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RECORD No. 1966/13

WESTERN QUEENSLAND RECONNAISSANCE GRAVITY SURVEYS, 1957-1961

by

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SUMMARY

The Bouguer anomaly pattern is interpreted in terms of two major geological units: the Cloncurry Fold Belt and the Great Artesian Basin.

The extension of the Fold Belt to the south-east, under a relatively thin cover of Mesozoic and Palaeozoic sediments, is inferred. In general, gravity 'highs' and 'lows' in this region are related to dense metamorphic-igneous basement and less dense granitic intrusions respectively.

In the Great Artesian Basin the Bouguer anomalies are correlated with a major density break between the Palaeozoic-Mesozoic sediments and a metamorphic-granitic basement of probably Lower Palaeozoic age. In this region gravity 'lows' and 'highs' are related to pockets of light sediments and high-standing basement respectively.

1. INTRODUCTION

Between 1957 and 1961 the Bureau of Mineral Resources, Geology and Geophysics (BMR) made gravity observations over some 144,000 square miles of Western Queensland. The area surveyed is shown in Plate 1. Prior to this, in 1951, pendulum stations had been established by the Bureau at Birdsville, Boulia, Cloncurry, Longreach, and Hughenden.

From 1957 to 1959 a network of road traverses was surveyed and tied to the pendulum stations. Between 1959 and 1961, helicopter gravity traverses were flown in the area and tied to the road network, and to the pendulum stations at Birdsville, Boulia, and Cloncurry. During the 1959 helicopter survey, readings were taken on an approximate 10 mile north by 5 mile east grid, but in the 1960 and 1961 surveys a 7 x 7 mile grid was used to give a more uniform coverage.

Since 1957 a total of 2858 reconnaissance gravity stations, made up of 969 road stations and 1889 helicopter stations, has been established in the survey area. The Bouguer anomaly map (Plate 3) prepared from all this work includes also some gravity results obtained by private companies working in the area.

The BMR is making gravity surveys of Australian sedimentary basins in order to define their limits and to define provinces favourable for oil accumulation. The more detailed objectives of the survey under discussion are set out in Chapter 4.

Practically the whole stratigraphic sequence from Precambrian to Quaternary is present in the three structural units surveyed, viz. the Cloncurry Fold Belt, the eastern parts of the Georgina Basin, and part of the Great Artesian Basin. The geology of the area is shown in Plate 2.

2. GEOLOGY

Queensland can be divided into three major structural units (Hill, 1960). These are the Precambrian Shield exposed in the north-west and north, the Tasman Geosyncline mainly of Palaeozoic age in the east, and the Great Artesian Basin of Mesozoic and Cainozoic sediments, occupying a central position between the older units to the north-west and east.

The area described in this report covers the tract of Precambrian rocks south of Cloncurry, the eastern margins of the Georgina Basin to the west and south-west, and the adjacent areas of the Great Artesian Basin to the east and south (Plate 2).

Cloncurry Fold Belt

The Precambrian rocks are exposed in the Cloncurry area. These rocks are thought to be continuous under the Great Artesian Basin sediments along the Euroka Ridge, re-appearing at the surface in the Georgetown area. This Ridge separates the Carpentaria Basin in the north from the Eromanga Basin in the south.

The Cloncurry Fold Belt has been described as a meridional Lower Proterozoic geosyncline, which was folded and faulted by east-west compression between a hypothetical stable foreland to the west and an even more hypothetical stable shelf to the east (Carter & Brooks, 1960). This geosyncline is divided into eastern and western troughs by a narrow axial zone of uplift, which, along with the stable areas to the east and west, was a source of sediment for both troughs in Lower Proterozoic times. This axial zone of uplift lies a little west of longitude 140°; in it occur the Leichhardt Metamorphics and the Kalkadoon Granite, which are among the oldest Precambrian rocks in the area.

The Leichhardt Metamorphics are metamorphosed lava, gneiss, schist, and migmatite with numerous associated intrusions of metadolerite and amphibolite.

The Lower Proterozoic deposits in the eastern and western troughs are acid lavas overlain by basic lavas interbedded with metasediments, which are in turn overlain by several sedimentary formations. Sedimentation continued in the western geosyncline while earth movements brought about folding on meridional axes and extensive faulting of strata in the eastern geosynclinal area. This phase was probably accompanied by metamorphism, granite intrusion, and metasomatism. In a later orogenic phase, accompanied by granite intrusion and uplift, the whole region was highly deformed and sedimentation ceased. Particularly in the eastern belt, basic igneous rocks were intruded on several occasions throughout the history of the area.

Seven major bodies of granite are exposed in the area: four (Naraku, Wimberu, Williams, and Wonga Granites) in the eastern belt, one (Kalkadoon Granite) in the medial zone already mentioned, and two (Sybella and Ewen Granites) in the western belt. These granites crop out mainly in meridional zones. At least three ages of Lower Proterozoic basic intrusion have been recognised. These rocks are now amphibolite, metadolerite, dolerite, and gabbro.

Upper Proterozoic rocks are exposed over a large area south-west of Mount Isa and in a smaller area south-south-east of Duchess in the Burke River structural belt.

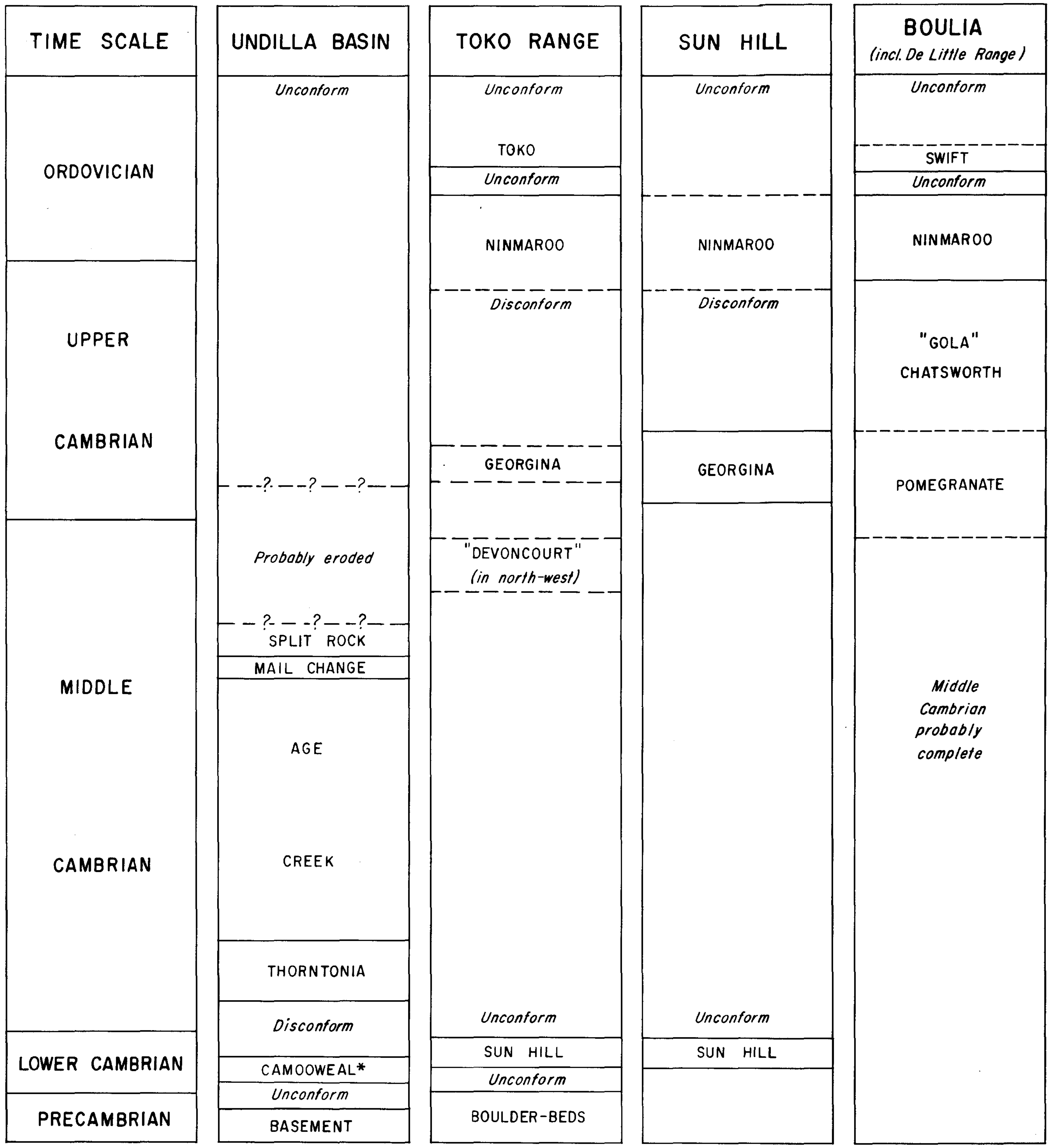
Even from this short account of the Precambrian geology, there is evidence of a wide range of densities in the different Precambrian rock types. Large positive gravity anomalies may be expected from the dense metamorphic and basic igneous rocks, whereas negative gravity anomalies may be expected from the less dense acidic granites. This general conclusion may not always hold, because the range in density of granites is known to be from about 2.5 to 2.75 g/cm^3 and only where there is significant density contrast between adjoining structural units will they give rise to large gravity anomalies. An inspection of Plates 2 and 3 shows that the density differences of these Precambrian rocks do in fact cause large gravity anomalies.

Eastern parts of the Georgina Basin

Lower Palaeozoic rocks occur extensively around the western and southern peripheries of the Precambrian area. These rocks range in age from Lower Cambrian to Middle Ordovician. The main areas of outcrop are the Georgina River plain and Oban Basin, the Toko Syncline, and the Burke River structural belt. The deposits of the Georgina River plain are thick bedded Camooweal Dolomite of Middle Cambrian to Ordovician age. Middle Cambrian to Ordovician deposits occur also in the Oban Basin. In the Toko Range area in the south-west, there is an asymmetrical

TABLE 1

Stratigraphical Sequence, Eastern Margins of Georgina Basin



TIME SCALE

ORDOVICIAN

UPPER CAMBRIAN

MIDDLE CAMBRIAN

LOWER CAMBRIAN

PRECAMBRIAN

UNDILLA BASIN

Unconform

--?--?--?--

Probably eroded

--?--?--?--

SPLIT ROCK

MAIL CHANGE

AGE CREEK

THORNTONIA

Disconform

CAMOOWEAL*

Unconform

BASEMENT

TOKO RANGE

Unconform

TOKO

Unconform

NINMAROO

Disconform

GEORGINA

"DEVONCOURT" *(in north-west)*

Unconform

SUN HILL

Unconform

BOULDER-BEDS

SUN HILL

Unconform

NINMAROO

Disconform

GEORGINA

Unconform

SUN HILL

BOULIA *(incl. De Little Range)*

Unconform

SWIFT

Unconform

NINMAROO

"GOLA" CHATSWORTH

POMEGRANATE

Middle Cambrian probably complete

**Later information gives the age of the Camooweal Dolomite as Middle Cambrian to Ordovician*

(After Opik, 1960)

TABLE 1 (continued) (To face page 5)

Formation Name	Lithology
Age Creek Formation	Sandy dolomite & limestone, 4000' max.
Camooweal Dolomite	Dolomite with chert, 2000' max.
Chatsworth Limestone	Dolomitic limestone & marl, 2000' max.
Devoncourt Limestone	Bituminous limestone
Georgina Limestone	Flaggy, sandy limestone, 100' max.
Gola Beds	Crystalline limestone
Mail Change Limestone	Limestone, 20'
Ninmaroo Formation	Dolomite & limestone with sandstone & shale, 2000' max.
Pomegranate Limestone	Impure bituminous limestone, 60' max.
Split Rock Sandstone	Sandstone & siltstone interbeds, 70'
Sun Hill Arkose	Arkose, shale, & conglomerate, 1000'+ max.
Swift Beds	Shale, chert, & sandstone, 60'
Thorntonia Limestone	Dolomite & limestone, 200' max.
Toko Group	Sandstone & shale, 2000' max.

B. MARGIN

syncline trending south-east composed of dolomite and limestone of Upper Cambrian and Lower Ordovician age, and a thick sequence of sandstone and shale of Middle Ordovician age. The Burke River structural belt is faulted and folded and contains diverse lithologies. The Palaeozoic outcrops of this belt are in the form of an outlier in the north bordered by Precambrian rocks, and of an inlier protruding through the Mesozoic cover in the south. The northern segment is a graben structure bounded by faults to the north, east, and west. The stratigraphical sequences at four localities in the Georgina Basin are listed in Table 1 (Opik, 1960).

The densities of the Lower Palaeozoic sediments range from 2.8 g/cm^3 (limestone) to as low as 2.1 g/cm^3 (Ordovician sandstone in the Toko Syncline). The high density of the limestone may mask any anomalies arising from less dense Upper Proterozoic sediments, and may add considerably to anomalies arising from dense Lower Proterozoic metamorphic rocks. The low-density Ordovician sandstone could contribute to the considerable gravity 'low' observed in the Toko Syncline.

Great Artesian Basin

The Mesozoic sequence of the Great Artesian Basin is fairly well established. Continental beds of Triassic and Jurassic age are known only in boreholes in the area. Several thousand feet of marine and non-marine sediments was deposited in Cretaceous times. Present-day outcrops of these beds are widespread. Offlap is a characteristic of these Cretaceous beds, and indicates the gradual withdrawal of the sea from the ancient coastlines (Plate 2).

The stratigraphic sequences in the eastern and western margins of this part of the Great Artesian Basin are shown in Table 2.

It is not known what part of the Blythesdale Group is the time equivalent of the Longsight Sandstone, but the Longsight Sandstone is at least equivalent to the upper members of the Group (Casey, 1959). The Longsight Sandstone is transitional between freshwater and marine deposits.

The Wilgunya Formation, a marine deposit, follows conformably on the Longsight Sandstone. On fossil evidence the Upper Wilgunya Formation and the Toolebuc Member are equivalent to the Tambo Formation. The Lower Wilgunya Formation is equivalent to the Roma Formation (Reynolds, Olgers & Jauncey, 1961). The Upper and Lower Wilgunya beds are shale and siltstone and the Toolebuc Member is a limestone and siltstone series.

The Winton Formation is of Lower/Upper Cretaceous age. In the west it consists of non-marine arkose and siltstone, and in the east it consists of shale and sandstone with some coal seams. The Mackunda Beds are transitional between the marine Wilgunya and non-marine Winton Formations.

Tertiary deposits follow unconformably on the Cretaceous sediments and generally form scattered capping deposits on hills. In places, however, as in the Old Cork Basin on BRIGHTON DOWNS[☆] and MACKUNDA they reach a thickness of up to 350 ft. Much of the area is covered by later Quaternary deposits

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[☆] In the text the 1:250,000 sheets are denoted by capital letters, e.g. BEDOURIE, whereas townships, homesteads, etc., are shown in small type, e.g. Bedourie.

(To face page 6)

TABLE 2

Stratigraphic Sequence, Great Artesian Basin

	Western Margin			Eastern Margin		
LOWER/UPPER CRETACEOUS	Winton Formation	Thickly interbedded arkose & siltstone, non-marine	3000' + Patchawarra Bore	Winton Formation	Shale & sandstone coal seams, lacustrine	1400' +
LOWER CRETACEOUS	Mackunda Beds	Thinly interbedded arkose & siltstone, transitional beds				
	Upper Wilgunya Formation	Shale, siltstone, & clay, marine	3000' + Adria Downs Bore	Tambo Formation	Mudstone, shale, sandstone, & limestone beds	3200' +
	Toolebuc Member	Calcareous sandstone & calcareous siltstone				
	Lower Wilgunya Formation	Shale, siltstone, & clay, marine		Roma Formation	Mudstone, shale, sandstone, & limestone beds	
LOWER CRETACEOUS/ UPPER JURASSIC	Longsight Sandstone	Mainly sandstone & conglomerate, marine & fresh-water deposits	450' +	Transition Beds		
UPPER JURASSIC				Blythesdale Group	Shale & sandstone, non-marine	1200' +
MIDDLE JURASSIC				Walloon Coal Measures	Shale, siltstone, sandstone, & coal seams	

Notes: The above successions are known from boreholes to rest on variable basement rocks ranging in age from Triassic to Precambrian

The **square** brackets enclose formations shown as one unit in Plate 2.

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BINDING MARGIN

such as gibbers, ironstone, gravel, sand, and alluvium.

In Plate 2 most of the Tertiary and Quaternary cover has been omitted to reveal the Cretaceous geology.

The densities of the Mesozoic sediments are in general low (about 2.2 g/cm^3) and any thick development of these sediments could cause fairly large gravity 'lows' because of the density contrast with the denser basement rocks below.

The rocks forming the basement of the Great Artesian Basin are known from many boreholes in the area. Many bores such as Kamaran Downs No. 3, Lucknow No. 10, Glenmore, and Corfield No. 1 show the Mesozoic beds to lie directly on granitic basement. Some other deep holes (and their total depths) are listed in Table 3 with their pre-Mesozoic sequences. In these holes Palaeozoic sediments, often several thousand feet thick, have been proved to be present below the Mesozoic cover.

TABLE 3

SOME DEEP HOLES IN THE GREAT ARTESIAN BASIN

Hole	Pre-Mesozoic Sequence	Total Depth, ft
Ooroonoo No. 1	Triassic-Permian/granite	3852
Warbreccan No. 1	Palaeozoic/granite	5433
Springleigh No. 3	Permian/Lower Palaeozoic	7009
Etonvale No. 1	Permian/Devonian/Lower Palaeozoic/granite	11,368
Cothalow No. 1	Palaeozoic	6025
Buckabie No. 1	Palaeozoic/phyllite	9070
Betoota No. 1	Lower Palaeozoic ?	9824
Innamincka No. 1	Permian/Devonian ?	12,638
Dullingari No. 1 (S. of Innamincka)	Permian/Ordovician	11,588

Permian deposits occur sporadically around the eastern margin of the Great Artesian Basin, often in overdeepened valleys and basins in Precambrian bedrock. On the eastern margin of the Great Artesian Basin, Permian sandstone, often several thousand feet thick, is known in the Bowen Basin. Marine strata are thin, and lava flows attain considerable thickness (Sprigg, 1958). From these marginal outcrops and from boreholes that have proved the presence of thick marine Permian deposits, it may be concluded that local pockets of Permian sediments occur in the Great Artesian Basin beneath the cover of Mesozoic sediments.

Geological history

The Cloncurry Fold Belt is considered to be a mobile zone between two hypothetical stable blocks, to the west and east, which are now covered by younger sediments. This central geosynclinal zone has experienced at least two major orogenic phases in Lower Proterozoic times, and was probably uplifted and stabilised towards the end of Lower Proterozoic times. Upper Proterozoic sedimentation was generally confined to the western stable block or shelf.

In Lower Palaeozoic times the western shelf and the southern end of the Fold Belt received marine sediments (Cambro-Ordovician of the Georgina Basin). Some instability was still present, as shown by disconformities in the Lower Palaeozoic sediments (Opik, 1960). The whole region was uplifted and became stable in late Ordovician times. It probably remained as dry land until the present time, except for the Cretaceous transgression period, traces of which still remain on the Fold Belt.

A problem so far unsolved is the easterly extent of the relatively unaltered Lower Palaeozoic sediments of the Georgina Basin. Unaltered shales of this age have recently been discovered in Dullingari No. 1 well, about 45 miles south of Innamincka. The pre-Mesozoic rocks found in other deep bores in the Great Artesian Basin have been dated as Carboniferous and Devonian with evidence of several local Permian occurrences. Below the Carbo-Devonian rocks, granite has been encountered in some holes, pre-Silurian phyllite was found in Buckabie No. 1 well, and at Etonvale No. 1 well a thick sequence of marine sediments, indefinitely dated as Lower Palaeozoic, rests on granite. If these marine sediments at Etonvale are only of Lower Devonian age*, then it is possible that the phyllite encountered in Buckabie No. 1 is of Lower Palaeozoic rather than Precambrian age. This phyllite has been dated as pre-Silurian by radioactive dating methods.

This argument has some support from the occurrence of similar phyllite (age from Proterozoic to Silurian) cropping out in the Anakie Structural High to the east of the Drummond Basin, which borders the Great Artesian Basin in the east. Folded Carbo-Devonian sediments of the Drummond Basin lie unconformably on the metamorphic rocks of the Anakie Structural High; this is a similar association to that found in Buckabie No. 1 well. Although no fossils have so far been found in them, the metasediments of the Anakie Structural High have been dated as Lower Palaeozoic by many authors (including Bryan & Jones, 1946; David and Browne, 1950). It may be a southward extension of the Anakie Structural

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* They in fact have since been dated as Middle and Lower Devonian and Upper Silurian (Phillips Petroleum, 1964).

High, beneath the Great Artesian Basin, that forms the Nebine Ridge (Hawthorne, 1950). This postulate gives additional weight to the theory that the metamorphic basement of the eastern Great Artesian Basin comprises Lower Palaeozoic rocks which rest unconformably on the Precambrian Shield.

If the age of the metamorphic basement of the Great Artesian Basin is accepted as being Lower Palaeozoic, then the boundary between the unaltered Lower Palaeozoic sediments in the west and the metamorphic Lower Palaeozoic rocks in the east must lie between the most easterly known occurrences of unaltered sediments, in the Burke River structural belt and at Dullingari No. 1 well, and the most westerly known occurrence of metamorphosed sediments, viz. at Buckabie No. 1 well.

The final solution to this problem of the exact configuration of the basement rocks of the Great Artesian Basin must wait for results from new boreholes.

It is possible that the orogenic phase, in which the Proterozoic to Silurian (or Lower Palaeozoic?) sediments of the Anakie Structural High were metamorphosed, also affected the Lower Palaeozoic sediments in the eastern part of the Great Artesian Basin. This area, after a period of prolonged erosion in ?Silurian times, was again depressed to receive the great accumulation of freshwater and terrestrial red beds of Carbo-Devonian age known from deep bores in the Great Artesian Basin. These beds can probably be correlated with known outcrops of similar age in the Drummond Basin.

Further erosion took place in the re-emergent area, followed by a period of oscillation initiated in Permian times and culminating in the widespread Cretaceous transgression.

Major faults

In the Cloncurry Fold Belt, faulting was probably active several times during the formation of the Belt. Most of the faults dip at high angles, often steeper than 70°. Several major faults have been mapped in the area, but only those of interest in the present report will be mentioned here.

The Burke River structural belt is faulted in both the west and the east. At the northern end of this belt the nearly vertical Pilgrim Fault separates upthrown Precambrian rocks to the west and downthrown Lower Palaeozoic sediments to the east. This down-faulted tract of lower Palaeozoic sediments is faulted against granite in the north (Roaring Fault) and against granite and metamorphic rocks in the east. The Pilgrim Fault line extends southwards and is known in several inliers of Lower Palaeozoic rocks (Plate 4). The eastern fault line is also mapped to the south where it borders the western edge of the Momedah Anticline. The structure is thus a graben, the bounding faults of which may have originated in Lower Proterozoic times with later post-Ordovician movements.

The Burke River structures are complemented to the west by the Smokey Anticline, a broad uplift of Precambrian rocks. This anticline plunges south and south-west, and older rocks re-appear at Sun Hill and Sylvester Creek, indicating another anticlinal trend.

Another major fault line known as the Cloncurry Overthrust occurs to the east of the Burke River structures. This overthrust is a high-angle, easterly-dipping reverse fault in which the Soldiers Cap Formation to the east has been thrust over the Corella Formation to the west; both formations are of

Precambrian age.

The Toko Syncline is bounded to the south-west by another major fault. This fault, known as the Pulchera Fault, brings Lower Palaeozoic sediments (dip 50^{o} to 60^{o}) of the Toko Syncline against Precambrian rocks. This fault line has been traced to the south-east into the BEDOURIE sheet, where it displaces Mesozoic sediments; these later movements apparently occurred along the same ancient fault line.

3. PREVIOUS GEOPHYSICAL SURVEYS

Gravity surveys

Gravity surveys were made in Western Queensland by the Bureau of Mineral Resources in 1957 and 1958 (Neumann, 1959a and 1959b). The gravity data of these surveys are incorporated in the present gravity map (Plate 3). These surveys indicated the southward extension of the Precambrian rocks of the Cloncurry Fold Belt below the cover of Lower Palaeozoic and Mesozoic sediments. The gravity effects of major faults in the Duchess area were mapped. A gravity 'low' (feature 8 in Plate 3) was correlated with a thickening of relatively unaltered Proterozoic sediments of low density, which underlie the Cambrian beds. A gravity 'high' (feature 20 in Plate 3) west of Boulia was interpreted as a Precambrian horst below the later sedimentary cover. In general the gravity 'lows' in this area were correlated with areas of possible thickening of low-density Proterozoic sediments.

A gravity survey was done in the Boulia area in 1959 by The Papuan Apinaipi Petroleum Company (1962). The results of the two BMR surveys mentioned above were included in the Company's gravity maps. In this area the surface geology comprises Lower Palaeozoic and Mesozoic sediments which lie on Precambrian basement rocks.

Four major belts of gravity 'highs' were defined (corresponding to features 18; 20; 3 and 4; and 12 in Plate 3). Two major gravity 'lows' (features 1 and 9) were also mapped. The 'highs' have been interpreted as southward extensions of dense Precambrian rocks below the cover of later sediments. In some cases these older structures have influenced younger structures in the Lower Palaeozoic and Mesozoic sediments. The eastern gravity 'low' (feature 9) was interpreted as the gravity effect of a granitic basement ridge named the Lucknow Granite (this corresponds to the Williams Granite of the present report). The western gravity 'low' (feature 1) was thought to be caused by either a thickening of the Mesozoic sediments or a structure in the Precambrian basement.

Several faults were postulated and some were correlated with known faults that extend south from the Cloncurry Fold Belt. The area was regarded as worthy of further investigation.

A reconnaissance gravity survey was made in the North Winton area in 1959 by Magellan Petroleum (1961). The surface rocks here are Mesozoic, and the area lies within the Great Artesian Basin. The gravity results showed the division of the area into two main parts, one of low gravity anomalies to the west and one of high gravity anomalies to the east. A steep gravity gradient trending north-east separates these two areas. This gradient coincides approximately with the position of a fault interpreted from previous aeromagnetic data. Two alternative interpretations were presented: the gravity 'low' could be caused either by the presence of low-density granite below the Mesozoic cover, or by the presence of low-density pre-Mesozoic sediments.

A seismic traverse was made by the Bureau of Mineral Resources to resolve this problem. The results indicated a consistent north-westerly dip component below the Mesozoic beds, suggesting a thick sequence of pre-Mesozoic sediments. They also indicated a series of faults coinciding with the steep gravity gradient; this confirmed the existence of the fault zone from gravity and aeromagnetic data.

The results of the North Winton survey show that variations in Mesozoic thickness are often not sufficient to explain the large gravity 'lows' found in the Great Artesian Basin. In this area the presence of pre-Mesozoic sediments has been proved; thus by analogy it is probable that the low gravity anomalies in other parts of the Great Artesian Basin could be caused by low-density pre-Mesozoic sediments. However, this is not always so: e.g. in the Roma district, a correlation between gravity 'lows' and low-density granitic basement was found (Dooley, 1950).

A gravity survey was done in the Eromanga area by Smart Oil Exploration (1961). The gravity results showed good correlation of basement domes with gravity 'highs'. Three known anticlines were defined: viz. the Pinkilla, Tallyabra, and Kyabra Anticlines. A large gravity 'low' corresponds to the Tallyabra Syncline. This 'low' is probably caused by a thick sequence of low-density pre-Permian sediments lying on denser basement rocks (?Precambrian). These sediments do not occur on the crests of the Pinkilla and Tallyabra Anticlines, which are considered to be bald-headed structures.

Three smaller gravity surveys have been completed in the area of the Great Artesian Basin discussed in this report. These are as follows:

(a) A regional gravity survey, for the Tallyabra Oil Company (Narain, 1956).

(b) A gravity survey in the Quilpie area by Smart Oil Exploration (unpublished).

(c) A detailed gravity survey in the Warbreccan area by the Westland Oil Company (unpublished).

(a) and (b) above were reconnaissance surveys, and few conclusions were reached in the short accounts of the results available to the author. On the basis of the Westland Oil Company's gravity results the Warbreccan bores were drilled; these bores provide important stratigraphic information (Plate 8).

Seismic surveys

A seismic traverse was run in 1960 from Marree in South Australia to Boulia in Queensland by the South Australian Mines Department (Milton & Seedsman, 1961). Part of this traverse lies in the present area where seismic lines were shot between Birdsville, Bedourie, and Boulia, and between Birdsville and Betoota.

A reflector at the base of the Mesozoic beds was picked up in most areas of the traverses. Thus reliable Mesozoic thicknesses could be calculated. This thickness is 735 ft at Breadalbane Homestead which lies about 30 miles north of Bedourie; south of Birdsville it increases to 6500 ft, and south-east of Birdsville it increases to 7500 ft at Cordillo Downs. A sudden increase in Mesozoic thickness 40 miles south of Birdsville suggests faulting with a throw of about 700 ft.

Below the Mesozoic, two main refractors with velocities of about 16,000 ft/sec and 18,000 ft/sec have been correlated with Palaeozoic (?Devonian) red beds and Lower Palaeozoic limestone respectively. Proterozoic slate at Marree in South Australia has a velocity of 19,300 ft/sec and similar high velocities were found at Cluny (north of Glengyle Homestead), Roseberth (north of Birdsville), and Rainbow Plain (north-west of Cordillo Downs). Granite found at Kamaran Downs has a seismic velocity of 18,500 ft/sec.

These results indicate that the Mesozoic sediments lie unconformably on Proterozoic, Lower Palaeozoic, and ?Devonian rocks in different areas. The ?Devonian red beds occur in two main areas: at Innamincka, where they have also been proved by drilling, and at Breadalbane Homestead where they rest on Lower Palaeozoic limestone. A bore in this last-mentioned area penetrated pre-Mesozoic red beds that may be Upper Palaeozoic.

A seismic survey was done in 1960-61 in the Boulia, Springvale, and Toko areas (Phillips/Sunray, 1961a). The seismic work was concentrated in two areas of potentially thick Cambro-Ordovician sediments, viz. the Burke River structural belt and the Toko Syncline. The results are of importance in the present report.

From the Momedah Fault zone in the eastern line of the Burke River structural belt to a point 18 miles to the east, reflections were obtained indicating pre-Mesozoic sediments from 9000 to 27,000 ft thick with a steep easterly dip. Beyond this point to the east no reflections were obtained below the Mesozoic cover. This is consistent with borehole information that the

Mesozoic beds here lie directly on granitic basement (Lucknow or Williams Granite).

Between the two lines of the Burke River structural belt the reflections indicate doming of the sediments; amplitude is about 6000 ft and depth to the top of the dome about 12,000 ft. To the west of the western line of the Burke River structural belt the structure is complex, with a synclinal structure bounded to the east by a normal fault and to the west by a thrust fault or unconformity.

In the Springvale area reflections were correlated with the base of the Mesozoic from boreholes, and faulting was located in two places on the Black Mountain Fault trend. The only pre-Mesozoic reflections obtained were in the vicinity of Canary on the Springvale Sheet. These were from 5000 ft to 10,000 ft deep and very local. The gentle dip of these reflections suggests Palaeozoic rather than Proterozoic strata.

Reflections recorded from Springvale to Toko were mainly poor except at 60 miles south-west of Marion Downs, where westerly dipping reflections indicate that about 10,000 ft of sediments may be present.

In the Toko (Netting Fence) area 6500 ft of sediments is indicated by the seismic results.

It is of interest to note that at the time of writing, Phillips Petroleum has commenced drilling a stratigraphic bore near Black Mountain.[✯]

[✯] This bore, of total depth 5511 ft, bottomed in dense shale believed to be the Lower Cambrian equivalent of the Mount Birnie Beds.

During 1960-61 Philips/Sunray (1961b, 1961c) have done extensive seismic work in the Adavale area. The presence of a large sub-basin of pre-Mesozoic sediments with a north-east trend was established. Known as the Adavale Basin, it is some 60 to 70 miles in width and contains up to 18,000 ft of pre-Mesozoic sediments.

In the north-east of the Adavale Basin several structural features divide the basin axis; one branch of the axis follows Blackwater Creek and the other passes close to the north-western flank of the Etonvale Dome and the Hope Creek Nose. On the north-western flank of this Basin the south-easterly dipping pre-Mesozoic sediments thin to extinction against rising basement rocks. The south-eastern flank is steeply upturned and truncated. In the central part of the Basin the pre-Mesozoic strata are stongly folded and faulted with structural relief of hundreds and even thousands of feet. These beds are truncated at steep angles across structures. Seismic results suggest onlap of the deeper section on the pre-existing Cothalow Arch and possibly on the Etonvale Dome.

The Etonvale Dome, twelve miles long and six miles wide, is well defined by faulting in the north and west.

Other structures mapped by Phillips/Sunray include structural 'highs' at Log Creek and Gilmore Creek and the Hope Creek Nose.

The Mesozoic sediments are tilted regionally to the south-east and range in thickness from 4000 to 9000 ft. Local Mesozoic structures are often draped on older Palaeozoic structures.

The Conorada Petroleum Corporation (1962a, 1962b) has done seismic work in the Mayne and Stonehenge areas of Queensland during 1961. In the Mayne area traversing was done using both the refraction and reflection methods, mainly on BRIGHTON DOWNS and MANEROO. North-south and east-west cross-sections show the geological interpretation of the seismic results. The north-south cross-section indicates a fairly uniform Mesozoic sequence 4000 ft thick overlying in the north a thin layer of possible limestone, dolomite, or metamorphosed rock (velocity 20,600 ft/sec) of probable Palaeozoic age, and overlying in the south a ?Permian sequence (velocity 16,950 ft/sec) thickening to the south-west. Both these formations rest on a presumed granitic basement (velocity 19,300 ft/sec).

The east-west cross-section shows about 1000 ft of ?Permian resting on ?granite in the west, which is faulted against a thicker sequence (about 3000 ft) of ?Permian overlain by about 1500 ft of ?Triassic-Jurassic beds which do not occur west of the fault. The basement east of the fault is again interpreted as granitic.

The seismic results indicate several faults and structures all showing a distinct north-east trend.

The Stonehenge survey was an extension of the Mayne survey to the south-west. The seismic results show that the pattern of faulting suggested in the Mayne area continues to the south-west. Local reflections suggest a thickening of the pre-Jurassic sequence in this area.

Aeromagnetic surveys

In 1958 the Bureau of Mineral Resources flew some reconnaissance aeromagnetic traverses across parts of the Great Artesian Basin (Jewell, 1960). The results show that both the western and eastern lines of the Burke River structural belt are marked by lines of positive magnetic anomalies that indicate basement rocks at shallow depth. On magnetic evidence there is a similar structure east of Marion Downs and west of Boulia extending north to the Cloncurry Fold Belt. The anomalies over the Boulia Shelf are very irregular in contrast to the smooth anomalies farther east in the Great Artesian Basin. An abrupt change occurs 20 miles east of Brighton Downs and 110 miles east of Hamilton (i.e. 135 miles west of Muttaburra). This change marks the eastern edge of the Boulia Shelf.

The Bureau's areomagnetic results in the Betoota/ Cordillo Downs area indicate thick sediments (up to 9000 ft) which would mask even significant changes in basement topography or lithology. A line of positive anomalies through Betoota, Cadelga, and a point 20 miles north-west of Cordillo Downs may represent a basement ridge. Magnetic basement depths have been estimated at several places, and in general these compare favourably with borehole depths and geological estimates of depths in the Great Artesian Basin.

In 1960 Phillips/Sunray (1961d) did an aeromagnetic survey over parts of the Eulo Shelf and Nebine Ridge and the adjacent parts of the Great Artesian Basin to the north and west of these features. The results indicate two types of basement anomalies which suggest two types of basement (i.e. crystalline rocks in this case). The aim of the survey was to map the Precambrian surface, but over large areas the basement is probably Upper Permian granite of the Eulo Shelf.

In several pre-Mesozoic basin areas the results indicate thick Palaeozoic sediments; this has been confirmed by seismic work and drilling. In some places these sediments rest on metamorphic rocks, which in turn rest on the crystalline basement. The Mesozoic rocks, which are very thin or absent on the Eulo Shelf, thicken to 5000 ft in the north-west of the area surveyed by Phillips/Sunray.

The results also indicate that the Nebine Ridge is separated from a ridge of similar trend by an area of possible pre-Mesozoic sediments.

4. OBJECTIVES OF THE SURVEY

From a consideration of chapters 2 and 3 above, the following specific objectives were established for the survey:

(a) To trace the extension of the gravity anomalies of the Cloncurry Fold Belt to the south, where the older rocks are blanketed by the Mesozoic cover. Previous gravity surveys had been successful in defining such anomalies.

(b) To investigate the structure of the Cloncurry Fold Belt. Granitic intrusions had been shown to correspond to areas of low anomaly, whereas gravity 'highs' had been shown to be caused by dense Precambrian metamorphic rocks and basic intrusions.

(c) To delineate the southerly extent of the Cloncurry Fold Belt and to discover the nature of its southern boundary; e.g. large-scale faulting, a change in the basement rocks, or a change in basement topography could produce conditions that might cause the known variation in aeromagnetic anomaly.

(d) To delineate the likely extent, in the Georgina Basin and the Toko Syncline, of the Lower Palaeozoic sediments below the Mesozoic cover.

(e) To discover any correlation between known buried geological structures and gravity anomalies in the Great Artesian Basin.

(f) To delineate any sub-basins of pre-Mesozoic sedimentation in the Great Artesian Basin. The existence of sub-basins had already been shown by gravity and seismic methods and from deep boreholes.

5. GRAVITY ANOMALY FEATURES

The Bouguer anomalies are shown in Plate 3. The principal gravity features have been numbered in Table 4. The numbering is a convenient form of reference which will be used in the text. Table 4 contains a brief description of each gravity feature as well as appropriate names suggested for many of the major features.

The first 22 units constitute the Cloncurry Regional Gravity High; this is defined as the gravity expression of the southern extension of the Precambrian basement rocks of the Cloncurry Complex, which is present below the Lower Palaeozoic and Mesozoic cover beds. The units are listed under four headings: Tectonic Land Zone, Eastern Geosynclinal Zone, Julia Creek Gravity Shelf, and Western Geosynclinal Zone. These divisions are based on those of Carter *et al.* (1961).

TABLE 4

GRAVITY ANOMALY FEATURES

Tectonic Land Zone	
1. Well defined gravity 'low' trending north-north-west in BOULIA	Kalkadoon Gravity Low
Eastern Geosynclinal Zone	
2. North-trending elongated gravity 'high' west of Duchess.	Duchess Gravity High
3. North-north-west-trending gravity 'high' in BOULIA.	
4. North-north-west-trending gravity 'high' in SPRINGVALE.	Burke River structural belt

5.	Gravity 'low' trending north-north-west from SPRINGVALE to BOULIA.	Burke River structural belt
6.	North-north-west-trending gravity 'high' in BOULIA.	Momedah Gravity High
7.	Local gravity 'high', spur between 8 and 9 in DUCHESS.	
8.	Gravity 'low' in north of DUCHESS.	Wimberu Gravity Low
9.	North-north-west-trending gravity 'low' from MACKUNDA to DUCHESS.	Williams Gravity Low
10.	North-east-trending local gravity 'low' in BRIGHTON DOWNS.	Brighton Downs Gravity Low
11.	Local gravity 'low' 15 miles south of Cloncurry.	
12.	North-north-west-trending elongated gravity 'high' from MACKUNDA to DUCHESS.	

Julia Creek Gravity Shelf (Eastern Shelf of Carter)

13.	Gravity 'low' in JULIA CREEK.	
14.	Local gravity 'low' in JULIA CREEK.	
15.	Local gravity 'low' in McKINLAY.	
16.	Local gravity 'low' in McKINLAY.	

Western Geosynclinal Zone

17.	Series of gravity 'highs' in MOUNT WHELAN, BEDOURIE, and MACHATTIE.	Bedourie Gravity Ridge
18.	North-north-west-trending gravity 'highs' from MOUNT WHELAN to GLENORMISTON.	
19.	North-north-west-trending elongated irregular gravity 'low' from SPRINGVALE to GLENORMISTON.	Glenormiston Gravity Low
20.	Belt of elongated gravity 'highs' trending north-north-west from SPRINGVALE to URANDANGI.	Boulia Gravity Ridge

21.	Eastern margin of gravity 'low' in MOUNT ISA and URANDANGI open to west.	Sybella Gravity Low
22.	Uniform gravity gradient extending from south-west BEDOURIE to north-east BRIGHTON DOWNS, defining the southern margin of the Cloncurry Gravity High.	Diamantina Gravity Gradient
Georgina Basin		
23.	Extensive, broad, north-west-trending gravity 'low' in MOUNT WHELAN and BEDOURIE.	Toko Syncline
Outer Zone of Gravity Lows		
24.	Local gravity 'low' centred on Annandale.	Cacoory Gravity Depression
25.	Small local gravity 'low' about 20 miles north of Birdsville.	
26.	Local gravity 'low' south of Durrie Downs on BETOOTA.	
27.	Local gravity 'low' in north-east of BETOOTA.	
28.	Extensive gravity 'low' in CONNEMARA widening considerably to WINTON.	Vergemont Gravity Depression
29.	Local north-east-trending gravity 'low' extension of feature 30 in WINTON	Richmond Gravity Depression
30.	Postulated extensive gravity 'low' in MANUKA open to north.	
31.	Two north-west-trending spurs or gravity 'highs' open to south in BIRDSVILLE.	

Betoota-Curalle-Warbreccan Gravity Ridge (Central Zone of Gravity Highs)

32.	North-north-east-trending elongated gravity 'high' 6 miles south-east of Betoota.	Betoota Dome
33.	Extensive, narrow north-east-trending belt of gravity 'highs' from CANTERBURY to JUNDAH.	Curalle Dome and Warbreccan Gravity Ridge
34.	Two gravity 'highs' on Longreach Ridge	Longreach Gravity Highs
35.	Gravity 'low' between 33 and 34.	Tocal Gravity Low

Inner Zone of Gravity Lows

36.	Large gravity 'low' open to the east, centred on Jundah.	Jundah Gravity Low
37.	Gravity 'high', north-trending, open to the north on WINDORAH.	Grey Range Gravity Ridge
38.	Extensive gravity 'low' on QUILPIE, open to the north but known from gravity traversing (Reid, 1962) to extend to Blackall.	South end of Adavale Basin
39.	Gravity 'low' in EROMANGA extending south into THARGOMINDAH.	Tallyabra Syncline
40.	Gravity 'low' almost centred on Quilpie.	Bulloo Syncline
41.	Gravity 'high' east of Quilpie; possible northerly extension of Eulo Shelf.	
42.	Gravity 'high' open to the south on borders of EROMANGA and QUILPIE.	Pinkilla Dome
43.	Gravity 'high' in EROMANGA with north-west trend.	Harkaway Dome
44.	Gravity 'low' in south of CANTERBURY, open to the south.	Lake Barrolka Gravity Low

6. DISCUSSION OF THE GRAVITY RESULTS

The Bouguer anomalies are shown in Plate 3 at a scale of 40 miles to one inch. The station density is about one per 50 square miles. Thus only regional gravity features have been mapped. The gravity contours of these features are subject to modification by more detailed work, but the present spacing is sufficient to define these features for a preliminary interpretation of the gravity anomalies in terms of geological structure.

On the basis of the geology and the Bouguer anomalies, the survey area is readily divisible into three major zones. These are the Cloncurry Fold Belt and its extension to the south and west below the younger sediments, the Georgina Basin, and that part of the Great Artesian Basin considered in this report. These areas will be briefly discussed in turn.

Cloncurry Fold Belt

The term Cloncurry Regional Gravity High has been used to describe the gravity unit associated with the Cloncurry Fold Belt and its southerly extension, which are closely defined by the Bouguer anomalies (Plate 3). This area is a structural 'high' and may be considered as a raised block in relation to the surrounding depressed areas to the south, west, and east. The gravity anomaly over the block is a regional 'high' with many superimposed more local gravity 'highs' and 'lows'. Either upwarping or thinning of the crust or an increase in the density of the crustal rocks below this area could account for the regional 'high'.

The boundaries of the block are well-defined in the south, west, and east (Plate 3). In the south the Bouguer anomalies trace the southern extension of the Cloncurry Fold Belt below the cover of Palaeozoic and Mesozoic sediments. The distinctive north- and north-north-west-trending anomalies of the Belt are sharply terminated in the south by a fairly uniform gravity gradient (feature 22), which extends from BIRDSVILLE to BRIGHTON DOWNS. This feature, named the Diamantina Gravity Gradient, marks the southern edge of the Cloncurry Regional Gravity High.

The western boundary of the block is also expressed by a sharp gravity gradient between the predominantly negative gravity anomalies of the Georgina Basin and the generally positive gravity anomalies of the block (Plate 3). This gradient marks the westerly extension of the block below the Palaeozoic sediments of the Georgina Basin. It is not, however, the eastern boundary of this Basin, because sediments belonging to this Basin extend as far east as the Burke River structures and are known in water bores in BOULIA and SPRINGVALE. A large gravity 'low' (feature 23), delineating the extent of the Toko Syncline, cuts this western boundary forming a deep embayment of the Basin. The irregularity of the western boundary is in contrast to the smoothness of the southern boundary. This is illustrated by several spurs of positive anomaly trending north-west in URANDANGI and GLENORMISTON.

The eastern boundary of the block is marked by a north-west-trending gravity gradient in MACKUNDA and McKINLAY which separates the block from the Julia Creek Gravity Shelf (Plate 3).

A fairly good correlation between the geological units of the Cloncurry Fold Belt (Carter & Brooks, 1960) and the Bouguer anomalies is shown in Plate 3. The geological zones defined in chapter 2 contain the following gravity features which will be discussed in the next chapter.

Geological Zone (after Carter & Brooks)	Gravity features
Tectonic land zone	1
Eastern geosynclinal zone	2 to 12
Eastern shelf or Julia Creek Gravity Shelf	13 to 16
Western geosynclinal zone and shelf	17 to 21

Eastern margins of the Georgina Basin

The Bouguer anomalies of the Georgina Basin will be described in a separate report (Barlow, in preparation). As stated above, the eastern margins of the basin extend over the south and west of the Cloncurry Fold Belt. Most of the anomalies in this region probably arise from density variations in the Precambrian basement below the Palaeozoic cover. An important exception to this is feature 23, an extensive gravity 'low' which trends north-west in MOUNT WHELAN and BEDOURIE. The north-western end of this feature coincides with the Toko Syncline of Cambro-Ordovician rocks as mapped by the geologists. The gravity results prove that this feature extends for a considerable distance to the south-west below the Mesozoic sediments.

Great Artesian Basin

In this region the Bouguer anomalies are predominantly negative in contrast to the generally positive anomalies of the Cloncurry Fold Belt. The anomaly trends are mainly north-east with some more local east- and north-trending axes. These younger axes are quite distinct from the prevailing north and north-north-west trends of the Precambrian area.

The anomalies in this part of the Great Artesian Basin fall into three zones. These are as follows:

(a) An outer zone of gravity 'low' borders the southern and eastern boundaries of the Cloncurry Fold Belt. This zone comprises the Cacoory Gravity Depression, the Vergemont Gravity Depression, and the Richmond Gravity Depression (Plate 3).

(b) A narrow central strip of relatively high gravity anomalies follows the same north-east trend as the outer zone of gravity 'lows' and the Diamantina Gravity Gradient. This zone of 'highs' includes the Betoota Anticline (32), the Curalle-Warbreccan Gravity Ridge (33), and feature 34 which comprises two spurs of high gravity anomaly which coincide with the Longreach Ridge.

Feature 31, a gravity 'high' open to the south and not completely surveyed, is treated separately.

(c) An inner zone of mainly low gravity closures. Although this zone is marginal to the main area of the survey, several low gravity features have been wholly or partly defined; these include features 36, 38, 39, 40, and 44. Several smaller gravity 'highs' have been mapped including features 37, 41, 42, and 43.

7. INTERPRETATION OF THE GRAVITY RESULTS

The discussion of the interpretation of the gravity results in terms of geological structure is subdivided into the three major zones defined in chapter 6.

Before considering the individual gravity anomalies a note on the method used in the interpretation is appropriate. By means of a mechanical integrator it is possible to evaluate the gravity effect at the surface of a vertical cross-section of a buried two-dimensional body. The errors introduced in assuming a body to be two-dimensional are small provided the body is much longer in the direction perpendicular to the cross-section. Using all available information from geology, boreholes, and density measurements, a cross-section is drawn of the model structure which agrees best with the known facts. The gravity effect of this model is calculated at several points at the surface and the anomaly curve thus obtained is compared with the actual Bouguer anomaly. This process may be repeated until the two curves are in close agreement. In the present interpretation there is little point in striving for an exact fit because the gravity data were obtained from a reconnaissance survey and thus are not sufficiently detailed for such precision.

As the ambiguity inherent in all gravity interpretation applies to the present model studies, the interpretation is, of course, not unique. However, the results presented should agree with all the known facts and should be geologically plausible. If these requirements are met, then the interpretational model will contribute useful information on geological structure and more particularly on density distribution, until such time as it is proved right or wrong by drilling or by geophysical methods having a greater resolution.

Cloncurry Regional Gravity High

In an area such as this, where the Bouguer anomaly closures over known Precambrian structures extend into an area covered by younger sediments, it is logical to begin correlation in the known area and to infer the extension of the known structures on the gravity evidence.

Tectonic Land Zone

The main gravity feature (1) in this zone is a large elongated gravity 'low' with a north-north-west trend (Plate 3). The northern end of this feature coincides with exposures of the Kalkadoon Granite. This granite, in fact a granodiorite, forms part of the zone which was tectonic land during part of Lower Proterozoic times. The gravity 'low' extends to the south across BOULIA in an area covered by Lower Cretaceous sediments which are probably underlain by Lower Palaeozoic deposits of the Georgina Basin. It is almost certain that the lower-density granodiorite, bounded by higher-density Precambrian metasediments and volcanic rocks on either side, is the source of the gravity 'low'. If this explanation is accepted then the Kalkadoon Granite, as delineated by the Kalkadoon Gravity Low, extends far beyond the present-day outcrops in the south of DUCHESS to the north of SPRINGVALE.

A cross-section D-D' cuts the Kalkadoon Granite as shown in Plate 7. A graphical regional anomaly was removed from the Bouguer anomaly to obtain a residual anomaly over the granite. This residual differs little from the Bouguer anomaly, so more elaborate methods of removing the regional gradient are unlikely to alter the residual significantly. The calculated anomaly curve agrees favourably with the residual curve when a density contrast of 0.1 g/cm^3 is used between the lighter postulated granitic mass and the denser surrounding medium. On the basis of the model used in the interpretation, the eastern edge of the granite has a steep dip of 79 degrees whereas the western contact dips at an angle of 11 degrees. The buried granite lies at a depth of 4000 ft and extends down to some 22,000+ ft along the line of section.

In the north, surveying does not extend over the Leichhardt Metamorphics which comprise the other main rock type of this zone. There is, however, an indication of the southern end of a gravity 'high' in the south-west of CLONCURRY. This 'high' may correlate with these dense metamorphic rocks. This hypothesis will have to be tested by a northward extension of the gravity survey.

Eastern Geosynclinal Zone

The gravity anomalies in this zone are complex. The prevailing trends are again north-north-west. In the west of this zone two belts of gravity 'highs' (features 2, 3, and 4, and features 6 and 7) are separated by a strip of low gravity anomalies (feature 5). These gravity features are located in and adjacent to the Burke River structures. This name refers to the almost north-trending belt of structures which extends from the trough of Middle Cambrian sediments in DUCHESS, south across BOULIA, and includes all structures appearing in or through the Mesozoic cover east of the main Burke River (Casey et al., 1960). The belt comprises a western and eastern line and the intervening area. The western line extends from the Pilgrim Fault east of Duchess, south through Signal Hill, Black Ridge, Black Mountain, Mount Ninmaroo, and Mount

Datson, with its surface expression evident as far south as south-west of Springvale. The main eastern line extends from DUCHESS to Chatsworth, east of Datchet Downs homestead to Momedah Creek. Beyond this point it is obscured by alluvium of the Hamilton River.

The intervening area between the two structural lines is bounded to the west and east by more or less continuous zones of faulting. Features 2, 3, and 4 occur along the western side of the western fault. Feature 2, the Duchess Gravity High, coincides with outcrops of the Corella Formation in the north and the Kalkadoon Granite in the south and west. The Corella Formation is composed of metamorphic rocks such as schist, gneiss, granulite, slate, and amphibolite. To the east of this 'high' the Wimberu Granite and Lower Palaeozoic sediments crop out. The high anomaly cannot be caused by the rocks of the Corella Formation because the 'high' extends to the south over the less dense Kalkadoon Granite. Metadolerites and metabasalts have been mapped in the area of the Duchess Gravity High, and in the east, near Bushy Park homestead, the Kalkadoon Granite is hybridised with basic material. From this geological evidence and from the gravity information it is extremely probable that a buried basic igneous mass is located here. Such a body, some 40 miles long, of high-density material intruded into the Kalkadoon Granite and the Corella Formation, could explain the high gravity anomaly. The position of this suggested basic mass is shown in cross-section A-A' (Plate 4) in relation to the geological section taken from Carter, Brooks and Walker (1961).

The position of the Pilgrim Fault coincides with the very steep eastern gravity gradient of the Duchess Gravity High.

The steepness of the gradient suggests that this fault is almost vertical. The gravity gradients bounding features 3 and 4 to the east trace the western fault line from the Pilgrim Fault southwards. To the east a steep gradient traces the line of the Momedah Fault, part of the eastern fault line. This gradient forms the western side of an extensive gravity 'high' some sixty miles long and twelve miles wide, named the Momedah Gravity High. The 'high' coincides with the Momedah Anticline which is an inlier of Lower Palaeozoic sediments which protrude through the younger Mesozoic beds.

Phillips Petroleum Corporation made a seismic traverse along the Boulia-Winton road crossing features 4, 5, and 6. The original seismic interpretation was reduced to a scale of four miles to one inch so that it might be compared with the Bouguer anomaly profile along the same line (see cross-section B-B', Plate 5). According to the authors of the oil company's report their interpretation is extremely speculative with several other interpretations possible. This interpretation indicates a complex system of faulting and thrusting based on abrupt changes in rate and directions of dip and shift in position of dominant energies. A phantom horizon throughout the section indicates a generalised structure for the basement. However, the position of this phantom is completely arbitrary.

The seismic interpretations suggest a complex graben-like structure with overthrusting of the basement rocks from the east. The postulated faults on the western side of the graben all show downward displacement to the east whereas the suggested eastern fault system indicates a consistent downward displacement to the west.

The Bouguer anomaly profile consists of a broad 'high' of 25 milligals in the west and a 'high' of 37 milligals in the east with an intervening gravity 'low' over the centre of the structure. The superficial deposits are Mesozoic overlain by Tertiary in the west affording little evidence about the older buried structures. However, the regional geological setting known from surrounding exposures and water bores shows that the Mesozoic rocks overlie a Lower Palaeozoic sequence mainly composed of limestone and shale of Lower Ordovician and Cambrian age.

The gravity interpretation also shown in Plate 5 does not reveal the structural detail possible in a seismic interpretation. However, the low gravity anomaly (5) directly over the southern extension of the graben known to the north indicates an excess of low-density material in this down-faulted region. The recent borehole at Black Mountain penetrated about 5500 ft of Cambrian strata without reaching basement. The total depth reached was 5511 ft in dense shale of Lower Cambrian age, equivalent to the Mount Birnie Formation. A downthrow of 1000 ft in post-Ordovician times results in approximately 6500 ft of Lower Palaeozoic strata in the graben. The gravity data on the density assumptions shown suggest that some 6000 ft of light material of ?Precambrian age are present below the Lower Palaeozoic beds in the downfaulted region.

In calculating the gravity effect of this light material a graphical regional was removed from the Momedah Gravity High (6) so that the anomaly level on either side of the graben might be similar. This technique assumes similar density relations on either side of the graben within the basement rocks. In the calculations a density contrast of 0.2 g/cm^3 has been used between the lighter material (2.6 g/cm^3) and the surrounding medium (2.8 g/cm^3). The calculated anomaly is not a perfect fit but corresponds fairly well with the Bouguer anomaly.

After the removal of the graphical regional there remains an excess gravity 'high' of 13 milligals over the Momedah structure. A dense buried body (Plate 5) could account for this 'high'. A body which meets the requirements lies at a depth of 5000 ft and extends to a depth of 16,500 ft within the basement. A density contrast of 0.15 g/cm^3 was used to obtain the calculated curve. Thus a density of 2.95 g/cm^3 must be attributed to such a body. This high density is indicative of ultrabasic material, but the presence of such a mass at this depth is in conflict with the sparse reflections indicated in the seismic cross-section. However, the body that causes this anomaly could lie at a depth as great as 17,000 ft, which would be below the source of the deeper seismic reflections. At this depth it would require a density contrast of 0.4, which means an unlikely value of 3.2 g/cm^3.

This dense mass of probable basic igneous material is analogous to the source of feature 2, the Duchess Gravity High.

Thus the gravity evidence suggests the intrusion of basic lenses along each side of the bounding faults of the Burke River structural belt. It is probable that feature 3 south of the Duchess Gravity High (2) has a similar explanation.

Widespread exposures of basic material in the area between features 8 and 9 delineated by a gravity 'high' (7) lend more evidence to support this hypothesis. Thus feature 7 on the eastern side of the Burke River structural belt is a continuation of the eastern line of intrusions.

At the northern end of the Burke River structural belt the Wimberu Gravity Low (feature 8) is proof that the preserved Palaeozoic sediments are underlain by the Wimberu Granite. The presence of this granite at depth links the eastern mass of exposed Wimberu Granite, over which feature 8 is centred, with the western exposures of Wimberu Granite which are also embraced by the gravity 'low' and bounded by the Roaring Fault. This gravity 'low' is a good example of how the extent of a granitic mass of lower density than the country rocks can be mapped by gravity measurements.

Feature 9 is a similar example. In the north the Williams Gravity Low (9), coincides with sporadic exposures of the Williams Granite which is covered over most of its extent by superficial Mesozoic sediments. This large gravity 'low' shows that the known exposures of granite are merely part of a huge mass extending over DUCHESS, BOULIA, and MACKUNDA with a north-north-west trend. The presence of the granite below the Mesozoic cover was known from water-bores but the Bouguer anomalies now clearly depict the size and position of the mass.

Cross-section C-C' was drawn across the strike of feature 9. A size and shape for the granitic body was calculated, and the model giving the best fit is shown in Plate 6. The cross-section shows the granite as underlying Mesozoic strata some 3000 ft thick and intruded into undifferentiated Precambrian basement. The eastern boundary of the granite is shown as vertical but the western boundary has a dip of 10 degrees to the west. The granite extends down to at least 23,000 ft. A density contrast of 0.15 g/cm^3 was used in the calculation. Thus if the granite density is 2.65 g/cm^3 then the Precambrian basement density is 2.8 g/cm^3.

North of features 8 and 9 a similar gravity 'low', feature 11, indicates the widespread occurrence at depth of the Naraku Granite which is exposed only in small isolated outcrops protuding through the Corella Formation.

Feature 12 is a large elongated gravity 'high' with a north-north-west trend bounding the eastern side of the Eastern Geosynclinal Zone. This feature reflects the dense Lower Proterozoic beds, which crop out east of the low-density granitic belt. The Lower Proterozoic beds here are the Soldier's Cap Formation which is mainly schist interbedded with altered basalt, quartzite, slate, and 'felsites'.

Julia Creek Gravity Shelf

The predominant north and north-north-west trends of the Cloncurry Regional Gravity High are not apparent in this zone which is characterised by more local, rounded anomalies. This zone corresponds to the hypothetical eastern stable shelf of Carter et al. (1960). The gravity anomalies indicate fairly high-standing basement intruded by granite and overlain by the younger Mesozoic cover beds. The Mesozoic cover is thin as shown by several water bores; e.g. at St Andrews station a bore penetrated metamorphic rocks at a depth of 902 ft.

Feature 13, a gravity 'low', undoubtedly shows the extent of a buried granite, outcrops of which are known in the south-west corner of the JULIA CREEK sheet. The outcrops coincide with the south-eastern boundary of feature 13. By analogy it is highly probable that features 14, 15, and 16 are caused by similar masses of less dense granite intruded into the denser metamorphic basement rocks.

Western Geosynclinal Zone

The correlation of this zone as a southerly extension of the western geosynclinal and western shelf zones of Carter et al. (1960) is tentative. However, the similarity of the gravity anomalies of this zone and those of the eastern geosynclinal zone is striking. The major gravity features consist of a central zone of gravity minima (features 21 and 19) bordered by strips of gravity maxima on each side (feature 18 to the west and feature 20 to the east). These anomalies are all elongated with axial trends in a north-north-west direction which is the prevailing trend of most of the anomalies of the Cloncurry Regional Gravity High.

The superficial geology is mainly flat-lying Lower Palaeozoic sediments with some Mesozoic to Recent cover. Only in the east of URANDANGI are the Precambrian basement rocks exposed.

The Sybella (Templeton) Granite which crops out in the east of URANDANGI is associated with feature 21, the Sybella Gravity Low. This gravity feature is mapped only on its southern and eastern margins so that the full extent of the granite to the north and west is not known. However, the anomaly indicates that the granite probably extends westwards beyond the known outcrops which disappear below a cover of alluvial black soil to the west.

In the south-east corner of URANDANGI the northern end of feature 20, a gravity 'high', is associated with outcrops of the Precambrian Eastern Creek Volcanics, a dense interbedded series of basalt and arenaceous sediments along with slate, limestone, schist, and gneiss. This series rests on the less dense Sybella Granite; thus the difference in density between these rock types would explain the gravity maximum in this area. It seems likely that the Eastern Creek Volcanics extend southwards below the Lower Palaeozoic and younger cover as indicated by the southerly extension of feature 20. Cross-section D-D' cuts this feature, and a tentative interpretation of the gravity 'high' is shown in Plate 7. The gravity effect of a postulated basic mass 0.15 g/cm^3 denser than the surrounding rocks has been calculated for several points along the cross-section. This calculated anomaly curve is shown along with the residual anomaly obtained by removal of the same graphical regional anomaly which was removed from the Kalkadoon Gravity Low. Thus a basic mass lying 6000 ft below the surface and extending down to some 21,000 ft gives a reasonable approximation to the observed effect. The dimensions of the postulated mass are as shown in Plate 7.

Further south feature 20, the Boulia Gravity High, extends west and south of Boulia. This feature suggests the presence of a buried ridge of dense Precambrian rocks or a change in density within the basement in this area.

To the west of feature 20, the Glenormiston Gravity Low (19) occupies a setting somewhat similar to the Williams Gravity Low (9) in the eastern geosynclinal zone. The main difference between these anomalies is the irregular shape of feature 19 which contrasts with the smoother outlines of feature 9.

It is suggested for several reasons that a granite emplacement is the best explanation of feature 19. The source of this low regional anomaly occupies a geological setting in a geosynclinal zone similar to that of the Williams Granite. Almost all the major gravity 'lows' of the Cloncurry Regional Gravity High can be correlated with acid igneous intrusions, and the trend and size of this anomaly are very similar to those of the

Williams Gravity Low and the Kalkadoon Gravity Low, both of which have been correlated with known granites. Some outcrops of granite have been mapped by BMR geologists at Yarra Waterhole, and further east a foliated granite is exposed. This geological evidence lends further support for the hypothesis. The postulated shape and position of such a granitic mass is shown, but only diagrammatically, in cross-section D-D' (Plate 7).

Feature 18 and feature 17, the Bedourie Gravity Ridge, reflect the high-density, high-standing Precambrian ridges which bound the Toko Syncline to the north-east and south-west.

Eastern parts of the Georgina Basin

The Bouguer anomalies of the Georgina Basin will be discussed in a separate report (Barlow, in preparation). However, feature 23, the Toko Syncline, will be briefly discussed here. This feature is a broad extensive gravity 'low' with a north-west trend, which forms a deep embayment of the Georgina Basin. The Toko Syncline is asymmetrical and contains a succession of dolomite and limestone of Upper Cambrian and Lower Ordovician age and thick Middle Ordovician sandstone with shale. The beds dip at about 50 to 60 degrees on the western flank of the Toko Range and about 5 degrees or less in the east. A fault (the Pulchera Fault) has been mapped along the western boundary of the syncline, and this is clearly shown by the steep gravity gradients over the fault line. The gravity gradients suggest that this faulted boundary continues to the south-east to beyond the point where the fault reappears in the Mesozoic sediments.

The gravity 'low' may be explained by a density contrast between the less dense Lower Palaeozoic sediments of the syncline and the underlying and adjacent denser basement rocks. If this is so then the Lower Palaeozoic syncline must extend from MOUNT WHELAN into BEDOURIE as shown by the gravity contours. In this area the structure is obscured by Mesozoic deposits. In view of the steep gravity gradient it is possible that the north-eastern boundary of the syncline is also faulted at depth, though this is not certain.

A cross-section D-D' drawn across the Toko Syncline is shown in Plate 7. A mean density of 2.50 g/cm^3 was taken for the sediments of Lower Cambrian to Middle Ordovician age, which range in density from 2.80 g/cm^3 to 2.10 g/cm^3. This value, which was obtained by weighting the densities against the bed thicknesses based on geological estimates, results in a density contrast of 0.3 g/cm^3 with the Precambrian basement rocks. The gravity effect of the synclinal shape shown in Plate 7 was calculated and the results when superimposed on the Bouguer anomaly curve are in fairly good agreement with the observations. According to the gravity evidence the Pulchera Fault is almost vertical and the estimated maximum Lower Palaeozoic thickness in the syncline, for the density assumptions made, is 7800 ft.

Great Artesian Basin

The Bouguer anomalies in this region are predominantly negative, in striking contrast to the positive anomalies of the Cloncurry Regional Gravity High. The anomaly trends are mainly north-east and east-west and are thus quite distinct from the prevailing north and north-west trends of the Precambrian belt to the north-west. These trends in the Great Artesian Basin can often be correlated with known structures; e.g. the Betoota and Curalle Anticlines coincide with local north-east-trending gravity 'highs'.

From a consideration of these trends and the known geology of the area, it can be concluded that the variations in the gravity anomalies of the Great Artesian Basin are not generally caused by density disturbances within the Precambrian, but arise largely from density contrasts between the rocks forming the basement of the Great Artesian Basin and the younger sediments which fill the basin. A thick sequence of Palaeozoic sediments, ranging in age from Lower Devonian to Permian, is known to underlie the Mesozoic strata in parts of the Great Artesian Basin. The presence of such beds has been interpreted from seismic work and confirmed by many deep bores. Two major density discontinuities will be considered as contributing to these anomalies, viz. one at the base of the Mesozoic sequence and one at the base of the Palaeozoic sequence. Density contrasts almost certainly do occur within these broad geological divisions, but for the purposes of this regional survey only these two density discontinuities will be considered as an approximation to the true conditions. From the results of available density measurements, mean densities of the Mesozoic beds and Palaeozoic beds are taken as 2.2. g/cm^3 and 2.4 g/cm^3 respectively.

The thickness of the Mesozoic sequence beyond the Cloncurry Regional Gravity High is known at various localities from drilling (Plate 2). From eight deep bores that penetrate pre-Mesozoic strata in the surveyed area, the average thickness of the Mesozoic beds is about 4800 ± 700 ft. These bores are widely distributed and presumably give a fairly representative idea of the Mesozoic thickness. The variation in Mesozoic thickness is therefore small, and it seems unlikely that variations in Mesozoic thickness alone could account for the variations in gravity anomaly found in the Great Artesian Basin. If the densities of the Mesozoic beds (2.2. g/cm^3) and the granitic-metamorphic basement (2.65 g/cm^3)

are considered, then a density contrast of 0.45 g/cm^3 is obtained. Using this value, it can be shown that 1000 ft of Mesozoic strata would cause an anomaly of 5.6 mgal. The variation in Mesozoic thickness has been shown to be less than ± 1000 ft, thus the variation in Bouguer anomaly should be less than ± 5.6 mgal. The variation in Bouguer anomaly actually reaches a maximum of ± 30 mgal in many places; consequently a variation in Mesozoic thickness of ± 6000 ft would be required to account for the variation in Bouguer anomaly. It is considered that these estimates show conclusively that variations in Mesozoic thickness alone cannot account for the observed variations in Bouguer anomaly in the Great Artesian Basin.

The base of the Palaeozoic sediments must next be considered as a possible density discontinuity contributing to these anomalies. Several deep bores have penetrated Palaeozoic sediments before striking granitic or metamorphic basement rocks. The Palaeozoic thickness is very variable as shown in the following bores: Warbreccan No. 1, about 350 ft; Buckabie No. 1, about 3600 ft; and Betoota No. 1, 4000+ ft. The density contrast between the Palaeozoic beds (about 2.4 g/cm^3) and the basement (about 2.65 g/cm^3) is considered to be about 0.25 g/cm3. Thus 1000 ft of Palaeozoic sediments will cause an estimated anomaly of 3.2 mgal. Therefore to account for the anomaly range, variations in Palaeozoic thickness of up to about 9000 ft must occur. This is quite possible; e.g. at Innamincka No. 1, which is to the south of the area, about 6000 ft of Palaeozoic sediments were penetrated without striking basement. Also seismic results in the Adavale Basin have shown the presence of up to 18,000 ft of presumed Palaeozoic sediments below the Mesozoic cover. From the above considerations based on geological and geophysical evidence, it is reasonable to accept variations in Palaeozoic thickness as being a major cause of the variations in Bouguer anomaly in this north-western part of the Great Artesian Basin.

Cross-section E-E' (Plate 8). To further analyse the above interpretation a cross-section E-E' was drawn in a south-easterly direction across the Cloncurry Regional Gravity High and the Great Artesian Basin passing through the following bores: Lucknow No. 10, Ooroonoo No. 1, Warbreccan No. 1, and Buckabie No. 1 (see Appendix C). The first two bores are located on the Cloncurry Regional Gravity High and the other two are in the Great Artesian Basin.

There are no pre-Mesozoic outcrops along the line of cross-section; thus any structures in the older formations are concealed. The Mesozoic thickness increases from 1000 ft at Lucknow No. 10 to 5000 ft at Buckabie No. 1. This increase is much more rapid in the north-west, whereas along the greater part of the section line the Mesozoic thickness is fairly constant. At Ooroonoo No. 1 the Mesozoic thickness is 3600 ft and it reaches 5000 ft at a point about 30 miles north-west of Warbreccan No. 1. Apart from these bores and some control from other bores reasonably near the section line, the Mesozoic thickness is unknown in detail. For this reason it has been necessary to interpolate between known points and thus ignore any local variations in the Mesozoic thickness.

The first step in the interpretation is to correct the Bouguer anomaly profile for the gravity effect of these Mesozoic sediments. The mean density of these beds is about 2.2 g/cm^3 which results in density contrasts of about 0.6 g/cm^3 with the basement rocks of the Cloncurry Regional Gravity High area and of about 0.45 g/cm^3 with the basement rocks of the Great Artesian Basin.

This change in density contrast is caused by the change in basement density which occurs at the southern end of the Cloncurry Regional Gravity High area (see below). In calculating the gravity effect of the Mesozoic strata at intervals along the section line, the usual approximation 12.77Δdh milligals was used, where Δd is the density contrast in g/cm3 and h is the thickness in kilofeet.

The Bouguer anomaly profile corrected by this method is shown in Plate 8. Because these light sediments have a negative gravity effect, the correction for the effect is positive, thereby making the corrected anomaly less negative. The applied correction takes into account the variation in bed thickness, resulting in a variable correction over the north-western part of the profile. However, over the greater part of the profile, where the Mesozoic beds have a fairly uniform thickness, the correction is approximately constant.

As seen in Plate 8 the corrected profile between Lucknow No. 10 and Ooroonoo No. 1, has been levelled off, showing the removal of the gravity effect of the Mesozoic sediments (about -15 mgal), shown in the original Bouguer anomaly profile. Over the remainder of the section line the local gravity anomalies remain with slight changes in gradient in some places.

The most pronounced feature of the cross-section is the fairly steep (1.3 mgal/mile) and very uniform gravity gradient, called the Diamantina Gravity Gradient (feature 22), which marks the edge of the Cloncurry Regional Gravity High. From the form and magnitude of this gravity gradient it is most probable that a major change in density within the basement, rather than a change in basement topography, is the main source of the anomaly. The density of the Precambrian metamorphic basement of the Cloncurry Fold Belt and its southerly extension is known to be about 2.80 to 2.85 g/cm^3, whereas the basement rocks of this area of the Great Artesian Basin, known from drilling, are mainly granite and low grade metamorphic rocks, e.g. phyllite and slate of probable Lower Palaeozoic age, which have a mean density of about 2.65 g/cm^3. Thus a density contrast of between 0.15 and 0.20 g/cm^3 is indicated.

The relation between the basement rocks of the Cloncurry Regional Gravity High and those of this part of the Great Artesian Basin was further investigated by calculating the gravity effect of several different structural models and comparing the results with the corrected Bouguer anomaly profile. The best fit was obtained using a gently sloping contact between the denser basement to the north-west and the less dense basement to the south-east. The total length of this slope is 18 miles and the dip of the slope is $8\frac{1}{2}^{\circ}$ except over the four miles at the lower end of the slope where the dip changes to 5°. A density contrast of 0.2 g/cm^3 was used in the calculations.

At its north-western or upper end the sloping contact may steepen to account for the 5-mgal difference between the two gradients. This discrepancy could also be explained by the presence of higher-density rocks within the Precambrian basement. These possibilities have not been further investigated at this stage.

The gravity data are thus consistent with the geological evidence of a major change in the composition of the basement rocks in the region of the southern edge of the Cloncurry Regional Gravity High.

To the north-west of feature 22, the Brighton Downs Gravity Low (10) of about 11 mgal has been interpreted as a local granite intruded into the Precambrian basement. Using a density contrast of 0.15 g/cm^3, a rectangular body about 10 miles wide and 6500 ft thick, lying below a 3500-ft-thick Mesozoic cover gives a calculated gravity effect that agrees favourably with the corrected Bouguer anomaly. Only 10 miles to the north-west, Ooroonoo No. 1 borehole penetrated granitic basement, which lends some support to this interpretation. However, the trend of this anomaly is north-east in contrast to the prevailing north-north-west trends of the major granites of the Cloncurry Fold Belt. The north-east trend is more comparable with the north-east trends found in the Vergemont Gravity Depression (28), and the possibility that light sediments may cause the anomaly (10) cannot be excluded. If this is so, the density contrast would be larger, about 0.4 g/cm^3, indicating a maximum thickness of just over 2000 ft of excess light sediments.

In the Great Artesian Basin the cross-section cuts three major gravity 'lows' (features 28, 36, and 38) and two major gravity 'highs' (features 33 and 37). Feature 37 is not completely surveyed by the available gravity data. For this reason feature 37 was interpolated in part for the drawing of the continuous gravity profile. This interpolation is shown by a dashed line in Plate 8.

That part of feature 38 penetrated by Buckabie No. 1 borehole is known to open out and extend to the north-east forming the Adavale Basin of pre-Mesozoic sediments which has been defined by seismic work and drilling (Phillips/Sunray, 1961e). Buckabie No. 1 bore penetrated about 3600 ft of Palaeozoic sediments (informally named the 'Buckabie Beds'), which have been tentatively dated as Carboniferous. These beds rest on a phyllite basement. Thus good depth control is available at this point for drawing the geological cross-section. The mean density of these sediments is about 2.4 g/cm^3 which gives a density contrast of 0.25 g/cm^3 with the metamorphic basement (2.65 g/cm^3). Using this value it has been shown that a maximum thickness of 9500 ft of these Palaeozoic sediments must be present to account for the maximum anomaly of -25 mgal. The calculated anomaly for the assumed shape of the pre-Mesozoic sedimentary basin is shown in Plate 8. This embayment of the Adavale Basin is some 36 miles wide and the sediments thicken rapidly towards the centre of the basin as shown by seismic work and a BMR gravity traverse from Quilpie to Blackall.

To the north-west these sediments thin to about 500 ft and may be absent altogether on the basement rise postulated to explain feature 37, the Grey Range Gravity Ridge. However, for reasons mentioned above, too much emphasis must not be placed on this feature on gravity evidence alone. However, seismic work by the Phillips Petroleum Co. in this area indicates a similar structure.

Feature 36, the Jundah Gravity Low, lying to the north-west of feature 37, appears to be an extensive gravity 'low' although incompletely surveyed in the east. The interpretation of this 'low' is similar to that of the Adavale Basin. Using the same density contrast as above, a maximum of 8500 ft of Palaeozoic sediments is required to account for the Bouguer anomaly over this area. This pre-Mesozoic basin is some 104 miles wide and is bounded to the north-west by a fault of 3500 ft throw or a steep contact suggested by the 1 mgal/mile gravity gradient at this point.

To the south-east the sediments probably thin towards feature 37 as shown in Plate 8. Because the calculated anomaly is about 2.5 mgal less than the corrected Bouguer anomaly at the maximum anomaly point, the sedimentary thickness may be nearer to 9300 ft than 8500 ft.

The residual gravity 'low' which is part of the Vergemont Gravity Depression (28), was isolated by subtracting the calculated gravity effect of the basement density change at feature 22 from the corrected Bouguer anomaly. This process is analagous to the removal of a regional gradient. The residual 'low' has a maximum value of -9 mgal and may be explained by a trough of light pre-Mesozoic sediments. The maximum pre-Mesozoic sedimentary thickness estimated for this trough is about 3500 ft using the same density relations as before. In Plate 3 the Vergemont Gravity Depression (28) is seen to extend over a considerable area; from 28 in Plate 8 the sediments are shown as thinning to the south-east as far as CONNEMARA where the gravity suggests a local thickening to about 2000 ft in an embayment of the Vergemont Gravity Depression.

From here to the south-east the pre-Mesozoic sediments thin to 350 ft, as proved in Warbreccan No. 1 borehole. Here these beds overlie the granitic basement of the Warbreccan Gravity Ridge (33). The boundaries of this ridge are not defined precisely in Plate 8. This gravity 'high' (33) is caused by the relatively high-standing basement ridge separating the Vergemont Gravity Depression from the Jundah Gravity Low. The granite as mentioned before is assumed to have a density similar to the low grade metamorphic basement (2.65 g/cm^3), which is also present in parts of the cross-section. Thus there is no significant density contrast within the basement.

This preliminary quantitative analysis of the Bouguer anomalies in the Great Artesian Basin shows fairly conclusively that gravity 'lows' in general are caused by thickening of the pre-Mesozoic sediments which lie unconformably on a granitic/metamorphic basement and below a cover of Mesozoic sediments. Gravity 'highs', therefore, in general correspond to basement uplifts associated with thinning or absence of the pre-Mesozoic sediments.

On this basis the anomalies of the Great Artesian Basin will next be considered in conjunction with findings from other sources.

Outer zone of gravity 'lows'. An outstanding feature of the gravity anomalies in Plate 3 is the zone of gravity 'lows' which borders the Diamantina Gravity Gradient and runs from Annandale (in BIRDSVILLE) in the south-west to Richmond in the north-east. Four local gravity 'lows' have been mapped in the south-west of this zone. These are features 24, 25, 26, and 27 and together they comprise the Cacoory Gravity Depression. From a comparison with the conclusions drawn from cross-section E-E', it is probable that these 'lows' represent local pockets of relatively light pre-Mesozoic sediments containing probable maximum thicknesses of 8700 ft, 3700 ft, 4700 ft, and 8100 ft of sediments, respectively, below the Mesozoic cover.

Seismic traverses were shot in this area by the South Australian Mines Department (Milton & Seedsman, 1961) before the present gravity results were available. Unfortunately none of the seismic lines cross these areas of low gravity anomaly. Such data would have further tested the possibility of thick pre-Mesozoic sediments. The main traverse from Birdsville almost due north to

Cluny runs parallel to the local trend of the gravity contours. Two other traverses, from Birdsville to the east, circumvent feature 26. From velocity correlations light pre-Mesozoic sediments were located locally at Breadalbane and Innamincka, which is of course south of the area under consideration. Otherwise along the seismic traverses the Mesozoic beds apparently lie unconformably on older rocks with much higher velocities. These velocities indicate two main types of basement e.g. granite known in Kamaran Downs No. 3 borehole (velocity 18,500 ft/sec) and Lower Palaeozoic limestone (velocity about 18,000ft/sec). This latter correlation suggests that the Lower Palaeozoic limestones of the Georgina Basin may extend at depth into this region. It may also be noted here that the basement rocks found in three deep bores in the general area strongly suggest a Lower Palaeozoic sequence developing southwards from Betoota where the basement conglomerate appears to be Lower Palaeozoic. The pebbles in this conglomerate are derived from Precambrian origins, and a Lower Cambrian age is possible. Farther south at Innamincka the red bed sequence has been tentatively placed in the Devonian; however, the authors state that a Middle Cambrian age is possible on the basis of lithology (Delhi-Frome-Santos, 1961). This age is perhaps more acceptable because Ordovician shale has been discovered farther south in Dullingari No. 1. This sequence of Lower and Middle Cambrian and Ordovician basement is more logical than the other suggested ages of Proterozoic, Devonian, and Ordovician basement respectively. These speculations however will have to await further work in the area before the correct answer is known.

The Vergemont Gravity Depression (28) forms a large part of the outer zone of gravity 'lows'. This feature is an extensive gravity depression with predominant north-east trends. In the north-east the feature is not wholly surveyed. A seismic line in a more or less east-west direction has been shot across the feature by the Conorada Petroleum Corporation (unpublished results). The seismic results (see Chapter 3) when interpreted in geological terms indicate a fairly uniform Mesozoic sequence about 4000 ft thick, overlying Permian beds on the western side of a major fault. On the eastern side of the fault the Mesozoic strata rest on Jurassic-Triassic beds, absent in the west, which rest in turn on a thicker Permian sequence. The pre-Permian basement under the whole sequence has been interpreted as granite on the basis of velocity. There are several points of similarity between the independent interpretations of cross-section E-E', and the seismic traverse. These cross-sections though not identical are close enough for comparison. The interpretations in both cases indicate a uniform Mesozoic sequence overlying pre-Mesozoic sediments which rest on a basement of uniform composition. The main difference shown by the seismic interpretation is the interpretation of part of the sequence as having a Triassic-Jurassic age. Neither gravity nor seismic methods can differentiate beds to this extent and the dating of these strata as Triassic-Jurassic must remain tentative even with velocity information. The seismic basement is shown uniformly as ?granite, whereas the gravity interpretation suggests a basement of uniform density which may be granitic or composed of low grade metamorphic rocks. An important point of agreement is the thickness of the pre-Mesozoic sequence which in both cases is roughly 4000 ft.

From all the available data it seems probable that this area of negative gravity anomalies is the site of a pre-Mesozoic sub-basin containing most probably Permian sediments with the possibility of some Carboniferous below the Permian, and local Triassic-Jurassic strata above the Permian in some places. These sediments rest on a basement of rather uniform density which may be granitic or metamorphic in parts.

The Richmond Gravity Depression (29 and 30) is a similar feature completing the arc of negative gravity closures. Feature 30 is not wholly defined but feature 29 has been surveyed in greater detail by the Magellan Petroleum Corporation in 1959. Feature 29 has been interpreted by Magellan as the gravity effect of a small basin of pre-Mesozoic sediments bounded to the south-east by a fault zone. Seismic work by the BMR confirmed the presence of such sediments and the zone of faulting (see Chapter 3). By analogy it is probable that feature 30 represents a much greater thickness of pre-Mesozoic deposits.

Central zone of gravity 'highs'. This zone of north-east-trending gravity 'highs' includes feature 32 which corresponds with the Betoota Anticline, feature 33 which corresponds with the Curalle Anticline and the Curalle-Warbreccan Gravity Ridge, and two gravity 'highs' (34) on the Longreach Ridge.

The Betoota Anticline has been defined by geological mapping, seismic work, and drilling. It was shown to be a long, wide anticlinal structure, plunging at both ends with a north-north-east trend. Shooting revealed the existence of the structure at depth within the Mesozoic sequence. At the base of the Mesozoic beds there is a strong unconformity where the Mesozoic sediments lie directly on indefinitely dated Lower Palaezoic rocks dipping from 50° to 80°.

The Curalle Anticline, which is not so well defined by the Bouguer anomalies, is thought to be similar in structure to the Betoota Anticline (Sprigg, 1958).

The Warbreccan Gravity Ridge is a granitic basement uplift at Warbreccan where a bore struck granite at 5399 ft. The gravity anomalies agree with the presence of only 350 ft of pre-Mesozoic sediments recorded in the bore. Here again the basement uplift and absence of thick pre-Mesozoic sediments result in a relative gravity 'high'.

Beyond the gap caused by feature 35 this granite ridge is associated with a gravity 'low' between two gravity 'highs' on the Longreach Ridge. The presence here of basement granite has long been known and more recently a bore, Brookwood No. 1 (T.D. 4806') struck granitic basement about 66 miles north-north-east of Longreach. However, in places around Longreach metamorphic basement has been penetrated; e.g. at Penrith No. 1 in the north-east corner of MANEROO phyllitic basement was encountered at 4008 ft.

Inner zone of gravity 'lows'. South-east of the Curalle-Warbreccan Gravity Ridge towards the centre of the Great Artesian Basin, there is another zone comprising several gravity 'lows', some well-defined and others not yet wholly surveyed. Of these the Adavale Basin (38), although not completely defined by gravity surveys, is perhaps the best known. Phillips Petroleum Corporation (Phillips/Sunray 1961e, 1961f, 1961g, 1962) has made a large contribution to unravelling the pre-Mesozoic structure by an intensive programme of seismic work and drilling in this area. The company has interpreted the Adavale Basin as the remnant of a Devonian and ?Carboniferous depositional basin which extends across ADAVALE with predominant north-east trends. ?Carboniferous beds, informally known as the 'Buckabie Red Beds; found in Buckabie No. 1, Gumbardo No. 1, and Cothalow No. 1 form the upper part of the pre-Permian sequence. These beds are non-marine and overlap the marine or estuarine Devonian eastward and north-eastward. They locally overlie metamorphic basement at Buckabie where the Devonian beds are absent. Earth movements and erosion resulted in the removal of the Palaeozoic strata south-east of a steeply dipping zone of truncation which marks the south-eastern edge of the Palaeozoic Adavale Basin. Non-marine Permian shale and sandstone were deposited locally and unconformably on the older Palaeozoic remnants. These Permian beds are present at Cothalow and Etonvale but absent at Gumbardo and Buckabie. To the north-west of the basin the Mesozoic/Permian sequence lies directly on high-standing basement.

A further report on the Bouguer anomalies in this area and in the Quilpie-Thargomindah areas will be available later (Darby, in preparation).

From the knowledge gained in the Adavale Basin it is reasonable to draw analagous conclusions about the other large gravity 'lows' in this zone. Such prominent features as the Jundah Gravity Low (36), the Lake Barrolka Gravity Low (44), the Tallyabra Syncline (39), and the Bulloo Syncline (40) are likely to have similar depositional histories with light Upper and Middle Palaeozoic sediments lying on denser basement being the major cause of the negative Bouguer anomalies.

In this area of generally low gravity anomalies some local 'highs' occur. The Grey Range Gravity Ridge (37) has been discussed in cross-section E-E'. Future gravity surveys may show that this feature is linked to feature 34 forming a continuous basement uplift between features 36 and 38.

The Pinkilla Dome (42) and the adjacent Tallyabra Syncline (39) have been studied in a BMR seismic survey (Bigg-Wither & Morton, 1962). A basement uplift of possible metamorphic composition was found. This was flanked by thick pre-Mesozoic sediments (12,000 ft) which were in turn overlain by the Mesozoic cover beds. These pre-Mesozoic sediments occur to the west of the uplift in the Tallyabra Syncline which is in agreement with the structure of other large gravity 'lows' in this area. Feature 43, though not wholly surveyed, appears to correlate with the Harkaway Dome. Finally, feature 41 is another gravity 'high' of a similar type which is likely to be caused by a basement uplift as in the Pinkilla Dome. These features will be discussed in more detail later by Darby (in preparation).

8. CONCLUSIONS

The objectives of the survey set out in Chapter 4 above have been achieved with varying degrees of success.

The gravity survey has been successful in defining the boundaries of the buried extension of the Cloncurry Fold Belt. Thus the Fold Belt and its extension would appear to be wholly defined by the Cloncurry Regional Gravity High. This is a regional gravity 'high' reflecting a structurally high area of basement rocks. Local gravity 'highs' and 'lows' often of large magnitude and extent are superimposed on the regional 'high'. These local variations have been attributed to changes in density within the Precambrian fold belt. In general the gravity 'lows' are associated with granite and gravity 'highs' with dense metamorphic rocks and basic intrusions.

An attempt has been made to correlate the gravity anomalies in a generalised manner with the several zones within the Fold Belt which have been described by Carter _et_ _al_. (1961). With a future extension of the gravity survey to the north a better analysis of this tentative correlation will become possible.

The southern limit of the Cloncurry Regional Gravity High is marked by the Diamantina Gravity Gradient. The possible causes of this large change in the Bouguer anomaly field have been studied. It is concluded that this gradient is the result of a density discontinuity between the Precambrian basement of the Cloncurry Regional Gravity High and the basement rocks of the Great Artesian Basin which are probably mainly low grade metamorphic rocks with granitic intrusions. The discontinuity may take the form of a low-angle fault plane or an unconformity.

The south-easterly extent of the Lower Palaeozoic beds of the Toko Syncline below the Mesozoic cover has been defined by the Bouguer anomalies, which show this structure to be a major geological feature.

The unaltered Lower Palaeozoic sediments of the Georgina Basin do not extend eastwards beyond the Williams Granite. To the south, Ordovician shale has recently been found in Dullingri No. 1 borehole, so these beds certainly occur as far south as this point. However, their occurrence is sporadic and it is probable that such occurrences are mainly remnants of uniform deposits laid down during a widespread transgression. More information from drilling is required to fully determine the eastern limits of these sediments.

In the Great Artesian Basin the gravity survey has successfully defined several proven and several very probable sub-basins of pre-Mesozoic sedimentation. Gravity 'lows' correspond to such sub-basins of Middle and Upper Palaeozoic sediments.

9. REFERENCES

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APPENDIX A

NOTE ON FIELD METHODS AND GRAVITY REDUCTIONS

During helicopter operations, heights were measured using microbarometers on traverse with a suitable base barometer recording the diurnal variation. A network of spirit-levelled road traverse stations was established in advance throughout the area by the Department of the Interior, and read for gravity by BMR land parties. This basic network was used as a control for both heights and gravity values, since all helicopter loops were tied to one or more such stations. Initially the road network was linked to the previously established Australia-wide pendulum network.

Station positions were pricked on airphotos with final control from astro-fixes and slotted-template mosaic assemblies done by the Division of National Mapping.

The usual corrections were applied to the gravity observations to calculate the Bouguer anomaly at each station. A density of 1.9 g/cm^3 was used in the Bouguer correction. No terrain corrections have been made. The final Bouguer anomaly values were plotted, and contoured gravity maps were drawn showing the Bouguer anomalies for each 1:250,000 sheet. A fuller account of the field method employing helicopters is given by Vale (1962).

Estimate of the errors in the Bouguer anomaly. Errors in the Bouguer anomaly arise from three major sources. These are:

(a) Observational errors. An estimate of observational errors is given by repeat-readings with the gravity meter at the same station on different traverses. The reoccupation accuracy has an upper limit of 0.2 mgal (Vale, 1962) which means that the standard deviation can be taken as ±0.14 mgal. This value is much higher than that obtained in normal road traversing.

(b) Errors due to plotting. In general, location is no better than 1000 ft of true latitude and longitude, but station intervals are within 600 ft. These errors will cause a maximum error of ±0.25 mgal in the Bouguer anomaly (Vale, 1962).

(c) Errors in station height. Using the barometer method it is probable that the standard deviation of the height is ±20 ft, though in ideal conditions it is often nearer ±10 ft. (Vale, 1962). This source of error is by far the largest involved in the final error in the Bouguer anomaly. An error of ±20 ft results in an error of ±1.32 mgal in the combined elevation correction (using density 1.9 g/cm^3). Since this area was flown, new barometers and new techniques of flying, which reduce the maximum traverse distance from base to 20 miles, have improved the accuracy of the height measurements.

Thus ignoring errors due to density and terrain effects, an estimate of the standard deviation in the Bouguer anomaly is given by

$$\sqrt{0.14^2 + 0.25^2 + 1.32^2}$$

$$= \pm 1.35 \text{ mgal}$$

This error, although acceptable in helicopter reconnaissance surveys as defined by Vale (1962) is large when compared with the accuracy that can be achieved in conventional detailed surveys.

APPENDIX B

HISTORY OF THE SURVEYS

Year	Type	Remarks
BMR Surveys		
1952	Pendulum network	
1957	Road traverses	Georgina Basin
1958	" "	S.W. Queensland
1959	" "	" " "
1959	Gravity loops	S.W. Queensland to NT
1959	Pendulum station ties	Cloncurry-Charters Towers
1959	Gravity along seismic traverses	Quilpie-Windorah
1959	Helicopter gravity survey	Boulia area
1960	Gravity along Phillips' seismic lines	Quilpie-Thargomindah
1960	Helicopter gravity survey	Mount Whelan
1961	" " "	Glengyle and Davenport Downs
1961	Gravity along Phillips' seismic lines	Quilpie-Blackall
Private Company Surveys		
1957	Semi-detailed	L.H. Smart Oil Exploration Co. and Tallyabra Oil Co., Eromanga area.
1957	" "	Westland Oil Co. Longreach-Jundah area.

1959	Semi-detailed	Magellan Petroleum Corp., North Winton area.
1959	" "	Papuan Apinaipi Petroleum Co., Boulia area.

APPENDIX C

DEEP BORES IN THE AREA

Boreh
Adria
Betoo
Birds
Birkh
Black
Black
Bucka
Corfi
Cotha
Etonv
Glenm
Gumba
Kamar
Luckn
Ooroo
Penri
Sprin
St An
Tally
Warbr

Borehole	Authority	T.D. ft	Type	Bottomed In
Adria Downs		3090	water bore	Longsight Sandstone
Betoota No. 1	Delhi - Frome - Santos	9824	stratigraphic	red beds, Pz or Pc
Birdsville Town	Delhi Aust. Pet.	4006	stratigraphic	Blythesdale Group
Birkhead No. 1	South Pacific Pty	5185	stratigraphic	Permo-Carboniferous
Blackall No. 2		2590		Walloon Coal Measures
Black Mtn No. 1	Phillips - Sunray	5511	stratigraphic	Lower Cambrian
Buckabie No. 1	Phillips - Sunray	9070	stratigraphic	pre-Silurian phyllite
Corfield No. 1	Magellan	4507	stratigraphic	granite
Cothalow No. 1	Phillips - Sunray	6025	stratigraphic	red beds
Etonvale No. 1	Phillips - Sunray	11,368	stratigraphic	granite
Glenmore		3415	water bore	weathered granite
Gumbardo No. 1	Phillips-Sunray	12,960	stratigraphic	?Silurian-Devonian
Kamaran Dns No. 3	-	1225	water bore	granite
Lucknow No. 10		1165	water bore	granite
Ooroonoo No. 1	Conorada Pet. Co.	3582	stratigraphic	gneissic granite
Penrith No. 1	A.A.O.	4078	stratigraphic	phyllite
Springvale No. 5		1413	water bore	granite
St Andrews Station Bore	-	902	water bore	metamorphics
Tallyabra	Tallyabra Oil	2580	stratigraphic	Cretaceous
Warbreccan No. 1	W.O.L.	5433	stratigraphic	granite

APPENDIX D

ROCK DENSITIES

Bouguer anomalies result from variations in the densities of the rocks which constitute the crust of the Earth. In particular the anomalies of interest to oil prospectors have their source in the top or sedimentary layer of the crust. Therefore a knowledge of the densities of all the rock types which occur superficially and at depth in any area to be surveyed, is of fundamental importance in the subsequent interpretation of the Bouguer anomalies in terms of geological structure.

Density measurements may be obtained in two ways: from laboratory measurements using hand specimens collected from outcrop or cores from boreholes, and from gravity meter traverses over selected topographic features or down bores or shafts. All the data available to the author have been obtained from laboratory measurements of hand specimens and cores.

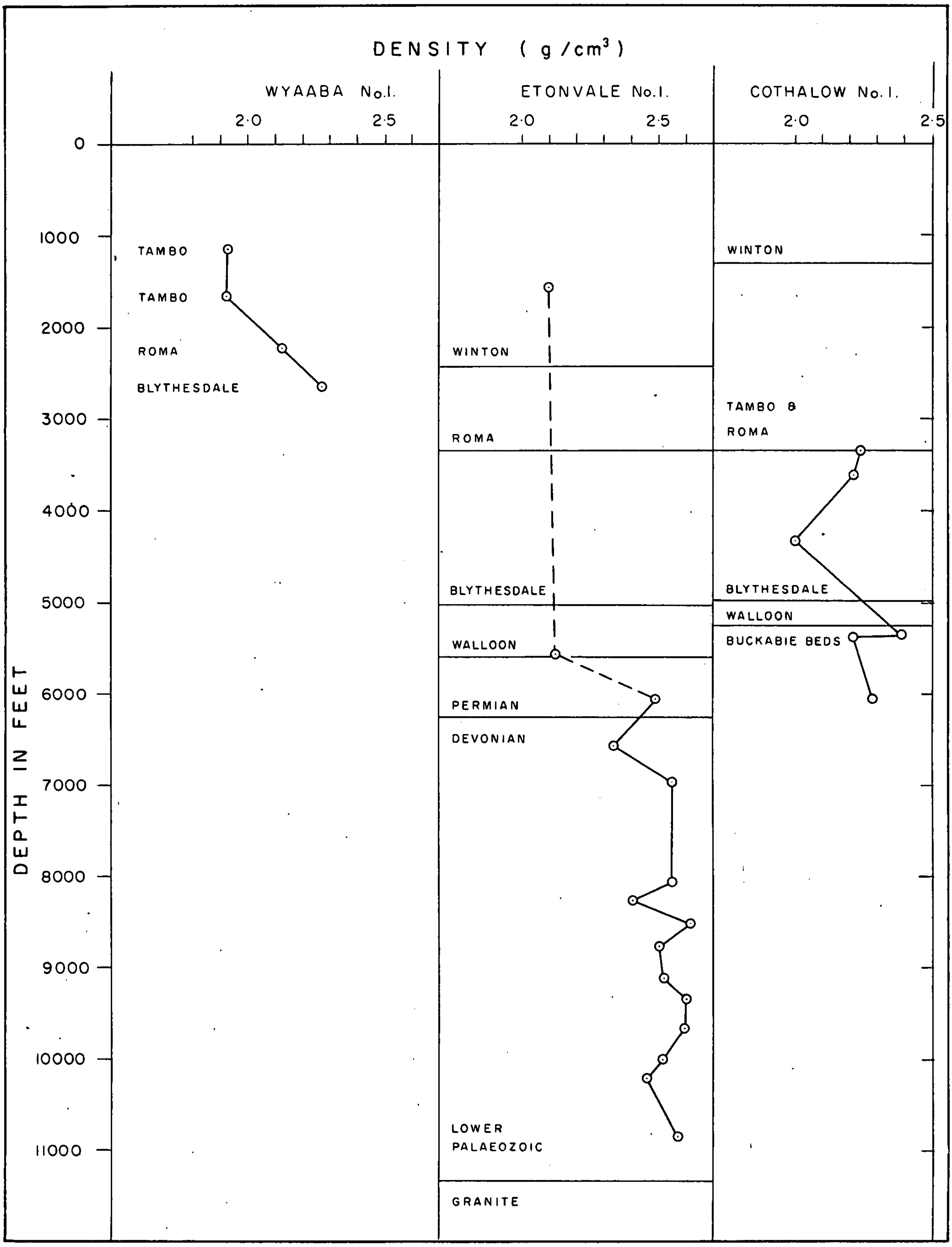
The density information in the area is not comprehensive. However, the table below, modified from one by Neumann (1959b), summarises the results obtained from Precambrian and Lower Palaeozoic hand specimens.

The results of measurements made on core samples from three deep bores in the area are shown in Figure 1.

Age	Sample	Density, g/cm^3	Locality
Precambrian	greenstone	2.92	Dajarra
"	shale	2.73	"
"	ribbon stone	2.62	Cloncurry
"	phyllite	2.55	"

(To face page 80)

FIG. 1



DENSITY MEASUREMENTS FROM CORES

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.
To accompany Record 1966/13 F54/B2-27

Age	Sample	Density, g/cm^3	Locality
Upper Proterozoic/ Lower Cambrian	Camooweal Dolomite	2.82	Urandangi
Upper Cambrian	Chatsworth Limestone	2.71	Mean density from several localities.
" "	Georgina Limestone	2.65	Mt. Whelan area.
" "	Mungerebar Limestone	2.67	
Lower Ordovician	Ninmaroo Formation	2.69	
Ordovician	limestone	2.72	Linda Downs
"	"	2.82	" "
Upper Ordovician	sandstone	2.12	Toko Range

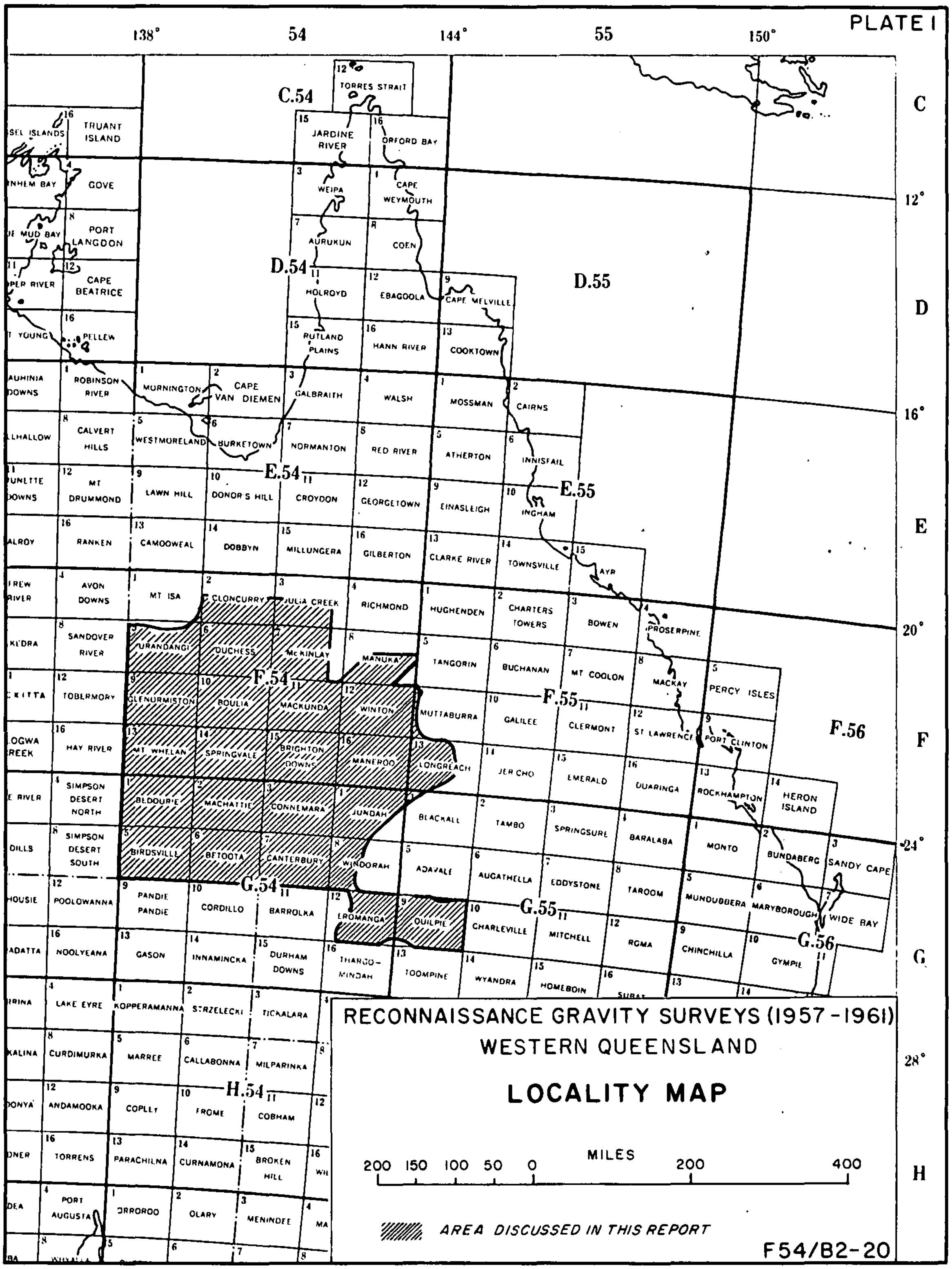
From a consideration of the scant density information available the following mean densities have been selected for use in the interpretation of the gravity anomalies:

Mesozoic	2.20 g/cm^3
Upper and Middle Palaeozoic	2.40 g/cm^3
Lower Palaeozoic limestone	2.70 - 2.80 g/cm^3
Precambrian metamorphics	2.80 - 2.85 g/cm^3
" granite	2.65 - 2.70 g/cm^3
" basic intrusive rocks	2.90 - 2.95 g/cm^3
Basement rocks of the Great Artesian Basin (age unknown) granite	2.65 g/cm^3
Basement rocks of the Great Artesian Basin (age unknown) metamorphics	2.65 g/cm^3

These values bear comparison to those of Dooley (1950) from the Roma area in the Great Artesian Basin given below:

Mesozoic	2.25 g/cm^3
Permian	2.40 g/cm^3
Basement metamorphics	2.65 g/cm^3
Basement granites	2.55 g/cm^3

PLATE I

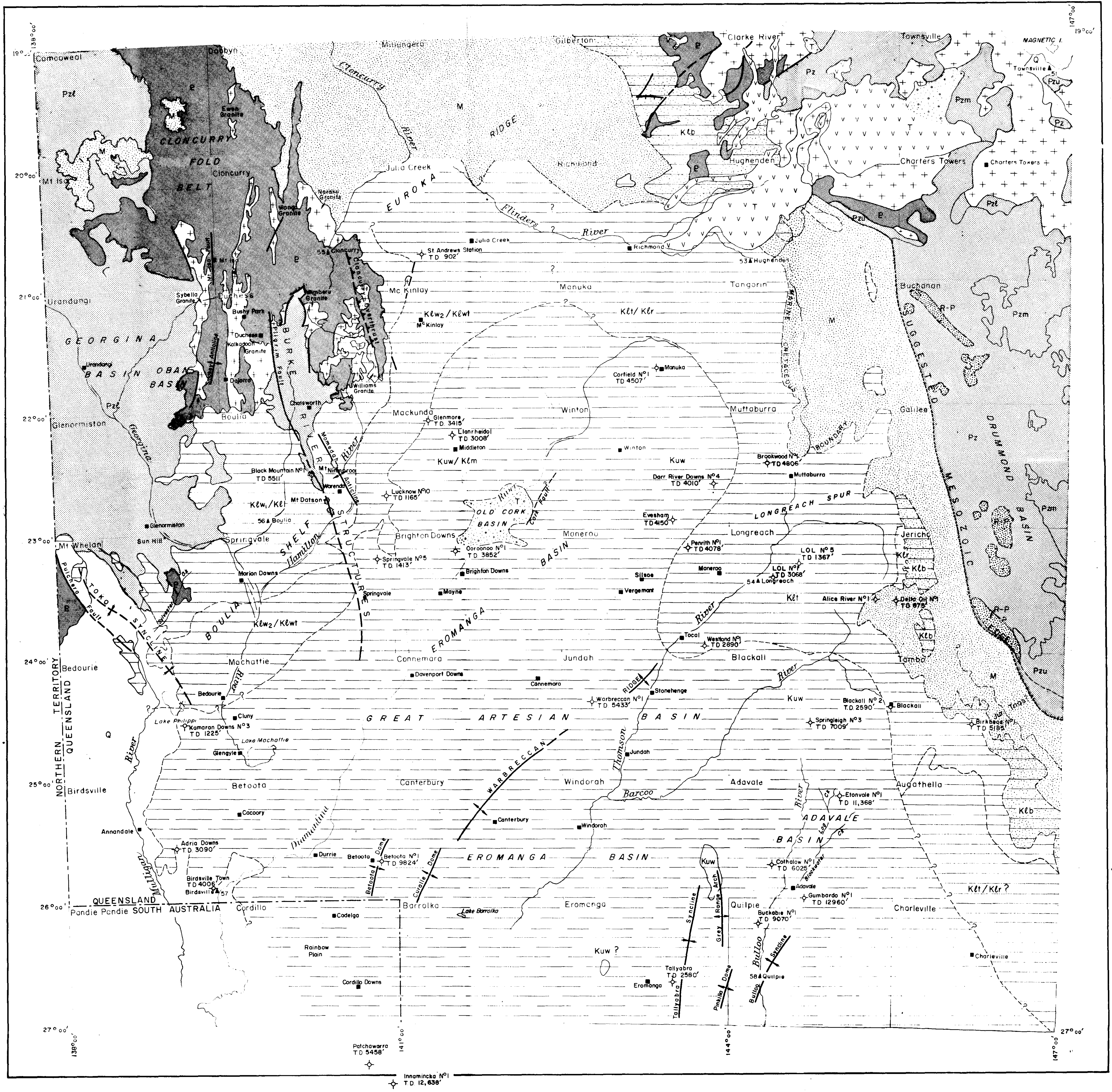


RECONNAISSANCE GRAVITY SURVEYS (1957-1961)
WESTERN QUEENSLAND

LOCALITY MAP

F54/B2-20

TO ACCOMPANY RECORD No. 1966/13



Q Quaternary

T Tertiary

M Mesozoic

Kuw / Kℓm Winton and Mackunda beds — Lacustrine

Kℓw₂ / Kℓwt Upper Wilgunya and Toolebuc member

Kℓw₁ / Kℓl Lower Wilgunya and Longsight sandstone

= Kℓt / Kℓr Tambo / Roma — Marine — CRETACEOUS

= Blythesdale transition beds (in part)

Kℓb Blythesdale sandstone — Non-marine — JURASSIC

R-P Triassic- Permian sandstone

Pz Pzu Pzm Pzℓ Palaeozoic

P Proterozoic and Archaean

+ Granite

v T v Volcanics (Tertiary)

▲57 BMR gravity pendulum station

Mt Isa BMR 1:250,000 gravity map area

Fault

Anticlinal axis

Synclinal axis

Compiled August 1962

RECONNAISSANCE GRAVITY SURVEYS(1957-1961)
WESTERN QUEENSLAND
GEOLOGY

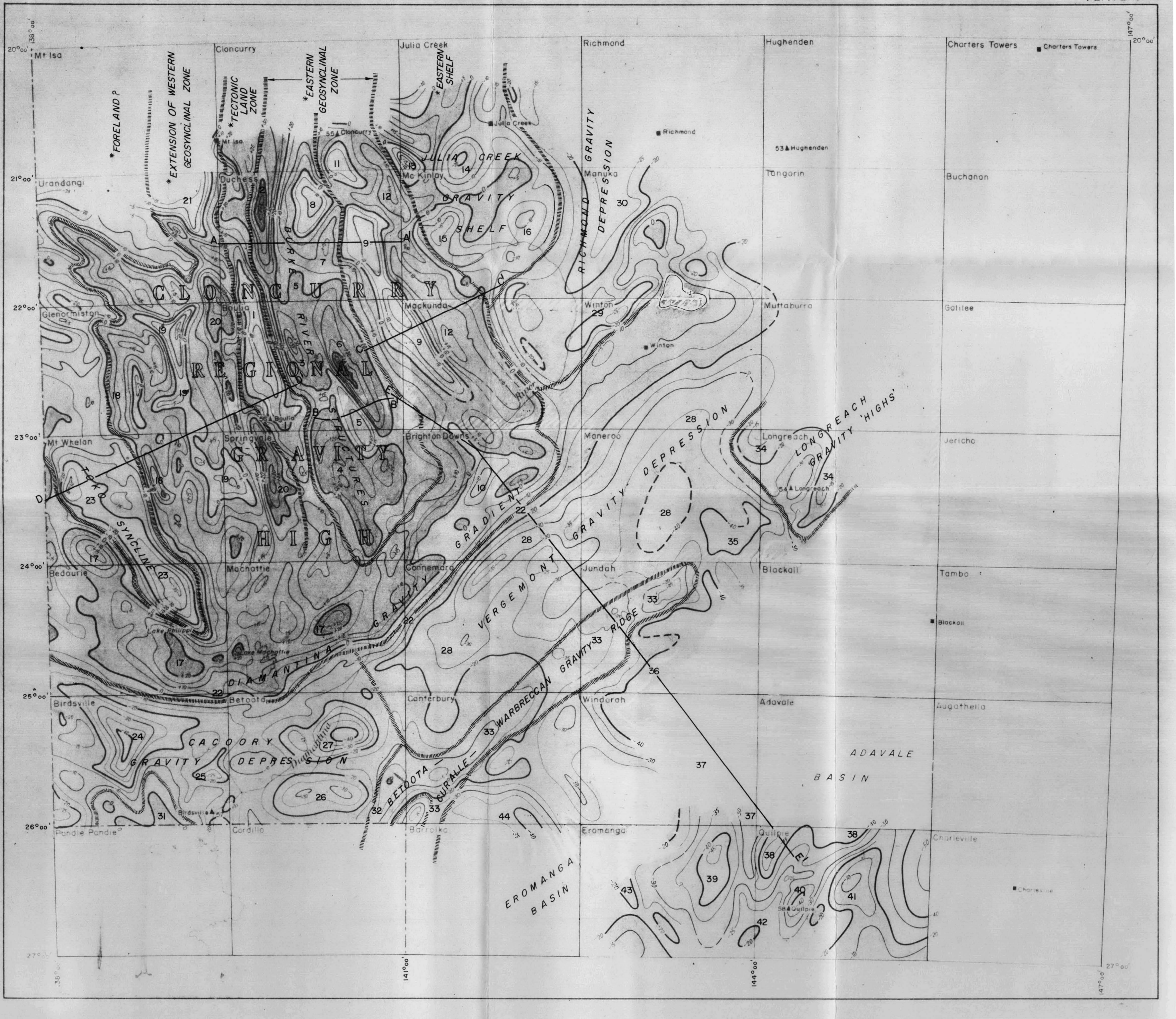
SCALE IN MILES

40 0 40 80 120

Reference – Division of National Mapping 40 miles to 1 inch topographic map, BMR tectonic map, and geological map of Queensland, Queensland Department of Mines. Additional geological information supplied by Great Artesian Basin Party, BMR Geological Branch.

TO ACCOMPANY RECORD No. 1966/13

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS F 54/B2-21



LEGEND

0 -5 -10	Isogals, values in milligals
▲ 56	BMR gravity pendulum station
Mt Isa	BMR 1:250,000 gravity map area
▨	Gravity. 'High'
○	Gravity 'Low'
12	Anomaly number
A —— A'	Line of section

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

No 54 Longreach	978,789.8	milligals
No 55 Cloncurry	978,650.7	"
No 56 Boulia	978,793.2	"
No 57 Birdsville	979,003.0	"
No 58 Quilpie	979,006.5	"

For the calculation of Bouguer anomalies 1.9g/cm^3 has been adopted as an average rock density

Elevation datum: Queensland State.

* After Carter, Brooks and Walker (1961)

RECONNAISSANCE GRAVITY SURVEY (1957-1961)
WESTERN QUEENSLAND

BOUGUER ANOMALIES

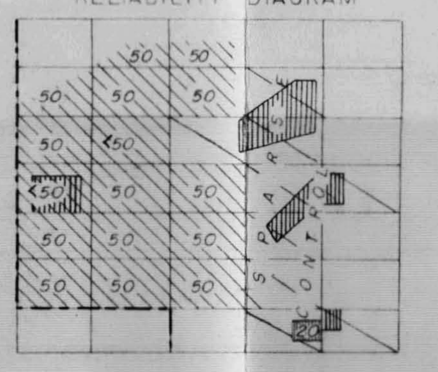
WITH SHADING EMPHASIS AND GRAVITY UNITS

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

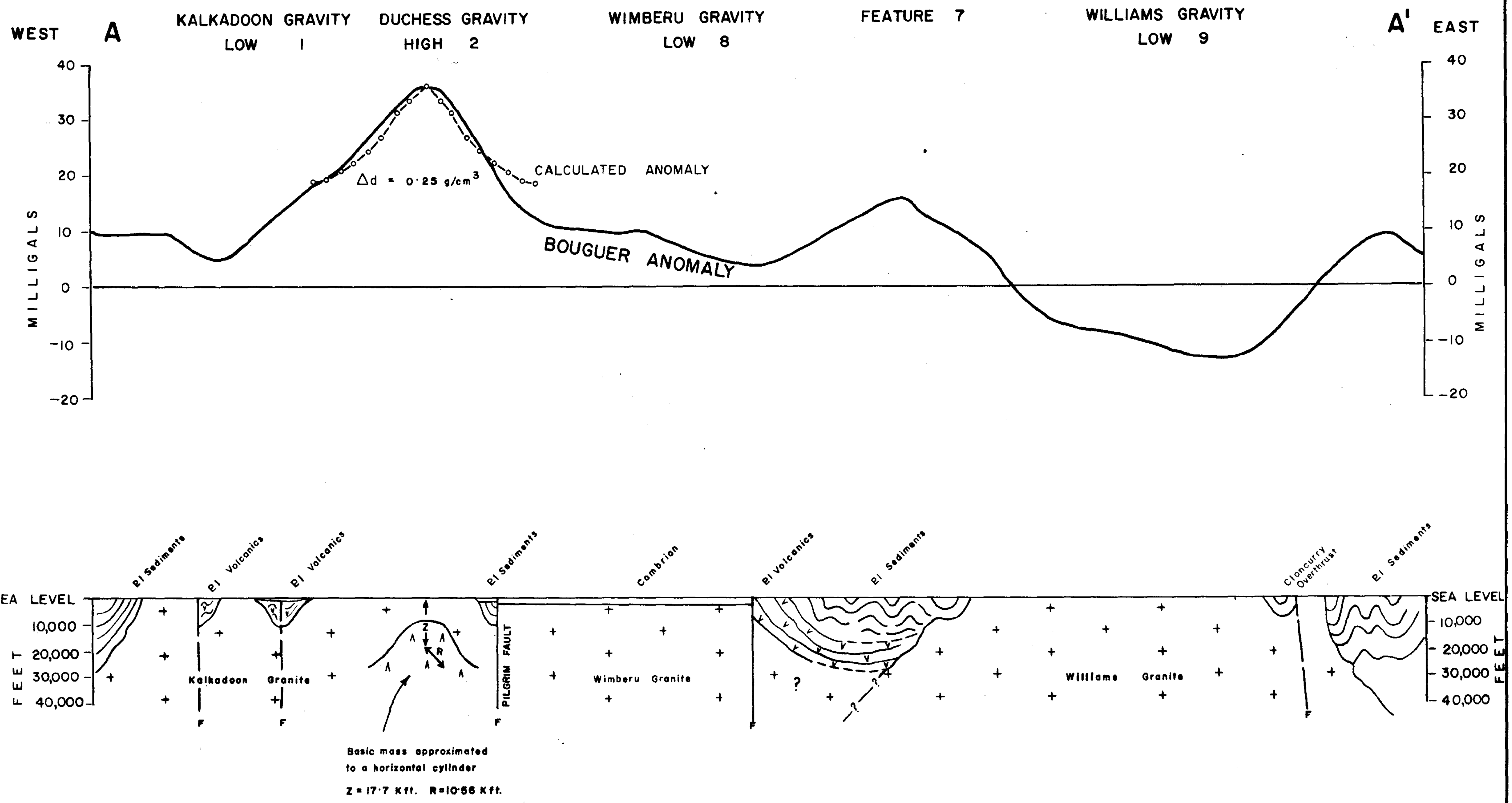


GRAVITY		
SURVEY		METHOD
▨	GROUND TRAVERSES & HELICOPTER BY BMR	REGULAR GRID COVERAGE, AIR PHOTOGRAPHY, BAROMETRIC LEVELLING.
⧅	GROUND TRAVERSES BY BMR	WIDELY DISPERSED TRAVERSES, AIR PHOTOGRAPHY, CONVENTIONAL LEVELLING, ASTROFIXES.
▥	SEMI-DETAILED BY PRIVATE COMPANIES	GROUND TRAVERSES, CONVENTIONAL LEVELLING.

FIGURE IN EACH AREA DENOTES SQUARE MILES PER ONE BMR GRAVITY STATION

Compiled September 1960
Revised November 1961, July 1962, January 1963

TO ACCOMPANY RECORD No. 1966/13
GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS (BMR) F 54/B2-17-2



GEOLOGICAL SECTION MODIFIED FROM CARTER, BROOKS, & WALKER, 1961.

CROSS-SECTION A-A'

(SEE PLATE 3 FOR SECTION LINES)

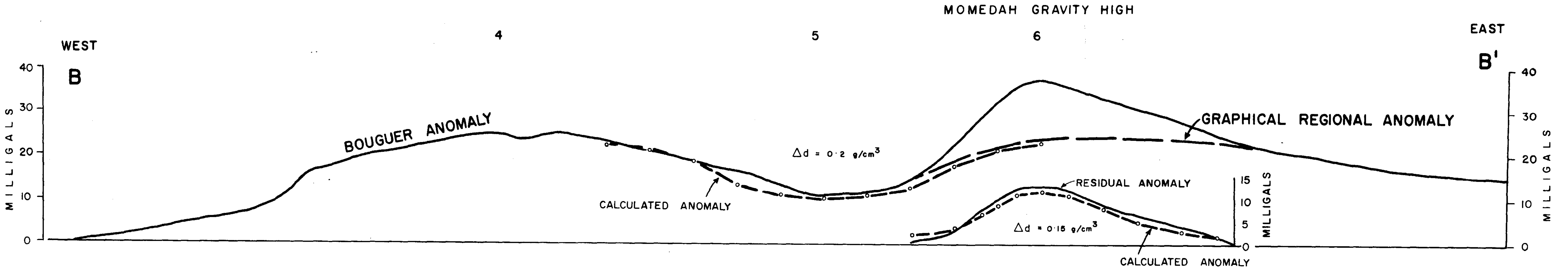
SCALE IN MILES

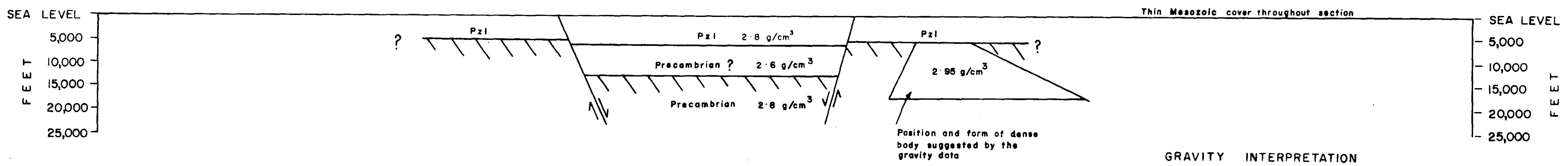
HORIZONTAL = VERTICAL SCALE

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics F54/B2-22

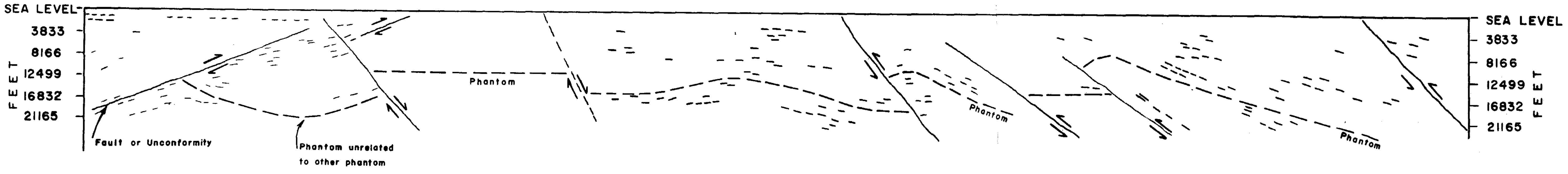
TO ACCOMPANY RECORD No. 1966/13

PLATE 5





GRAVITY INTERPRETATION



SEISMIC INTERPRETATION (BY PHILLIPS PETROLEUM CORPORATION).

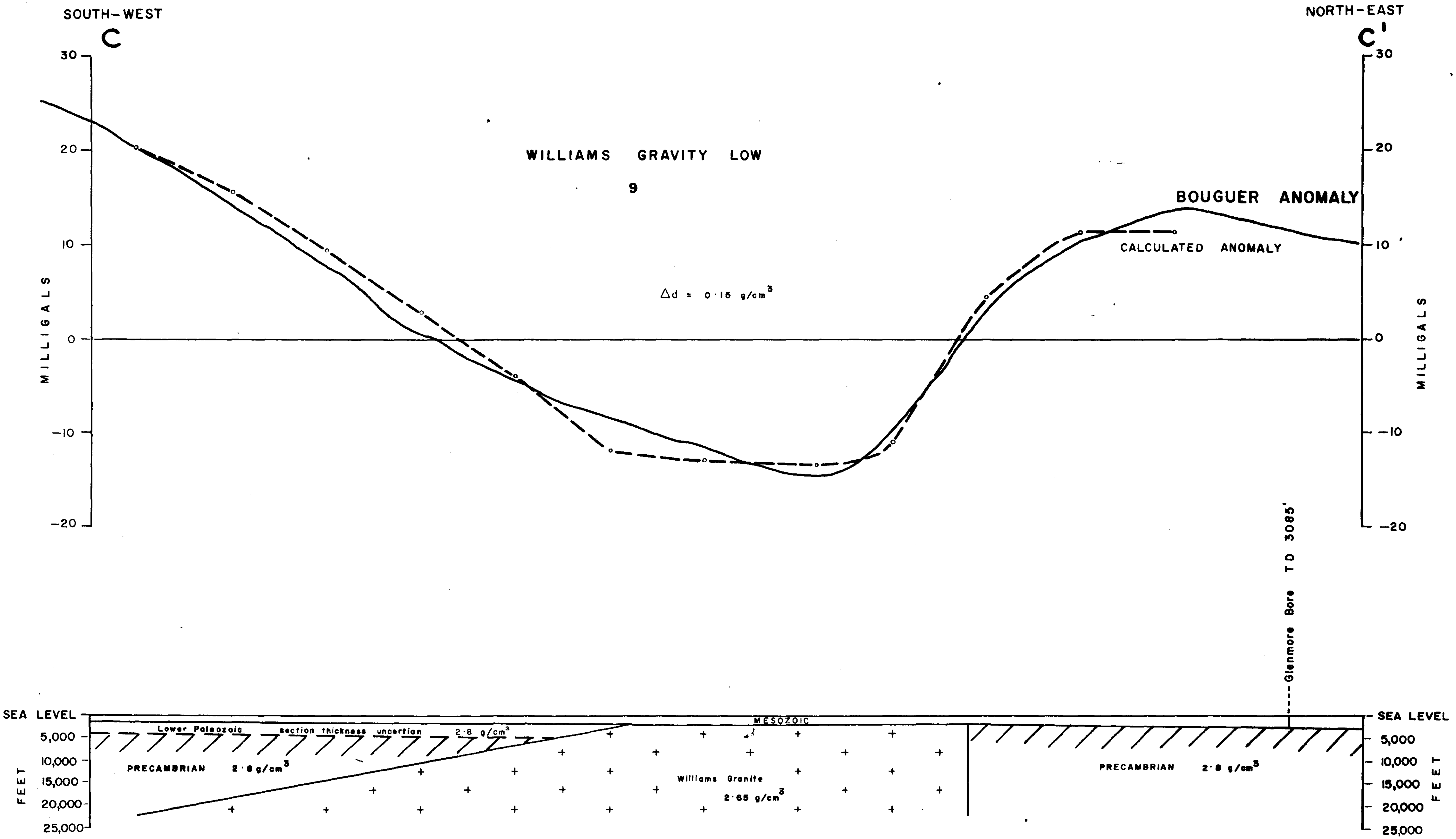
CROSS-SECTION B-B'

VERTICAL SCALE - AS SHOWN ON SECTIONS

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics F54/B2-23

TO ACCOMPANY RECORD No. 1966/13

PLATE 6



CROSS-SECTION C-C'

SCALE IN MILES

4 3 2 1 0 4 8 12

HORIZONTAL = VERTICAL SCALE

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics F54/B2-24

TO ACCOMPANY RECORD No. 1966/13

PLATE 7

CROSS-SECTION D-D'

SCALE IN MILES

4 3 2 1 0 4 8 12

HORIZONTAL = VERTICAL SCALE

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics F54/B2-25

TO ACCOMPANY RECORD No. 1966/13

CROSS-SECTION E-E'

F54/B2-26

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics.

TO ACCOMPANY RECORD No.1966/13