5B is not mapped in any detail, but it is unlikely that its source is wholly sedimentary. Anomalies 4B and 5B, when compared with 2B, are wider and smoother suggesting that at least part of the source of the anomalies originates from within the basement. On the basis of 6 mGal being attributable to a sedimentary source, then the thickness of sediments would not be more than 5000 ft.

Oscar Gravity Ridge (Unit C)

The Oscar Gravity Ridge, shown in Plates 3 and 6, is a series of closed gravity 'highs' with a general northwest trend. Its southwest border is a gravity gradient which corresponds to the Pinnacle Fault (see Plate 2) and Derby Ramp (Veevers & Wells, 1961). Precambrian rocks crop out at the Oscar Range and Virgin Hills.

There are eight major positive culminations along the ridge. They are anomalies 1C, 2C, 3C, 4C, 5C, 6C, 7C, and 8C occurring in DERBY, LENNARD RIVER, NOONKANBAH, and MOUNT RAMSAY. Plate 13 shows an axial Bouguer anomaly profile along the ridge. The method of obtaining the best-fit curves is described in Appendix E. In the first-order approximation the negative gradient away from the coast is +.14 mGal per mile. This gradient probably represents the gravity effect of the increase in thickness of the crust away from the coast. The fourth-order curve, which would delineate only major density variations within the crust, shows a minimum feature (6C) which corresponds to outcropping Upper Proterozoic quartzite. This intra-basement 'low' is probably caused by a deep-seated effect as well as an unknown thickness of relatively light Upper Proterozoic quartzite which is exposed at the Oscar Range.

The source of the ridge is considered to be an igneous and metamorphic complex related to tectonic activity which took place in the Precambrian. Igneous activity of post-Cambrian age (Prider, 1960; WAPET, 1962a) is known in the Fitzroy Basin area, but its extent, intensity, and timing are not known; at present it is assumed that the source of the Oscar Gravity Ridge, a major gravity feature, originated during the Precambrian.

Anomalies 2C and 3C appear to have a composite source. In the Devonian, extensive reef development took place along an ancient submarine ridge which probably corresponded to the present-day Oscar Gravity Ridge. Density determinations on the resulting limestone and dolomite (Appendix A) suggest that a density reversal for the Devonian to basement discontinuity is possible in some areas. Meda Nos 1 and 2 were drilled on the culmination of anomaly 2C and encountered some 3000 ft of Devonian reef sediments. Feature 2C could therefore be partly sedimentary in origin. On the other hand features 1A, 3C, and 4C, because they trend parallel to the basement tectonics of the area, probably have a basement source; the source is either basement topography or intrabasement density variations. The southern margin of the ridge is an extensive Bouguer anomaly (9C), which corresponds to the Derby Ramp of Veevers & Wells (1961). This gradient also marks the southwest border of the Lennard Shelf (Playford & Johnstone, 1959). It is considered to be a zone where the basement dips gently towards the deeper parts of the Fitzroy Trough. On southeast NOONKANBAH the intensity of the gradient increases along the trace of the Pinnacle Fault. The gravity profiles (Plate 14) across the Pinnacle Fault indicate that a considerable displacement of the Permian rocks has taken place. A Bouguer anomaly profile across the Pinnacle Fault will be discussed later in this chapter.

The overall intensity and width of the gradient vary greatly along its length. Table 3 summarizes properties of the gradient along its length.

It can be seen that apparent displacement across the gradient varies greatly from place to place. The variations in gradient along the feature suggest that the basement slope varies considerably. The most intense gradient is over the Pinnacle Fault, a well established geological feature. However, while it is known that at least part of the sedimentary column is faulted, faulting in the basement has not been proved. Local intensification of part of the gradient south and southwest of the 67 mile bore and in northwest DERBY suggests that faulting or at least a steepening of the Derby Ramp occurs in these areas (see Table 3).

TABLE 3. (see also Plate 18)

Location	Width (miles)	Gravity displacement (mGal)	Gradient (mGal/mile)	Possible displacement (using plate formula* and $\Delta d = 0.1$)
Prices Creek	3.1	30	9.7	23 500 ft
South of Oscar Range	3.2	12	3.8	9 400 ft
South of 67 mile bore	7.8	27	3.5	21 100 ft
South of Meda No. 1	13.8	22	1.6	17 200 ft
Northwest DERBY	8.5	23	2.7	18 000 ft

* In this report 'plate formula' refers to the general formula $\Delta g = 12.77 \_ \times \Delta d$ where Δg = gravity displacement in milligals, Δd = density contrast in g/cm^3, and L = displacement in kilofeet.

The northeast margin corresponds to a gravity gradient (10C) which varies in intensity along its length. Faults downthrown to the north are possible in places; e.g. the northeast margin of anomaly 5C.

The southeast margin of the unit is in northwest MOUNT BANNERMAN, where it is bordered to the east and southeast by the Halls Creek Gravity Ridge.

It is interesting to note that on NOONKANBAH several prominent geological and gravimetric features trend northeast, parallel with the strike of the Halls Creek Gravity Ridge.

Fitzroy Regional Gravity Complex (Unit D)

The gravity expression (Plates 3 and 6) of the Fitzroy Trough and the Jurgurra Terrace (Playford & Johnstone, 1959) is a pronounced gravity 'low'. It is bounded to the northeast by feature 9C and to the southwest by the gravity expression of the Fenton and Dampier Faults (12F, 13F & 14F). To the southeast, the unit is terminated by the Mount Bannerman Gravity Depression (H), while to the northwest, near Broome, it narrows to a few miles in width. Except for one area, the anomalies have the following properties:

(1) The Bouguer anomaly is low with respect to surrounding areas.

(2) Regional trend is parallel or subparallel to the trends of the major fault systems in the area.

(3) On a reconnaissance scale the Bouguer anomalies do not exhibit sharp or sudden changes in value; gradients are low.

Therefore the sources of the anomalies (see Chapter 4) in this area are:

(1) Of low density

(2) Deep seated and of relatively uniform density.

In general the area of the depression is postulated to be one where extensive sedimentation took place during the Palaeozoic. Thick sequences of Ordovician, Devonian, Carboniferous, and Permian sediments have either been mapped on the surface or cut by the drill. No drill holes have penetrated to basement within the area.

Density determinations, summarized in Appendix A, show that there is a major density discontinuity between the Permo-Carboniferous sediments and the Lower Carboniferous Laurel Formation. The nature of the basement is unknown, but it is assumed that a density contrast also exists between the Lower Palaeozoic sediments and crystalline or metamorphic basement.

The northwest and southeast margins of the Fitzroy Regional Gravity Complex are areas of unusual Bouguer anomalies. The northwest margin is the Yeeda Gravity Platform (E), discussed later in this chapter. The southeast part of the Fitzroy Regional Gravity Complex (6D, 7D, 8D, 9D, 10D, 11D, 12D & 13D) is an area in which the Bouguer anomaly does not exhibit a marked regional trend. In addition the individual Bouguer anomaly features are smaller and more intense than the Bouguer anomaly features found to the northwest.

The Fitzroy Regional Gravity Complex consists of three major negative Bouguer anomaly features (2D, 3D plus 5D, & 4D):

(1) Feature 2D is a gravity 'low' which corresponds to the Jurgurra Terrace. Its source is a thick sequence of Devonian and perhaps

Ordovician sediments overlain by 1000-4000 ft of Permian sediments. The Upper Carboniferous Anderson Formation is not present. The feature is bounded on the south and southeast by relatively steep gradients (12F & 13F) which are the gravity expression of subsurface faulting (WAPET, 1961b & 1962b).

(2) Features 3D and 5D are closed negative Bouguer anomalies adjacent to the Fenton Fault. Their source is postulated to be a large thickness of Palaeozoic sediments. As no bores have penetrated the Anderson Formation in this area, the thickness of Lower Palaeozoic sediments is unknown. Seismic data have shown that the surface Permian structure does not persist at depth. The regional Bouguer anomaly feature does not correlate with surface Permian structure, but can be correlated with basement topography (Ferrand, 1963). However, because the Permo-Carboniferous sediments are considerably lighter than the older sediments, the regional 'lows' should correspond to areas of thick sediments of Permo-Carboniferous age. It is possible that the surface of the Upper Carboniferous sediments (i.e. the plane of the density discontinuity) is not conformable with the surface Permian structure.

(3) Feature 4D is a major Bouguer anomaly 'low' in north central NOONKANBAH. It occupies a position corresponding to a major embayment along the northern margin of the Fitzroy Trough. The gravity expression of this embayment is postulated to have a sedimentary source. Only one relatively shallow bore (Condon & Henderson, 1960a) has been drilled in this area.

The area in southeast NOONKANBAH, northeast CROSSLAND, and northwest MOUNT BANNERMAN has a relatively low Bouguer anomaly, but the pattern is somewhat disturbed. This zone of anomalies marks the confluence of two gravity units, the Fitzroy Regional Gravity Complex (D) which trends southeast and the Mount Bannerman Gravity Depression (H) which trends east in MOUNT BANNERMAN and northeast in BILLILUNA.*

Features 6D to 13D appear to be a composite of the two adjacent major trends corresponding to units D & H. The source of these Bouguer anomalies could therefore be a composite of the Palaeozoic sediments and structure associated with the Fitzroy Trough and a possible Upper Proterozoic structure associated with the Mount Bannerman Gravity Depression. The sharpness of

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* Recent gravity work (WAPET, 1964d) has shown that anomalies 1H and 1S are more appropriately a part of unit D. This would imply that thick Palaeozoic sediments would extend southeast to central CORNISH and that extensive Upper Proterozoic sediments do not extent farther west than central MOUNT BANNERMAN.

the individual Bouguer anomalies suggests near-surface density variations. Since seismic data (Williams, 1955, 1956; Smith, 1955; Ferrand, 1963) indicate thick sediments (20 000 + ft) the density variations probably occur within the sedimentary column. The source of the variations could be:

(a) Igneous intrusions

(b) Salt structures

(c) Limestone reefs

(d) Large density variations within the basement

(e) Juxtaposition of Palaeozoic and Upper Proterozoic structure.

Because of the known presence of Palaeozoic sediments in the Fitzroy Trough and suspected presence of Upper Proterozoic sediments within the area of the Mount Bannerman Gravity Depression, (c) or (e) or both are considered to be the most likely source.

The Pinnacle Fault has been mapped in southeast NOONKANBAH and southwest MOUNT RAMSAY and is represented by a steep gravity gradient. Feature 9C forms the southwest margin of the Oscar Gravity Ridge. This feature has been discussed in the previous section, and probably represents a prominent hinge-line; there is a considerable variation in width and slope.

Plate 15 is a Bouguer anomaly profile across the Pinnacle Fault near Prices Creek. The readings were taken along seismic traverse A-A' (Smith, 1955) at quarter-mile intervals. The following points are noted:

(1) A regional (basement) gradient of 1 mGal per mile is assumed mainly on the basis of the slope of the observed profile from SP 40 to 68. This regional gradient is considered to be a maximum value. While the regional anomaly as shown in Plate 16 drops 15 mGal in 15 miles, it is possible that the variation is localized over a much smaller distance.

(2) The second-derivative profile over the area of the Cadjeput and Pinnacle Faults is very irregular. It shows a minimum over the surface trace of the Cadjeput Fault, and this suggests normal faulting. However, the surface trace of the Pinnacle Fault does not coincide with a second-derivative maximum or minimum. This fact, when considered in conjunction wiith the seismic

data (Smith, 1955; Ferrand, 1963) suggests that the fault, as seen at the surface, does not affect the entire sedimentary column and is probably confined to the Permian sediments. The existence of prominent second-derivative maxima and minima south of the Pinnacle Fault suggests a basement configuration which approaches a monoclinal flexure with the steepest slope between station points 16 and 18. From SP 22 to 30 the slope decreases and from SP30 onwards the slope is constant and could vary between 0 and 5 degrees to the south.

(3) It is probable that lateral density variations (Appendix A) occur both within the basement, so causing the regional gravity variations, and within the sediments. A reduction in the overall density of the sedimentary column could be caused by:

(a) a thickening of the relatively light Permian sediments

(b) a basinward decrease in density of the Lower Carboniferous, Devonian, and perhaps Ordovician sediments.

(4) The geological cross-section in Plate 15 illustrates a possible basement configuration. No attempt has been made on the section to estimate thicknesses of the variationsous formations other than the Permian.

(5) The anomalous disturbance shown on the derivative curves at SP 52 and 53 is probably related to near-surface effects, viz. variations in the thickness of alluvium.

(6) The calculated Bouguer anomaly profile shown in Plate 15 deviates appreciably from the observed values north of the Fenton Fault; the calculated values are too low. It is assumed therefore that the positive culmination shown in Plate 15 is partly caused by a near-surface intrabasement body. A BMR stratigraphic bore (Condon & Henderson, 1960b) penetrated relatively dense volcanics and metamorphics in this area.

(7) The 'possible regional' shown in Plate 15 probably reflects changes in crustal density; it was derived qualitatively. The usefulness of a qualitatively derived regional curve depends very much on the skill and experience of the person making the analysis. 'Possible regionals' are shown in Plates 15, 16, and 19. They have not been used for any quantitative analysis.

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The Fenton/Dampier Fault system is the geological boundary between the Broome Swell and Fitzroy Trough. It is represented by a steep continuous gravity gradient (12F, 13F & 14F). Five sections across the Fenton/Dampier fault system have been measured. The fault is expressed gravimetrically as a steep gravity gradient. Set out below is a table summarizing the properties of various Bouguer anomaly profiles across the fault:

TABLE 4

Location	Width (miles)	Amplitude (mGal)	Gradient (mGal/mile)	
20 miles southeast of Barnes Flow	6.0	22.0	3.7	Plate 17
6 miles southeast of Barnes Flow	7.0	26.0	3.7	Plate 16
4 miles northwest of Barnes Flow	7.4	21.5	2.9	
South of Nerrima No. 1	8.0	21.0	2.6	
Near Babrongan No. 1	4.0	14.0	3.5	Plate 18

Two possible explanations of the fault and associated anomaly profiles are given below:

(1) The simplest explanation is that the major part of the gravity gradient is caused by displacement along the Fenton Fault. The high Bouguer anomaly values of the Broome Gravity Ridge could be caused by near-surface intrabasement effects plus deep-seated basement effects.

(2) Because part of the gradient cannot be attributed to change in sedimentary thickness there is possibly a basement density change across the fault system. Plates 16 and 17 show that the gravity gradient immediately on the upthrown side of the fault is either reversed or reduced. The profiles suggest that the steep part of the gradient is associated with the displacement of sediments, while the less steep gradient would be associated with a basement density change.

The gravity gradient (12F, 13F & 14F) of the Fenton Fault is not linear. Small changes in direction of the gradient coincide with changes in direction of the surface expression of the fault. A directional changes is usually associated with a change in amplitude and gradient. The Fenton Fault is therefore probably a system of faults. It forms the northeast margin of unit F from central east MOUNT ANDERSON to central CROSSLAND. A reduced gradient continues southeast from this point to central CORNISH.

With respect to Plate 16, which shows a gravity profile across the Fenton Fault 6 miles southeast of Barnes Flow, it is noted that:

(1) The surface trace of the Fenton Fault occurs at a point where there is a pronounced change in gravity gradient.

(2) A pronounced second-derivative minimum coincides with the surface trace of the fault.

(3) The second-derivative maximum associated with the fault is not sharp, suggesting a variation in either the slope of the density discontinuity plane or of the density contrast.

(4) The residual 'high' southwest of the Fenton Fault could be caused either by a thinning in the Permian and Mesozoic sediments immediately on the upthrown side of the Fenton Fault or by dense intrabasement material injected along the fault plane.

(5) Seismic reflection data (Vale & Smith, 1959) were used as a guide in drawing the geological section.

A second profile which crosses the Fenton Fault in southwest NOONKANBAH is shown in Plate 17. On this profile the residual 'high' is more pronounced and there is a second residual 'high' which coincides with the surface expression of the Fenton Fault. The second-derivative maximum and minimum are more pronounced than in Plate 16, suggesting in general terms that the structure of the Fenton Fault is simpler in this area.

The Dampier Fault has been mapped seismically (WAPET, 1961b & 1962b). It is a subsurface fault which effects the Lower and Middle Palaeozoic and possibly the Lower Permian (Grant Formation).

Plate 18 shows a gravity profile across the Dampier Fault northwest of Babrongan No. 1 (WAPET, 1962b). The second-derivative curve across the fault is irregular. The presence and position of several large maxima and minima on the second-derivative curve suggest that:

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(a) because second-derivative culminations occur across the fault plane, consierable density variations could occur between the various sedimentary formations involved in the faulting.

(b) because second-derivative culminations occur southwest of the position of the fault as defined by the absence of seismic reflections, complex faulting including reverse faulting could occur.

Plate 19 is a Bouguer anomaly profile across the widest part of the Fitzroy Regional Gravity Complex from Barnes Flow to the Oscar Range and also shows the two important gravity ridges which border the Complex. The Complex is fault controlled along both margins (WAPET, 1962a).

A regional gradient, probably caused by basement density variations near the gravity ridges, is shown. The slope of the regional within the Complex is shown as .1 mGal per mile. The geological section shown in Plate 16 shows a thickness of 20 000 ft.

If the sedimentary thickness under the McLarty Syncline is 25 000 ft then the overall density contrast could be 0.08 g/cm^3 and the contrast between basement and the Lower and Middle Palaeozoics is about 0.05 g/cm^3.

As shown in Plate 18 the Dampier Fault has affected the Lower and Middle Palaeozoic rocks and a displacement of these sediments of at least 6000 ft is suggested from seismic reflection data. A throw in the Permian of 800 ft is suggested from seismic reflection data. Therefore:

(1) The variation in the thickness of the Permian sediments would cause a 2.5 milligal variation.

(2) A regional (basement) variation of 2 milligals across the width of the fault is assumed.

(3) A throw of about 6000 ft in the Devonian and Ordovician is thus represented by a drop of $14 - (2.5 + 2) = 9.5$ mGal, which gives a density contrast of 0.12 g/cm^3.

The above reasoning is based on several rather arbitrary assumptions, but nevertheless suggests that the basement to Lower Palaeozoic density contrast for the Jurgurra Terrace in the neighbourhood of the profile is about double that for the same discontinuity within the Fitzroy Trough. The Devonian and Ordovician sediments of the Fitzroy Trough are assumed (Guppy et al., 1958) to be of the deep-water type and of lower density than the shelf and reef sediments. However, it is possible that increased depth of burial has increased their density.

Feature 4D is an embayment southwest of feature 9C which occupies a position analogous to feature 2D. Because of this and its somewhat higher anomaly value it is assumed that the geological section in this area is similar to the Jurgurra Terrace because the Upper Carboniferous Anderson Formation is absent.

The narrow 'low' (1D) which extends seawards near Broome is possibly caused by a narrow shallow trough of Permian sediments. Permian was absent in Barlee No. 1 (WAPET, 1962a) which is situated 20 miles north of 1A.

In summary, the Fitzroy Trough is bounded on two sides by steep gravity gradients. On its northeast margin there is surface faulting, which coincides with steep gravity gradients. In the area of steepest gradient the gravity data suggest that the surface faulting is confined to the Permian and that the basement structure is a monoclinal flexure.

The Fenton/Dampier Fault, on the evidence of the illustrated gravity profiles, could affect both basement and sediments. The Fenton Fault is represented by a gravity gradient which in places is affected by basement density variations. It is possible that the Dampier Fault represents a lineament along which the Broome Ridge was overthrust on to the Fitzroy Trough. The Fenton and Dampier Faults are offset from each other, and cross-faulting has been mapped by seismic methods. Strong gravity gradients (13F) also suggest a cross-faulted connexion between the two fault systems.

There is evidence that the basement density varies across both fault systems. It is suggested that the basement along the Oscar and Broome Gravity Ridges is metamorphic and that the basement within the Fitzroy Trough is granitic. Variation in sedimentary density is likely to be affected by at least two factors:

(1) As noted in Appendix A the Devonian, Lower Carboniferous, and possibly Ordovician sediments are less dense within the Fitzroy Trough.

(2) Increased depth of burial within the Fitzroy Trough is likely to increase the overall sedimentary density.

No Lower and Middle Palaeozoic sediments have been cut by bores within the Fitzroy Trough.

Yeeda Gravity Platform (Unit E)

Northwest of the Fitzroy Gravity Trough is a group of anomalies which, unlike surrounding Units, do not possess a pronounced northwest trend. The overall trend is somewhat indefinite although some features strike northeast. Features 1E, 2E, and 3E have relatively high magnitude, and 4E and 5E constitute a pair of negative closed anomalies. Feature 6E, a relative 'high', extends seawards and is only partly mapped.

Two deep bores, Fraser River No. 1 and Barlee No. 1 (WAPET 1962a), have been drilled in the area. The geological information (WAPET 1962a; Brunnschweiler, 1957; Playford & Johnstone, 1959) shows that:

(1) The Mesozoic sequence is thicker here than within the Fitzroy Trough.

(2) The Permian sequence is much thinner here than within the deepest part of the Fitzroy Trough.

(3) The base of the Upper Carboniferous Anderson Formation has not been penetrated by either bore. The Anderson Formation is intruded by dolerite and gabbro which is therefore of Upper Carboniferous or younger age. Dolerite flows in the Upper Carboniferous were not detected in any deep bores drilled within the Fitzroy Trough.

Except for a small detailed survey near Barlee No. 1 (WAPET, 1961a), no detailed or semi-detailed gravity information is available for study. The following comments are based on a qualitative appraisal of the data:

(1) The relative 'high' (1E, 2E & 3E) is assumed to have as its source basic igneous material.

(2) The absence on a regional scale of sharp gradients within this 'high' suggests that the major part of the source is deep-seated.

(3) The general level of the Bouguer anomaly value compared with that in the Fitzroy Trough suggests that the rise in gravity anomaly could be due to a disturbing (igneous) mass of such size and density contrast as to produce an anomaly of amplitude as high as 40 mGal.

(4) However, thinning of the Permian to the northwest could cause an increase in the Bouguer anomaly and be a partial cause of the rise in Bouguer anomaly. From Grant Range No. 1 to Fraser River No. 1 the thickness decreases by about 3900 ft causing an increase in the Bouguer anomaly of 10 to 15 mGal.

Features 1E, 2E, and 3E are therefore caused partly by heavy intrabasement basic igneous bodies and partly by thinning of the relatively light Permian sediments. Feature 2E is a relative 'low' and is possibly due to a local thickening in the Permian or to a variation in igneous effects.

A major 'low' is formed by features 4E and 5E. Its source could be:

(a) A continuation of the sediments of the Fitzroy Trough including the Permian, but without igneous intrusions.

(b) A thick sequence of Mesozoic sediments.

(c) A granitic batholith.

(d) Upper Proterozoic sediments.

It is considered that (a) above is the most likely because the resultant geological picture would be the simplest. Features 6E is not completely mapped.

Broome Gravity Ridge (Unit F)

The Broome Gravity Ridge is a southeast-elongated gravity 'high' extending from Broome to central CORNISH. The shape and extent of the ridge in DUMMER and CORNISH are not well defined because the station density is low.

The northeast margin of the ridge is a prominent gravity gradient representing the Fenton/Dampier Fault system (12F-15F), along which considerable sedimentary displacement has taken place. The southwest flank of the unit is also a gravity gradient (16F & 17F) which is generally less intense than the northeast margin.

The Broome Gravity Ridge probably represents a present-day basement ridge with a relatively high density. Therefore the gravity effect of the ridge could be a combination of two effects: basement uplift, and basement density change.

The gradient, 16F and 17F, like gradients 12F to 15F is considered to have two causes: a change in basement effect and a change in sedimentary thickness. The degree to which one cause rather than the other is dominant should provide the key to the interpretation of the anomalies found on the Munro Gravity Platform.

Seismic (WAPET, 1964a) and drilling (WAPET, 1961c) results suggest that the basement southeast of anomaly 1F in LA GRANGE dips regionally to the southwest at a very low angle. Faulting across the southern margin has been detected, but the displacement is considerably less than that along the northern margin. The Broome Gravity Ridge probably represents a basement ridge, with considerable displacement (6000 - 20 000 ft) across its northeast margin and a small displacement (1000 to 10 000 ft) across the southwest margin. The gravity gradients (12F-15F and 16F-17F) corresponding to these margins are probably caused by sedimentary displacement and intrabasement density effects. This is now regarded as the most reasonable picture of the basement relationship for the Broome Gravity Ridge and the Munro Gravity Platform. However, it must be emphasized that only two wells in the area (Thangoo No. 1A & Goldwyer No. 1) have drilled to basement and that the seismic refraction results are not conclusive.

If it is assumed that the basement slopes to the southwest at a low angle, then features 1F-10F could represent shallow intrabasement effects. Irrespective of the basement configuration, the presence of a gravity ridge in this area has a structural significance, which is discussed in chapter 4.

9. NORTHEAST CANNING BASIN

The Northeast Canning Basin was first described by Casey & Wells, (1960). The corresponding gravity Province consists of the following gravity Units:

(1) Halls Creek Gravity Ridge (Unit G)

(2) Mount Bannerman Gravity Depression (Unit H)

(3) Stansmore Gravity Trough (Unit I)

(4) Billiluna Gravity Plateau (Unit J)

(5) Thornton Gravity Ridge (Unit K)

The above Units do not form a coherent gravity pattern in that the various Units are not aligned parallel to each other. Gravity coverage south of latitude 20° is sparse. As discussed in chapter 4 the various trends are probably related to Upper Proterozoic and Lower Palaeozoic sediments.

Halls Creek Gravity Ridge (Unit G)

The Halls Creek Gravity Ridge corresponds to extensive outcrops of the Halls Creek Metamorphics and Granites. The ridge is associated with the

Halls Creek Mobile Zone (Traves, 1955), and its southern margin marks the southern margin of a zone of tectonic activity.

Recent mapping (Smith, 1963) of GORDON DOWNS shows the Upper and Lower Proterozoic to be faulted by the Old Halls Creek Fault. This fault cuts the Upper and Lower Proterozoic rocks.

Regionally, the Halls Creek Metamorphics on west GORDON DOWNS are interpreted as forming an extensive northeast-trending anticlinorium. Granites of the Lamboo Complex crop out to the northwest of the anticlinorium in northwest GORDON DOWNS and northeast MOUNT RAMSAY.

Correlation of gravity and regional geology is good. The Lower Proterozoic anticlinorium occupies a relative 'high', while the granites occupy a relative 'low'. The regional significance of the ridge is discussed in chapter 4.

Mount Bannerman Gravity Depression (Unit H)

The Mount Bannerman Gravity Depression is an extensive gravity 'low' in southeast CROSSLAND, south MOUNT BANNERMAN, northwest BILLILUNA and south central GORDON DOWNS. The major trend is north-northeast in GORDON DOWNS while on MOUNT BANNERMAN it ranges from northeast to east. The extent of the feature to the northeast, in GORDON DOWNS, is unknown.

In BILLILUNA the depression crosses the basin margin without any appreciable variation in the Bouguer anomaly. The major cause of the anomaly is therefore not related to the Palaeozoic and Mesozoic sediments of the Canning Basin. The source may be expected to be either an extensive deep seated granitic batholith, or a thick sequence of Upper Proterozoic sediments.

The second possibility is preferred, because:

(1) From regional structural considerations, shelf sedimentation may be expected to have occurred in areas adjacent to the regional gravity ridges (G and K).

(2) A gravity traverse (Plate 20) crosses the Old Halls Creek Fault at Ruby Plains Homestead. Halls Creek Metamorphics crop out on the upthrown (west) side, while Upper Proterozoic sediments are mapped on the down thrown (east) side.

The measured thickness of the Upper Proterozoic is 7700 ft on the downthrown side of the fault (Smith, 1963) which implies a density contrast of 0.25 g/cm^3. This contrast, between Upper Proterozoic sediments and Lower Proterozoic metamorphics, suggests a density of approximately 2.85 g/cm^3 for the Lower Proterozoic.

The profile across the Lower Proterozoic shows a value of about -20 mGal over the Olympio Formation (Lower Proterozoic), while a 'high' of amplitude 9 mgals occurs over the more basic Biscay Formation (Lower Proterozoic). A density of 2.95 g/cm^3 (i.e. contrast of 0.15 g/cm^3) indicates a thickness for the Biscay Formation, suggested by Smith (1963), of 5000 ft.

A Lower Proterozoic to Upper Proterozoic density contrast of 0.25 g/cm^3 is close to a maximum value and this density contrast implies that a thickness of 7700 ft is a minimum. The minimum value obtained within the depression is -60 mGals for features 3H, 4H, and 5H implying, for a density contrast of 0.25 g/cm^3, a minimum sedimentary thickness of 12 000 ft.

It is possible that anomalies 1H, 2H, 3H, and 4H have both Upper Proterozoic and Palaeozoic sediments as their source. The degree and extent of any post-Upper Proterozoic sediments is a matter of speculation.

It is interesting to note that the sedimentary structure within the Upper Proterozoic sediments trends east-northeast. Feature 4H also trends east-northeast.

<u>Stansmore Gravity Trough</u> (Unit I)

A narrow north-trending gravity 'low' has been mapped in southwest BILLILUNA, west LUCAS, west STANSMORE, west WEBB, and north MACDONALD.

This Unit is bounded on the west by the Thornton Gravity Ridge. The area is poorly outlined, but it appears to be a narrow gravity trough flanked by gravity 'highs'. The trend of feature 2I is not substantiated by adequate gravity data, and it may be a separate Unit from the Stansmore Gravity Trough.

Plates 21 and 22 are profiles across the gravity gradient (4I) which correlates with the Stansmore Fault in STANSMORE. The fault is evidently nearly vertical and has a throw (for a density contrast of 0.25 g/cm^3) of about 8000-10 000 ft. As this is estimated on a relatively large assumed density contrast it is considered to be a minimum figure.

In BLOODS RANGE, the Bloods Range Gravity Ridge is associated with Upper Proterozoic sedimentation; therefore the Stansmore Gravity Trough, which is connected to the Bloods Range Gravity Ridge, probably contains mainly Upper Proterozoic sediments, although faulting in the Permian across the Stansmore Fault suggests that movement along the fault ranges in age from Upper Proterozoic to Permian.

Billiluna Gravity Plateau (Unit J)

The geological significance of the Billiluna Gravity Plateau is discussed in chapter 5.

Thornton Gravity Ridge (Unit K)

The Thornton Gravity Ridge is not well mapped. It is connected to the Bloods Range Gravity Ridge and is interpreted as a zone of Proterozoic orogenesis (see chapter 4).

10. MUNRO GRAVITY PLATFORM

The Munro Gravity Platform is an area of moderate Bouguer anomaly variation, bounded to the northeast by the Fitzroy Basin, to the southwest by the Anketell-Warri Gravity Ridge, and to the south by the Dummer Gravity Platform. The seaward extent of the Province is unknown.

The Munro Gravity Plateau is composed of three major gravity Units:

(1) La Grange Gravity Plateau (Unit L) which consists of five prominent linear gravity 'highs' and 'lows' trending southeast.

(2) Oasis Gravity Depression (Unit M), a major gravity 'low' on McLARTY HILLS.

(3) Joanna Springs Gravity Ridge (Unit N) which is an east trending 'high' in northeast ANKETELL, north JOANNA SPRINGS, and northwest DUMMER.

La Grange Gravity Plateau (Unit L)

The area of the La Grange Gravity Plateau corresponds with the La Grange Platform of Veevers & Wells (1961). It consists of five linear southeast-trending gravity lows and highs (1L, 2L, 3L, 4L & 5L).

Geological mapping does not provide any information on subsurface structure. Flat-lying Mesozoic sediments crop out in the area. One deep bore, Goldwyer No. 1 has been drilled on feature 1L between two negative culminations. Depth to basement was 4660 ft of which 1877 ft was Ordovician. Basement density as determined from a core was 2.62 g/cm^3, which is relatively low. Analysis of unweathered basement for the entire basin gives an average value of 2.73 g/cm^3. Therefore in summary:

(1) Goldwyer No. 1 was drilled on the saddle of a linear gravity 'low' (1L).

(2) There is evidence to suggest that the basement density in this area is relatively low.

Feature 1L is probably caused partly by low-density basement material. The density of the Ordovician ranges from 2.60 to 2.70 g/cm^3 and basement density from 2.62 to 2.78 g/cm^3. There is thus overlap in densities and density reversal is possible.

A BMR party carried out a reflection seismic survey near La Grange (Smith, 1960). The results indicate that the sediments are flat-lying, and two possible basement depths of 4400 ft and 8000 ft are suggested. The figure of 4400 ft is accepted by Veevers & Wells (1961) as being more likely from geological reasoning. The Bouguer anomalies in the area show little variation and could be related to basement effects.

A recent subsidized survey by WAPET (1964a) in east LA GRANGE suggests that sedimentary thickness is approximately 4000-5000 ft and increases to the southwest. There does not appear to be any correlation between gravity and geology in that the feature 1L does not represent a major sedimentary structure.

Drilling, seismic, and aeromagnetic data are all consistent with a uniform sedimentary thickness. If the sedimentary thickness is relatively uniform the observed features could represent basement density variations. The trend of these apparent density variations is parallel to the Broome and Anketell-Warri Gravity Ridges. It is reasonable to assume that geological events causing these anomaly variations are probably related to events that caused the two major gravity ridges (Broome and Anketell-Warri Gravity Ridges).

However, two closed features with relatively high negative amplitudes (1L & 5L) could have sediments as their source. The basement to Lower Palaeozoic density contrast is apparently low and therefore any thick accumulations of sediment of this age may have small effect. The density contrast at Goldwyer No. 1 is between 0.05 and 0.1 g/cm^3, and a variation in Lower Palaeozoic sedimentary thickness of 10 000 ft on this basis would cause a variation in Bouguer anomaly of only 6 to 12 mGal. Therefore the pattern produced by large horizontal variations in thickness should be of low order and difficult to separate from deep-seated effects. Geological data from bores, which are few and widely separated, suggest that in this area variations in thickness of the Permian and Mesozoic would not be great. From Goldwyer No. 1 to Samphire Marsh No. 1 the Mesozoic thickness increases from 1566 to 2258 ft while the Grant Formation thickens from 750 to 1811 ft. Poole Sandstone (467 ft thick) is present in Goldwyer No. 1 but is absent in Samphire Marsh No. 1; variations in thickness of the Mesozoic and Permian do not appear to be great.

Oasis Gravity Depression (Unit M)

The Oasis Gravity Depression is a large gravity 'low' with two important culminations (1M & 2M) in south McLARTY HILLS. Gravity gradients within the unit are gradual. The northeast and southwest boundaries are fairly steep gravity gradients (16F, 5M & 5N).

There is a single BMR aeromagnetic traverse extending southeast across unit M and additional aeromagnetic work has been done recently by WAPET (1964b). The BMR profile suggests a sedimentary thickness of less than 3000 ft over the Broome Gravity Ridge (F) and less than 10 000 ft over the Oasis Gravity Depression, while the WAPET data suggest thicknesses of up to 12 000 ft. Bouguer anomaly variation between the ridge and the depression is approximately 60 mGal. The basement density variation on the north side of the Broome Ridge is postulated to cause a variation of 15 to 20 mGal. A similar effect across the southern margin of the Broome Ridge could also cause 15 to 20 mGal of relief. The possible sources of the depression are listed below:

(1) The anomaly variation from the ridge to the depression is caused entirely by variations in sedimentary thickness. If the density contrasts relative to basement for Mesozoic, Upper Palaeozoic, and Lower Palaeozoic sediments are taken as 0.4, 0.25, and 0.1 g/cm^3 respectively, the approximate maximum corresponding sedimentary thickness for the various ages assuming that all sediment was of the same age would then be:

Mesozoic	-	12 000 ft
or		
Upper Palaeozoic	-	20 000 ft
or		
Lower Palaeozoic	-	40 000 ft

(2) The sedimentary thickness, according to the figures obtained from the aeromagnetic survey, has a variation of 7000 ft. The anomaly variation would then be:

(a) Mesozoic sediments	35 mGal
Basement effect	25 mGal
or	
(b) Upper Palaeozoic	22 mGal
Basement effect	38 mGal
or	
(c) Lower Palaeozoic	9 mGal
Basement effect	51 mGal

But if, as stated above, a shallow basement effect of 20 mGal across the southern margin of the Broome Gravity Ridge exists then there could be a maximum sedimentary effect of 40 mGal. The Bouguer anomaly values show a regional decrease (Plate 5) toward the southwest, and if a gradient caused by crustal effects of 0.1 mGal/mile is assumed, then the total basement effect over 100 miles could be 30 mGal with a maximum sedimentary effect of 30 mGal. For the sediment to basement density contrasts mentioned in (1) the thickness would be:

Mesozoic	5900 ft
or	
Upper Palaeozoic	9400 ft
or	
Lower Palaeozoic and Upper Proterozoic	23 500 ft

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There is a possibility that the gravity variation lies wholly within the basement. The source of the unit M would then probably be a granitic batholith or similar structure.

The possibilities described above refer to extreme cases, and the most likely situation is a combination of some of the possibilities described. The following points should be noted:

(1) Basement depth calculations carried out on magnetic data suggest a variation in thickness of 7000 ft within the area.

(2) Since at least 30 of the 60 mGal total contrast can be reasonably attributed to a basement effect, it can be assumed that 30 mGal of the anomaly difference is caused by sediments.

(3) Boreholes in the coastal area have penetrated a maximum thickness of 1500 ft of Mesozoic sediments, and it is suggested that this is a maximum figure for the area.

(4) The thickness of the Upper Palaeozoic is assumed to range from 1500 to 7000 ft. The average thickness of the Permian on the La Grange Platform (Veevers & Wells, 1961) is 1500 ft. The thickness of the Permian outside the Fitzroy Trough is nowhere greater than 7000 ft. Up to 14 000 ft of sediments of this age could be postulated if the area was one of major Permo-Carboniferous sedimentation such as the Fitzroy Trough. There is no direct geological evidence for the presence of Lower Palaeozoic and Lower Proterozoic sediments.

The steepest bordering gradients of the feature extend generally east along the northern margin of the Joanna Springs Gravity Ridge (N). It is probable that the Joanna Springs Gravity Ridge represents an east-trending basement ridge and that extensive sedimentation within the area of the depression was related to tectonic activity along the ridge. No other major east-trending gravity features have been mapped in the Canning Basin. It is interesting to note that the Cambro-Ordovician and Upper Proterozoic sedimentation of the Amadeus Basin also trends east. This may be taken as weak evidence of related tectonism, thus leaving open the slight possibility of extensive thick sedimentation in the Lower Palaeozoic and Upper Proterozoic.

The following is a possibility:

(a)	Mesozoic	1500 ft	(Maximum from drilling data and Veevers & Wells, 1961)
(b)	Permian	1500 ft	(Maximum from Veevers & Wells, 1961)
(c)	Lower Palaeozoic and Upper Proterozoic	12 000 ft	(Maximum to which Bouguer anomaly can be attributed).

This gives a maximum total thickness of 15 000 ft.

Joanna Springs Gravity Ridge (Unit N)

The Joanna Springs Gravity Ridge is an east-trending gravity 'high' extending from southwest MUNRO to northwest DUMMER. Gravity control for this feature is not complete except along its northern margin. Some of the individual anomalies (3N & 4N) are poorly defined and it is therefore impossible to detect any steep gradient anomalies. The gravity change from the Oasis Gravity Depression to the Joanna Springs Gravity Ridge is 20 to 30 mGal. The source of the ridge could be:

(a) An intrabasement phenomenon.

(b) A basement ridge with the absence of Lower Palaeozoic and Upper Proterozoic sediments plus a slight increase in basement density.

The only other subsurface information is a single aeromagnetic traverse which does not indicate any structural change. Case (b) is preferred because the steep gradient along the northern flank of the feature suggests a source close to the surface rather than density phenomena deep within the crust.

11. ANKETELL-WARRI REGIONAL GRAVITY RIDGE

The Anketell-Warri Regional Gravity Ridge is an extensive linear gravity 'high' trending southeast from the coast on MANDORA. It has been shown in some detail to extend to the southern boundary of ANKETELL. Further mapping to the south of ANKETELL has shown that it extends in length over some hundreds of miles. In this report the part forming the southwest margin of the Basin is discussed.

Three gravity units within the ridge are recognized:

(1) Mandora Gravity Plateau (unit O)

(2) Rudall Gravity Plateau (unit P)

(3) Patience Well Gravity Plateau (unit Q)

The regional structural implications of this Province were discussed in chapter 4 in which it was stated that because of its large dimensions the ridge is postulated as marking the axis of a zone of major tectonic activity.

The ridge is bordered along both sides by intense gravity gradients. There is insufficient gravity detail to determine the definite shape of the gradients, so speculation on the related rock and density discontinuities is very tentative. Plate 23 shows an east trending cross-section across ANKETELL. The section has the following properties:

(1) The 'high' is bordered by intense gradients on both sides.

(2) The crest of the 'high' is fairly flat and there are minor anomaly fluctuations of relatively short wavelength.

(3) The eastern 'low' which is a feature of the Ural Gravity Depression (1T) is interpreted on aeromagnetic evidence as covering an area of considerable sedimentary thickness.

The western 'low' has been incompletely mapped, and the nature of its source is conjectural.

Plate 24 shows a profile across the ridge near the coastline. It should be noted that:

(1) The ridge is wider here than in ANKETELL and is asymmetrical.

(2) There is a marked positive culmination associated with the southwest margin of the ridge.

(3) The northeast margin of the feature is not prominent, but it is recognized as such by virtue of its continuity with the same gradient in ANKETELL.

(4) The Bouguer anomaly shows a regional reduction in value toward the north. The average gradient of the anomaly over this part of the profile is 0.35 mGal/mile.

(5) In Plate 24 the gravity variations are of relatively large amplitude and short wavelength, indicating near-surface sources. Therefore the northern part of the Province (10 to 80) can be divided into two parts:

(1) An intense gravity 'high' which could be caused by a dense intrusive body, possibly related to a fault line (See chapters 4 & 5).

(2) A wide zone in which the anomaly value is relatively high and wavelength short. The anomalies in this zone exhibit a regional decrease to the northeast which is possibly of deep-seated origin. (See Plate 24). It is not possible to assign a probable geological source to the component features of this zone and in particular to differentiate between intra-basement density variations and basement topography variations.

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According to Playford & Johnstone (1959) drilling and seismic data suggest that at least one of the 'lows' is of sedimentary origin.

Despite sparse gravity data in PATERSON RANGE, RUDALL, TABLETOP, RUNTON, and MORRIS it has been possible to trace the southern extent of the ridge (unit P) from ANKETELL to WARRI where it is continuous with the 'high' in WARRI, BROWNE, COBB and BENTLEY (unit Q).

Feature 1Q is a gravity spur that appears to link the Patience Well Gravity Plateau with the Thornton Gravity Ridge, and this represents the probable southern margin of the Canning Basin separating it from the Officer and Amadeus Basins.

12. SOUTH CANNING BASIN REGIONAL GRAVITY LOW

The South Canning Basin Regional Gravity Low is bounded on all sides by prominent gravity ridges. The three major bounding gravity Units are the Anketell-Warri Regional Gravity Ridge (Units O, P, & Q), the Joanna Springs Gravity Ridge (Unit N), and the Thornton Gravity Ridge (Unit K). The southeastern end of the Broome Gravity Ridge (Unit F) forms a part of the northern margin.

The Province can be divided into three main areas:

(1) Dummer Gravity Platform (R)

(2) Helena Gravity Shelf (S)

(3) Ural Gravity Depression (T)

The area is in general characterized by low Bouguer anomalies. Bouguer anomaly values away from the bordering ridges range from -45 to -80 mGal. Within the area there is a regional negative trend towards the southeast. The effect of elevation changes on this negative trend is discussed in chapter 5.

It is assumed that the source of the unusually low Bouguer anomalies is partly sedimentary. Surface geological data are sparse and the estimated maximum thicknesses are assumptions relating to relative contributions to the low Bouguer anomaly from the crust and the sedimentary column. The gravity/aeromagnetic correlation is reasonable and the maximum depth suggested by the aeromagnetic evidence (WAPET, 1964b) of 30 000 ft is consistent with the low Bouguer anomalies and density assumptions. Assuming that the gradient away from the coast arising from deep-seated sources is 0.14 mGal per mile, then within the area, 5 to 30 mGal can be attributed to

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near-surface (sedimentary and basement) phenomena. Using the average density contrasts (Appendix A) the following source conditions could hold:

(a) Granitic batholith

(b) Mesozoic 1500 ft, Permian 5000 ft, Lower Palaeozoic and Upper Proterozoic 5000 ft. Total thickness 11 500 ft.

(c) Mesozoic 500 ft, Permian 1500 ft, Lower Palaeozoic and Upper Proterozoic 18 000 ft. Total thickness 20 000 ft.

While the aeromagnetic evidence favours thick sediments, it is possible that the major source is a non-magnetic acidic granite. However, of the three possible sources quoted above (c) is considered to be the most likely for the following reasons:

(1) aeromagnetic data suggest 30 000 ft of sediments.

(2) as discussed in chapter 4 a gravity 'low' adjacent to a major Gravity Ridge is likely to be caused by a considerable thickness of shelf sediments.

The following are areas where sediments in excess of 20 000 ft are more likely to occur:

(1) The central part of the Ural Gravity Depression

(2) Features 2R, 4R, 1S, 2S, and 3S.

13. CONCLUSIONS

The following general conclusions have resulted from a study of the gravity data:

(a) The Canning Basin sediments, in particular those of the South Canning Basin, are separated from the Amadeus and Officer Basins by basement uplifts which are marked by gravity ridges. From a generalized consideration of the gravity ridges and their structural significance, it is further concluded that these ridges are related to ancient zones of tectonic activity and thus divide from each other zones of different sedimentary environments.

(b) The gravity results show that the Fitzroy Basin consists of a central trough, separated by faults and monoclinal flexures from two basement ridges. This is in agreement with the geology of the Fitzroy Basin (Veevers & Wells, 1961) as well as the seismic and aeromagnetic surveys of the area. Both marginal gravity ridges are of tectonic significance in that the Oscar Gravity Ridge is correlated with Proterozoic (Upper and Lower) tectonic activity and the Broome Gravity Ridge with Devonian tectonic activity.

The northwestern margin of the Fitzroy Trough is characterized by Bouguer anomalies which are attributable to post-Carboniferous volcanic activity.

(c) Two major gravity 'lows' have been mapped within the Northeast Canning Basin. From consideration of gravity and geology these 'lows' probably represent a thick sequence of Upper Proterozoic sediments.

(d) The Munro Gravity Platform covers an area in which the sedimentary thickness, from considerations of geology and seismic, aeromagnetic and gravity results, is less than 10 000 ft. But, two areas where thick sediments might occur have been delineated by the gravity data; one is localized and the other of regional extent. The southern margin of the Munro Gravity Platform is a basement ridge represented by the Joanna Springs Gravity Ridge.

(e) The Anketell-Warri Regional Gravity Ridge is a major gravity feature which probably spans the continent from northwest to southeast. Most of the individual anomalies which occupy the ridge are believed to be attributable to intrabasement phenomena and elevated basement topography.

(f) An extensive gravity 'low', the South Canning Regional Gravity Low, corresponding to the South Canning Basin is caused partly by thick sediments. Despite the sparse gravity coverage two separate 'lows' have been delineated, an east-trending 'low' and a major northwest-trending 'low' which borders the Anketell-Warri Regional Gravity Ridge. Because of the spatial relations of these 'lows' to the Joanna Springs and Anketell-Warri Gravity Ridges, the age of thick sediments could range from Upper Proterozoic to Ordovician.

(g) An examination of the elevation-corrected Bouguer anomalies suggests that, for the coastal areas at least, the Canning Basin is in regional isostatic equilibrium.

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APPENDIX A

DENSITY OF ROCK FORMATIONS

A considerable amount of density data on rocks from the Canning Basin has been collected. Some density determinations have been made on surface samples, but the most important measurements have been made on cores from deep bores. Set out below is a table showing the number of determinations made on various rock units:

TABLE 1

Rock Unit	Number of determinations	Average density g/cm^3	Variation (standard deviation) g/cm^3	Comments
Mesozoic	25	2.1	0.1	
Liveringa Formation (Permian)	4	2.6	(0.2)	
Noonkanbah Formation (Permian)	43	2.34	0.14	
Poole Sandstone (Permian)	56	2.28	0.12	
Grant Formation (Permian)	131	2.44	0.04	
Anderson Formation (Upper Carboniferous)	168	2.57 (2.50) (2.65)	0.10	The data suggest a bimodal density distribution.
Laurel Formation (Lower Carboniferous)	16	2.65		Langoora No. 1, Meda No. 1, Hawkstone Peak No. 1
Devonian - non-reef formations	57	2.63	0.08	Mainly determinations on Fairfield Formation and Clanmeyer Siltstone.
Devonian reef complex	85	2.70	0.1	Large density variations recognized within the complex.
(a) Terrigenous facies	6	2.61	0.04	
(b) Porous dolomite facies	31	2.72	0.06	
(c) Reef complex	12	2.74	0.07	
(d) Back reef facies	27	2.71	0.07	
(e) Sandstone unit	4	2.55	0.04	
(f) Basal conglomerate	5	2.69	0.04	
Laurel Formation	13	2.55	0.04	Laurel Downs BMR No. 2
Fairfield Formation	5	2.57	-	Offshore equivalents of Devonian reef facies found in Laurel Downs BMR No. 2
Virgin Hills Formation	17	2.51		
Gogo Formation	5	2.51		

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Rock Unit	Number of determin-ations	Average density g/cm^3	Variation (standard deviation) g/cm^3	Comments
? Virgin Hills Formation	7	2.71		Babrongan No. 1
Goldwyer Formation (Ordovician)	7	2.59	0.06	
Thangoo Limestone (Ordovician)	28	2.71	0.2	
Lower Ordovician (Samphire Marsh No. 1)	9	2.60	0.06	
All Ordovician (including surface samples from Prices Creek)	50	2.62	0.10	
Upper Proterozoic sediments	2	2.60	-	Surface samples only
Gabbro and dolerite intrusives	5	2.93	0.02	
Leucitite lamproite intrusives	3	2.40	-	This value considered low as petrological examination suggests a basic parent magma.
Basement (all determinations)	15	2.73	0.06	
Granitic basement	1	2.70		Samphire Marsh No. 1
Granitic basement	1	2.62		Goldwyer No. 1
Slate & phyllite	4	2.74		Thangoo No. 1A
Biotite-chlorite-hornblende schist	2	2.85		Langoora No. 1
Metaquartzite	1	2.67		Hawkstone No. 1
Schist and quartzite	3	2.71		Meda No. 1
Lower Proterozoic metamorphics	2	2.82		Surface samples

A major density discontinuity occurs between the Mesozoic and older rocks. However, the Mesozoic is not believed to be anywhere thicker than 2500 ft. A second discontinuity occurs between the Permian and older sediments while a third discontinuity is between the oldest sediments (Ordovician to Upper Proterozoic) and the basement. The table below summarizes the densities which may be considered appropriate for present analysis of the regional gravity data. It must also be remembered that important density discontinuities occur in the basement and that the densities within the Lower Proterozoic metamorphics range from 2.7 to 3.0 g/cm^3.

TABLE 2

Age of rocks	Density, g/cm^3
Mesozoic	2.10
Permian	2.40
Upper Carboniferous	2.55
Lower Carboniferous) Devonian) Ordovician) Upper Proterozoic)	2.60
Devonian reef facies	2.70
Basement (granitic)	2.70
Basement (high-grade metamorphics)	2.85
Intrusives	
Gabbro	3.0
Leucitite lamproite	? 2.4

Important local density changes occur in the Devonian. Reef development has taken place along the Oscar Ridge and the density of the reef complex averages 2.70 g/cm^3. This high value of density means that reef development will probably show as a Bouguer anomaly 'high' (or residual high). The Devonian rocks also show important horizontal density variations. Densities of the Devonian rocks cut in BMR 2, Laurel Downs, are considerably lower (Condon & Henderson, 1960a) than those to the northeast on the Lennard Shelf.

Devonian sediments occurring within the Fitzroy Trough are likely therefore to have a density of approximately 2.50 to 2.65 g/cm^3.

Devonian rocks sampled in Babrongan No. 1 include a dolomitic formation which is probably equivalent to the Virgin Hills Formation. The density of this formation is relatively high.

Basement rocks are broadly of two types:

(1) High-grade metamorphics of Lower Proterozoic age which are intruded in places by basic igneous rocks. The overall density of these rocks is high and probably averages 2.85 g/cm^3.

(2) Granite and granitic gneisses, which intrude the metamorphics but are assumed to be of Lower Proterozoic age.

In this report the Upper Proterozoic sediments are considered to be a part of the sedimentary column. In places the sediments have been metamorphosed and folded. The density for the unaltered sediments is 2.60 g/cm^3; when mildly metamorphosed their density is likely to be about 2.70 g/cm^3.

Other formations which exhibit horizontal density variations are the Anderson and Laurel Formations.

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APPENDIX B

CLASSIFICATION OF BOUGUER ANOMALIES

Bouguer anomaly contours, which are used to illustrate the anomaly pattern over large areas, are presented on a map base at a scale of 40 miles = 1 inch. For a station density of one station per 50 square miles or better, contours are shown at 5-milligal intervals.

Areas of distinctive contour pattern characteristics are recognized on the map and these features are classified according to size:

(i) Gravity Province. Usually a large area over which the gravity pattern exhibits at least one characteristic property, such as trend, or where there is a clear correlation of a Bouguer anomaly with a major geological entity. Within the Canning Basin, the average size of a province is 24 000 square miles.

(ii) Gravity Unit. A gravity unit is a major anomalous area but is smaller than a gravity province; the pattern exhibits at least one characteristic property, such as trend. The average size of a unit is 8000 square miles. A province may contain one or more gravity units.

(iii) Gravity Subunit. A gravity subunit is a single Bouguer anomaly feature; it is usually a 'low' or a 'high' with at least one closure, a gradient, or part of a gradient.

Characteristic properties of a Bouguer anomaly feature are:

(i) Trend - The Direction of the contour lines of the major gradient is called the trend of a gravity feature.

(ii) Sign - Whether Bouguer anomaly feature has positive or negative closure relative to the background value.

(iii) Amplitude - The value of a Bouguer anomaly feature relative to the background value.

(iv) Intensity - The intensity of a Bouguer anomaly feature is defined as the ratio of anomaly amplitude to half-width.

(v) Shape - The shape of an anomaly can be expressed as the ratio length of major axis to length of minor axis.

All of the above properties are capable of quantitative description. When gravity Provinces are recognized, the most important characteristic properties are trend and shape.

APPENDIX C. DEEP BORES IN THE CANNING BASIN

Name	Authority	Depth (ft)	Bottomed in	Date	Thickness penetrated (feet)						
					Mesozoic	Permian	Upper Carbon-iferous	Lower Carbon-iferous	Devonian	Ordovician	Cambrian
Bahrongan No. 1	WAPET	6395	Devonian	1962	230	1953	-	-	4200+	-	-
Barlee No. 1	WAPET	8101	Upper Carboniferous	1960	1562	-	6507+	-	-	-	-
Dampier Downs No. 1	WAPET	3028	Ordovician	1956	1022	1588				403+	
Fraser River No. 1	WAPET	10,144	Upper Carboniferous (gabbro intrusion)	1955-56	678	4262	5065(+?)	-	-	-	
Frome Rocks No. 1	WAPET	4003	Rock salt (age uncertain)	1958	694	-	-	-	1522	?1747+ (Rock Salt)	
Frome Rocks No. 2	WAPET	7500	Devonian	1959	176	3351	-	-	3947+		
Goldwyer No. 1	WAPET	4720	Precambrian (Granite)	1958	1500 (Approx.)	1217				1877	
Grant Range No. 1	WAPET	12,915	Upper Carboniferous	1954-55	-	7800	5115+	-	-	-	-
Hawkstone No. 1	WAPET			1963	-	751	-	379	2675	-	-
BMR No. 1 (Jurgurra Ck)	BMR	1680	Permian (Poole Sandstone)	1955	-	1600+					
Langoora No. 1	WAPET		Precambrian (Schist)	1963	314	3729	143	580	370	-	-
BMR No. 2 (Laurel Downs)	BMR	4000	Devonian	1955-56		170		1400	2390		
Meda No. 1	WAPET	8809	Precambrian (Schist)	1958	654	3487	734	548	3380	-	-
Meda No. 2	WAPET	7628	Devonian	1959	Not available						
Mount Wynne No. 3	Freney-Kimberley Oil Co.	2154	Permian (Grant Formation)	1923-25	Not available						
Myroodah No. 1	Associated Freney Oil Fields N.L.	6001	Permian (Grant Formation)	1955-56	-	6001+	-	-	-	-	-
Napier Downs	W. Aust. Govt.	1587	Precambrian (quartzite)	?	Total Depth 1587 in Precambrian						
Nerrima No. 1	Associated Freney Oil Fields N.L.	9072	Upper Carboniferous	1955		8010	1062+				
Poole Range No. 3	Freney-Kimberley Oil Co.	3264	Permian	1927-30	Not available						
Prices Creek No. 1	Freney-Kimberley Oil Co.	1008	Ordovician	1922	"	"					
BMR No. 3 (Prices Creek)	BMR	694	Precambrian (metamorphics and volcanics)	1956						680 (Approx.)	
Roebuck Bay No. 1	WAPET	4000	Ordovician	1956	1533	1787				659+	
Samphire Marsh No. 1	WAPET	6664	Precambrian (granite)	1958	2224	1811				2141	?400
Sisters No. 1	Associated Freney Oil Fields N.L.	9828	Devonian	1956-57	500 (Approx.)	4150	667	340	3638	-	-
67-mile bore	W. Aust. Govt.	3012	Precambrian (quartzite)	1906-10		1000 (Approx.)			1433		
Thangoo No. 1A	WAPET	5429	?Precambrian (phyllite)	1959-60	1366	1377				2318	
BMR No. 4A (Wallal)	BMR	2223	Precambrian (granitic gneiss)	1958	1912	234					

APPENDIX D

HISTORY OF SURVEYS

A 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.

Some of the gravity data have been analysed in four unpublished BMR reports (Wiebenga & van der Linden, 1953; Everingham, 1962; Flavelle & Goodspeed 1962; Lonsdale & Flavelle, 1963).

Year	Type	Remarks
	(a) Gravity	
1952	Semi-detailed gravity	Studied the Nerrima Dome and Fenton Fault. Report by Wiebenga & 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	Reconnaissance gravity	Canning Basin. Barometer. Helicopter survey.
1962	Reconnaissance gravity	South Canning Basin. Barometer. Helicopter survey.

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Year	Type	Remarks
	(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.
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.
1962	Seismic reflection and refraction	Poole Range area.

In 1954 BMR 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 the work done prior to 1960 has not been published. However, for the vicinity of Sisters No. 1 and Nerrima No. 1 WAPET has released gravity data on a 10 x 5 mile grid basis. Since 1960, most of the private company geophysical work has been subsidized by the Australian Government and has been made public. Associated Freney Oil Fields N.L. has done detailed gravity and seismic traversing, but the results have not been published.

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

In recent years, a number of geophysical surveys by private companies and subsidized by the Australian Government have been carried out by Hawkstone Oil Company (1963), Oil Development N.L. (1963), and WAPET (1963a, 1963b, 1963c, 1963d, 1964d).

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APPENDIX E

COMPUTATIONAL METHODS

Most of the Fitzroy Basin has been covered by conventional land gravity surveys. However, an extensive part of the central and southern part of the Basin has been covered by helicopter gravity surveys. Station density for the helicopter surveys ranges from 1 per 50 sq. miles with regular station spacing to 1 per 250 sq. miles at irregular intervals. The helicopter gravity coverage to the south and southeast of the Basin is on a regular 7 x 7 mile grid.

The accuracy of the individual Bouguer anomalies ranges from 0.2 mGal for detailed surveys to 2-3 mGal for regional surveys. The maximum error for the systematic helicopter survey stations is less than 2 mGal.

Helicopter Gravity Surveys

When helicopters are used as transport for the gravity meters the elevations are obtained by barometer. The resulting uncertainty in elevation is the major source of error in the Bouguer anomalies. The standard deviation of the elevation error is close to 7 ft.

Automatic computing procedures are used for calculating the Bouguer anomaly from the raw data. The following corrections are made to the readings:

A. Gravity

(1) Correction for instrumental drift

(2) Correction for internal loop misclosures combined with

(3) Correction for ties to external fixed stations.

B. Barometric

(4) Correction for instrumental drift

(5) Correction for diurnal barometric changes

(6) Correction for air temperature and humidity

(7) Correction for internal loop misclosures combined with

(8) Correction for ties to external fixed stations.

(9) Correction for isobaric gradient.

C. Bouguer Anomalies

(10) Correction for latitude (theoretical anomaly)

(11) Correction for elevation (combined Bouguer and free-air correction)

The Bouguer anomaly is not corrected for:

(1) Near-surface geological phenomena such as variations in the thickness of alluvium.

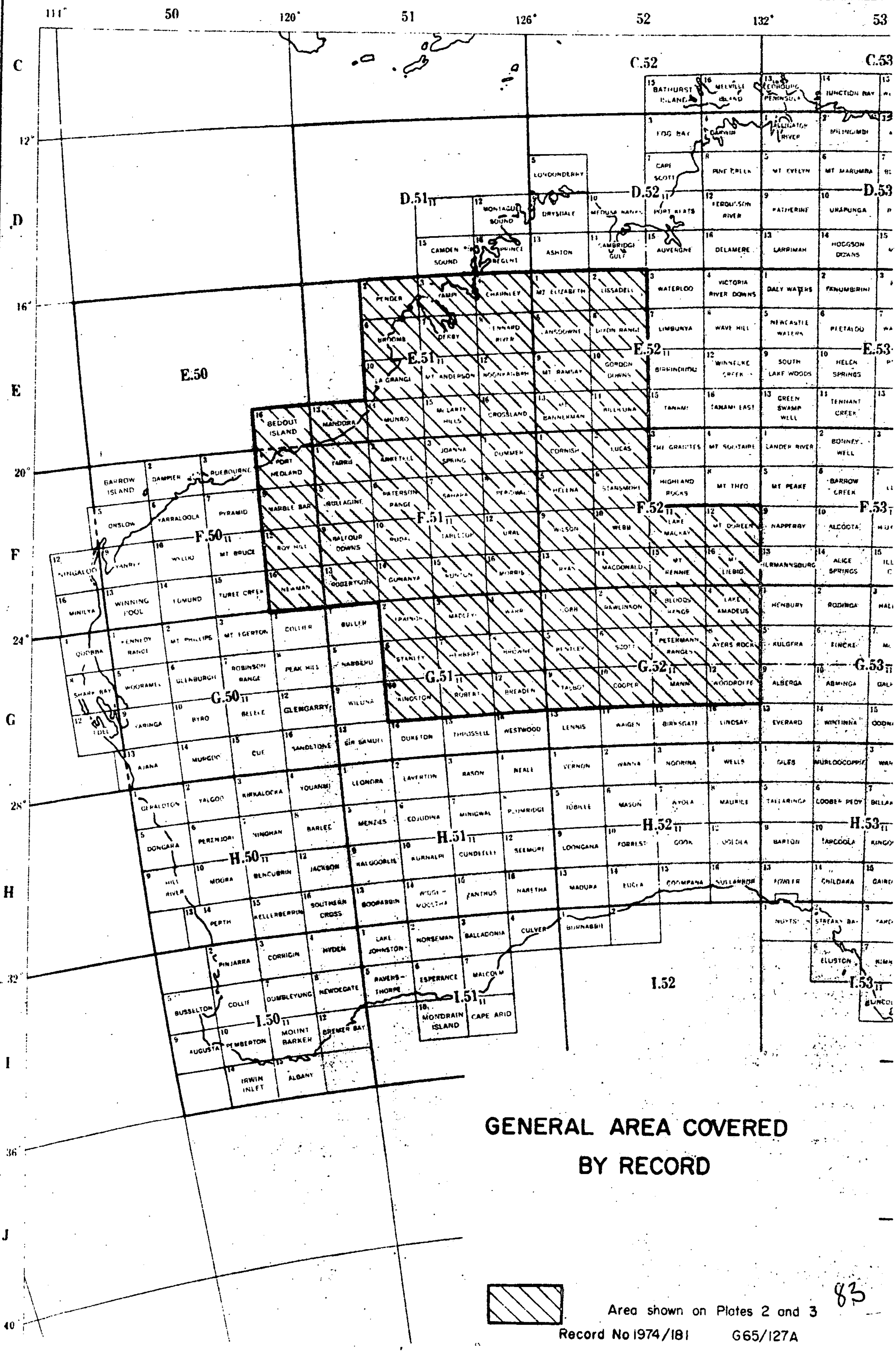
(2) Topographic effects

Mathematical Techniques

The 'possible geological cross-sections' presented were tested on the automatic computer. Each body was drawn in the shape of a polygon and assigned a density. The automatic computer was used to calculate a Bouguer anomaly profile given the shape of the individual bodies and their densities. An exact correspondence with the observed Bouguer anomaly was not attempted.

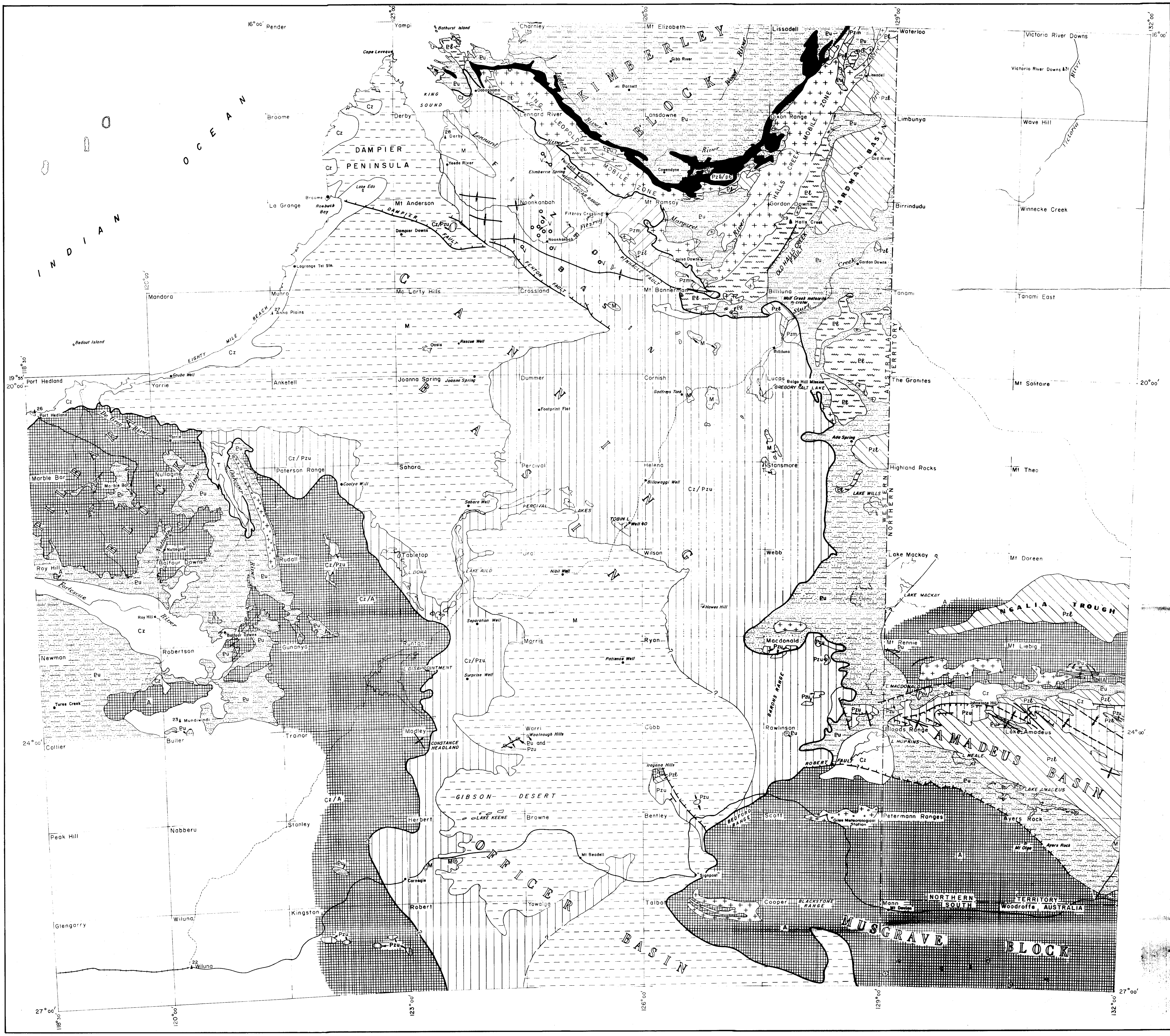
The recent horizontal derivative curves shown in some of the figures were calculated from the actual anomaly values recorded at closely spaced stations (1/2 or 1/4 mile station intervals). The resultant curve is most sensitive to near-surface effects but in general (Bott, 1962) major maxima and minima points on the curve are caused by changes in direction of density discontinuity planes.

The work was done on a Ferranti Sirius computer operated by Monash University. The programs have been described in detail by Bott (1962).

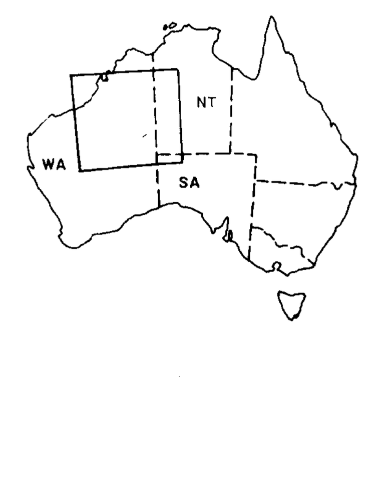


GENERAL AREA COVERED BY RECORD

Record No 1974/181 G65/127A



LOCATION



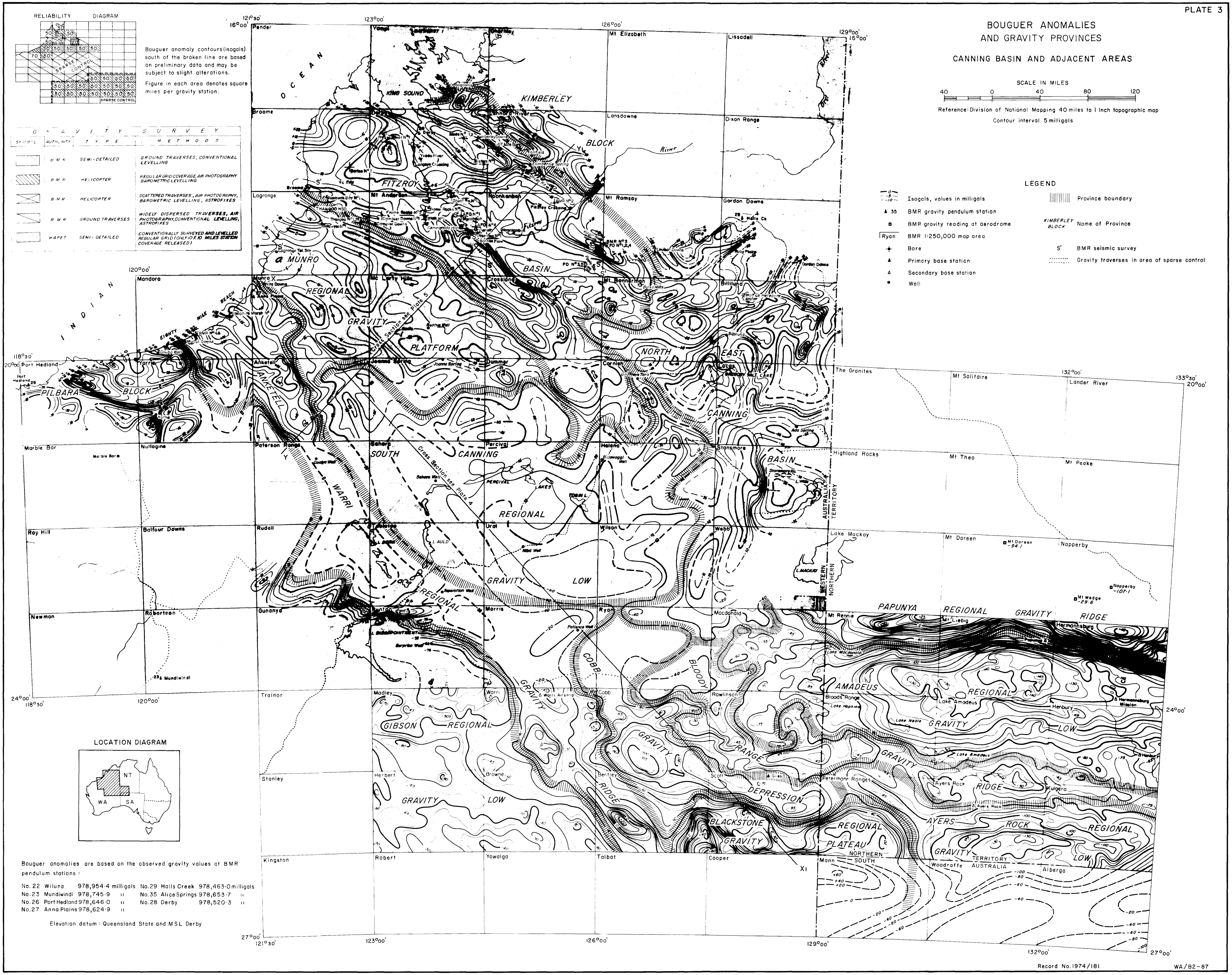
▲31	BMR gravity pendulum station
Mann	BMR 4-mile or 1:250,000 gravity map area
	Railway
	Road
	Basin boundary
	State boundary
	Fault; Fault, indefinite
	Anticlinal axis
	Synclinal axis

Cz	Alluvium, limestone		Cainozoic
T	Marine and continental sediments		Cainozoic
M	Sandstone, siltstone, shale	Mesozoic	
Pzu	Marine and continental sediments	Upper	Palaeozoic
Pzm	Mainly limestone, shale, sandstone, and siltstone	Middle	Palaeozoic
Pzℓ	Lower Palaeozoic	Lower	Palaeozoic
Pzℓ/pЄ	Belt of Lower Palaeozoic basic intrusions following edge of Kimberley Block		
Pu	Mainly sandstone and shale		Proterozoic
Pℓ	Metamorphic rock		Proterozoic
	Porphyry		Proterozoic
A	Archaean (undifferentiated including Proterozoic)		
+ +	Granite		
o V	Leucitite - Lamproite intrusives		

CANNING BASIN AND ADJACENT AREAS
GEOLOGY

40 0 40 80 120 MILES

Geology after Veevers and Wells (1961), BMR tectonic map of Australia and 1:250,000 geological mapping



Bouguer anomalies are based on the observed gravity values at BMR pendulum stations :

No. 22	Wiluna	978,954·4 milligals	No. 29	Halls Creek	978,463·0 milligals
No. 23	Mundiwindi	978,745·9 "	No. 35	Alice Springs	978,653·7 "
No. 26	Port Hedland	978,646·0 "	No. 28	Derby	978,520·3 "
No. 27	Anna Plains	978,624·9 "			

Elevation datum : Queensland State and MSL Derby

Record No. 1974/181

WA/B2-87

PLATE 4

HORIZONTAL SCALE

MILES 0 25 50 75 MILES

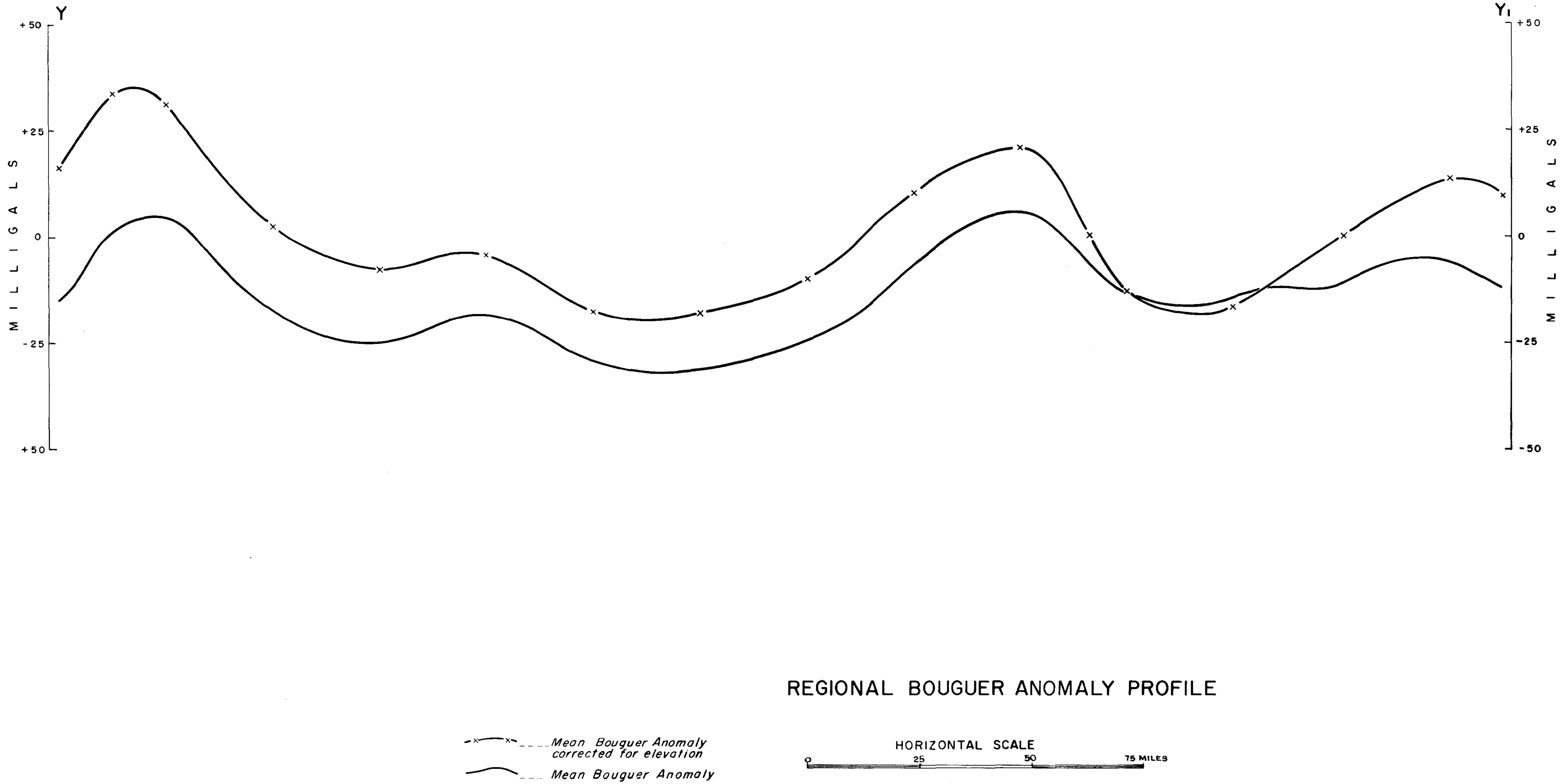
REGIONAL BOUGUER ANOMALY PROFILE, ALONG X–X1

Record No 1974-181

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

F51/B2-17

PLATE 5



REGIONAL BOUGUER ANOMALY PROFILE

Record No. 1974/181

Geophysical Branch, Bureau of Mineral Resources, Geology & Geophysics E51/B2-22

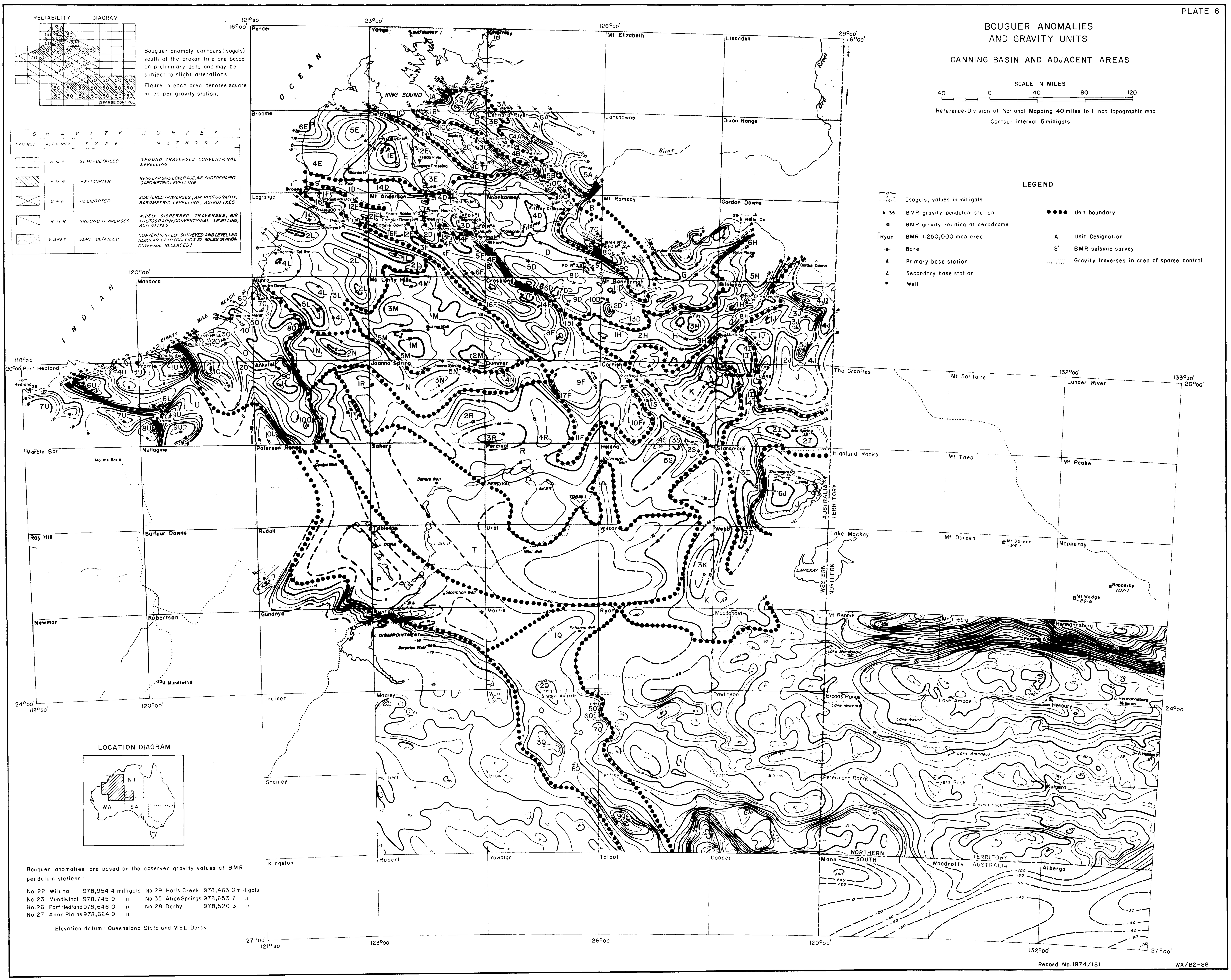
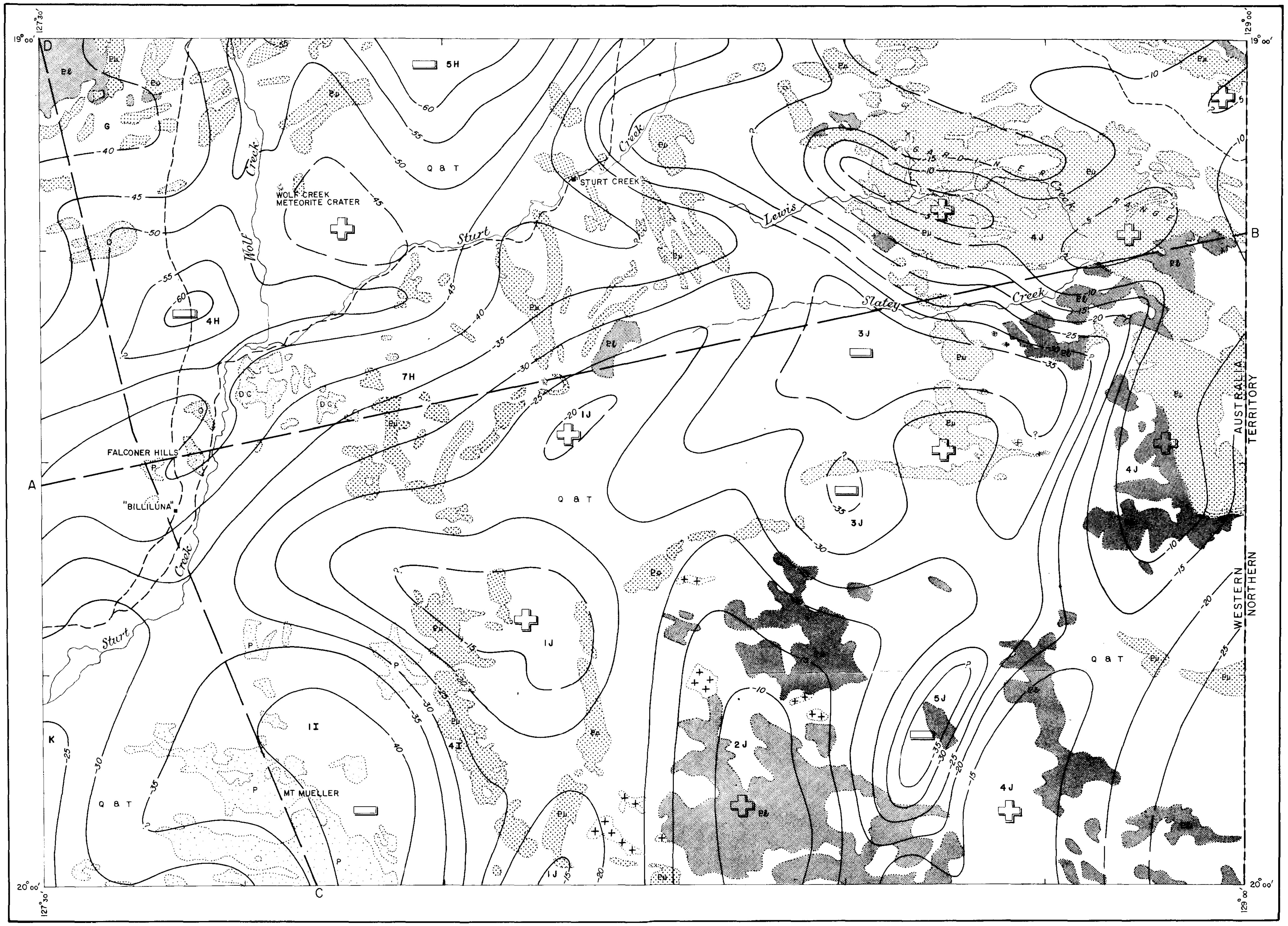


PLATE 6
BOUGUER ANOMALIES AND GRAVITY UNITS
CANNING BASIN AND ADJACENT AREAS
SCALE IN MILES
40 0 40 80 120
Reference: Division of National Mapping 40 miles to 1 inch topographic map
Contour interval 5 milligals
RELIABILITY DIAGRAM
SPARSE CONTROL
Bouguer anomaly contours (isogals) south of the broken line are based on preliminary data and may be subject to slight alterations.
Figure in each area denotes square miles per gravity station.
GRAVITY SURVEY
SYMBOL AUTHORITY TYPE METHODS
B.M.R. SEMI-DETAILED GROUND TRAVERSES, CONVENTIONAL LEVELLING
B.M.R. HELICOPTER REGULAR GRID COVERAGE, AIR PHOTOGRAPHY BAROMETRIC LEVELLING
B.M.R. HELICOPTER SCATTERED TRAVERSES, AIR PHOTOGRAPHY, BAROMETRIC LEVELLING, ASTROFIXES
B.M.R. GROUND TRAVERSES WIDELY DISPERSED TRAVERSES, AIR PHOTOGRAPHY, CONVENTIONAL LEVELLING, ASTROFIXES
WAPET SEMI-DETAILED CONVENTIONALLY SURVEYED AND LEVELLED REGULAR GRID (ONLY 10 X 10 MILES STATION COVERAGE RELEASED)
LEGEND
Isogals, values in milligals
BMR gravity pendulum station
BMR gravity reading at aerodrome
BMR 1:250,000 map area
Bore
Primary base station
Secondary base station
Well
Unit boundary
Unit Designation
BMR seismic survey
Gravity traverses in area of sparse control
INDIAN OCEAN
KING SOUND
EIGHTY MILE BEACH
WESTERN AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
Pender
Yampi
Kimberley
Mt Elizabeth
Lissadell
Broome
Derby
Lennard River
Lansdowne
Dixon Range
Lagrange
Mt Anderson
Noonkanbah
Mt Ramsay
Gordon Downs
Mandora
Munro
Mc Larty Hills
Crossland
Mt Bannerman
Billiluna
Port Hedland
Yarrie
Anketell
Joanna Spring
Dummer
Cornish
Lucas
The Granites
Mt Solitaire
Lander River
Marble Bar
Nullagine
Paterson Range
Sahara
Percival
Helena
Stansmore
Highland Rocks
Mt Theo
Mt Peake
Roy Hill
Balfour Downs
Rudall
Tabletop
Ural
Wilson
Webb
Lake Mackay
Mt Doreen
Napperby
Newman
Robertson
Gunanya
Runton
Morris
Ryan
Macdonald
Mt Rennie
Mt Liebig
Hermannsburg
Trainor
Madley
Warri
Cobb
Rawlinson
Bloods Range
Henbury
Stanley
Herbert
Browne
Bentley
Scott
Petermann Ranges
Kulgera
Kingston
Robert
Yowalga
Talbot
Cooper
Mann
Woodroffe
Alberga
L. DISAPPOINTMENT
LAKE MACKAY
Lake Amadeus
Ayers Rock
16°00' 121°30' 123°00' 126°00' 129°00' 120°00' 118°30' 20°00' 132°00' 133°30' 24°00' 27°00'
LOCATION DIAGRAM
NT WA SA
Bouguer anomalies are based on the observed gravity values at BMR pendulum stations:
No. 22 Wiluna 978,954·4 milligals No. 29 Halls Creek 978,463·0 milligals
No. 23 Mundiwindi 978,745·9 " No. 35 Alice Springs 978,653·7 "
No. 26 Port Hedland 978,646·0 " No. 28 Derby 978,520·3 "
No. 27 Anna Plains 978,624·9 "
Elevation datum: Queensland State and MSL Derby
Record No. 1974/181
WA/B2-88



Track

Homestead

Watercourse

Isogals

'High' anomaly

'Low' anomaly

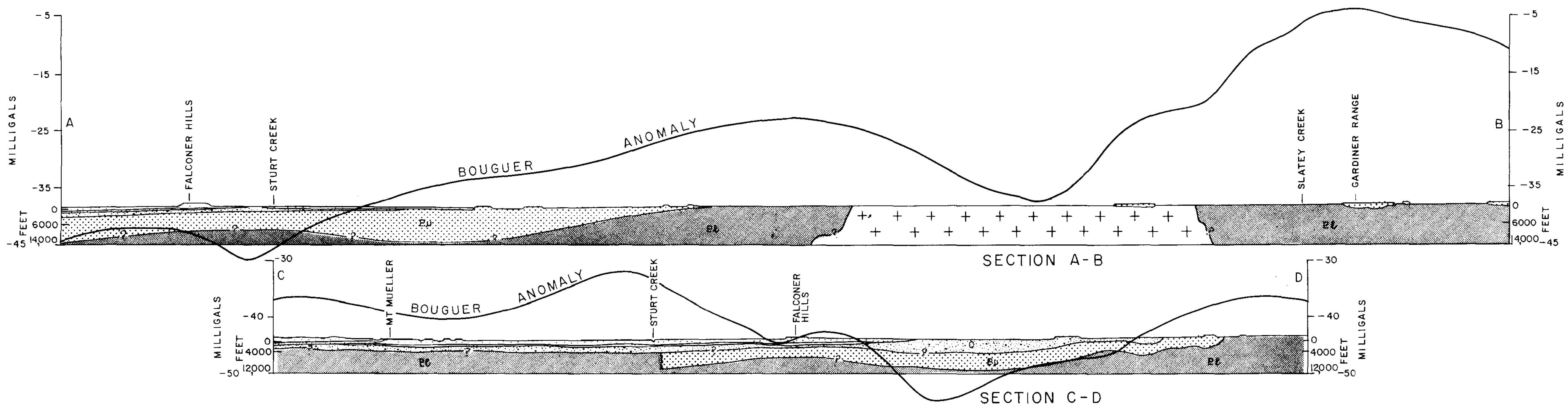
Q & T	Quaternary and Tertiary	– Cainozoic
P	Permian	– Upper Palaeozoic
D C	Devonian Carboniferous	– Middle Palaeozoic
O	Ordovician	– Lower Palaeozoic
Pu	Upper Proterozoic	
	Lower Proterozoic	
+ +	Lewis granite	– Lower Proterozoic

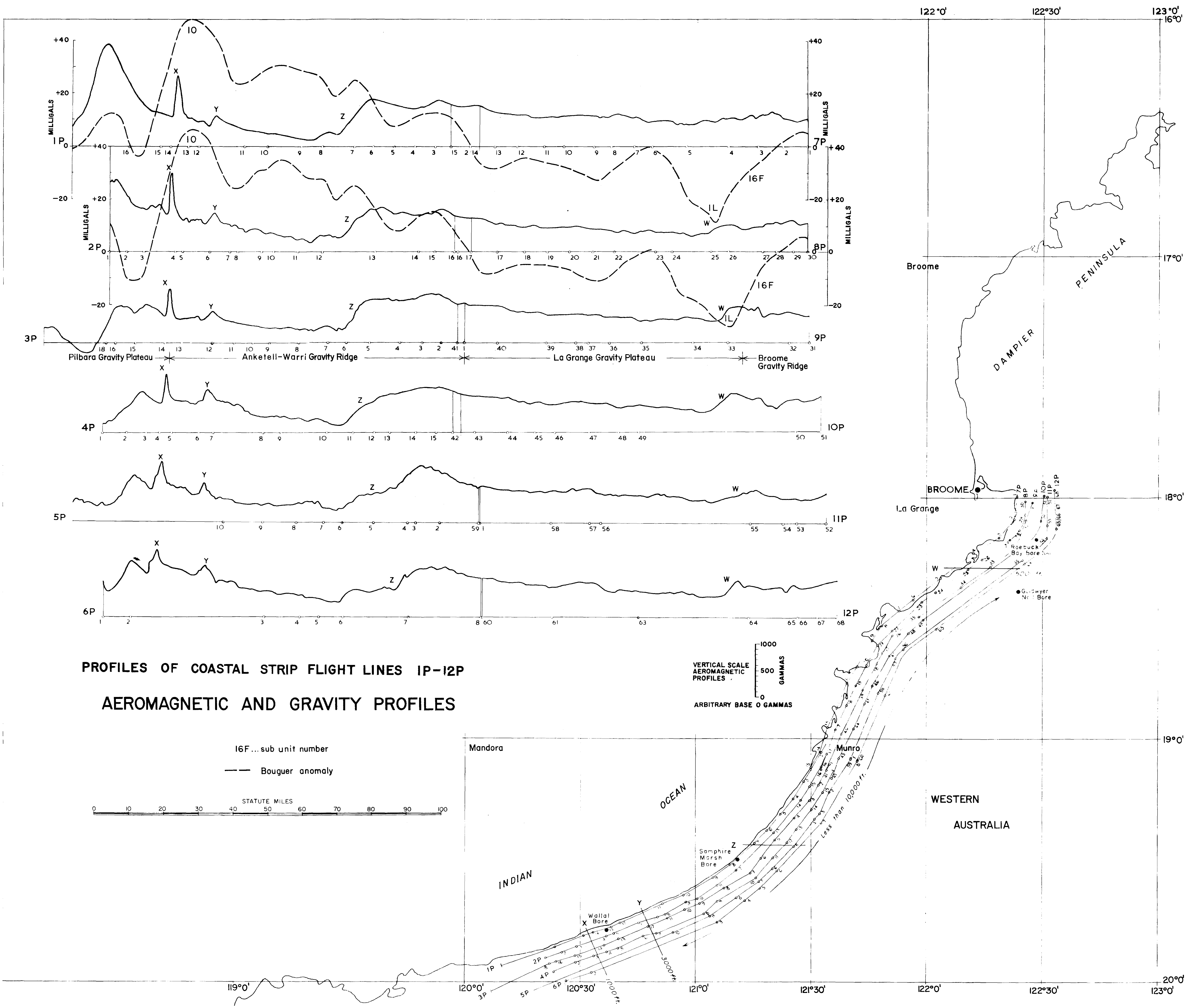
Geology after BMR 4-mile map Billiluna, E52-14

BILLILUNA, WA

BOUGUER ANOMALIES AND GEOLOGY

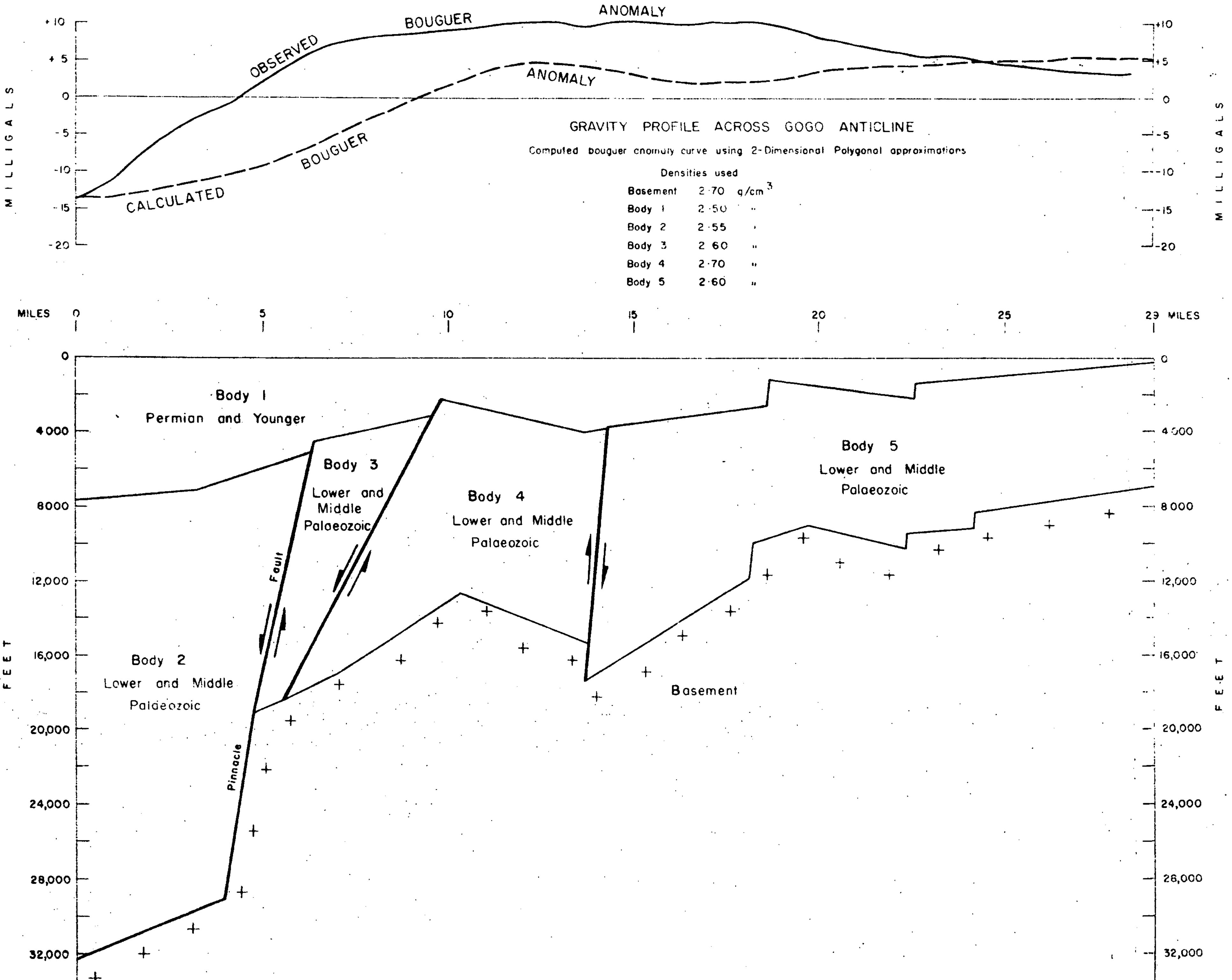
5 0 5 10 15 MILES





Record No. 1974/181 Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics E51/B2-20

Record No. 1974/181



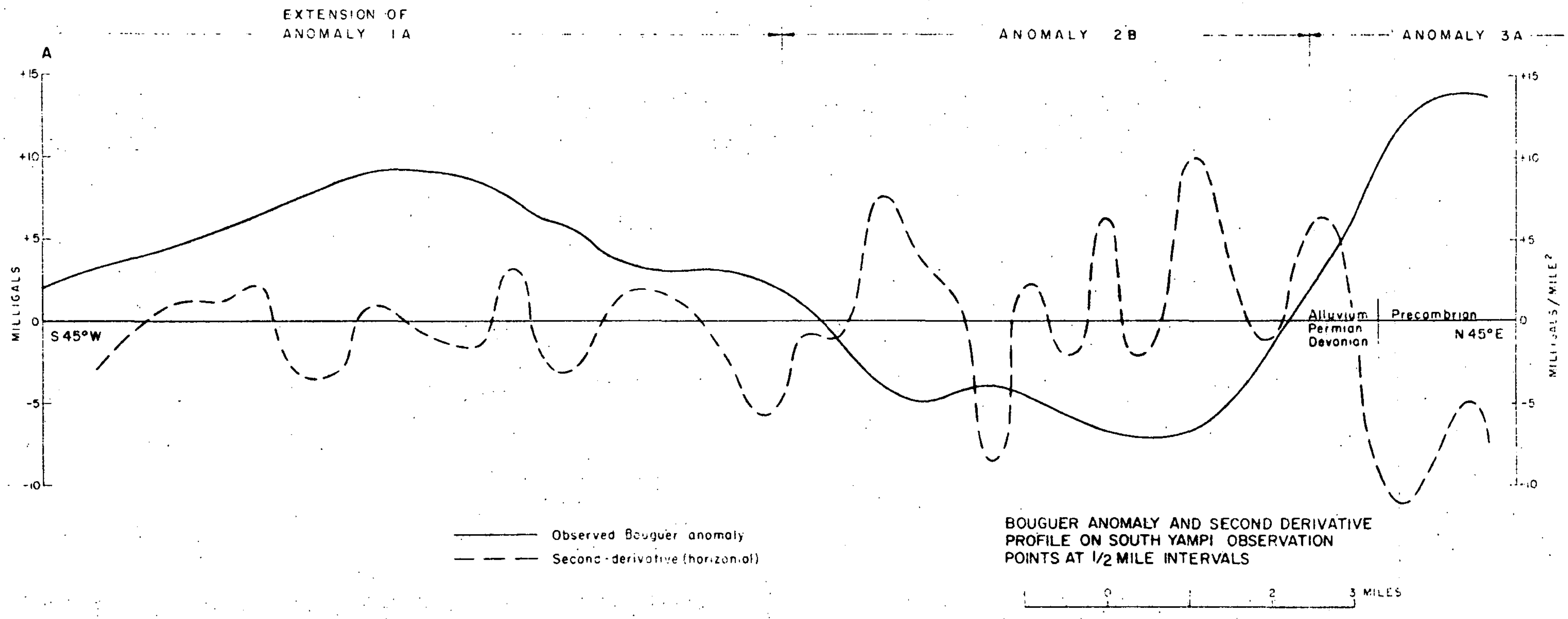
GEOLOGICAL CROSS-SECTION

Based on Seismic Interpretation Data-(WAPET,1963e)

E51/B2-21A

PLATE 9

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

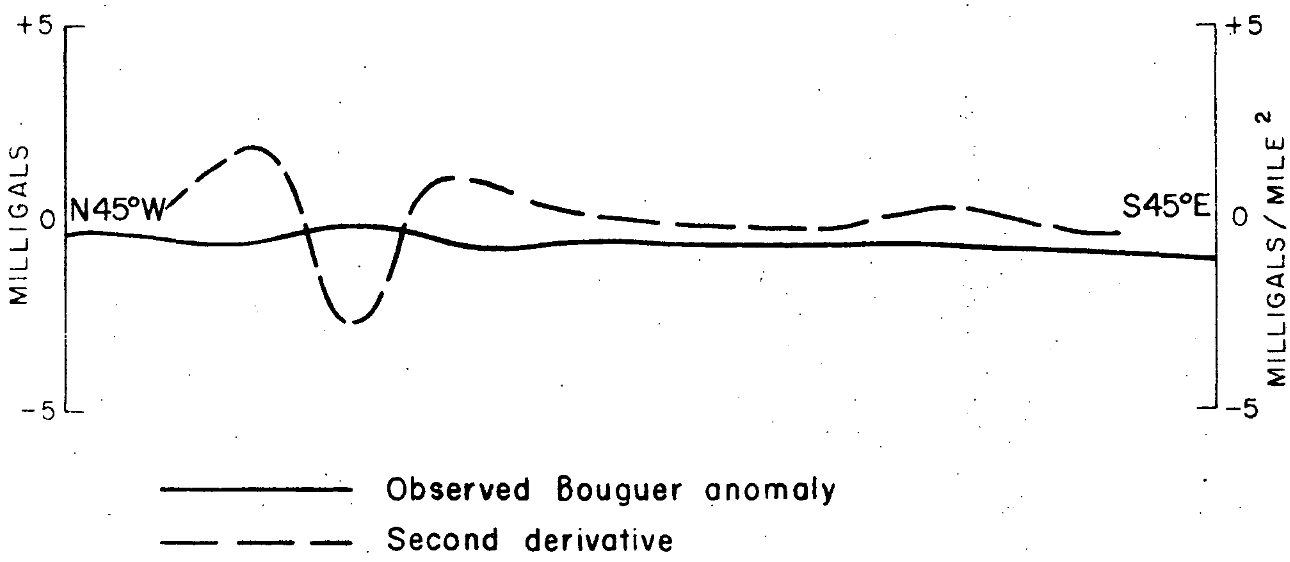


BOUGUER ANOMALY AND SECOND DERIVATIVE PROFILE ON SOUTH YAMPI OBSERVATION POINTS AT 1/2 MILE INTERVALS

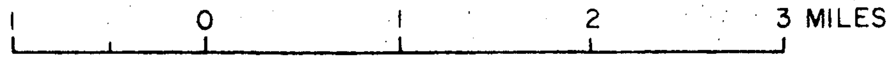
PLATE 10

G 65-112A

85



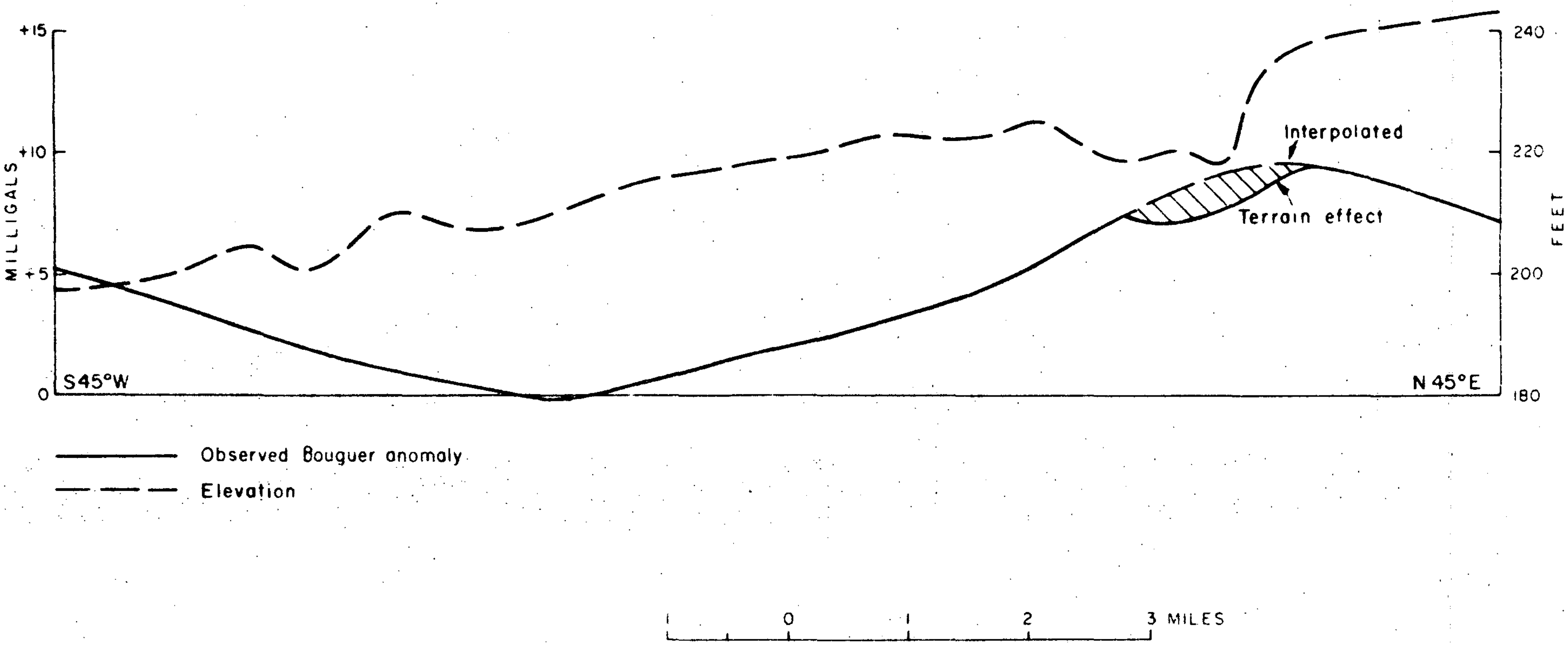
BOUGUER ANOMALY AND SECOND DERIVATIVE
PROFILE ON SOUTHEAST YAMPI
OBSERVATION POINTS AT 1/2 MILE INTERVALS



96

Record No.1974/181

BOUGUER ANOMALY PROFILE ACROSS NAPIER GRAVITY DEPRESSION ON NORTH-WEST LENNARD RIVER



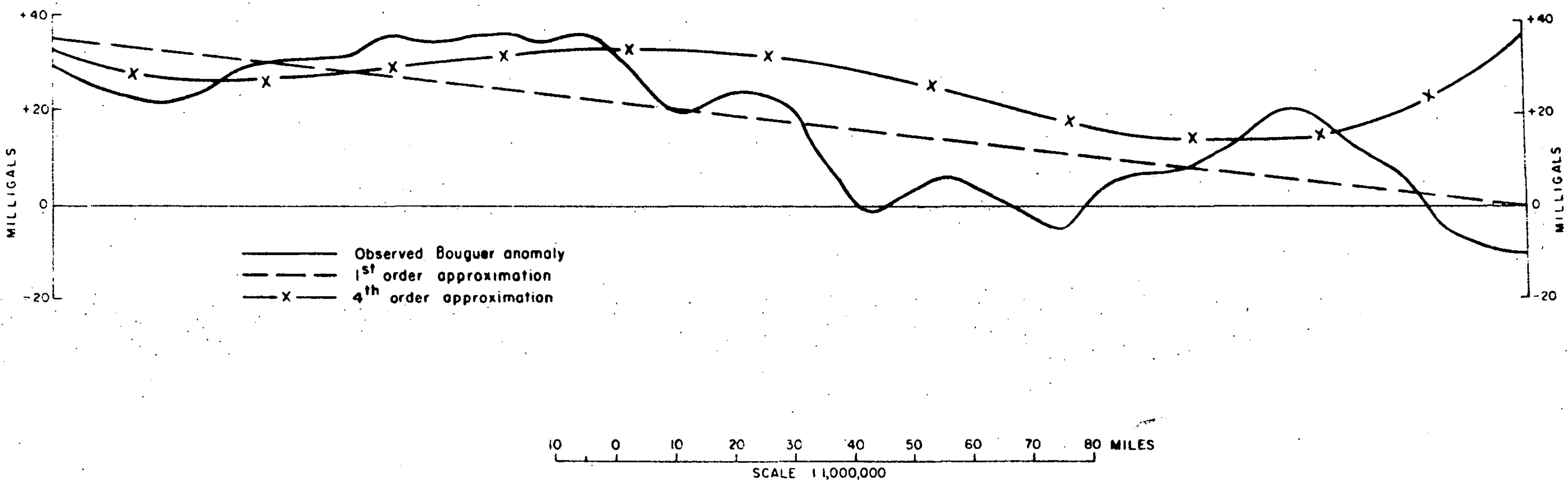
G 65-114A

PLATE 12

87

Record No.1974/181

AXIAL (STRIKE) BOUGUER ANOMALY PROFILE
ALONG THE OSCAR GRAVITY RIDGE



G65-115A

PLATE 13

88

Record No. 1974/181

BOUGUER ANOMALY PROFILES ACROSS THE PINNACLE FAULT (DERBY RAMP)

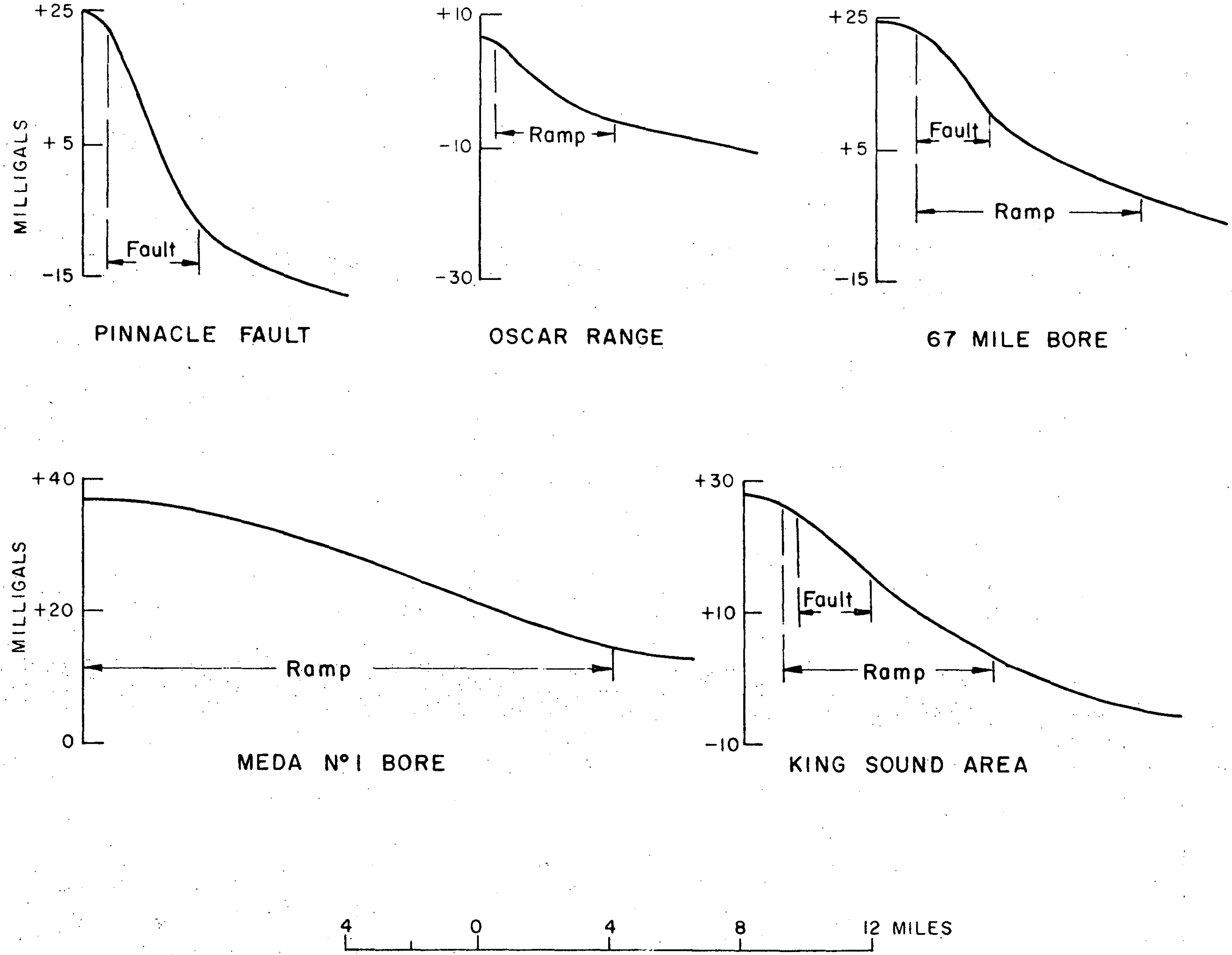
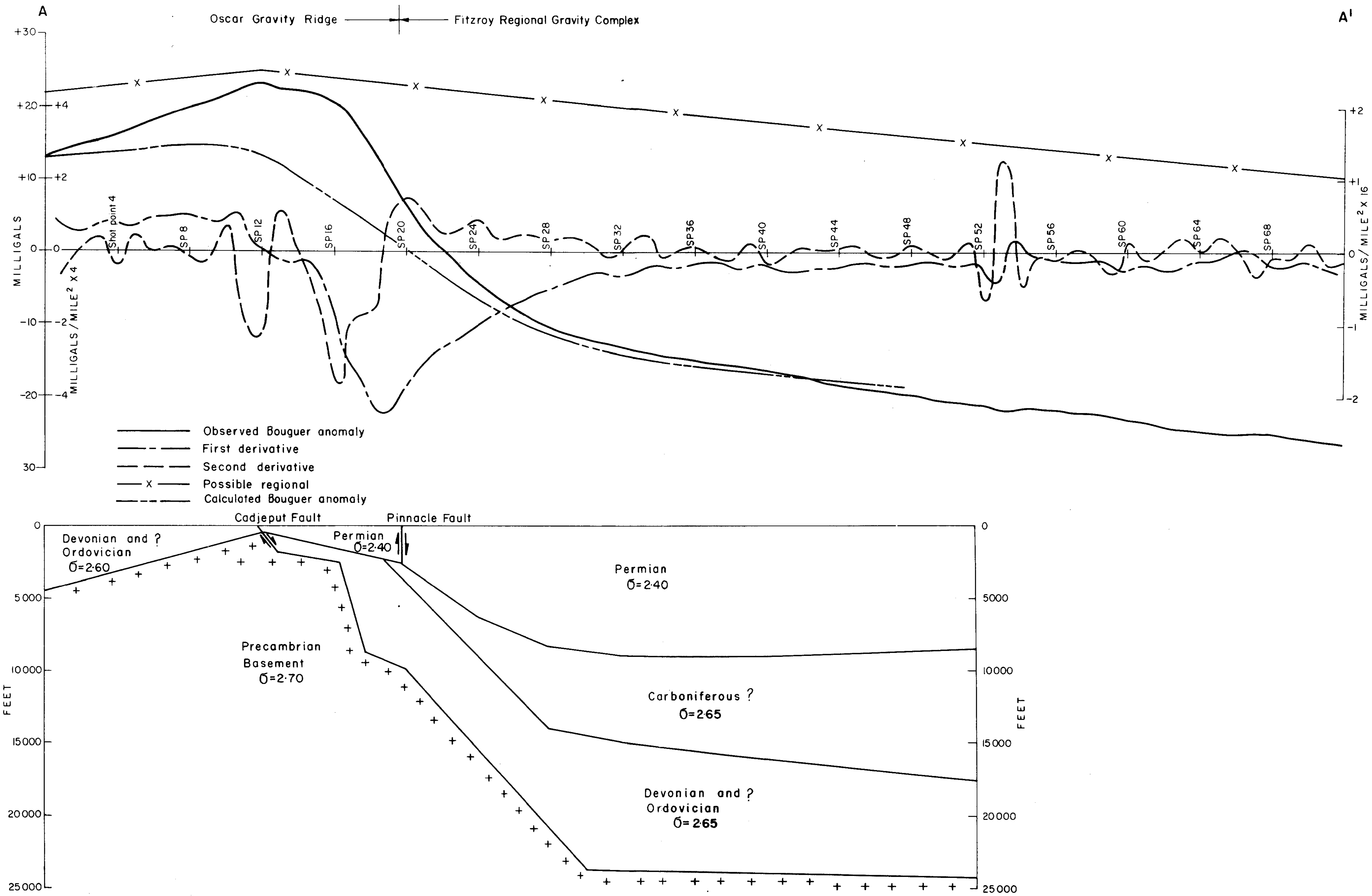


PLATE 14

G65-116A

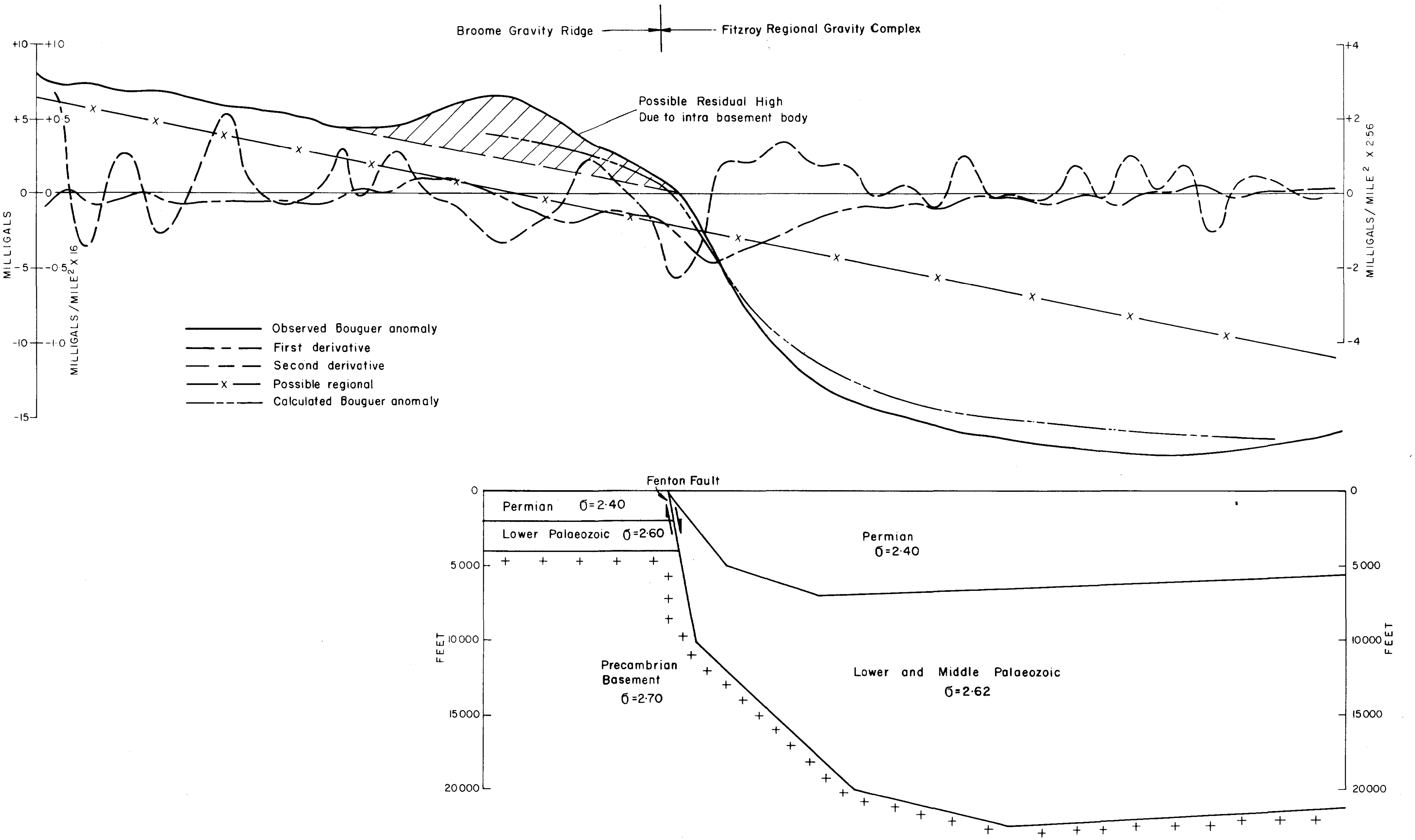
69



GRAVITY PROFILE ACROSS PINNACLE FAULT, OBSERVATION POINTS AT 1/4 MILE INTERVALS, POSSIBLE GEOLOGICAL SECTION SHOWN

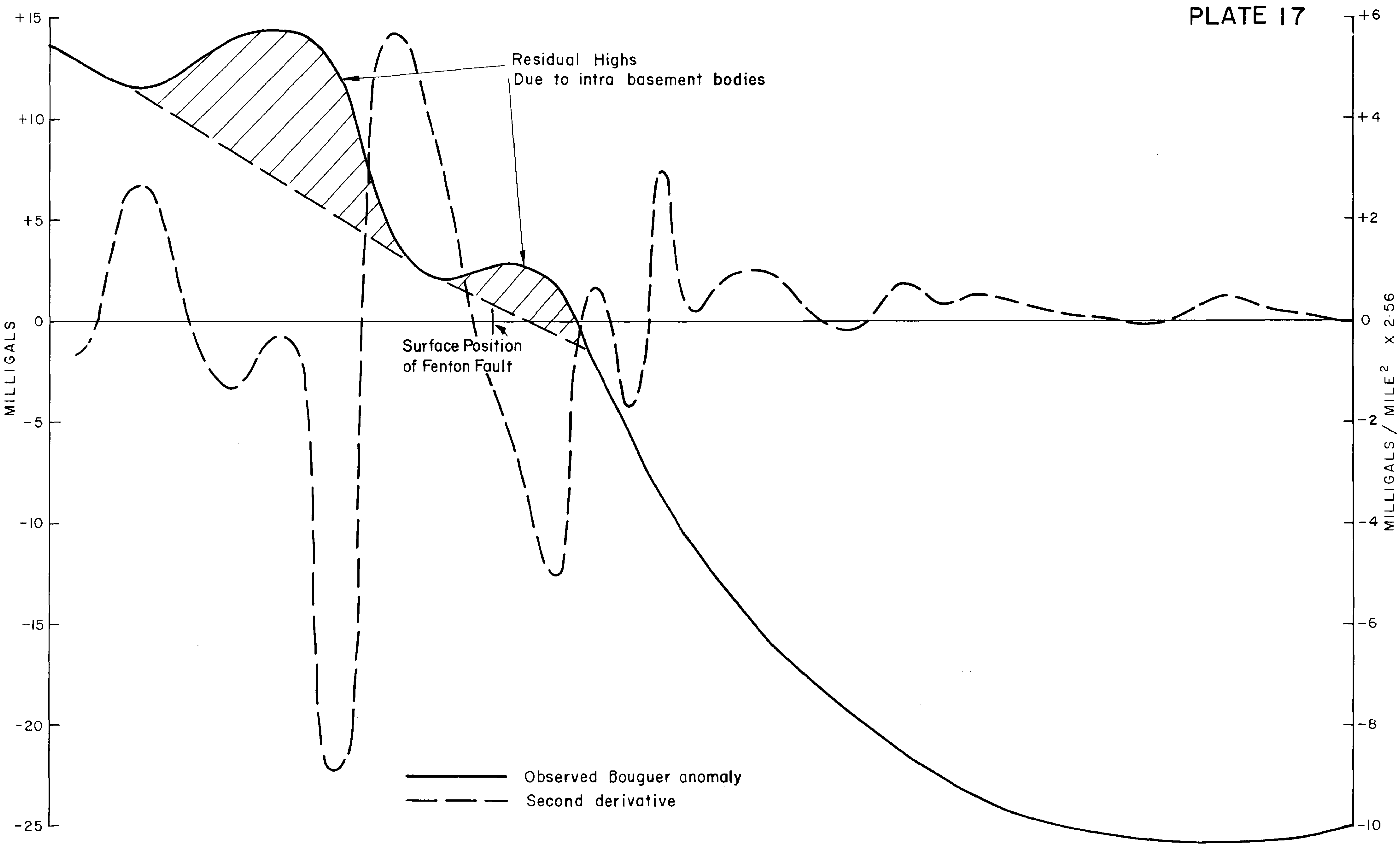
Record No 1974/181

G 65 - 117

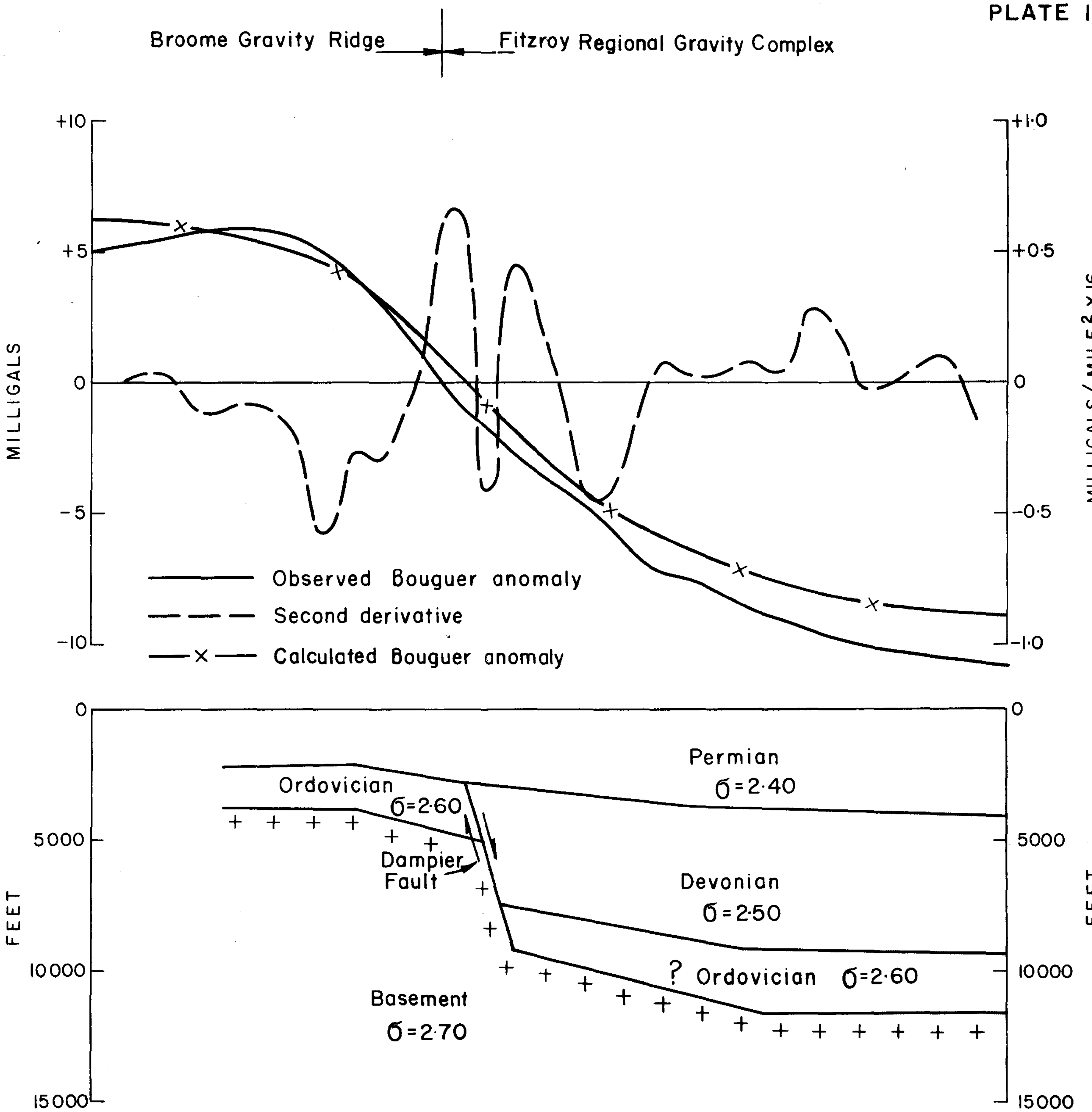


GRAVITY PROFILE ACROSS FENTON FAULT, OBSERVATION POINTS AT 1/2 MILE INTERVALS, POSSIBLE GEOLOGICAL SECTION SHOWN

PLATE 17

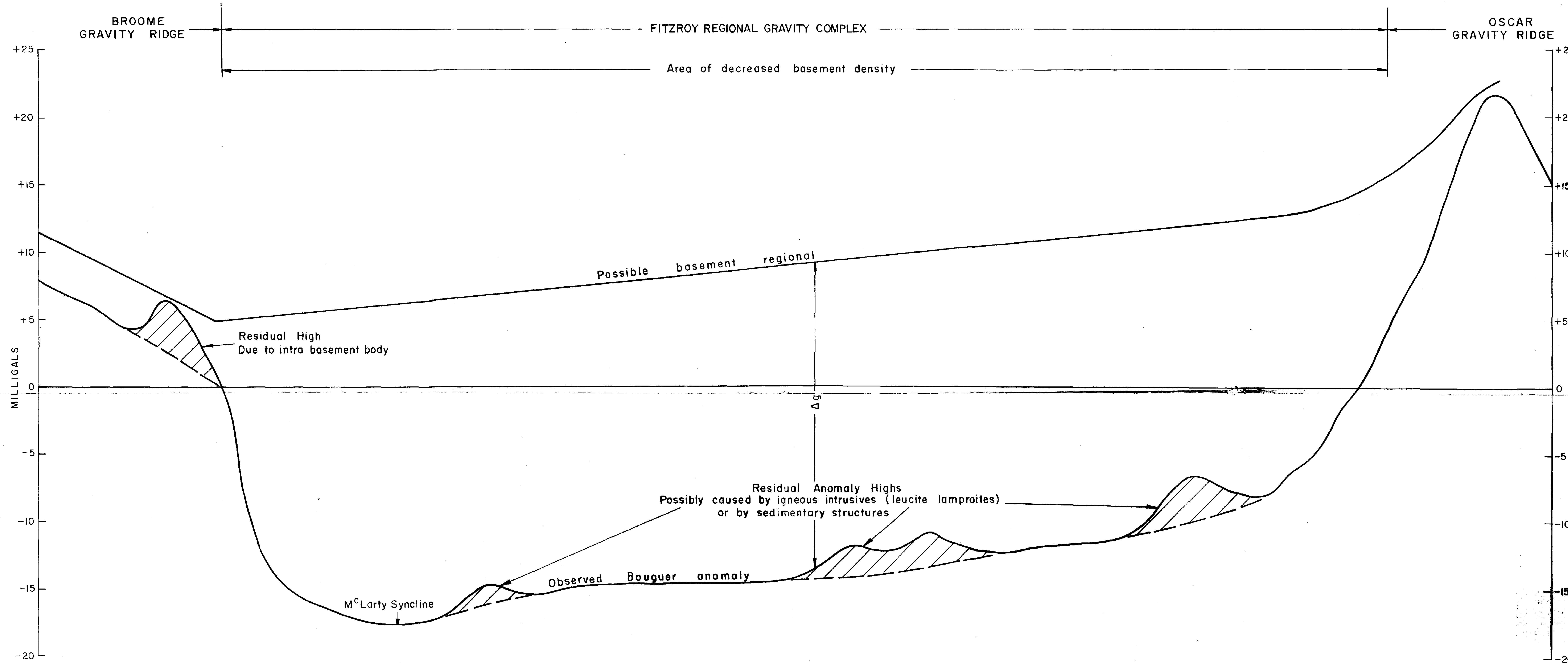


BOUGUER ANOMALY AND SECOND DERIVATIVE PROFILE ACROSS THE FENTON FAULT OBSERVATION POINTS AT 1/2 MILE INTERVALS



BOUGUER ANOMALY AND SECOND DERIVATIVE PROFILE ACROSS DAMPIER FAULT OBSERVATION POINTS AT 1/2 MILE INTERVALS

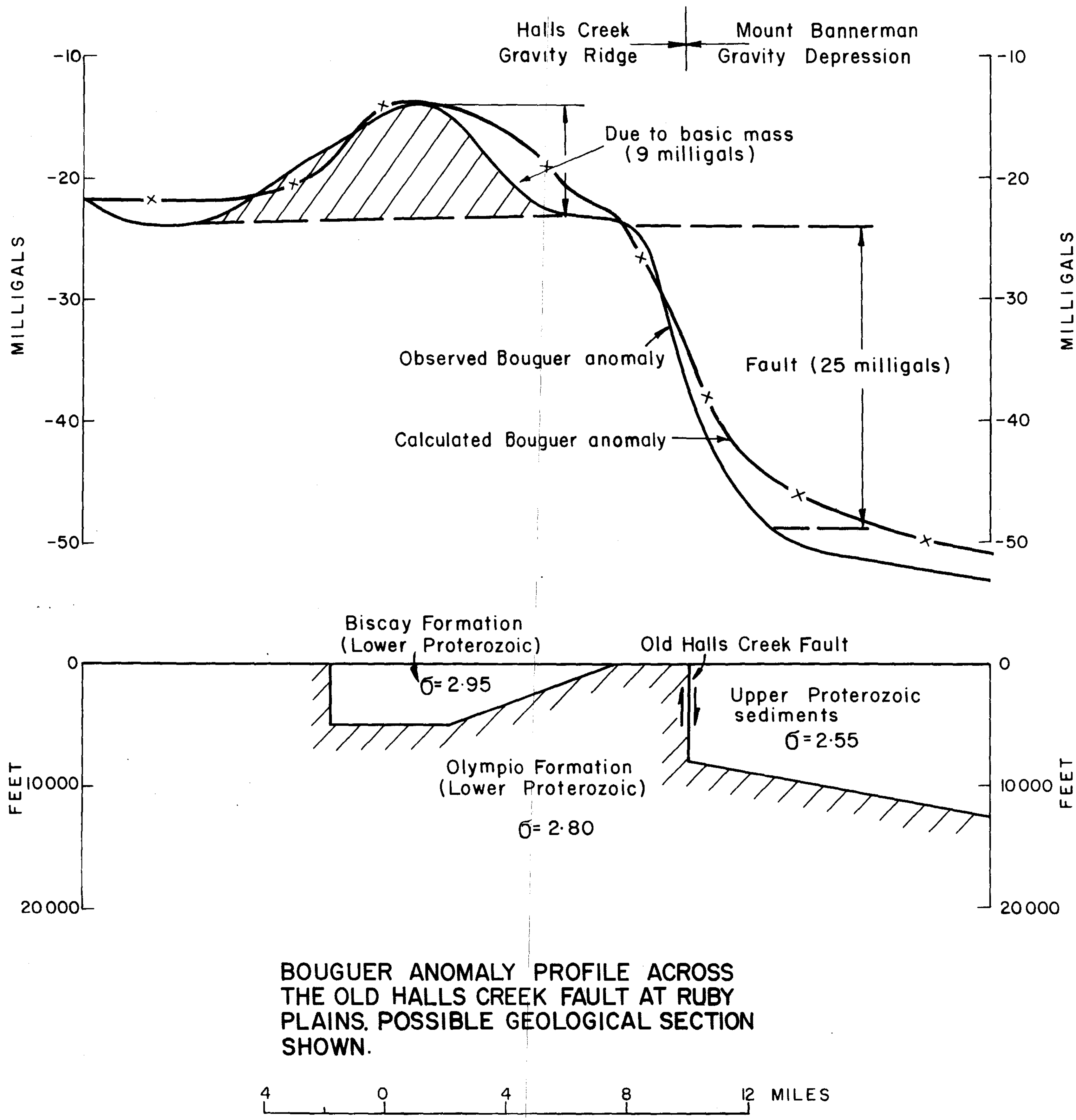
90



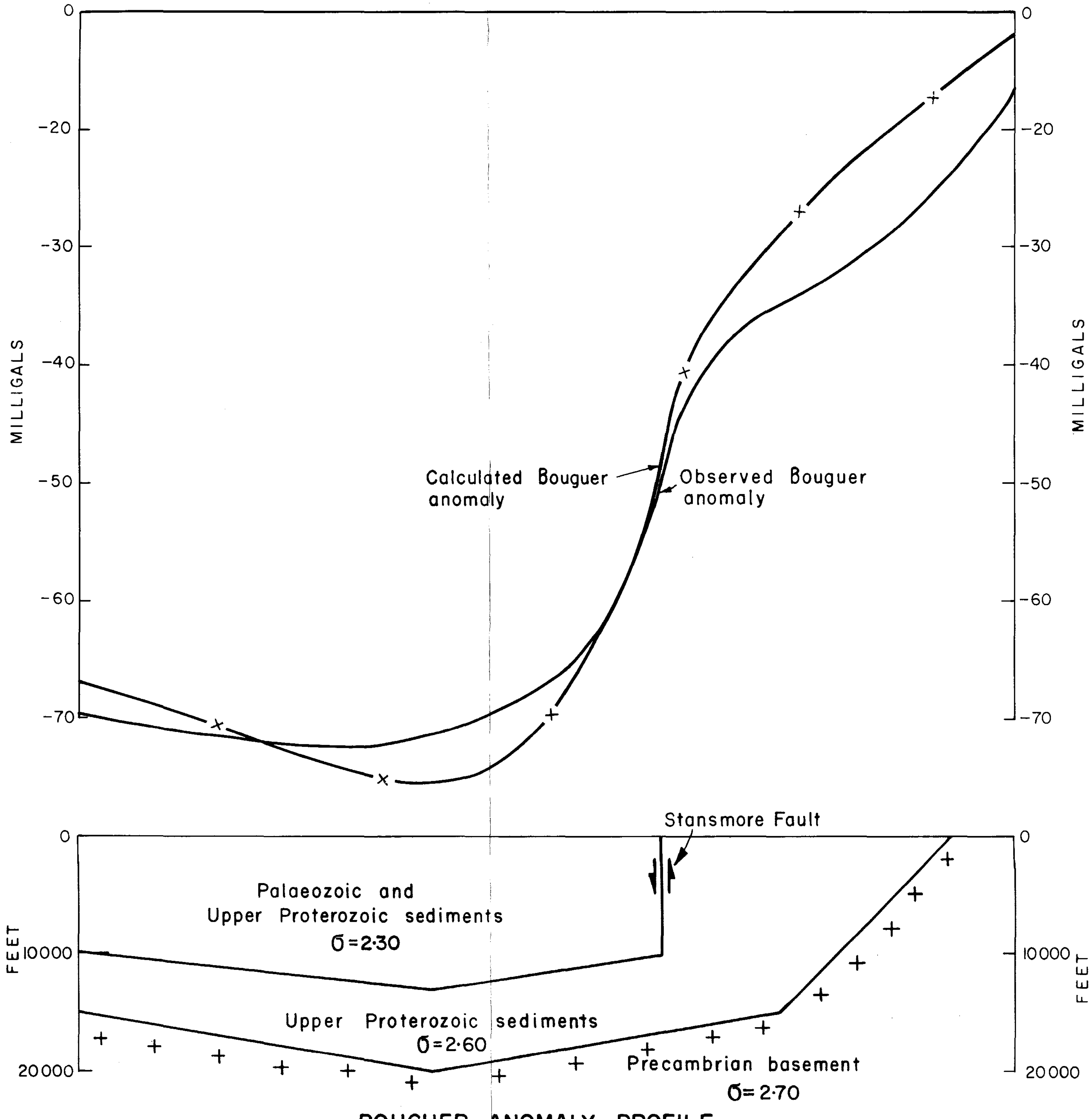
**BOUGUER ANOMALY ACROSS FITZROY GRAVITY TROUGH
OBSERVATION POINTS AT 1/2 MILE INTERVALS. POSSIBLE
BASEMENT ANOMALY CURVE SHOWN. SEDIMENTARY DEPTH
WOULD BE GIVEN BY $\Delta g = 12{\cdot}77\sigma L$**

Δg = (Observed Bouguer anomaly − basement regional) in milligals
σ = Sedimentary/basement density contrast in g/cm^3
L = depth in kilofeet

4 0 4 8 12 16 20 MILES

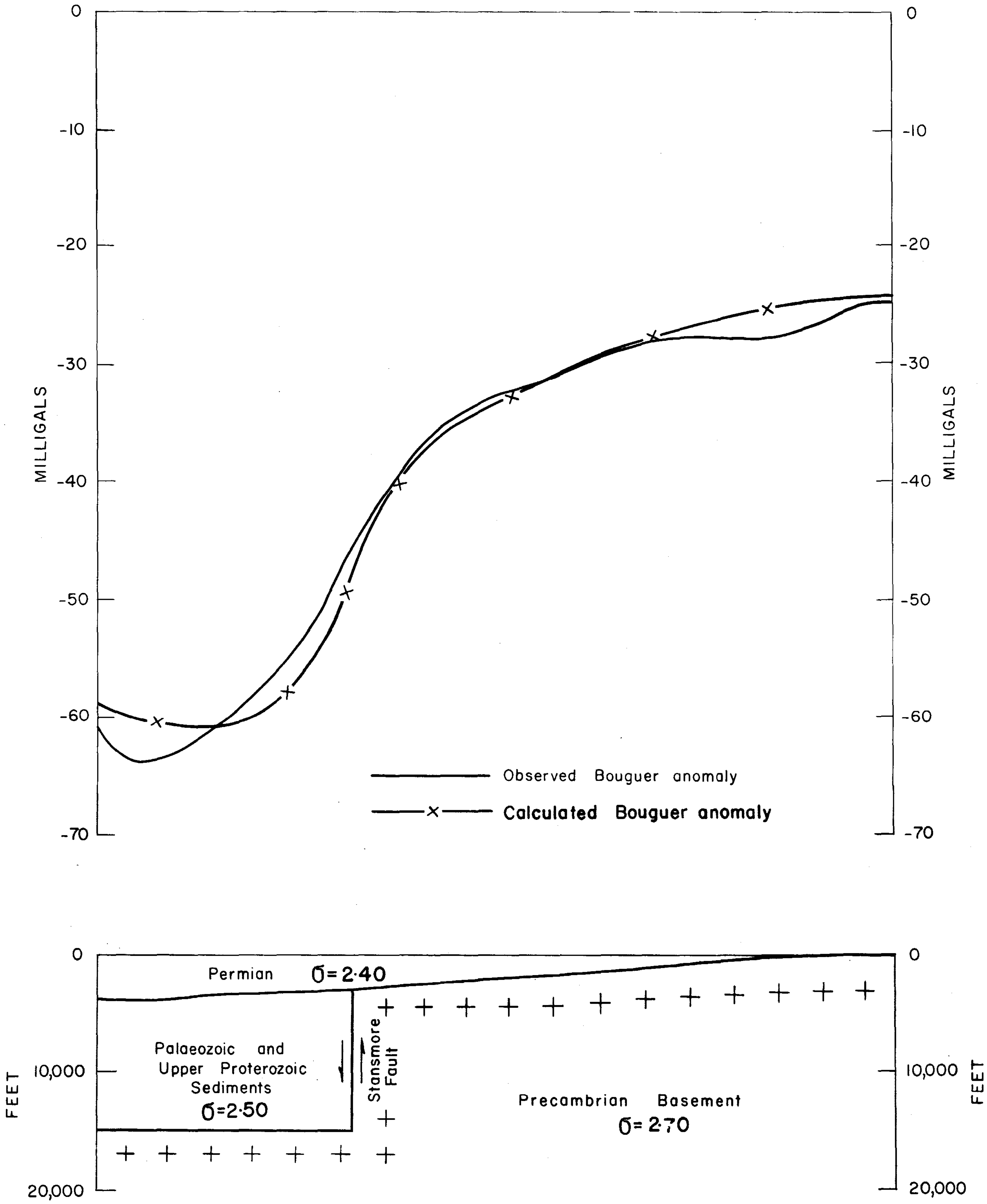


BOUGUER ANOMALY PROFILE ACROSS THE OLD HALLS CREEK FAULT AT RUBY PLAINS. POSSIBLE GEOLOGICAL SECTION SHOWN.



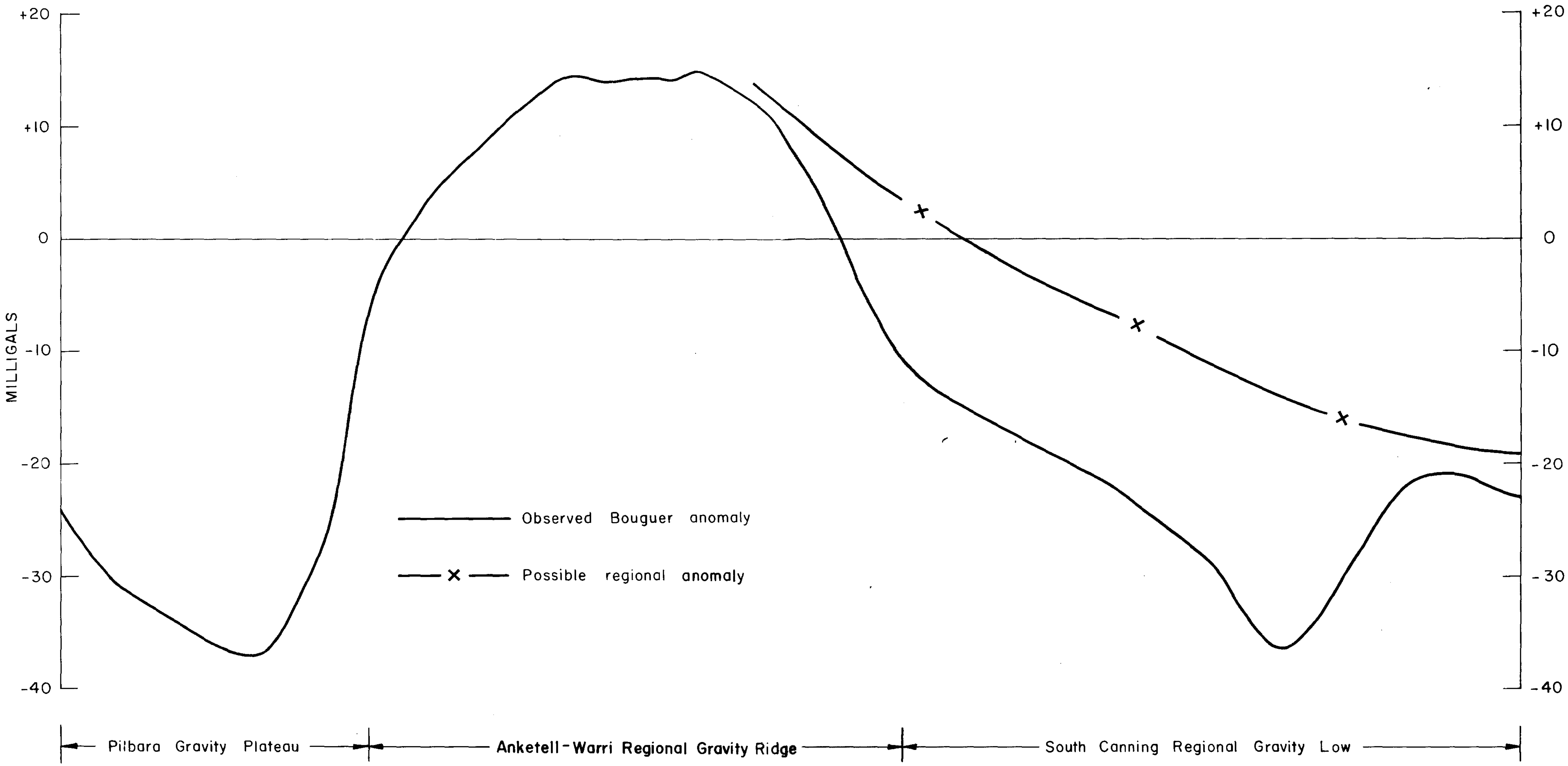
BOUGUER ANOMALY PROFILE ACROSS STANSMORE FAULT POSSIBLE GEOLOGICAL SECTION SHOWN

92



BOUGUER ANOMALY PROFILE
ACROSS STANSMORE FAULT
POSSIBLE GEOLOGICAL SECTION SHOWN

93



BOUGUER ANOMALY PROFILE ACROSS ANKETELL-WARRI REGIONAL GRAVITY RIDGE

5 0 5 10 15 20 25 30 35 MILES

SCALE 1:500,000

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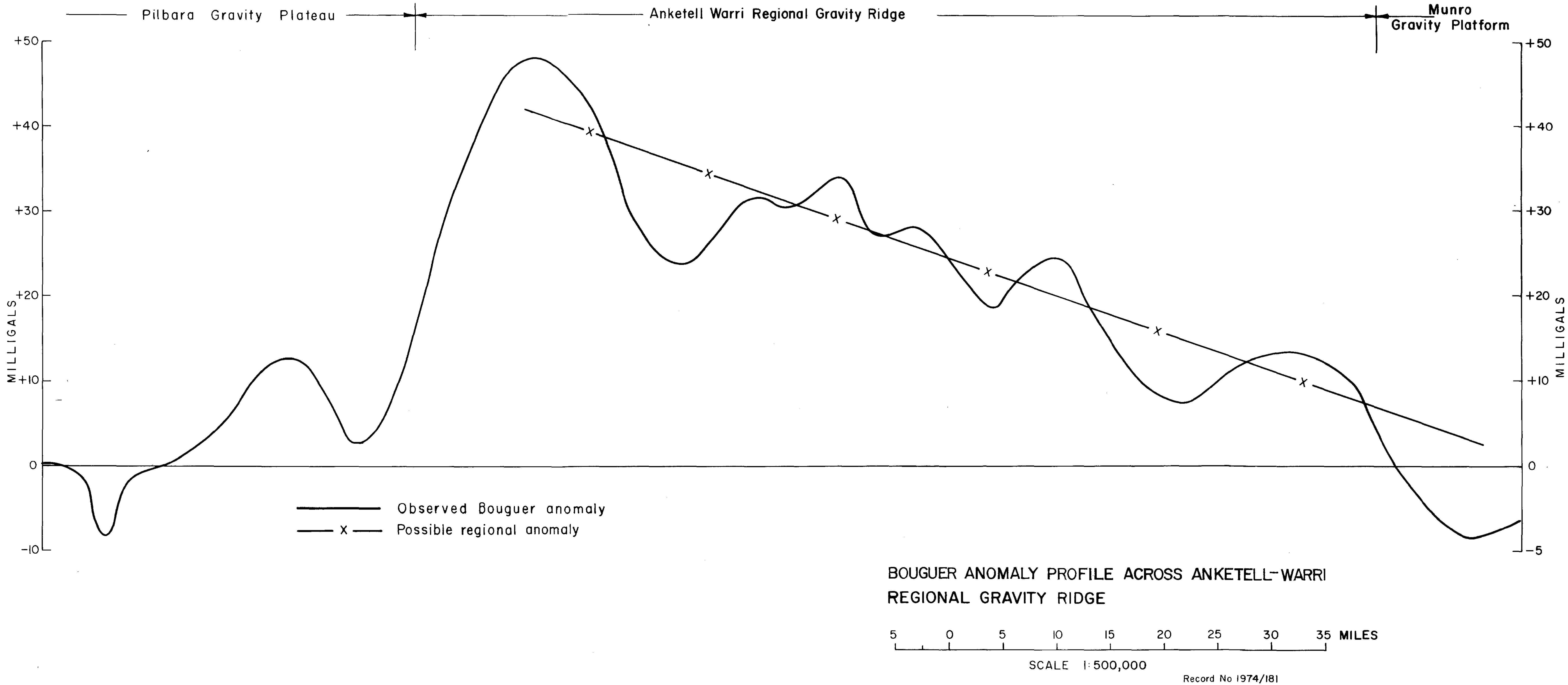

BOUGUER ANOMALY PROFILE ACROSS ANKETELL-WARRI REGIONAL GRAVITY RIDGE

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